

**Investigating the effects of child
maltreatment and household dysfunction
on child physical development in a
British birth cohort**

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I, Rachel Denholm, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

A handwritten signature in black ink, appearing to read "Rachel Denholm".

Abstract

Recent evidence suggests that adverse childhood experiences (maltreatment and household dysfunction) may have a long-term effect on disease risk in adulthood. The underlying mechanism is complex. One possible pathway is through physical development, which has been linked to later health outcomes. This thesis investigated the prevalence of child maltreatment and household dysfunction in a population sample, and assessed their association with child-to-adult height and pubertal development.

The 1958 British birth cohort includes all children ($\approx 17,000$) born in one week, March 1958, followed up throughout childhood to age 50y. Retrospective and prospective measures of child maltreatment and household dysfunction were obtained. Repeated measurements of height and pubertal development were recorded by trained medical personnel. Multivariate response models were adopted to examine the influence of child maltreatment and household dysfunction on height at different ages simultaneously, accounting for the within individual correlations. Multinomial logistic regression models were adopted to investigate the relationship between adverse childhood experiences and categorical markers of puberty.

Approximately one third of the cohort was identified as high risk for maltreatment (abuse and neglect) in childhood: more than one in ten reported any form of abuse (physical, emotional and sexual abuse and witnessing abuse). Childhood maltreatment tended to be experienced in multiple forms; of those reporting abuse, two thirds also reported another form of child maltreatment. Children from dysfunctional family backgrounds were at an increased risk. Although the association between adverse childhood experiences and physical development attenuated after adjustment for demographic and socio-economic factors, some relationships persisted. . Early exposure to neglect was related to short stature at ages 7, 11, 16y and in adulthood. Associations were generally stronger at 7y (deficits ranged from 0.8 to 2.0cm) than at 45y (0.3 to 0.7cm). Neglect was also associated with late maturation, as indicated by a greater relative risk ratio (RRR) of pre-pubertal development at 11y (e.g. late pubic hair growth RRR=1.2-1.6 for boys and 1.5 for girls) and menarche at ≥ 14 y (RRR=1.4) in girls.

Sexual abuse was associated with early menarche in girls (RRR: 2.41; 1.19, 4.88), and advanced testicular development at 11y in boys (RRR: 5.50; 1.00, 30.17).

In conclusion, childhood indicators of neglect were associated with delayed physical development. The associations between abuse and physical development were mostly explained by socio-economic factors; although there was some indication that sexual abuse may be related to early pubertal development. These growth patterns may have an impact on health outcomes in adulthood.

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1 Introduction

In the past, studies investigating potential risk factors for adult disease have focused on exposures in adulthood. More recently, a life-course framework has been developed to conceptualise adult disease aetiology. Increasing evidence suggests that social, biological and psychological exposures during gestation, childhood, adolescence and adulthood may have long-term effects on disease risk.

A life-course approach to adult disease suggests that exposures at different life stages may influence later health in several ways. There are critical periods when development may be particularly vulnerable to early life exposures. Early childhood exposures may have lasting consequences on the structure or function of organs, tissues or body systems, independent of later experiences. For example, retarded foetal growth, an indicator of prenatal exposures, has been associated with increased risk of cardiovascular disease¹. Markers of socio-economic position (SEP) in childhood, such as father's occupational status and household tenure and overcrowding, have been related to biomarkers for chronic inflammation in adulthood². Factors in later life may still affect disease risk, but it has been hypothesised that childhood exposures could permanently alter anatomical structures, influencing later adult health³.

Some early exposures may only be important to adult disease risk amongst individuals who are exposed to other risk factors in later life, i.e. in the presence of effect modifiers. For example, children who are relatively small at birth (an indicator for retarded foetal growth) and experience accelerated catch-up growth in infancy, are at a greater risk of coronary heart disease in adulthood compared to those who do not⁴. Thus the critical period may only be important for individuals who experience other exposures at subsequent life stages⁵.

It is also possible that exposures for adult disease may accumulate across the life-course⁶. Low SEP across the life-course has been shown to have a cumulative effect on adult inflammatory markers^{7:8} and coronary heart disease⁹. In addition, exposures are often clustered in a socially patterned way. For example, children from disadvantaged backgrounds are more likely to be of low birth weight, live in overcrowded households

in poor neighbourhoods, be exposed to environmental tobacco smoke and have fewer educational opportunities than other children. Therefore, early life circumstances may set individuals onto life-course trajectories that influence health status over time. A New Zealand study showed that socio-economic disadvantage was associated with increased risk of drug dependency in adolescence and a high risk cardiovascular profile by young adulthood¹⁰.

While the association between socio-economic disadvantage and adult health has been well studied, there has been increasing interest in the long-term impact of adverse childhood experiences on adult health. It is well recognised that child maltreatment and household dysfunction, as two main aspects of adverse childhood experiences, are of considerable social and public health concern. A recent United Nations International Children's Emergency Fund (UNICEF) report on child well-being ranked the UK in the bottom third for family relationships, subjective well-being and risky behaviours amongst 21 rich countries¹¹. The immediate consequences of adverse childhood experiences, including death, injury and poor emotional health, are well documented, whilst less is known about the long-term effect on later disease risk¹²⁻¹⁴. Furthermore, the mechanisms through which adverse early life experiences may affect adult health are not well understood. It is possible that adverse childhood experiences may operate through multiple aspects of child development¹⁵⁻¹⁷. Thus understanding the relationship between adverse childhood experiences and developmental pathways could inform effective prevention programmes to reduce the risk of later ill health.

In this Chapter I shall first review the literature on the extent of child maltreatment and household dysfunction, their co-occurrence and associated short and long-term consequences. Second, I shall describe potential pathways through which child maltreatment and household dysfunction may influence later health outcomes, and the methodological challenges associated with studying their relationship. Finally, I will propose the aims and objectives of my thesis.

1.1 Child maltreatment

There has been much debate about the definition of child maltreatment (detailed description in §1.5.1). But conventionally, child maltreatment encompasses any acts by a care giver that causes harm, or has the potential (or threatens) to cause harm to a child. There are two categories of maltreatment: abuse (psychological, physical and sexual) and neglect. Recently, witnessing intimate-partner violence has been recognised as a form of child maltreatment.

1.1.1 *Prevalence of child maltreatment*

Estimating the population prevalence of child maltreatment is not straightforward as it varies widely depending on the data source used, the form of maltreatment being measured and the study sample adopted. In addition, prevalence estimates have been shown to change over time.

Three types of data sources are common in child maltreatment studies: agency reports (e.g. child protection or police), self-reports and parent-reports. In England, agency reports estimate that 0.4% of the population aged 0 to 17y were maltreated in 2010-2011^{18;19}. Population studies based on self and parent-reports suggest that the actual prevalence of child maltreatment may be much higher. For example, a recent National Society for the Prevention of Cruelty to Children (NSPCC) survey found 2.5% of children aged <11y in the UK and 6% aged 11–17y were abused or neglected by a care giver in 2008-9²⁰. Each type of measure have their own biases and inconsistencies (reviewed in §1.5.3), thus a range of estimates are often given. Each method of case-ascertainment suggest that neglect and psychological abuse tend to be the most frequently reported forms of maltreatment, followed by physical and then sexual abuse²⁰⁻²⁵.

Despite some agency reports from England and the US indicating that the incidence of child abuse and neglect may be declining, child maltreatment remains a significant social problem²⁶⁻²⁹. A recent Lancet review of international trends in child maltreatment found no consistent evidence of a change in the frequency of abuse and neglect between the mid-1990s and the mid-2000s³⁰. American community studies

have also shown no significant change in reported physical abuse and neglect, and witnessing intimate-partner violence during the same period³¹.

1.1.2 Co-occurrence of child maltreatment

Abused and neglected children tend to experience multiple forms of maltreatment³², although the extent to which they co-occur varies across studies. Agency reports suggest that 50% to 94% of maltreated children experience multiple forms of maltreatment³³⁻³⁵. In such studies, sexual abuse is most likely to co-occur with other forms of maltreatment compared to other forms of abuse and neglect^{32;34;36}. In self-report studies, 34% to 66% of participants retrospectively report multiple forms of abuse and/or neglect^{32;37;38}. Self-report studies suggest psychological abuse is most likely to co-occur with other forms of maltreatment than others^{32;34;36}.

The variation in findings between studies is due to differences in data sources and definitions used to collect information on child abuse and neglect³⁹. Agency reports tend to classify a child's experience using only one form of maltreatment, i.e. that which brought the child to the attention of the authorities, or the easiest to substantiate⁴⁰. Agencies also define the 'predominant' form of maltreatment, prioritizing sexual and physical abuse, followed by neglect and psychological abuse³⁴. Thus, neglect and psychological abuse may go unrecognised, despite evidence suggesting that they are frequently experienced by children who are physically and sexually abused⁴¹.

It is important to investigate a wide range of abuse and neglect to prevent underestimating the prevalence of child maltreatment and the extent to which they co-occur in the population. When such co-occurrence is ignored, associations with later outcomes may be attributed to one form of abuse, without considering the influence of other forms of maltreatment. Thus data on a range of maltreatment experiences provides a more precise and complete base upon which to develop hypotheses regarding the long-term outcomes associated with child maltreatment.

1.2 Household dysfunction

In addition to maltreatment, household dysfunction also has a negative influence on children by affecting the parent-child relationship, parental care and family stability. Factors such as parental mental health and substance use issues may directly affect parenting function, whereas parental divorce/separation and parental imprisonment may affect the familial environment⁴². These household dysfunction measures are often inter-related, and children are likely to experience multiple forms of household dysfunction. Child maltreatment and household dysfunction are also highly correlated: children from dysfunctional families are at increased risk of being maltreated⁴³⁻⁴⁶. Below I summarise different forms of household dysfunction and their influence on parenting behaviour and family environment.

1.2.1 *Factors affecting parenting function*

Parental mental health has been associated with parental behaviour and an increased risk of children being placed into care^{47;48}. For example, mothers with schizophrenia show decreased verbal and emotional responsiveness compared to mothers without^{49;50}. Parents with depression have been shown to limit interactions with their children and undertake minimal responsibility for their care⁵¹, engage in more hostile behaviour and adopt harsh discipline methods compared to others⁵²⁻⁵⁶. Parental separation/divorce is also more common among families in which a parent has a mental illness⁴⁸.

Parental substance misuse: In the UK, nearly half of families known to child welfare agencies have at least one parent with a drug or alcohol dependency^{57;58}. Parental substance misuse increases children's vulnerability to harm⁵⁹ and is associated with a chaotic lifestyle and household instability⁶⁰. Excessive alcohol intake or drug use may mean parents are less attentive to their children's needs⁶¹, and can result in lapses in hygiene and supervision⁶². Drug or alcohol misuse may also affect the parent-child relationship⁶⁰⁻⁶². Increased parental drug involvement is related to the use of harsh discipline methods⁶³ and a greater risk of child maltreatment⁶⁴⁻⁶⁸.

1.2.2 *Factors affecting familial environment*

Family conflict is linked to less supportive parenting and engagement in parenting activities⁶⁹⁻⁷⁴. Marital conflict is thought to trigger emotional and psychological reactions in offspring. Children exposed to family conflict have been found to display more negative emotions and cognitions which reflect hostile family relationships than those who are not^{75;76}.

Parental divorce/separation is associated with an increased risk of household instability⁷⁷ and maternal mental health problems, and a decrease in household income⁷⁸. Children whose parents are divorced/separated are more likely to have been brought up in poverty, and have parents with a drug dependency or mental illness and who use harsh discipline methods compared to others⁷⁹⁻⁸¹.

Parental imprisonment: In England and Wales, it is estimated that each year between 125,000 and 150,000 children have a parent in prison⁸². Parental imprisonment may affect children due to parent-child separation, family poverty⁸³ and household instability⁸⁴. Parental imprisonment is also associated with poor childhood supervision^{83;85-87} and the use of harsh discipline methods⁸⁰. Households with an imprisoned family member tend to be less educated, from lower socio-economic backgrounds and at greater risk of mental and physical health problems than others^{80;88}.

Institutional care: On 31 March 2011, 65,520 children in England were provided with substitute care (59 per 10,000 children < 18y). Children had been placed into care as a consequence of abuse or neglect (62%) or family dysfunction (14%), acute stress (9%), illness or disability (9%) or an absent parent (6%)⁸⁹. Children in care are at particular risk of harm and often experience a combination of poverty, household and schooling instability, parental substance abuse and mental illness and maltreatment⁹⁰⁻⁹².

Physical punishment is associated with parental stress⁹³ and an increased risk of child abuse and neglect^{45;94}. Parents who feel their child has a more difficult temperament, who have low self-esteem, a predisposition towards anger, poor mental health or financial trouble are more likely to resort to physical punishment than others⁹⁵⁻⁹⁷.

1.3 Consequences of child maltreatment and household dysfunction

Adverse childhood experiences have been associated with mortality and injury in children. Child maltreatment and household dysfunction also affect childhood physical, cognitive, social and emotional development. More recently, evidence suggests that adverse childhood experiences may have a long-term influence on disease risk in adulthood. The established literature on the short and long-term outcomes of adverse childhood experiences is presented below.

1.3.1 Mortality and injury in childhood

Mortality: Globally, the World Health Organisation (WHO) estimated that in 2000 nearly 57,000 children aged < 16y died as a consequence of a maltreatment related injury^{12;98}. In the UK, two children die each week from abuse and/or neglect¹³. More children die from neglect than any other form of maltreatment^{14;99}. The highest number of deaths occur amongst infants aged < 1y, and teenagers aged 16 and 17y in the UK¹⁰⁰ and elsewhere^{99;101}. The rate is also higher in boys than girls^{99;102;103}.

Injury: Child maltreatment is linked to physical injuries, such as bruises, burns, fractures, and brain and central nervous system damage¹⁰⁴. A frequent consequence of an injury to the head or internal organ is permanent disability^{12;105;106}. A systematic review estimated that 2-10% of all children admitted to hospital emergency departments were victims of abuse and/or neglect¹⁰⁷. Children from dysfunctional family backgrounds are also at greater risk of injury than others, possibly due to a decrease in adequate parental supervision¹⁰⁸. Parental alcohol use has been associated with an increased risk of unintentional childhood injury^{109;110}. Children of parents with mental health problems and those from single parent households are more frequently admitted to hospital¹¹¹⁻¹¹³, and at greater risk of injury than other children¹¹⁴⁻¹¹⁷. However, it is difficult to identify victims due to the broad range of injuries associated with adverse childhood experiences, and uncertainty in diagnosing maltreatment or household dysfunction by professionals^{29;118}.

1.3.2 *Child development*

Adverse childhood experiences are associated with poor cognitive¹¹⁹⁻¹²⁶, social^{125;127;128} and emotional¹²⁹⁻¹³⁷ development during childhood and adolescence. Studies using the 1958 cohort show that psychological distress associated with adverse childhood experiences continues throughout childhood into mid-adulthood¹³⁸. Elsewhere there is some evidence of an association between child maltreatment and behaviour problems, e.g. criminal behaviour¹³⁹, lower education attainment^{119;120} and delays in cognitive development¹⁴⁰ in childhood and adolescence. Child maltreatment and household dysfunction have also been related to physical development.

Evidence suggests that child maltreatment may be associated with shorter stature in childhood¹⁴¹⁻¹⁴⁵. However, there are important gaps in knowledge as studies are mostly cross-sectional^{141;143} or follow children for only a short period^{142;144;145}. Thus it is unclear whether child maltreatment influences final adult height. In addition, little is known about how the tempo of growth is affected by child maltreatment. There is some evidence to suggest that there is a significant relationship between child abuse and neglect and the timing of pubertal development. In particular, sexually abused girls have been found to reach menarche earlier than non-abused peers^{146;147}. Child maltreatment has also been associated with an increased risk of obesity in adolescence¹⁴⁸. Specifically, increased rates of weight gain have been found amongst neglected children compared to those exposed to other forms of maltreatment^{149;150}.

Elements of household dysfunction such as family conflict, familial distress, parental substance abuse and divorce/separation have also been linked to short childhood stature and adult trunk length¹⁵¹⁻¹⁵⁴. Likewise, studies have suggested that household dysfunction may be associated with pubertal timing. Earlier pubertal development has been related to parental divorce/separation, family conflict, parental mental illness or parental substance abuse during early life¹⁵⁵⁻¹⁶³. There is some evidence that markers of household dysfunction, such as single parent households¹⁶⁴, maternal mental health issues and family conflict¹⁶⁵, may be associated with an increased risk of being overweight or obese in childhood and adolescence.,

1.3.3 *Adult outcomes*

The established literature on the long-term consequences of adverse childhood experiences have tended to focus on outcomes related to educational attainment^{119;120;122;124;125;140;166}, mental health disorders^{131-137;167;168} and behavioural outcomes¹⁶⁹⁻¹⁷⁶. There is growing evidence to suggest that adverse childhood experiences are also associated with a range of adverse physical health outcomes, including musculoskeletal¹⁷⁷⁻¹⁷⁹, gastrointestinal^{180;181} and respiratory conditions^{182;183} and increased risk of cardiovascular disease¹⁸³⁻¹⁸⁵. However, these studies have mostly focused on child abuse and less is known about other forms of maltreatment or household dysfunction. Evidence largely comes from American retrospective studies^{182;186-189}, with a limited number of UK studies with prospective data on child maltreatment or household dysfunction^{20;190}. Furthermore, there has been little research investigating pathways from adverse childhood experiences to long-term adult outcomes. If the burden of adverse childhood experiences on adult health outcomes is to be minimised, there is a need to understand the processes by which child maltreatment and household dysfunction influence disease risk at different life stages.

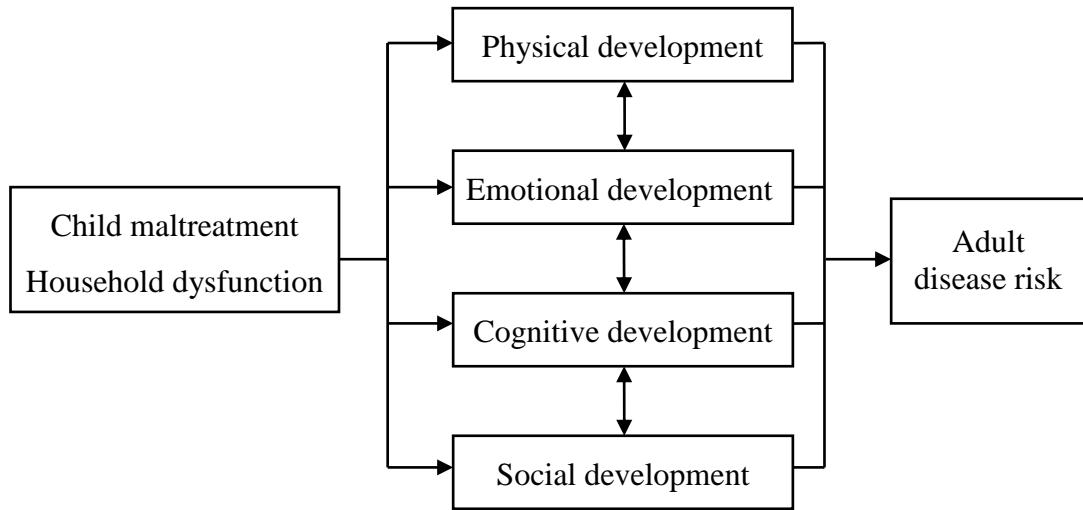
In the existing literature, child abuse and neglect have been associated with a greater risk of cardiovascular disease morbidity in adulthood^{184;185}. A recent meta-analysis, drawing on seven studies that collectively included 34,135 adults, found that child abuse had a medium-to-large association with cardiopulmonary symptoms in adulthood, including non-fatal heart attacks and strokes¹⁸³. Several studies have indicated that child maltreatment may be associated with biomarkers of cardiovascular disease in mid-adulthood. Women exposed to severe physical and/or sexual abuse prior to age 18y have been shown to be 20% more likely to develop hypertension, independent of adult BMI, compared to those that were not¹⁸⁶. A New Zealand prospective study estimated that 11.2% of all cases of all low-grade inflammation in the general population may be attributable to child maltreatment (abuse and neglect), after adjustment for co-occurring child and adult risk factors¹⁹¹. In some studies, women in particular appear to be at greater risk of later ill health than men. In the American National Comorbidity Survey (CMS), a reported history of child maltreatment (physical or sexual abuse, or neglect) was associated with an almost nine-fold increase in cardiovascular disease in women, after adjustment for age, ethnicity, marital status, education and income. In comparison, a weak relationship was found in men¹⁸⁷.

Multiple experiences of child maltreatment and household dysfunction have been shown to increase the risk of poor cardiovascular health in later life^{182;192}. The Coronary Artery Risk Development in Young Adults (CARDIA) study found that adverse childhood experiences (including emotional, verbal and physical abuse, living with a substance abuser or in an unorganised and ill-managed household) were associated with an increased 10-year risk of cardiovascular disease in adulthood¹⁸⁹. The American Adverse Childhood Experiences Study (ACE) showed a strong cumulative relationship between self-reports of child maltreatment and household dysfunction and increasing risk of cardiovascular disease¹⁸². A dose-response relationship was found between multiple factors of adverse childhood experiences and the odds of having ischemic heart disease (non-fatal heart attack, pain or heavy pressure in chest or use nitroglycerine) in adulthood¹⁸⁸. Multiple experiences of child maltreatment and household dysfunction have also been linked to elevated inflammation biomarkers and metabolic risk factors¹⁹¹.

1.4 Potential pathways between adverse childhood experiences and later ill health

Given the important knowledge gaps on the extent of, and explanations for, long-term outcomes of child maltreatment and household dysfunction, it is important to delineate associated pathways from childhood to adulthood in the general population. The pathways through which adverse childhood experiences may translate to disease risk in adult life are not well understood. A framework developed for life-course research on childhood socio-economic disadvantage and adult outcomes has been adopted to further understand this process, as shown in Figure 1.1. The framework presents four major developmental pathways (physical, emotional, cognitive and social) through which child maltreatment and household dysfunction may influence adult health outcomes. These pathways could operate independently, cumulatively or interactively. Identifying and targeting potentially modifiable connections between adverse childhood experiences and adult health may help reduce the lifelong burden of child maltreatment and household dysfunction.

Figure 1.1: Life-course framework linking adverse childhood experiences to adult disease risk



1.4.1 *Physical development*

An important potential pathway in which adverse childhood experiences may influence adult disease is through physical development. Growth in height and weight and pubertal development are representative of the biological reserves which children accumulate as they grow up, and have been found to be associated with health in adulthood¹⁹³⁻²⁰³. A range of anthropometric measures have been used to measure physical development, including tempo of growth, components of height, child-to-adult BMI trajectories and the development of secondary sexual characteristics.

A wide range of factors have been shown to be associated with physical development. These include genetics, ethnicity, diet, illness and socio-economic factors in childhood^{154;204-212}. There is some indication that child maltreatment and household dysfunction may also be associated with physical development. Here, two important indicators of childhood physical development are outlined; child-to-adult height trajectories and pubertal development.

Child-to-adult height trajectories

Height growth is influenced by both genetic and environmental factors^{205;208;213}. Factors that affect height start to act in early childhood, and their impact on final adult height can be mitigated by catch-up growth or, for some factors, through their influence on maturation, by extending the growth period. In particular, childhood height is more sensitive to early environmental conditions. For example, children from socio-economic disadvantaged backgrounds tend to be shorter in childhood, experience puberty later, continue to grow for a longer period, and are not necessarily short as adults compared to children who do not^{152;214}. Growth of children has been recommended by the WHO as one of the best indices to assess the overall health and nutritional status of a population¹⁹³. Thus, trends in height growth are important indicators of the health status and socio-economic conditions of a population.

There is some evidence linking adverse childhood experiences to deficits in childhood height. Abused and/or neglected children admitted to hospital for maltreatment-related disorders are shown to be short for their age, with disproportionately shorter legs than matched controls¹⁴¹. In foster care studies, maltreated children are more likely to be below the normal standards for height in the population¹⁴²⁻¹⁴⁵. Family conflict, parental substance abuse and parental divorce/separation have also been associated with short stature in childhood¹⁵¹⁻¹⁵⁴. Findings from British cohort studies indicate that parental divorce/separation may be related to deficits in childhood height¹⁵² and adult trunk length¹⁵⁴. It is also known that children with growth deficits who are placed into care can experience catch-up growth²¹⁵. However, most studies have been limited to specialised cohort, such as children in foster care, and summary measures of child maltreatment and household dysfunction. It is unclear whether different forms of child abuse, neglect and household dysfunction influence height growth in the general population. Less is known about the association between adverse childhood experiences and final adult height, as studies have mostly been cross-sectional^{141;143} or follow children for only a short period^{142;144;145}.

Shorter adult stature has been associated with an increased risk of adult mortality^{216;217}, stroke¹⁹⁴, chronic obstructive pulmonary disease²¹⁸ and cardio-respiratory mortality^{195;196}. In a Finnish study, a 1cm increment in height was related to a 2%

decrease in all-cause mortality²¹⁶. Adult leg length has been found to be inversely associated with an increased risk of cardiovascular mortality in both men and women^{219;220}. Childhood growth patterns have also been linked to risk factors for cardiovascular disease in adulthood^{194;221-223}. Males who develop coronary heart disease have been shown to be smaller at birth, shorter during infancy and experience rapid growth in later childhood compared to those who do not^{4;224}. Height itself is not considered a risk factor for adult outcomes, as once adult height is achieved it changes little during adulthood (although shrinkage occurs, mostly in later decades of life). Instead, it is thought that the height-disease association may reflect the long-term consequences of early life exposures during physical development in childhood²²⁵.

Pubertal development

Puberty is an important period in human development during which the body experiences rapid growth and achieves sexual maturation¹⁹³. Markers of pubertal development include development of the testes, pubic and facial hair, and voice change for boys, and breast development, pubic hair growth and the onset of menarche for girls^{226;227}. The timing of pubertal development, and in particular age of menarche, is considered to be a good measure for secular changes in the rate of maturation and tempo of growth²⁰⁵. Genetic and environmental factors influence the onset of puberty^{207;228-232}, as well as race and early nutrition²³³⁻²³⁵. Recent declines in age of pubertal onset have been attributed to improvements in general health, nutrition and living conditions during childhood^{236;237}.

There is some evidence to suggest that sexual abuse may be associated with the onset of puberty: for example sexually abused girls have been found to reach menarche earlier than non-abused peers^{146;147}. A weak relationship between other forms of child maltreatment and early onset of puberty has been found^{147;238}, although there have been few studies investigating such relationships. Less is also known about whether child maltreatment is linked to other markers of maturation (e.g. breast development or pubic hair growth). There is limited evidence of an association between child maltreatment and pubertal development for boys, though there is some indication that sexual abuse may be related to early onset of voice change and beard growth²³⁸.

Household dysfunction may also predict pubertal timing. Family structure has been shown to affect puberty, with girls growing up in households without their biological father more likely to experience menarche at younger ages than others^{155;158;160;163}. Father's contribution to the family dynamic, indicated by emotional supportiveness, marital conflict and depression, may have a greater influence on pubertal development, compared to mothers^{162;159}. For boys, there is some suggestion that an absent biological father accelerates pubertal development, although the relationship appears to be weaker than that found for girls^{156;157;161}. However, most of the established literature is limited to female cohorts, and few studies have examined the relationship between family structure and pubertal development in boys. Less is also known about the relationship between other forms of household dysfunction, such as parental mental illness or substance abuse, and pubertal development.

As with height, the timing of pubertal development has been related to adult health outcomes. Earlier pubertal onset has been shown to increase the risk of total mortality²³⁹ and breast cancer in women²⁴⁰⁻²⁴³ and testicular cancer in men²⁴⁴⁻²⁴⁶.

Adverse changes in insulin, glucose and lipid levels²⁴⁷, and increased blood pressure in childhood, adolescence and young adulthood^{197;198;198-202} have been linked to early maturation. There is also some indication that late pubertal development may also be associated with increased disease risk and mortality in females²⁴⁸.

1.4.2 Cognitive, social and emotional development

There are several other possible pathways through which adverse childhood experiences may affect adult health outcomes (Figure 1.1). Child maltreatment and household dysfunction could influence other aspects of childhood development, such as behaviour, emotion and cognitive ability, which may impact on disease outcomes in adulthood. Adverse childhood experiences may lead to the uptake of adverse health behaviours that are risk factors for disease in adulthood. Victims of child maltreatment are more likely to abuse alcohol and drugs^{171;171;173;174;249}, smoke^{182;250-253}, and take part in risky sexual behaviour^{238;254-258}. Such behaviours may be used as coping devices by survivors of child maltreatment, or they may be a consequence of other developmental outcomes associated with child abuse and neglect. For example, poorer educational attainment amongst maltreated children may affect socio-economic circumstances in adulthood

such as employment and financial stability. These factors could further impact upon adult emotional health, health behaviours and ultimately disease risk.

1.5 Methodological challenges

Research concerning adverse childhood experiences presents at least three methodological challenges. First, there is a need for clear and concise definitions of child maltreatment and household dysfunction. Second, the inter-relationship between adverse childhood experiences and socio-economic disadvantage leads to difficulties in disentangling the two concepts. Finally, study results are affected by data collection methods used to ascertain cases of child maltreatment and household dysfunction. Consequently, there are limited data available on the long-term outcomes of adverse childhood experiences in the UK. These issues are discussed below.

1.5.1 Defining child maltreatment and household dysfunction

Definitive measurements of child maltreatment and household dysfunction are required to identify children at risk, target intervention programmes and assess associated short and long-term outcomes^{259,260}.

Child maltreatment

A persistent challenge in the research, policy and practice of child maltreatment is the lack of a universal definition. It has been proposed that a functional classification of child maltreatment requires defined objectives, conceptual clarity, discrete subtypes and practical measures²⁶¹. Instead, the term is used by multiple sectors (including child protection services, legal and medical communities, public health professionals, academics and advocates) to encompass a wide range of concepts. Each profession characterises child abuse and neglect according to their own aims, goals and interests, which are often incompatible with one another²⁶². A complete and unified definition is required to maximise the utility of data and ensure reliable and practical estimates of child maltreatment are obtained²⁶³⁻²⁶⁶.

Constructs

There has been little consensus regarding a theoretical framework in which to conceptualise child maltreatment. Disagreement exists over whether abuse and neglect should be defined by the actions of the perpetrator or the effect on the child, and if intent or the environmental context should be considered²⁵⁹. Thus, multiple constructs have been developed. Here, three approaches are discussed: a ‘developmental psychopathology’ approach, an ecological framework and parent-child interaction theory²⁵⁹.

A ‘developmental psychopathology’ approach defines child maltreatment in the context of ‘normal’ child development²⁶⁷, such that any threat to any aspect of a child’s development is characterised as maltreatment²⁶⁸⁻²⁷⁰. Defining maltreatment in relation to the child’s overall wellbeing ensures that attention remains on the victim rather than the perpetrator^{269,271}. Advantages of such an approach are that it can be used in different cultural contexts, and provides an underlying construct in which all forms of maltreatment can be defined^{262,270}. A limitation of a ‘developmental psychopathological’ definition is its inability to separate child maltreatment and the consequences of maltreatment²⁷². Many maltreated children show little concurrent effect of being maltreated. Thus defining child abuse and neglect in the context of deviations from normal development will under-estimate maltreatment in the population²⁷².

An ecological perspective acknowledges the complex interactions between individual, family and community factors associated with child maltreatment²⁷³, encouraging a comprehensive approach to assessing the causes and consequences of child abuse and neglect^{42,274-276}. Ecological models recognise that children develop in a number of social contexts, nesting individuals within levels of environmental influence²⁷⁷. Thus child maltreatment is a consequence of damaging parent behaviours that occur when stressors from each domain accumulate and outweigh supports, and risks are greater than protective factors²⁷⁶. Limitations of an ecological model include difficulties in disentangling parental and environmental factors, deriving concise and functional definitions²⁷⁸ and, in practice, increased targeting of vulnerable groups (e.g. socio-economically disadvantaged families) by professionals^{275,279}.

Parent-child interaction theory categorises child maltreatment as any parenting behaviour that has the potential to cause any short or long-term harm to the child²⁸⁰. Incidents can therefore be classified as maltreatment without any immediate evidence of physical harm²⁷². Neglect is particularly difficult to define using a parent-child interaction model as it is characterised by omissions in parenting behaviour. Challenges arise from: 1) identifying parental behaviours necessary for healthy development, and 2) recognising that they are missing. Establishing which actions are harmful is another potential problem, as debate surrounds the operational definition of harm, i.e. immediate, long-term and potential harm.

Despite issues associated with using a parent-child interaction approach, it remains a popular tool, especially for government organisations. In these settings, child maltreatment is defined according to specific actions towards the child, characterised by immediate and long-term harm as shown in Table 1.1. Five distinct forms of child maltreatment are widely used: psychological (or emotional) abuse, physical abuse, sexual abuse, neglect and witnessing intimate-partner violence²⁹. Conventional definitions adopted are discussed below.

Table 1.1: Conventional definition of child maltreatment²⁹

Maltreatment	Definition
Physical abuse	Intentional use of physical force or implements against a child that results in, or has the potential to result in, physical injury.
Sexual abuse	Any completed or attempted sexual act, sexual contact, or non-contact sexual interaction with a child by a caregiver.
Psychological (or emotional) abuse	Intentional behaviour that conveys to a child that he/she is worthless, flawed, unloved, unwanted, endangered, or valued only in meeting another's needs. <i>In the UK the definition includes harmful parent-child interactions which are unintentional: “persistent emotional ill-treatment of a child such to cause severe & persistent adverse effects on the child’s emotional development”.</i>
Neglect	Failure to meet a child's basic physical, emotional, medical/dental or educational needs; failure to provide adequate supervision or to ensure a child's safety.
Witnessed intimate-partner violence	Any incident of threatening behaviour, violence or abuse (psychological, physical, sexual, financial or emotional) between adults who are, or have been, intimate partners or family members.

Child abuse

Abuse has been categorised as acts of commission, whereby intentional words or actions cause harm or have the potential (or threaten) to harm a child²⁶⁵.

Psychological, or emotional abuse is categorised as intentional behaviour that conveys to a child that he/she is worthless, flawed, unloved, unwanted or endangered²⁸¹, such as blaming, belittling, intimidating, isolating, restraining and exploiting²⁶⁵. In the UK, a broader definition has been adopted to include any unintentional interaction that could be classified as abusive²⁸². Psychological abuse is the most difficult abuse category to define as the immediate consequences are more elusive than those of other forms of abuse. Moreover, distinguishing between less than adequate parenting, parenting mistakes and psychological abuse is challenging, as many parents acknowledge using behaviours that are considered abusive, e.g. yelling, insulting or threatening their children²⁸⁰.

Physical abuse: The Center for Disease Control and Prevention (CDC) 2008 guidelines define physical abuse as the ‘intentional use of physical force against a child’²⁶⁵. Actions range from those that do not leave a physical mark to those that cause permanent disability, disfigurement or death²⁸³. Physical abuse can be caused by disciplinary methods, and, in some contexts, any form of physical punishment constitutes abuse²⁸⁴. However, international opinion varies as in the case of smacking: 12 European countries consider smacking a form of assault²⁸⁵, whereas, in the UK, guardians are permitted to use ‘reasonable punishment’, including smacking, when disciplining their own children²⁸⁶.

Sexual abuse is defined as forcing or enticing²⁸² a child in sexual activity that he/she does not fully comprehend, is unable to give informed consent for or is not developmentally prepared for²⁸⁴. Actions encompass those that require physical contact, such as touching²⁶⁵, to non-contact activities, e.g. looking at or producing sexual images or grooming a child²⁸², and can be performed by the perpetrator on the child or vice versa^{265;284}.

Child neglect

Theoretically and practically, neglect has been more difficult to define than abuse, as neglectful behaviours are less visible, often culturally determined and co-occur with socio-economic disadvantage²⁶⁵. Yet, neglect has been broadly defined as the persistent failure to meet a child's basic physical and/or psychological needs²⁸².

As the nature of neglect is very heterogeneous, two comprehensive categories have been developed. First, 'failure to provide' reflects a caregiver's competence in meeting the physical, emotional, medical and educational needs of the child. Physical neglect encompasses failures in providing adequate nutrition, hygiene and shelter. Emotional neglect is defined as ignoring the child, denying emotional responsiveness or providing inadequate access to mental health services. Withdrawal of appropriate medical, vision or dental care falls under medical neglect, whilst educational neglect refers to failing to ensure the child receives an adequate education. Second, 'failure to protect', refers to a failure by the caregiver in ensuring the child's safety within and outside the home, such as allowing the child to participate in unsafe activities and exposing them to unnecessary hazards²⁶⁵. Though there are conceptual distinctions between each form of neglect, in reality the two categories overlap.

Witnessed intimate-partner violence

In the US and UK, failure to protect a child from violence between caregivers is currently included in the working definition of neglect, under the broad and vaguely defined concept of 'failure to protect'^{265;282}. More recently, studies have indicated that any exposure to household violence (physical or non-physical) is emotionally harmful to children^{287;288}. Thus, researchers have begun to categorise intimate-partner violence as a separate form of child maltreatment²⁸⁹. Here, Gilbert et al's definition of intimate-partner violence is used, namely any threatening behaviour, violence or abuse between members of the household (Table 1.1)²⁹.

Household dysfunction

There is no definitive list of household dysfunction measures. Studies investigating the effects of adverse childhood experiences have used a range of exposures to examine the impact of childhood trauma on later outcomes. As with child maltreatment, measures of household dysfunction vary depending on the cultural context. Thus selected measures have to be flexible enough to adapt to cultural specificities and reflect the characteristics of each setting. A further challenge of identifying household dysfunction measures is the wide range of adversity children experience. It is therefore possibly unrealistic to expect studies to assess every type of childhood trauma, all possible mediators and moderators, and the many potential outcomes²⁹⁰.

In 2009, an expert consultation between the WHO and CDC on adverse childhood experiences discussed standardising the questions used in order to promote cross-country and study comparisons. Potential categories were assessed using the following criteria: 1) biological relevance (i.e. whether the factor produces a biological stress reaction), 2) policy sensitivity, 3) prevalence in all societies (neither too high nor too low), 4) how quickly and easily the factor can be measured, and 5) proximity in respect to causality²⁹¹. The agreed upon household dysfunction categories are presented in Box 1.1.

Box 1.1: WHO and CDC household dysfunction categories

<ul style="list-style-type: none">• Parental substance abuse• Parental mental illness• Mother/father/sibling/household member treated violently• Imprisoned household member	<ul style="list-style-type: none">• Parental separation/loss of a parent• Childhood involvement in caring for a critically (chronic) ill parent• Parental discord• Residential mobility/instability
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1.5.2 *Socio-economic disadvantage*

The association between socio-economic disadvantage and adverse childhood experiences is one of the most consistent observations in the established literature. Although child maltreatment and household dysfunction are reported across the socio-economic spectrum, they are disproportionately reported amongst families of low SEP²⁹².

Child maltreatment: Several family and neighbourhood indicators have been used to investigate the relationship between socio-economic disadvantage and child maltreatment. Low family income has been associated with an increased risk of child abuse and neglect^{293,294}. High rates of unemployment, both at the family and neighbourhood level, have been linked to greater rates of child maltreatment⁹⁴. In particular, areas with high male unemployment have a higher prevalence of child maltreatment reports than areas with low unemployment²⁹⁵. The established literature also indicates that there is a greater risk of abuse and neglect in families with poor social networks and low levels of social support than others²⁹⁶⁻²⁹⁸. At a neighbourhood level, increased levels of social support, as indicated by higher morale and community integration, is associated with lower rates of child abuse compared to neighbourhoods with fewer social resources²⁹⁹.

Evidence indicates that the rates of different forms of maltreatment vary across socio-economic groups. Prevalence studies have consistently found child sexual abuse to be equally represented across all social classes²⁹⁵. In contrast, neglect has been found to be more prevalent in low socio-economic households compared to others³⁰⁰. Neglect may be linked to socio-economic disadvantage as several criteria used to define neglectful behaviour are related to material advantage, e.g. adequate nutrition, hygiene and shelter²⁹. Some researchers have noted housing and financial insecurity are the underlying issues in families with an agency report of child neglect^{301,302}. Others have suggested that socio-economic disadvantage is a reflection of greater overall need, and disadvantaged families are at greater risk of neglect causing an overrepresentation in caseloads³⁰²⁻³⁰⁴.

Household dysfunction is also related to socio-economic disadvantage. Rates of mental health disorders and substance abuse are higher in low-income populations compared to high-income groups, as the poorest individuals are most vulnerable to mental health problems³⁰⁵. At the neighbourhood level, increases in unemployment rates, proportion of the population in poverty and number of households on public assistance are associated with increased intravenous drug use rates³⁰⁶. Single parent households^{307;308} and families with a parent in prison³⁰⁹ tend to be of low SEP compared to those that do not. Multiple indicators of socio-economic disadvantage have been associated with maternal harsh discipline methods⁴⁵: for example low income, unstable employment and receipt of public assistance are associated with increased risk of parents smacking their children^{45;294;310}.

Despite substantial research suggesting an association between socio-economic disadvantage and adverse childhood experiences, there is concern that reporting bias may influence study results. Socio-economically disadvantaged families may be more visible to welfare agencies, and therefore more likely to receive a report for maltreatment or household dysfunction compared to other families³⁰³. If low SEP children are frequently reported to welfare agencies due to systematic bias, then studies will overestimate the relationship between socio-economic disadvantage and adverse childhood experiences. However, there is little evidence of systematic bias in agency reports. Instead, an American study concluded that economically disadvantaged families were over-represented in agency reports because poverty, and conditions associated with financial hardship, placed families at greater risk of abuse and neglect than others³⁰³.

A few theories have been developed to explain the relationship between socio-economic disadvantage and child maltreatment and household dysfunction. A widely accepted hypothesis is that factors associated with socio-economic disadvantage, such as financial hardship and unemployment, negatively impact on parenting quality by increasing parent's vulnerability to stress^{94;311;312}. Alternatively, children from socio-economically disadvantaged backgrounds may be more likely to experience child maltreatment or household dysfunction because parents possess fewer resources that enable them to provide adequate levels of care²⁹⁴. Budget constraints may limit families

access to health care and basic necessities such as shelter, food, and clothing, making good parenting more difficult²⁹⁴.

However, the nature and direction of the association between adverse childhood experiences and socio-economic disadvantage remains unclear. Socio-economically disadvantaged families and neighbourhoods often experience multiple, inter-related problems. Thus, as discussed, a range of indicators have been used to measure SEP³¹³. The presence of multiple markers of socio-economic disadvantage, as well as adverse childhood experiences, has led to disjointed findings in the established literature^{94;314}. In addition, though adverse childhood experiences and SEP are highly correlated, disentangling the relative influence, as well as direction, of specific measures is difficult^{315;316}. Some researchers have suggested that the relationship between adverse childhood experiences and socio-economic disadvantage may be reciprocal and interdependent^{317;318}. Families affected by child maltreatment and household dysfunction often have multiple problems; adverse childhood experiences may be a part, or a consequence, of a broader continuum of disadvantage. The interdependent nature of SEP and adverse childhood experiences means disentangling constructs, measures and associated outcomes in research is challenging. Thus it may not be possible to separate the independent effect of adverse childhood experiences from factors associated with socio-economic disadvantage.

1.5.3 *Data collection methods*

Multiple methods have been adopted to ascertain cases of child maltreatment and household dysfunction, including agency, parent and self-reports as well as health care services data. Prevalence estimates and the strength of association between exposures and outcomes have been found to vary depending on the method used to collect data³¹⁹. Thus the strengths and weaknesses of each approach need to be considered when interpreting and comparing findings.

Agency or parent-reports, when collected prospectively, are considered accurate and rigorous measurements of child maltreatment and household dysfunction and, with follow up, can indicate the natural history of adverse childhood experiences³²⁰. However, maltreated children identified prospectively are more likely to receive some

form of intervention (i.e. placed into care or medical treatment) compared to those who remain unidentified in childhood. Life trajectories of identified children are therefore likely to differ from those of unidentified children, reflecting alterations to behavioural, biological or psychological processes caused by the intervention. In addition, prospective data collection methods may miss cases due to parents' under-reporting of abusive or neglectful behaviour, and not all incidents of maltreatment are identified by agencies^{321;322}. For example, a study of 'at-risk' adolescents found that self-reports of psychological, physical and sexual abuse were four to six times higher than agency estimates³²³. Unreported cases of abuse and neglect may be more severe. When maltreatment is identified in childhood, in most cases it stops, whereas if it remains unknown it can continue, and may even escalate³²⁴. Thus, agency and parent-reports alone cannot be relied upon to identify all cases of child maltreatment in the population, since children identified may not be representative of adult survivors as a whole³²⁴.

In the UK, child maltreatment is thought to be under-reported and also under-recorded. Child welfare agencies publish data on the number of children classified as in need of protection and placed on Child Protection Registers. These registers are a record of children thought to be at risk of further abuse or neglect, rather than all children known to have been abused or neglected³²⁵. Thus, additional national statistics are used to measure the incidence and prevalence of child maltreatment in the population. Morbidity and mortality data have the advantage of being routinely collected, having standard internationally accepted diagnostic classifications (International Classification of Disease codes, WHO) and specific coding criteria³²⁶. Using these standardised methods allows trends in child abuse and neglect over time to be monitored and compared between countries³²⁷. However, it is thought that maltreatment related cause codes are under-utilised by health care professionals due to diagnostic uncertainty, inexperience and concerns regarding the ability of services to respond to maltreatment or household dysfunction^{118;328;329}. To provide a more complete estimate of adverse childhood experiences in the general population community studies are required.

Child maltreatment and household dysfunction can also be ascertained using retrospective self-reports. Such methods have the advantage of collecting information on childhood experiences from a segment of the population potentially missed by prospective studies³²⁴. However, as with all retrospective reports, recall bias is a

potential problem. Comparisons of prospective and retrospective data collection methods have shown that a large proportion of participants known to have experienced child maltreatment do not report it in later studies^{323;330}. For example, an American study found that 40% of participants with an agency report for physical abuse did not report any maltreatment 20 years later³³¹. Under-reporting of child maltreatment may be due to denial, forgetting, misunderstanding or embarrassment of cohort members³³⁰. Instead, self-reports of adverse childhood experiences in adulthood may reflect well-established and fixed ‘life-scripts’³²⁰, i.e. culturally shared expectations of the order and timing of life events in a ‘normative’ life-course³³². There is some indication that memories can be reconstructed, with recall of childhood events being unstable between adolescence and adulthood, and then stabilising in later life^{333;334}. The ability to recollect past events is also influenced by present-day factors, including an individual’s physical and mental health, and his or hers emotional and socio-economic circumstances³²⁰.

Reliance on a single method to detect child maltreatment and household dysfunction is likely to provide inadequate coverage, under-representing the true incidence of adverse childhood experiences in a population. Instead, different data collection methods may identify distinct sub-groups within the population who have experienced child maltreatment and household dysfunction³²⁴. Retrospective and prospective techniques provide valuable information regarding childhood experiences, and when used together can strengthen a study.

1.6 Data for long-term follow-up

Much of what is known about child maltreatment, household dysfunction and childhood physical development comes from cross-sectional surveys. Often participants are questioned simultaneously about adverse childhood experiences and outcomes of interest. Due to the nature of cross-sectional studies, cause and effect cannot be distinguished and causal relationships cannot be examined. In contrast, the potential for exposure measures to be collected before disease onset in longitudinal studies means that the ‘temporality criterion’ for causality can be met. In addition, many studies use specialised cohorts to investigate the relationship between adverse childhood experiences and physical development, such as children in foster care^{142;143;145;146} or

children admitted to hospital^{141;144;335}. By limiting the study samples to recipients of special intervention services, assessment of the consequences of maltreatment may be confounded by the effect of the intervention. Without evidence from national population samples, it is unknown how child maltreatment affects growth and maturation in the general population. To my knowledge, there have been no national longitudinal studies in the UK that have investigated the long-term consequences of child maltreatment on physical development. Such studies are necessary to understand the causes of disease in contemporary populations and to identify individuals at greater risk.

Current evidence linking child maltreatment and child-to-adult growth patterns has been restricted to height measurements at single ages. Little is known about the effect of child abuse and neglect on growth patterns throughout childhood. Previous research has indicated that adverse socio-economic environments in early life may be associated with deficits in childhood height, with these differences decreasing during adolescence and smaller effects found in adulthood¹⁵². Therefore, examining the effect of child maltreatment on height at a particular age may not capture the full consequences associated with the exposure. Studies investigating the influence of child maltreatment on the timing of puberty have focused on girls, and in particular, age of menarche. Little is known about how child abuse and neglect influences other markers of pubertal development, or whether the onset of puberty differs in maltreated boys. These areas need to be fully explored to provide greater understanding of the impact of child abuse and neglect on puberty.

Finally, little consideration has been given as to how household dysfunction affects children's physical development. Parental characteristics and family circumstances have been shown to increase the risk of abuse and neglect, and there is some indication that measures of household dysfunction influence final adult stature and the onset of puberty. It is important to determine how these factors relate to experiences of child maltreatment, and whether they affect physical development. By disentangling pathways towards developmental delays, it may be possible to detect 'at-risk' children sooner, and put in place effective intervention programmes.

1.7 Aims and objectives of this thesis

The aim of this thesis is to examine how adverse experiences in childhood, namely child maltreatment and household dysfunction, influence height growth and pubertal development. Using the 1958 British birth cohort I specifically investigated;

1. the extent of maltreatment (abuse and neglect) and household dysfunction in childhood and whether they co-occur (Chapter 4 and Paper (Appendix 1.1)).
2. whether child maltreatment and household dysfunction are associated with child-to-adult height trajectories, and if patterns of growth vary by experiences (Chapter 5).
3. whether child maltreatment and household dysfunction influence the timing of pubertal development (Chapter 6).

1.8 Plan of the thesis

Chapter 2 provides details of the study sample and measures used in this thesis.

Chapter 3 described statistical methods applied in subsequent chapters. In Chapter 4, I investigate the epidemiology of adverse childhood experiences in the 1958 British birth cohort. First I present the prevalence of each form of child maltreatment (psychological, physical and sexual abuse, witnessing intimate-partner violence and neglect) in the cohort. I examine the extent to which different forms of abuse and neglect co-occur, and identify distinct patterns of maltreatment (maltreatment groups). I examine the prevalence of each measure of household dysfunction and investigate their relationship with child maltreatment.

Chapters 5 and 6 each examine the relationship between adverse childhood experiences and a specific feature of physical development: height growth in Chapter 5 and pubertal development in Chapter 6. I establish the relationship between adverse childhood experiences (maltreatment and household dysfunction) and child-to-adult height growth, and adult leg length. Several markers of pubertal development are examined, including testicular development, pubic and facial hair growth, and age of voice change for boys, and breast development, pubic hair growth and age of menarche for girls. Child

maltreatment measures to be investigated are: 1) each form of child abuse and neglect reported at age 45y, 2) indicators of neglect collected at age 7y, and 3) maltreatment groups identified in Chapter 4. A range of household dysfunction (e.g. parental substance use and mental health problems and parental divorce) measures on physical development, as well as the cumulative effect of childhood neglect and household dysfunction are also examined.

In Chapter 7, implications of the main findings in the wider context of adverse childhood experiences and child development are discussed, alongside main strengths and limitations of the study and areas for further research.

1.9 Role of the researcher

Data from the 1958 British birth cohort data were downloaded from the UK Data Archive in April 2009 after a special license for sensitive data was obtained. I cleaned the data and constructed main exposure (child maltreatment and household dysfunction) and response (height and puberty) variables used throughout this thesis. I also derived covariate measures (e.g. socio-economic status and ever breastfeed) guided by syntax constructed by colleagues at UCL Institute of Child health (ICH). I designed the study, alongside my supervisors, Dr Leah Li and Professor Chris Powers, and performed all analyses presented in this thesis. I am lead author of one peer reviewed journal (Appendix 1) and presented results at three conferences, based upon research included in this thesis.

2 Study sample and measures

The 1958 British birth cohort was used in this thesis to investigate adverse childhood experiences, and their associations with height and pubertal development. Measures of child maltreatment and household dysfunction were obtained at multiple ages and from multiple informants. Height was repeatedly measured throughout childhood to adulthood. A range of pubertal development measures were recorded at ages 11 and 16y. This chapter describes the study samples and the main exposure and outcome measures, as well as potential confounding factors used in this thesis. The strengths and challenges of the study, including the impact of missing data and sample attrition, are summarised.

2.1 Data sample

The 1958 British birth cohort (National Child Development Study (NCDS)) is a continuing, multi-disciplinary longitudinal study, designed to monitor social, educational, behavioural and physical development of the participants and their adult outcomes. The study began as the Perinatal Mortality Study (PMS) which aimed to investigate still-birth and infant mortality. Mothers of all babies born in one week in March 1958 in England, Scotland and Wales (about 17,415) were interviewed by midwives, who completed questionnaires referencing all medical records³³⁶. To date, the cohort has been followed up at eight time points. As shown in Table 2.1, information has been collected from a variety of sources from birth to age 50y. The target and achieved sample at each sweep is presented in Table 2.1. Details on sample size are provided in §2.5.

Table 2.1: Sources of data in the 1958 British birth cohort

1958 British birth cohort data sources									
PMS	NCDS1	NCDS2	NCDS3	NCDS4	NCDS5	NCDS6	Biomedical	NCDS8	
1958	1965	1969	1974	1981	1991	2000	2003	2008	
Birth	age 7	age 11	age 16	age 23	age 33	age 42	age 45	age 50	
Parents	Parents	Parents	Parents						
	School	School	School						
	Tests	Tests	Tests						
Medical	Medical	Medical	Medical				Medical		
				Subject	Subject	Subject	Subject	Subject	
				Census	Census	Partner			
						Children			
Target (n)	17,638	16,729	16,756	16,896	16,472	15,750	15,639	12,999	12,313
Achieved (n)	17,415	15,425	15,337	14,654	12,537	11,468	11,419	9,377	9,790

During childhood surveys at ages 7, 11 and 16y, immigrants born in the study week were added to the cohort (n=920)³³⁶. Information was gathered from parents (predominantly the mother) using structured interviews by Local Authority health visitors, or from teachers using questionnaires and school records. Cohort members also underwent medical examinations and school assessments.

In adulthood, participants who contributed to any of the childhood follow-up surveys were contacted and followed up at ages 23, 33, 42, 45 and 50y³³⁷. A biomedical survey was conducted at age 45y and included a home interview by a research nurse, self-completed questionnaires, and blood and saliva samples. During adult follow-ups, no attempt was made to contact cohort members who had not participated since age 16y, lacked a valid address, had previously displayed threatening behaviour, were unable to give informed consent, had emigrated, were in the armed forces, or had permanently refused to take part in the study. Deaths were ascertained through receipt of a death certificate or notification to the study team³³⁸.

2.2 Exposure measures – adverse childhood experiences

Main exposure variables considered here were maltreatment and household dysfunction in childhood. Measures were collected retrospectively in adulthood (age 45y) and also prospectively in childhood (ages 7, 11 and 16y). At age 45y, 9,310 participants completed a detailed confidential questionnaire on early life experiences up to age 16y, using a hand-held computer assisted personal interview (CAPI) devise. The questionnaire was based on the Parental Bonding Instrument³³⁹, British National Survey of Health and Development,³⁴⁰ and the US National Comorbidity Survey³⁴¹, and was originally used in the Path Through Life Project³⁴². Prospective measures were identified from childhood surveys using conventional definitions for child maltreatment and household dysfunction, and the established literature.

2.2.1 *Child maltreatment*

Measures of maltreatment in the study included psychological, physical and sexual abuse, witnessing abuse of a family member, and neglect. Details of these measures (i.e. age and informant) are given in Table 2.2. These measures identify actual, threatened, or evidence of maltreating behaviour²⁷², and are consistent with current conventional definitions of abuse and neglect²⁹.

Child abuse

In the 45y survey, cohort members were asked about experiences of abuse by a parent or guardian during childhood (defined as age \leq 16y). Five questions on child abuse ('yes', 'no' or 'can't say') were asked (Box 2.1).

Box 2.1: Child abuse questions at age 45y

- i. I was verbally abused by a parent (or parent-figure)
- ii. I suffered humiliation, ridicule, bullying or mental cruelty from a parent (or parent-figure)
- iii. I was physically abused by a parent - punched, kicked or hit or beaten with an object, or needed medical treatment
- iv. I was sexually abused by a parent (or parent-figure)
- v. I witnessed physical or sexual abuse of others in my family

Table 2.2: Conventional definitions of child maltreatment²⁹ and representative variables at different ages in the 1958 British birth cohort

Definition	1958 British birth cohort		
	Age (y)	Informant	Variables
Psychological (or emotional) abuse Intentional behaviour that conveys to a child that h/she is worthless, flawed, unloved, unwanted, endangered, or valued only in meeting another's needs. <i>UK definition includes harmful (unintentional) parent-child interactions</i>	45	Cohort member	I was verbally abused by a parent
	-	-	I suffered humiliation, ridicule, bullying or mental cruelty from a parent
Physical abuse Intentional use of physical force or implements against a child that results in, or has the potential to result in, physical injury.	-	-	I was physically abused by a parent – punched, kicked or hit/beaten with an object, or needed medical treatment
Sexual abuse Any completed or attempted sexual act, sexual contact, or non-contact sexual interaction with a child by a caregiver.	-	-	I was sexually abused by a parent
Witnessing intimate-partner violence Any incident of threatening behaviour, violence, or abuse (psychological, physical, sexual, financial, or emotional) between intimate partners or adult family members, irrespective of gender or sexuality.	-	-	I witnessed physical or sexual abuse of others in my family
Neglect Failure to meet a child's basic physical, emotional, medical/dental, or educational need; failure to provide adequate nutrition, hygiene, or shelter; or failure to ensure a child's safety	-	-	I was neglected
	7 & 11	Teacher	Physical neglect indicator Child's appearance is scruffy/dirty /underfed
	45	Cohort member	Emotional indicators of neglect Mother unaffectionate Father unaffectionate
	-	-	Mother does not read to child Father does read not to child
	7	Parent	Hardly any outings with mother Hardly any outings with father
	-	-	Parent's wish child to leave school by minimum age
	7 & 11	-	Mother little interest in child's education
	-	Teacher	Father little interest in child's education
	-	-	
	7, 11 & 16	-	
	-	-	
	-	-	

A binary variable was derived for each question to indicate a positive response; 'can't say' was coded as not abused (Appendix 2.1). Responses to questions i. and ii. were strongly correlated ($r=0.92$); of those reporting verbal abuse, 67.0% also reported humiliation, ridicule, bullying or mental cruelty from a parent, i.e. psychological abuse. Similarly, three quarters of those psychologically abused were also verbally abused. Thus, responses to these two questions were combined to form a measure of psychological abuse.

Child neglect

Eleven measures of child neglect were collected; three retrospectively at age 45y and eight prospectively in childhood (Table 2.2). Binary variables were derived for these measures. Participants who did not give a clear response (i.e. 'can't say', 'don't know', etc.) were classified as having a negative response (i.e. no) (Appendix 2.1).

Child neglect measurements collected at age 45y included a general measure;

I was neglected ('yes', 'no' or 'can't say')

and two measures signifying some omission of care by the parent ('a lot', 'somewhat, a little', 'not at all', 'no mother/father figure', or 'can't say');

- i. Thinking about your childhood, up to the age of 16y, how affectionate was your mother (or mother-figure) towards you?
- ii. Thinking about your childhood, up to the age of 16y, how affectionate was your father (or father-figure) towards you?

Two binary variables were derived indicating whether mother or father was affectionate; yes (represents 'a lot', 'somewhat' or 'a little affectionate') vs. no (represents 'not at all affectionate'); no mother/father figure was coded missing (n=59 and 253, respectively).

Measures reflecting the parent-child relationship were also collected from the parent (predominantly the mother) at ages 7, 11 and 16y (Box 2.2). Binary variables were derived for mother or father: 1) never, or hardly ever reads to the child (vs. occasionally

or every week), 2) never, or hardly ever went on outings with mother or father (vs. occasionally or most weeks) and 3) had low aspirations, described as parents wish for the child to leave school at the minimum age (or as soon as possible) (vs. staying after the minimum school leaving age).

Box 2.2: Parent-child relationship questions at ages 7, 11 and 16y

7y survey

- i. Does the mother read to, or with, the child ('yes at least every week', 'yes occasionally', 'never', 'hardly ever', or 'don't know')
- ii. Does the father read to, or with, the child ('yes at least every week', 'yes occasionally', 'never', 'hardly ever', or 'don't know')
- iii. Does the mother take the child out? E.g. for walks, outings, picnics, visits, shopping ('yes most weeks', 'yes occasionally', 'never', 'hardly ever', or 'don't know')
- iv. Does the father take the child out? E.g. for walks, outings, picnics, visits, shopping ('yes most weeks', 'yes occasionally', 'never', 'hardly ever', 'don't know')
- v. Would the parents like the child to be able to stay on at secondary school after the minimum school leaving age ('yes', 'no', 'don't know', or 'other')

11y survey

- i. Does the mother go out with the child for walks, outings, picnics, visits? ('yes most weeks', 'yes occasionally', 'never', 'hardly ever', or 'other')
- ii. Does the father go out with the child for walks, outings, picnics, visits? ('yes most weeks', 'yes occasionally', 'never', 'hardly ever', or 'other')
- iii. 'Would you like (child's name) to leave school as soon as possible or stay on longer?' ('leave as soon as possible', 'stay on longer', or 'don't know yet')

16y survey

- i. Which of the following would the parent like the study child to do? ('leave at minimum school leaving age (i.e. end of this school year)', 'stay in full-time education beyond minimum school leaving age, but not beyond age 18y', 'continue some form of full-time education beyond age 18y', or 'uncertain')

A further two indicators of neglect were collected from the teacher at ages 7, 11 and 16y surveys;

With regard to the child's educational progress, do the mother and father appear;

- a) Over concerned about the child's progress and/or expecting too high a standard
- b) Very interested
- c) To show some interest
- d) To show little or no interest
- e) Can't say

For each survey, two binary variables were derived indicating whether each parent showed any interest in their child's education; yes ('over concerned', 'very interested' and 'some interest in education') vs. no ('little' or 'no interest'). At age 7y, over a third of teachers could not say what level of interest the father's showed in their child's education (Appendix 2.1). Sensitivity analyses were conducted using a binary variable that coded 'can't say' as missing (Appendix 2.2). The strength of association varied little between the two 'father little interest in education' measures (coding 'can't say' as: 1) not exposed or 2) missing) and outcome measures. Thus, results for 'father little interest in education' coding 'can't say' as not exposed are presented in subsequent chapters.

At ages 7 and 11y the teacher reported whether the appearance of study child was 'undernourished', 'scruffy' or 'dirty', using the Bristol Social Adjustment Guide³⁴³. Responses were used as a measure of physical neglect.

2.2.2 *Household dysfunction*

Measures of household dysfunction were identified using current WHO recommendations²⁹¹. Variables identified from the 1958 cohort encompassed substance abuse, mental illness, imprisoned household member, parental separation, parental discord and period in care (Table 2.3). Additional measures were ascertained from the literature^{32;342;344} and fell into two categories; family contact with welfare services and parenting behaviour.

Binary variables were derived for each measure indicating a positive response. Participants who did not give a clear response (i.e. 'can't say', 'don't know', 'other' etc.) were classified as having a negative response (i.e. no) (Appendix 2.3).

Substance abuse

Information on family difficulties with alcoholism ('yes', 'no', or 'don't know') was obtained from health visitor reports in the 7y survey.

At age 45y, cohort members reported whether either parent (or mother/father figure) had trouble with drinking or drug use (yes/no).

Mental illness

Two measures on the mental health status of family members were collected at age 7y; 1) any family difficulties involving mental illness or neurosis and 2) household member used the services of a psychiatric social worker ('yes', 'no', or 'don't know'). These two variables were combined to create a binary summary measure (Table 2.3).

In the 11 and 16y surveys, parents were asked;

'Has the study child since his/her 7th/11th birthday lived in the same household as anyone suffering from chronic physical or mental ill-health or disability?'

A binary variable was derived for each age and a positive response indicates that the participant had a parent with a chronic (i.e. >2 weeks) psychiatric condition.

In the 45y survey, cohort members reported whether either parent suffered from nervous or emotional trouble or depression.

Family contact with police or probation services

At age 7y, information on whether the family required the services of a probation officer ('yes', 'no', or 'don't know') was reported by the parent.

At age 11y, interviewers '*enquired or stated from their own knowledge if any member of the family has had contact with any social work, and/or welfare organisation since the child's 7th birthday, including the probation service*'.

In the 16y survey; interviewers '*enquired or stated from their own knowledge if any other member of the family, had had any contact with the police or probation officer since the child's 11th birthday*'.

At each age a binary variable was derived indicating whether the household had been in contact with the police or probation services.

Table 2.3: WHO definitions of household dysfunction and selected measures from the 1958 British birth cohort

WHO household dysfunction measures	1958 British birth cohort		
	Age (y)	Informant	Variables
Substance abuse	7 45	Health visitor Cohort member	Family difficulties with alcoholism Mother/father trouble with drinking or other drug use
Mental illness	7	Health visitor	Family difficulties with mental illness or neurosis/family visits psychiatric social worker
	11 & 16	Parent	Mother/father psychiatric chronic condition
	45	Cohort member	Mother/father suffered nervous or emotional trouble or depression
Imprisoned household member	7	Health visitor	Family required services of a probation officer
	11 & 16	Parent	Family member contact with probation services (11 & 16y)
Parental separation	7	Health visitor	Family difficulties with divorce, separation or desertion (7y)
	11 & 16	Parent	Child separated from parent because of divorce/separation (11 & 16y)
	33	Cohort member	Parents permanently separated/divorced by age 16y (33y)
Parental conflict (discord)	7	Health visitor	Family difficulties with domestic tension
	16	Cohort member	Gets on well with mother/father
	45	-	A lot of conflict/tension in household whilst growing up
Period in care (residential instability)	7, 11 & 16	Parent	In care of local authorities or voluntary organisation
Family contact with welfare services	7	Health visitor	Family required services of Children's Department/Dr Barnardo's or other children's society/NSPCC or RSSPCC
	11	Parent	Family contact with Children's Health, Welfare, Education and Social Services Department
	16	-	Child or family member contact with Social Services or Social Work Department
Parenting behaviour	45y	Cohort member	Strict, authoritarian or regimented upbringing
	-	-	Too much physical punishment: smacking, hitting etc.

Parental separation

Information on family difficulties relating to divorce, separation or desertion ('yes', 'no', or 'don't know') was reported at age 7y.

In the 11 and 16y surveys, if the study child was not living with either parent, health visitors enquired if this was because of divorce/separation (alongside other options). At age 33y, cohort members were asked if their parents had ever permanently separated or divorced, and if they had, how old they were when their parents last lived together.

Three binary measures were derived indicating if the study child was not living with a natural parent because of divorce/separation at age 7, 11 or 16y.

Parental conflict

At age 7y, information on whether there were family difficulties involving domestic tension ('yes', 'no', or 'don't know') was collected in parent interview.

At age 16y, cohort members were asked if they got on well with their mother and father ('very true', 'true', 'uncertain', 'untrue', or 'very untrue'). For each parent, a binary measure was derived, with 'very true', 'true' and 'uncertain' representing a positive response.

At age 45y, cohort members were also asked how much conflict and tension there was in their household whilst they were growing up ('a lot', 'some', 'a little', or 'none'). A binary measure was created; yes ('a lot') vs. no ('some', 'a little', or 'none').

Period in care

In the 7y survey, parents were asked;

Has the child been in the care of the local authority? ('yes, in care now', 'yes, in care only in the past, but not now', 'no, has never been in care', or 'don't know')

At age 11 and 16y, parents also responded to the following questions;

- a) Has this child ever been in the care of the Local Authority? ('yes, in care now', 'yes, in care only in the past', 'no, has never been in care', 'don't know', or 'other')
- b) Has this child ever been in the care of a Voluntary Society? ('yes, in care now', 'yes, in care only in the past', 'no, has never been in care', 'don't know', or 'other')

At each age, a binary variable was created signifying whether the child had spent time in, or was currently in the care of the local authority or a voluntary organisation (compared to never in care).

Family contact with Children's Department or charity

At age 7y, health visitors reported whether families had required the services of: 1) the Children's Department, 2) Dr Barnardo's or another children's society, or 3) the National Society for the Prevention of Cruelty to Children (NSPCC/ RSSPCC) ('yes', 'no', or 'don't know'). A binary variable was derived by combining these three variables.

At age 11y, interviewers '*enquired or stated from their own knowledge if any member of the family has had contact with any social work, and/or welfare organisation since the child's 7th birthday, including the Children's Health, Welfare, Education and Social Services Department*'.

In the 16y survey; interviewers '*enquired or stated from their own knowledge if a) the study child and b) any other member of the family, had had any contact with the Social Services or the Social Work Department*'.

At each age, a binary measure was derived indicating whether the family had been in contact any service (Table 2.3).

Parenting behaviour

Two measures were collected on parenting practices in the 45y survey;

- a) I had a strict, authoritarian or regimented upbringing /desertion ('yes', 'no', or 'don't know')
- b) I received too much physical punishment - hitting, smacking etc. /desertion ('yes', 'no', or 'don't know')

A binary variable was derived for each question. Too much physical punishment was not considered a measure of physical abuse as it included smacking, which is not legally classified as an act of physical abuse in the UK²⁸⁶.

2.3 Outcome measures – physical development

The main outcomes considered in this study were measure of child-to-adult height, adult leg length and pubertal development.

2.3.1 *Height*

Height, without shoes, was measured by trained medical personnel using a stadiometer at ages 7, 11, 16 (to the nearest inch), and 45y (to the nearest centimetre (cm)). At age 33y, study interviewers measured participant's height. Data have previously been checked to detect coding errors^{207;345}. Height at age 45y was used as adult height, and where missing was supplemented with height at age 33y. In the 45y survey, sitting height (cm) was measured. Leg length was calculated by subtracting sitting from standing height. Adult leg length measurements were excluded when the ratio

$$\frac{\text{height 45y}}{\text{sitting height age 45y}}$$
 was in the top or bottom 0.5% of the distribution (n=92)²⁰⁷. All height measurements and adult leg length were converted to cm.

The variance in height differed by age and gender; for boys variation in height was greatest at age 16y whilst for girls it was at age 11y (described in Chapter 5, Table 5.8). In order to make comparisons of the effect of childhood exposures on height at different ages and between genders, height at each age and adult leg length were converted to internally derived age and gender-specific standard deviation scores (SDS);

$$z = \frac{x - \mu}{\sigma}$$

where x is the individual observation, μ is the sample mean and σ is the sample standard deviation for each age and gender.

2.3.2 *Puberty*

Pubertal development was assessed by trained medical personnel during the medical examination and also reported by parents at ages 11 and 16y (Box 2.3 and Table 2.4).

Box 2.3: Measures of pubertal development

Boys	Girls
Age 11y; Tanner scale (range from 1 (preadolescent) to 5 (mature))*	
i. testicular development	i. breast development
ii. pubic hair growth	ii. pubic hair growth
Age 16y	
i. pubic hair growth (absent, sparse, intermediate, adult)*	i. age of menarche*†
ii. facial hair growth (absent, sparse, adult)*	
iii. whether voice had broken (yes, no)* †	

*obtained in the medical examination; †reported by parents

For boys, parents reported at what age the study child's voice broke (i.e. 'before 11th birthday', age 11, 12, 13, 14 or '15y or more', or 'not yet broken') in the 16y survey (Table 2.4). In the medical examination physicians reported whether subjects voices had broken; 'yes' or 'no'.

For girls, in the 11y survey, parents reported if their daughter had had her first menstrual period, and if so at what age (i.e. age '< 5y', '5-8y', 9y, '10-10y 6m', '10y 6m-11y', '>11y', 'yes but don't know when', 'don't know' or 'no not yet'). Age of

menarche was asked again at age 16y (age ‘<11y’, 11y, 12y, 13y, 14y or ‘≥ 15y’, or ‘don’t know’) (Table 2.4). A previous study assessed the validity of recalled data on age of menarche, and found mean age of menarche in the 1958 cohort was comparable to a similar UK study (Newcastle study)³⁴⁶.

Table 2.4: Summary of pubertal development measures in the 1958 British birth cohort

Stage of development	Pubertal development measures			
	Males; n (%)		Females; n (%)	
<i>Testicular development; 11y</i>				
Prepubescent (1)	2,410	(38.1)	2,220	(36.2)
2	2,856	(45.1)	2,199	(35.9)
3	962	(15.2)	1,259	(20.6)
4	96	(1.5)	397	(6.5)
Adult (5)	8	(0.1)	51	(0.8)
Total (n)	6,332		6,126	
<i>Pubic hair rating; 11y</i>				
Prepubescent (1)	4,017	(63.8)	2,522	(41.4)
2	2,038	(32.4)	2,223	(36.5)
3	190	(3.0)	877	(14.4)
4	44	(0.7)	430	(7.1)
Adult (5)	4	(0.1)	37	(0.6)
Total (n)	6,293		6,089	
<i>Pubic hair rating; 16y</i>				
Absent	111	(2.0)		
Sparse	537	(9.7)		
Intermediate	2,146	(38.8)		
Adult	2,731	(49.4)		
Total (n)	5,525			
<i>Facial hair rating; 16y</i>				
Absent	2,093	(37.4)		
Sparse	3,017	(53.9)		
Adult	491	(8.8)		
Total (n)	5,601			
<i>Age voice broke; 16y</i>				
≤ 11	168	(2.7)	750	(16.1)
12	457	(7.5)	1,089	(23.4)
13	1,021	(16.6)	1,551	(33.4)
14	1,678	(27.4)	924	(19.9)
≥ 15	2,812	(45.8)	332	(7.2)
Total (n)	6,136		4,646	

Previous classifications of pubertal development have depended on the study purpose and the distribution of each puberty variable (Appendix 2.4). For example, age of menarche has been used as continuous and categorical variables (age's ≤ 11 and ≥ 15 years, defined as 'early' and 'late' development respectively)³⁴⁶⁻³⁴⁹. In this study, categorical measures were derived. Categorical measures were also used as continuous measures to test for a trend (§3.3).

For pubertal development at age 11 years, Tanner scores for testicular (for boys), breast (for girls) and pubic hair development (for both) were used. Tanner scores of three to five were combined because only a small number of children reached these stages of development at age 11 years. Puberty measures were categorised as 'late' (stage 1), 'intermediate' (2) and 'early' (3 to 5) development. For pubic hair growth at age 11 years, only 3.9% (238) of boys had a Tanner score ≥ 3 . Thus, information collected at age 11 and 16 years were combined to create a summary variable (Table 2.5). Boys were categorised as 'late' developers (43.5%) if pubic hair growth was (1) rated one at age 11 years and intermediate or sparse at age 16 years; or (2) was absent at age 16 years. 'Intermediate' developers were either rated (1) one at age 11 years and adult at age 16 years; (2) two or three at age 11 years and intermediate or sparse at age 16 years; or (3) four at age 11 years and sparse at age 16 years. 'Early' developers (16.1%) were those rated (1) two or higher at age 11 years and adult at age 16 years; or (2) four or five at age 11 years and intermediate at age 16 years (Table 2.5).

Table 2.5: Number of boys classified by pubic hair development at age 11 years (Tanner stage) and ratings at age 16 years

Rating; 16y	Tanner stage; 11y					Total	Pubic hair development; %
	1	2	3	4	5		
Absent	66	12	1	-	-	79	'Late' 43.5
Sparse	340	97	4	2	-	443	'Intermediate'
Intermediate	1,158	550	32	5	-	1,746	40.4
Adult	1,290	779	103	23	4	2,199	'Early'
Missing	1,163	600	49	14	-	-	16.1
Total (n)	4,017	2,038	190	44	4	4,467	6,293

For boys, pubertal development at age 16y was measured using facial hair growth and age of voice change. A categorical variable was derived for age of voice change using parental reports and, where missing, supplemented with data from the medical examination; ‘late’ (≥ 15 y), ‘intermediate’ (13-14y) and ‘early’ (≤ 12 y). For girls, an age of menarche measure was derived using data from the medical examination at age 16y and, where missing, supplemented with parent-reports. Three categories were created; ‘late’ (≥ 14 y), ‘intermediate’ (12-13y) and ‘early’ (≤ 11 y). Girls yet to have experienced menarche by age 16y were included in the ‘late’ category (n=92).

2.4 Potential confounding factors

The observed relationship between child maltreatment, household dysfunction and physical development may be distorted by a third factor. A confounding factor is associated with the exposure (child maltreatment or household dysfunction) and also independently affects the response (e.g. height or onset of puberty). Several potential confounding factors were identified from the literature, and the corresponding variables in the 1958 cohort are described below. Results from chi-squared tests and linear regression models which examined potential confounding factors relationship with exposure and response measures are presented in Appendices 2.5-2.10, and discussed here. Factors which were significantly associated with the exposure, as well as height and pubertal measures were included in the adjusted analyses (Chapters 5 and 6).

2.4.1 Demographic characteristics

Demographic characteristics considered as potential confounding factors were *gender* and *ethnicity*. At age 33y, cohort members were asked which ethnic group they considered themselves belonging to; white, black Caribbean, black African, black other, Indian, Pakistani, Bangladeshi or Chinese. Ethnic group was also self-reported at age 42y. Categories included British, Irish, white other, white and black Caribbean, white and black African, white and Asian, other mixed race, Indian, Pakistani, Bangladeshi, other Asian, Caribbean, African, other black, Chinese or other ethnic group. Two broad categories (white and other) were derived due to small numbers of some ethnic groups. Where responses were inconsistent (n=63), the most recently reported ethnic group (age 42y) was adopted.

2.4.2 *Prenatal factors*

Maternal height (inches) was measured, without shoes, by the midwife in 1958. Where data were missing, it was supplemented with reported maternal height (inches) in 1969. Paternal height (inches) was reported (predominantly by the mother) in 1969. All height measures were converted to cm and standardised using SDS (§2.3.1). *Mid-parental height* SDS was calculated as the average height SDS of both parents. Where missing, either mother or father height SDS was used. *Maternal age of menarche* (in years) was reported by the mother in the 1969 survey. A continuous measure was used to indicate the genetic effect of pubertal timing for females, as information was rarely collected for male cohort members (missing data = 65%). *Maternal smoking during pregnancy* and *maternal age at study child's birth* was recorded in 1958. A binary variable was derived (smoker vs. non-smoker). *Birth weight* was measured in ounces and converted to grams. *Gestational age* (in days) was reported by the mothers, and converted to weeks. Pre-term was categorised as gestation of < 38 week. Mothers were asked how long they and the study child's father remained in school in 1958. *Mother and father's duration of schooling* were classified as leaving prior to the statutory school leaving age (age 14y born before April 1933, age 15y for those born subsequently) and up to, or over minimum leaving age.

2.4.3 *Early childhood factors*

Childhood factors obtained at birth or age 7y were used to ensure measures were recorded prior to, or in concordance with childhood exposure and response measures.

Social class at birth was based on the father's occupation in 1958, and where missing, was supplemented with information collected in the 7y survey. The Registrar General's classification was used: professional (I), managerial and technical (II), skilled non-manual (IIInm) and skilled manual (IIIm), semi-skilled (IV) and unskilled (V) worker^{350;351}. Four broad categories were derived; I & II, III non-manual, III manual, and IV & V. Children whose father was unemployed, sick or from lone-mother households were combined with the last group (IV & V).

Breast fed was reported in 1965 when cohort members were age 7y (not breastfed, breastfed <1 month and breastfed \geq 1 month). Exclusivity of breastfeeding was not asked. Two broad categories, never breastfed and ever breastfed, were used here.

Major disability (e.g. blindness, deafness, cerebral palsy, hydrocephalus etc.) was recorded by the medical examiner at age 7y. A binary measure (yes/no) was derived.

Body mass index (BMI) at age 7y was derived by using height in cm (converted to meters (m)) and weight (in kilograms (kg)) measured during the 7y medical examination; $BMI = \text{weight} / (\text{height} * \text{height})$.

The number of household members and number of rooms in accommodation were reported at age 7y. Number of persons per room was calculated. *Overcrowded household* was defined as ≥ 1.5 persons per room.

Housing tenure was reported at age 7y and classified as; 1) owner occupied, 2) private rental, 3) council or housing authority rental (social housing) and 4) other accommodation.

Household amenities were obtained at age 7y. The sole or shared use, or no access to a bathroom, indoor lavatory and hot water supply was established ('sole use', 'shared use', or 'no access'). An amenities score (range 0-6) was derived; a score of 6 indicating no access to a bathroom, indoor lavatory and hot water.

2.4.4 Confounding factors for height analyses

The established literature has found that child-to-adult height trajectories are influenced by genetic factors, prenatal exposures and early life socio-economic conditions^{205;208;213}.

Previous studies investigating the association between adverse childhood experiences and height growth have adjusted for parental height, birth weight and childhood diet, illness, socio-economic position (SEP) and household overcrowding^{141;144;152-154;352}. In Chapter 5, parental height, maternal smoking during pregnancy, pre-term birth, birth weight, social class at birth, breastfed and major disability, household overcrowding, housing tenure and amenity score at age 7y were considered as confounding factors for the association between adverse childhood experiences and height.

In the 1958 cohort, short parental stature was found to be associated with a history of maltreatment and household dysfunction (Appendices 2.5 – 2.7). A greater proportion of participants whose mother smoked during their pregnancy, who had a low birth weight and were born at < 38 weeks gestation reported abuse, neglect and household

dysfunction, compared to those who did not. Social class at birth, household overcrowding, housing tenure and amenities score were also related to adverse childhood experiences. A greater proportion of participants not breastfed experienced neglect and were from dysfunctional family backgrounds, than those who were breastfed. Major disability at age 7y was positively associated with childhood neglect and household dysfunction measures, although it was unrelated to retrospective reports of child maltreatment (Appendix 2.5).

Mid-parental height was positively associated with cohort member's height at age 7, 11, 16y and adult height and leg length (Appendix 2.8). Participants whose mothers smoked during pregnancy, who had a low birth weight and were born at < 38 weeks gestation, were, on average, shorter at each age, and had shorter legs in adulthood, compared to those who did not. Low social class, overcrowded households, social housing and few household amenities at age 7y were related to short childhood and adult height and adult leg length. Participants who were breastfed were, on average, taller in childhood, than those who were not breastfed. Major disability at age 7y was significantly related to height at all ages, but not adult leg length.

2.4.5 Confounding factors for pubertal development analyses

Genetic and environmental factors^{207;228-232}, as well as race and early nutrition²³³⁻²³⁵, have been shown to influence the onset of puberty. Previous studies investigating the association between adverse childhood experiences and puberty have adjusted for ethnicity, childhood SEP, level of parental education, maternal age of menarche, marriage and participants birth, and individual's BMI and height^{147;156;158-160;162;238;353-356}. In Chapter 6, ethnicity, birth weight, social class at birth, breastfeeding, major disability, household overcrowding, and maternal age of menarche (females only) were considered as confounding factors for the association between adverse childhood experiences and pubertal development. Level of parental education, maternal age at cohort member's birth were not associated with markers of pubertal development, therefore were not considered confounding factors. Although birth weight, preterm birth and BMI at age 7y were also not associated with adverse childhood experiences or pubertal development measures (Appendices 2.5-2.7), I examined their effect by including them in the adjusted models. The adjustment had little influence on the

associations, and thus they were not included as confounding factors in the final analysis.

A larger proportion of non-white participants reported child maltreatment and household dysfunction compared to white participants in the 1958 cohort (Appendices 2.5 - 2.7). Older maternal age of menarche was associated with physical abuse and several forms of neglect at age 7y (e.g. mother unaffectionate and mother hardly read, hardly any outings with parents and mother little interest in education) and household dysfunction measures (e.g. domestic tension and time in care) in females.

There was an ethnic difference in pubertal development in both boys and girls. More non-white boys compared to white boys were at advanced stages of testicular development at age 11y, developed pubic hair earlier, had adult facial hair at age 16y and were age \leq 12y when their voices broke (Appendix 2.9). A greater proportion of non-white girls had advanced breast development and pubic hair growth at age 11y, and experienced menarche at age \leq 11y compared to white girls (Appendix 2.10). For boys, low social class at birth was associated with late testicular and pubic hair development, but early age of voice change. For girls, low social class at birth was related to early and late age of menarche. Overcrowded household at age 7y was related to late pubertal development in both genders. For all markers of pubertal development in girls, late developers had an older mean maternal age of menarche compared to intermediate developers, whilst early developers had a younger mean maternal age of menarche.

2.5 Representativeness of the cohort

Generalising findings from the 1958 cohort to current British adults requires the study sample to be representative of the population. Demographically, 1958 cohort members are predominantly white, reflecting the demographic distribution of the time. An increase in immigration in recent decades has meant that the present British mid-adult population includes a range of ethnic groups³⁵⁷. Despite a concerted effort to diversify the cohort by enrolling immigrants born in the study week during childhood follow-ups, the 1958 cohort under-represents ethnic minorities³³⁸. However, the 33y sample has been shown to represent the national population with respect to several socio-economic characteristics³⁵⁸. The 45y survey has also been found to be broadly comparable with

respect to marriage status, employment and home-ownership, with contemporary British 45–49y olds³³⁸.

2.6 Missing data

Missing data are unavoidable in a longitudinal cohort study, and can lead to selection bias when the distribution of response measures among exposed and unexposed participants is dependent on whether they have complete data³⁵⁹. Selection bias may lead to spurious risk estimates of unpredictable magnitude and direction. There are three forms of missing data that affect the 1958 cohort; 1) sample attrition (i.e. permanent loss of cohort members in follow-ups), 2) wave non-response (i.e. temporary loss of cohort members in some follow-ups), 3) missing observations (i.e. participants fail to respond to specific questions). In the 1958 cohort, there was little difference between attrition and wave non-response after age 16y, as the majority of participants in later follow-ups had completed prior surveys³⁶⁰. In this section I focus on attrition and missing observations.

2.6.1 *Sample attrition*

In the 1958 cohort, the response rate for each follow-up has declined overtime and was 59% in the 45y survey. Details of the response to each survey, are given in Table 2.6, which is reproduced from Atherton et al (2007)³³⁸. Attrition due to death and emigration was greater between birth and age 7y than at other follow-ups, whilst most of the decline in adulthood was due to ‘non-response’³⁶¹. The largest loss of cohort members was between ages 16 and 23y, and corresponds with a change in the main informant, i.e. from parent to cohort member. By age 45y, there were 17,313 participants alive (total surviving cohort). Among them 12,999 were contacted and 9,377 (72.1%) took part in the biomedical survey. No attempt was made to contact 3,004 cohort members, a further 1,245 participants had died, 1,300 emigrated and 1,038 permanently refused to take part³³⁸.

A previous study of this cohort has shown that cohort members who are male, and had low reading scores, more behaviour problems, and moved more frequently in childhood were more likely to be non-respondents than others³⁶¹. Adult predictors of attrition or non-response include lower educational attainment, less stable employment patterns, lower SEP, and living with a parent³⁶¹. However, small biases were found between the original 1958 cohort and participants of the 45y sample with regard to childhood social class, housing tenure, and physical and maternal factors. Overall, the sample has been found to be broadly representative of the total surviving cohort at age 45y³³⁸.

Table 2.6: Response to 1958 British birth cohort surveys from birth to age 45y³³⁸

	Age at contact (years)							
	Birth	7y	11y	16y	23y	33y	42y	45y
Total cohort	17,638	18,016	18,287	18,558	18,558	18,558	18,558	18,558
Dead	0	812	829	862	888	992	1,120	1,245
Emigrant	0	475	702	800	1198	1,337	1,320	1,300
Eligible sample	17,638	16,729	16,756	16,896	16,472	16,229	16,118	16,013
No contact attempted	-	-	-	-	-	479	479	3,004
<i>Contact attempted</i>								
Non-respondents	223	1,304	1,419	2,242	3,935	4,282	4,220	3,622
Participants	17,415	15,425	15,337	14,654	12,537	11,468	11,419	9,377
(% of eligible sample)	98.7	92.2	91.5	86.7	76.1	70.7	70.8	58.6
(% of contact sample)	98.7	92.2	91.5	86.7	76.1	72.8	73.0	72.1

Sample attrition and childhood adverse experiences

As attrition has been associated with some demographic characteristics in the 1958 cohort^{338;361}, it is possible that the prevalence of adverse childhood experiences may differ between respondents and non-respondents of the 45y survey. To assess the effect of attrition, responses to the 7y neglect and household dysfunction measures amongst participants of the 45y follow up (n=9,377), relative to the total surviving cohort at age 45y (n=17,313) were investigated (Tables 2.7 and 2.8). The representativeness of specific groups in the 45y sample is described as a percentage bias (% bias), using the following formula^{362;363}:

$$\% \text{ bias} = \frac{\% \text{ with data at 45y} - \% \text{ total surviving cohort}}{\% \text{ total surviving cohort}} \times 100$$

For example, for neglected appearance at age 7y, the prevalence was 4.4% in participants of the 45y sample and 5.8% in the surviving cohort at age 45y. Thus, % bias is $\frac{4.4-5.8}{5.8} * 100 = -23.1\%$. A positive bias suggests an over-representation of a particular group in the 45y sample relative to the total cohort, whereas a negative bias indicates an under-representation. It has been suggested that a percentage bias greater than 10% (or less than -10%) indicates cause for concern^{358;362}. Thus, neglected appearance at age 7y was under-represented in the 45y survey.

Results indicated that neglected participants and those from dysfunctional households tended to be under-represented in the 45y sample (% bias reported for each adverse childhood experience shown in Tables 2.7 and 2.8). Neglected appearance had the largest % bias, compared to other neglect measures. There was a greater under-representation of 7y indicators of neglect, than measures reported at ages 11 and 16y (Table 2.7). For example, the % bias for 'hardly any outings with mother' at age 7y was -21.6% compared to -13.2% at age 11y. Amongst household dysfunction measures, domestic tension, alcoholism and family mental health problems reported at age 7y were under-represented in the sample of the 45y survey (Table 2.8). Large biases were associated with contact with the probation service or Children's Department and time in care reported at any age.

Table 2.7: Numbers (%) for indicators of neglect in the total sample and 45y sample

Neglect indicators	Surviving cohort at 45y; n (%)				
	Total n = 9,863-14,602	45y sample n = 5,832-8,379	Not in 45y sample n = 4,031-6,036	% Bias†	
Mother hardly reads; 7y	2,261 (16.0)	1,222 (15.0)	1,039 (17.5)	-6.5	
Father hardly reads; 7y	3,870 (28.4)	2,182 (27.6)	1,688 (29.5)	-2.7	
Hardly takes outings with mother	7y 11y	225 (1.6) 814 (6.1)	102 (1.2) 423 (5.3)	123 (2.1) 391 (7.3)	-21.6 -13.2
Hardly takes outings with father	7y 11y	817 (6.0) 1,213 (9.5)	405 (5.1) 656 (8.5)	412 (7.1) 557 (11)	-14.5 -10.3
Low parental aspirations	7y 11y 16y	613 (4.3) 720 (5.4) 4,098 (36.1)	277 (3.4) 351 (4.4) 2,290 (32.4)	336 (5.6) 369 (6.8) 1,808 (42.0)	-21.7 -18.5 -10.1
Mother little interest in education	7y 11y 16y	2,155 (14.8) 1,856 (13.7) 1,931 (17.0)	1,042 (12.4) 938 (11.8) 983 (14.2)	1,113 (17.9) 918 (16.5) 948 (21.2)	-15.7 -14.1 -16.2
Father little interest in education	7y 11y 16y	2,250 (15.5) 2,276 (17.6) 1,996 (18.8)	1,128 (13.4) 1,163 (15.2) 1,042 (16.0)	1,122 (18.1) 1,113 (21.1) 954 (23.1)	-12.6 -13.7 -14.6
Neglected appearance	7y 11y	597 (5.8) 548 (5.6)	264 (4.4) 258 (4.4)	333 (7.6) 290 (7.2)	-23.1 -20.4

†Percentage bias ((45y sample% - total surviving cohort%)/total surviving cohort%); positive bias represents an overrepresentation of the characteristic in the sample relative to the total cohort, negative bias an underrepresentation).

Table 2.8: Number (%) for household dysfunction measures in the total sample and 45y sample

Measures of household dysfunction	Surviving cohort at 45y; n (%)			
	Total n = 11,124-15,053	45y sample n = 6,897-8,740	Not in 45y sample n = 3,204-6,459	%Bias†
Domestic tension; 7y	740 (5.2)	359 (4.4)	381 (6.3)	-15.8
Alcoholism; 7y	125 (0.9)	58 (0.7)	67 (1.1)	-19.3
Household member mental health problems; 7y	660 (4.6)	312 (3.8)	348 (5.8)	-18.8
Mother mental health problem	11y 16y	241 (1.6) 169 (1.2)	142 (1.6) 86 (1.0)	99 (1.6) 83 (1.4)
Father mental health problem	11y 16y	116 (0.8) 169 (1.2)	68 (0.8) 48 (0.6)	48 (0.8) 39 (0.7)
Did not get on well with mother; 16y		591 (5.1)	335 (4.7)	256 (5.8)
Did not get on well with father; 16y		886 (8.0)	524 (7.6)	362 (8.6)
Contact probation services	7y 11y 16y	245 (1.9) 285 (1.9) 458 (3.2)	106 (1.4) 128 (1.4) 255 (3.0)	139 (2.6) 157 (2.6) 203 (3.5)
Contact Children Department	7y 11y 16y	605 (4.6) 241 (1.6) 460 (3.2)	270 (3.5) 109 (1.2) 217 (2.5)	335 (6.0) 132 (2.1) 243 (4.3)
Time in care	7y 11y 16y	297 (2.0) 453 (3.0) 442 (4.0)	146 (1.7) 222 (2.5) 202 (2.9)	151 (2.3) 231 (3.7) 240 (5.6)
Parents divorced	7y 16y	567 (4.2) 1,560 (13.5)	266 (3.4) 882 (10.6)	301 (5.2) 678 (21.2)

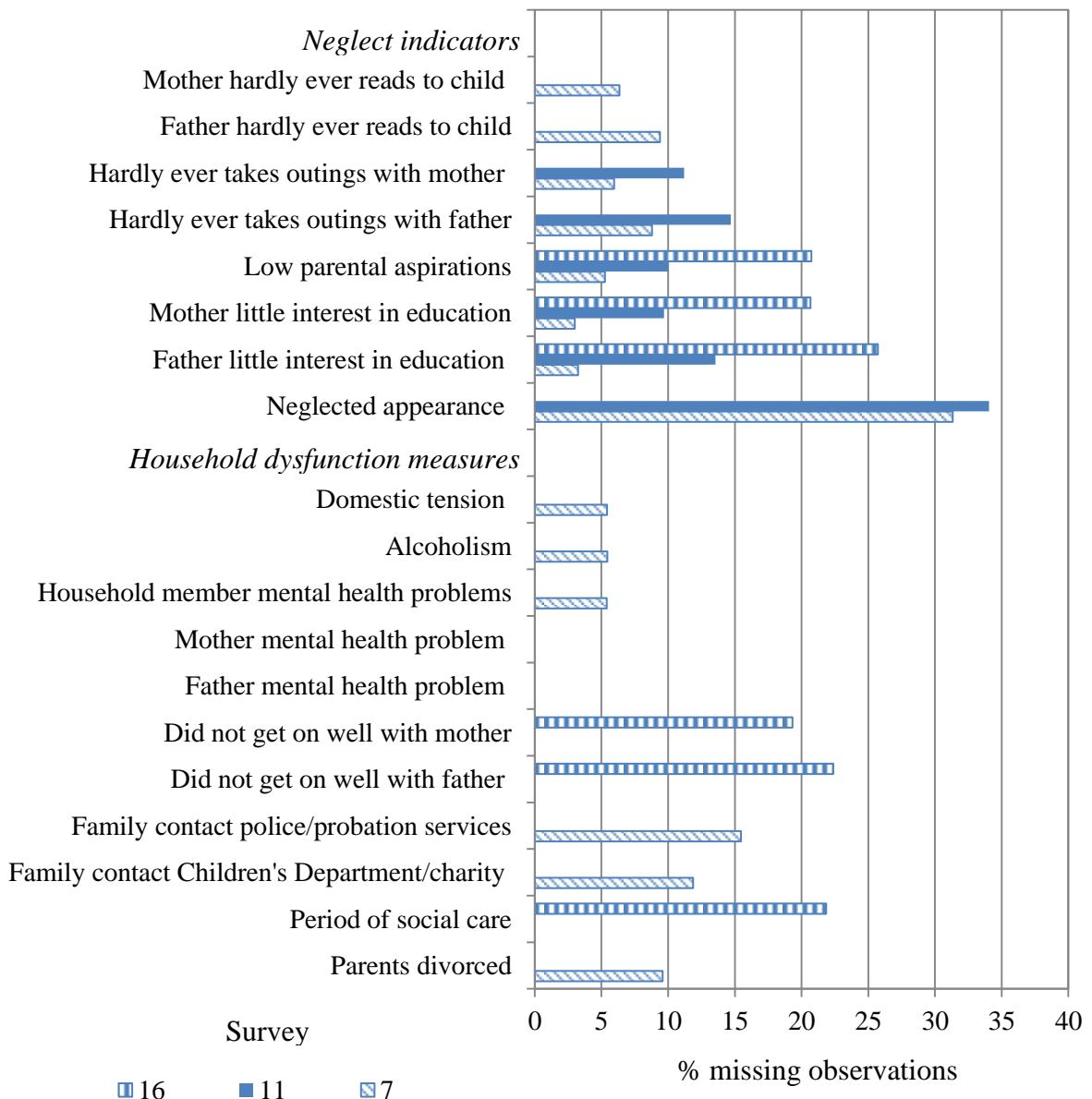
†Percentage bias ((45y sample% - total surviving cohort%)/total surviving cohort%); positive bias represents an overrepresentation of the characteristic in the sample relative to the total cohort, negative bias an underrepresentation).

2.6.2 *Missing observations*

In each survey, a proportion of participating cohort members had missing observations for some variables, i.e. child maltreatment and household dysfunction. Responses to adverse childhood experiences reported in childhood are shown in Figure 2.1. For indicators of neglect, the proportion of missing observations appeared to increase with each follow-up. For example, missing responses for father little interest in education was 3.2% at age 7y, increasing to 13.5% at age 11y and 25.7% at age 16y. The highest proportion of missing responses was for neglected appearance: around a third of cohort

members had missing data. Missing observations were also present in household dysfunction measures collected at ages 7 and 16y (Figure 2.1). The proportion of missing data for 7y measures ranged from 5.4-15.5%. The largest proportion of missing observations were for did not get on well with mother (19.3%) and father (22.4%) and time in care (21.8%) at age 16y.

Figure 2.1: Proportion of missing data for indicators of neglect and household dysfunction measures at 7, 11 and 16y



Total number of participants in each survey alive at age 45y; 7y 15,053, 11y 14,956, 16y 14,331; mother/father mental health problem were collected at age 11y

At age 45y, there was a high response rate to the confidential early life experiences questionnaire; of the 9,377 cohort members who took part in the survey, 99.3% (9,310) completed the questionnaire.

Demographic characteristics and non-respondents to adversity measures

Demographic characteristics of cohort members with data for each child maltreatment and household dysfunction measure were compared to those participating in the childhood survey and alive at age 45y, using % bias, as shown in §2.5.1. Demographic and childhood characteristics used were identified by Atherton et al include gender, ethnicity, social class at birth and cognitive ability at age 7y (additional information on measures in Appendix 2.11)³³⁸. Overall, there was only a small under-representation of adverse childhood experiences with respect to demographic characteristics (Tables 2.9 and 2.10 for 7y measures and Appendices 2.12-2.13 for 11 and 16y measures).

Indicators of neglect were under-represented amongst participants from lone-mother households and those who had spent time in care. In particular, large biases were found in father related neglect measures at age 7y, e.g. % bias for 'father hardly reads' was -90.2% for lone-mother household, and -15.4% for time in care (Table 2.9). Non-white cohort members were also under-represented in neglect measures collected at age 11y ('mother/father hardly any outings' and low parental aspirations (Appendix 2.12)) and 16y (low parental aspirations and 'father little interest in education' (Appendix 2.13)). Small biases were found for gender, maternal education, birth weight, and housing tenure, cognition, behaviour and physical stature at age 7y.

Household dysfunction measures collected at age 7y were also under-represented in cohort members from lone-mother households and those who had spent time in care. For example, moderate biases were associated with contact with probation services and lone-mother household (-13.6%) and time in care (-11.8%) (Table 2.10). Household dysfunction measures at age 16y under-represented non-white participants and cohort members with a low reading score at age 7y (Appendix 2.14). Overall, participants with complete information on household dysfunction were representative of the total cohort.

Table 2.9: Demographic characteristics and response to 7y indicators of neglect (% bias)

Demographic and social characteristics		7y indicators of neglect (% bias)								
		Total* (%) (n=15,053)	Mother hardly reads	Father hardly reads	Mother hardly outings	Father hardly outings	Low parental aspirations	Mother little interest in education	Father little interest in education	Neglected appearance
Gender	Male	7,680 (51.0)	0.1	0.0	0.1	0.0	0.1	0.1	0.0	-3.6
	Female	7,373 (49.0)	-0.1	0.0	-0.1	0.0	-0.1	-0.1	0.0	3.7
Ethnicity	White	13,523 (92.7)	0.4	0.6	0.4	0.6	0.3	0.1	0.1	0.5
	Non-white	1,073 (7.4)	-5.1	-7.1	-4.8	-7.2	-4.2	-1.4	-1.4	-6.1
Social class at birth	Non-manual	4,413 (31.1)	-0.1	2.6	0.1	2.6	-0.1	-0.6	-0.5	3.5
	Manual	9,370 (66.1)	0.1	2.7	0.0	2.7	0.0	0.3	0.3	-1.3
	Lone-mother	404 (2.9)	-0.3	-91.6	0.1	-90.2	0.1	-1.0	-1.7	-6.9
Mothers duration of schooling	>Statutory age	3,609 (24.9)	0.0	0.6	0.2	0.8	0.0	-0.2	-0.2	3.5
	≤ Statutory age	10,869 (75.1)	0.0	-0.2	-0.1	-0.3	0.0	0.1	0.1	-1.2
House tenure (7y)	Owned	6,012 (42.3)	0.1	1.3	0.2	1.4	0.0	-0.3	-0.1	2.0
	Rented	8,189 (57.7)	-0.1	-0.9	-0.1	-1.1	0.0	0.2	0.1	-1.5
Hospitalisation (7y)	No	7,656 (54.2)	0.2	0.2	0.2	0.4	0.1	0.4	0.4	1.0
	Yes	6,477 (45.8)	-0.3	-0.3	-0.2	-0.4	-0.1	-0.4	-0.4	-1.2
Period of social care (7y)	No	14,756 (98.0)	0.2	0.3	0.2	0.3	-0.1	0.1	0.1	0.0
	Yes	297 (2.0)	-8.8	-15.4	-7.8	-16.4	2.9	-4.7	-4.7	-1.2
Internalising problems at 7y	Normal	7,901 (54.2)	0.5	1.0	0.5	0.9	0.3	0.2	0.2	4.5
	Borderline	4,628 (31.8)	-0.6	-1.0	-0.6	-0.8	-0.6	-0.3	-0.2	-5.4
	Problem	2,039 (14.0)	-0.5	-1.6	-0.6	-1.8	-0.1	-0.1	-0.2	-5.5

Demographic and social characteristics		7y indicators of neglect (% bias)								
		Total* (%) (n=15,053)	Mother hardly reads	Father hardly reads	Mother hardly outings	Father hardly outings	Low parental aspirations	Mother little interest in education	Father little interest in education	Neglected appearance
Externalising problems at 7y	Normal	6,454 (44.3)	0.7	1.3	0.7	1.4	0.5	0.1	0.2	2.0
	Borderline	6,224 (42.7)	-0.1	-0.6	-0.2	-0.7	-0.3	0.0	-0.1	-1.8
	Problem	1,889 (13.0)	-2.0	-2.4	-1.8	-2.8	-0.9	-0.3	-0.4	-1.1
Reading score (7y)	Normal	13,661 (90.8)	0.4	0.6	0.4	0.4	0.6	-0.1	-0.1	0.5
	Low	1,392 (9.3)	-3.7	-5.4	-3.8	-3.8	-5.4	1.1	1.1	-4.5
Maths score (7y)	Normal	13,025 (89.6)	0.0	-0.2	-0.1	-0.2	0.0	0.0	0.0	-1.1
	Low	1,512 (10.4)	0.0	1.5	0.6	1.4	0.0	0.1	0.2	9.1
Low birth weight	Normal	14,376 (95.5)	0.1	0.2	0.1	0.2	0.1	0.0	0.0	0.0
	Low (<2500g)	677 (4.5)	-1.7	-3.7	-1.7	-4.4	-1.7	-0.2	0.1	-0.8
Short stature (7y)	No	12,202 (91.6)	0.1	0.2	0.1	0.2	0.4	0.1	0.1	0.2
	Yes	1,113 (8.4)	-0.6	-1.8	-0.6	-2.0	-4.1	-1.3	-1.0	-2.6
Overweight (7y)	No	11,977 (87.7)	0.1	0.3	0.1	0.1	0.0	0.1	0.0	0.5
	Yes	1,678 (12.3)	-0.9	-1.8	-0.8	-1.0	-0.2	-0.4	-0.2	-3.7
Smoking in pregnancy	No	9,605 (66.9)	0.3	0.7	0.3	0.8	0.2	0.1	0.05	0.8
	Yes	4,746 (33.1)	-0.7	-1.4	-0.6	-1.5	-0.4	-0.1	0.09	-1.5
Breast fed (7y)	No	4,466 (31.6)	-0.4	-1.0	-0.3	-1.1	0.1	-0.2	0.01	0.3
	≥ 1 month	9,683 (68.4)	0.2	0.4	0.1	0.5	0.0	0.1	0.01	-0.1

Percentage bias ((sample with complete indicator of neglect % - total 7y cohort%)/total 7y cohort%); positive bias represents an overrepresentation of the characteristic in the sample relative to the total cohort, negative bias an underrepresentation). *Total cohort includes participants of the 7y and alive at age 45y

Table 2.10: Demographic characteristics and response to 7y household dysfunction measures (% bias)

Demographic and social characteristics		7y household dysfunction measures (% bias)						
		Total* (%) (n=15,053)	Domestic tension	Alcoholism	Mental health problem	Contact probation service	Contact children department	Parent divorced
Gender	Male	7,680 (51.0)	0.1	0.1	0.1	-0.3	-0.3	-0.1
	Female	7,373 (49.0)	-0.1	-0.1	-0.1	0.4	0.3	0.1
Ethnicity	White	13,523 (92.7)	0.3	0.3	0.3	0.4	-0.3	0.4
	Non-white	1,073 (7.4)	-4.2	-4.1	-4.1	-5.3	-3.8	-4.4
Social class at birth	Non-manual	4,413 (31.1)	-0.3	-0.3	-0.4	2.0	0.1	0.0
	Manual	9,370 (66.1)	0.2	0.2	0.2	-0.3	0.2	0.0
	Lone-mother	404 (2.9)	-1.0	-0.6	-0.6	-13.6	-6.2	-1.0
Mothers duration of schooling	>Statutory age	3,609 (24.9)	-0.1	-0.1	-0.2	2.3	0.5	0.3
	≤ Statutory age	10,869 (75.1)	0.0	0.0	0.1	-0.8	-0.2	-0.1
House tenure (7y)	Owned	6,012 (42.3)	-0.1	-0.1	-0.1	1.7	-0.2	0.2
	Rented	8,189 (57.7)	0.1	0.1	0.1	-1.3	0.2	-0.2
Hospitalisation (7y)	No	7,656 (54.2)	0.2	0.2	0.2	0.0	-0.2	0.0
	Yes	6,477 (45.8)	-0.2	-0.2	-0.2	-0.2	0.2	0.0
Period of social care (7y)	No	14,756 (98.0)	-0.1	0.0	-0.1	0.2	-0.2	0.0
	Yes	297 (2.0)	2.4	1.9	2.4	-11.8	10.5	-1.2
Internalising problems at 7y	Normal	7,901 (54.2)	0.3	0.3	0.3	1.4	0.6	0.4
	Borderline	4,628 (31.8)	-0.3	-0.4	-0.3	-1.0	-0.5	-0.1
	Problem	2,039 (14.0)	-0.3	-0.3	-0.3	-2.8	-1.3	-1.2

Demographic and social characteristics		7y household dysfunction measures (% bias)						
		Total* (%) (n=15,053)	Domestic tension	Alcoholism	Mental health problem	Contact probation service	Contact children department	Parent divorced
Externalising problems at 7y	Normal	6,454 (44.3)	0.4	0.4	0.4	2.0	1.0	0.6
	Borderline	6,224 (42.7)	-0.2	-0.3	-0.2	-0.7	-0.4	0.0
	Problem	1,889 (13.0)	-0.7	-0.7	-0.7	-4.5	-2.1	-2.0
Reading score (7y)	Normal	13,661 (90.7)	0.3	0.3	0.3	0.9	0.5	0.4
	Low	1,392 (9.3)	-2.9	-3.0	-2.8	-9.2	-5.0	-4.1
Maths score (7y)	Normal	13,025 (89.6)	0.0	0.0	0.0	-0.3	-0.1	0.0
	Low	1,512 (10.4)	-0.2	-0.2	-0.2	2.8	1.0	0.4
Low birth weight	Normal	14,376 (95.5)	0.1	0.1	0.1	0.2	0.1	0.1
	Low (<2500g)	677 (4.5)	-1.5	-1.5	-1.7	-4.8	-2.2	-2.8
Short stature (7y)	No	12,202 (91.6)	0.0	0.0	0.0	0.3	0.0	0.0
	Yes	1,113 (8.4)	-0.2	-0.2	-0.1	-3.1	-0.1	0.4
Overweight (7y)	No	11,977 (87.7)	0.0	0.0	0.0	0.0	0.0	0.0
	Yes	1,678 (12.3)	-0.3	-0.3	-0.2	-0.2	-0.1	-0.2
Smoking in pregnancy	No	9,605 (66.9)	0.2	0.2	0.2	1.1	0.4	0.3
	Yes	4,746 (33.1)	-0.3	-0.4	-0.3	-2.1	-0.9	-0.6
Breast fed (7y)	No	4,466 (31.6)	0.0	0.0	0.0	-0.4	0.0	0.0
	≥ 1 month	9,683 (68.4)	0.0	0.0	0.0	0.2	0.0	0.0

Percentage bias ((sample with complete household dysfunction measure% - total 7y cohort%)/total 7y cohort%); positive bias represents an overrepresentation of the characteristic in the sample relative to the total cohort, negative bias an underrepresentation). * Total cohort includes participants of the 7y survey and alive at age 45y

2.7 Summary

The 1958 cohort is a unique dataset to investigate the influence of adverse childhood experiences on physical development, in order to better understand the long-term effects of child maltreatment and household dysfunction on adult health. To my knowledge, the 1958 cohort is the first non-clinical study with nationwide coverage in the UK with data on a wide range of adverse childhood experiences and measures of physical development.

A major strength of the study is the multiple measures of child maltreatment and household dysfunction collected both in childhood and adulthood from multiple informants. Prospective adverse childhood experiences measures were collected using parent and teacher reports, whilst retrospective reports were ascertained from cohort members. Each method has their own limitation: information from parents may be influenced by socially desirable responding and concealment³⁶⁴, whereas self-reports may be affected by recollection or current social, physical or psychological conditions³⁶⁵. It has been suggested that a wide range of measurements on adverse childhood experiences, both prospective and retrospective, from multiple informants, strengthens a study by minimising the risk of misclassification³²⁴. Thus the range of measures available in the 1958 cohort increases the likelihood of identifying all cases of child maltreatment and household dysfunction.

It is possible that available measures do not correspond with the conventional definitions of child maltreatment. For example, in the 1958 cohort witnessing abuse of a family member includes physical and sexual abuse, whereas Gilbert et al use a broader definition of intimate-partner violence which encompasses psychological abuse²⁹. In addition, some childhood measures reflect less severe adversities (i.e. parents hardly ever read or take study child on any outings) that, on their own, do not necessarily signify neglect, but indicate a decreased level of parental emotional involvement. Thus in the analyses, instead of only relying on single items, scores have been derived to reflect the burden of neglect in the cohort. Additional measures of household dysfunction, identified in the literature, may not fully correspond with the negative attributes associated with household dysfunction. For example, contact with a welfare service may denote help seeking behaviour. However, contact with a charity or

children's organisation does indicate that the family was in difficulty, although from the data it is not possible to determine whether the family contacted the organisation or were identified by outside sources. Thus, here it is used as a marker of family difficulty. Strict parenting may be authoritative, which characterizes good parenting, rather than authoritarian³⁶⁶. As strict upbringing was classified as authoritarian in the question, and was strongly correlated with 'too much physical punishment' ($r=0.56$; p -value <0.001) it was viewed as a negative parenting attribute here. The adequacy of measures on adverse childhood experiences is further discussed in Chapter 4.

Most importantly from a public health perspective, the study contains prospective markers of physical development. Repeated measurements of height were recorded by trained personnel from early childhood through to adulthood, and multiple measures of pubertal development were collected at two ages for males and females. Therefore, unlike previous studies, the influence of adverse childhood experiences on height at different ages, and pubertal development in both genders could be explored. The prospective nature of the data ensures that measures of physical development were recorded in a timely fashion, in contrast to retrospective data collection which may be affected by recall bias. Measurements were collected using verified methods, and for pubertal development, the gold standard had been adopted, i.e. physical examination by trained medical personal using Tanner scores³⁶⁷.

However, there are some limitations of the data. The widely spaced intervals between follow-ups prevent investigation of the effect of child maltreatment and household dysfunction on physical development between surveys. Thus critical periods, such as peak height velocity or age at onset of puberty have been missed. Nevertheless, the 1958 cohort is an important study in which to investigate the influence of early life exposures on physical development. In particular, the study allows trajectories of linear growth and the onset of puberty to be investigated, which in turn will advance understanding on the long-term health consequences of adverse childhood experiences.

In a longitudinal study, like the 1958 cohort, where data has been collected over fifty years, there are unavoidable missing data issues. The achieved sample has reduced from 18,558 participants at age 16y to 9,377 in the biomedical survey, when information on adverse childhood experiences was collected. Selection bias, mainly

due to attrition, and to a lesser extent missing observations, may affect results, as participants identified as neglected, or from dysfunctional family backgrounds, were more likely to be lost to follow-up by age 45y. Participants who had spent time in social care are particularly vulnerable to biases associated with missing data, as they are more likely to have experienced adverse childhood experiences than others³⁶⁸. However, the 45y sample did not differ from the original sample, or a nationally representative sample, with respect to several key factors^{338;358}. In addition, a wide range of demographic measures are available in the 1958 cohort, thus factors associated with missing data could be examined. Methods used to reduce possible bias associated with missing data and increase the precision of prevalence estimates are discussed in Chapter 3.

3 Statistical methods

This chapter describes statistical methods applied in subsequent chapters to address the main objectives of this thesis. Strengths and limitations of each method, where appropriate, are discussed. All statistical analyses were conducted using STATA versions 10-11³⁶⁹, Latent GOLD version 4.5³⁷⁰, or MLwiN version 2.22³⁷¹.

3.1 Literature review

For each aim, a literature review was undertaken to explore the available evidence in mostly primary studies. Online databases (PubMed, Scopus) were searched to identify articles which assessed the association between child maltreatment, household dysfunction and 1) height; and 2) puberty. Review articles were also cross-referenced. Information from studies identified, such as study design, participants year of birth, sample size, main exposure and outcome measures, adjustment and main findings, are presented in tables in the relevant chapter.

Limitations of a non-systematic review include the lack of transparency and replicability. In comparison a systematic review provides an explicit statement of objectives and materials and is conducted according to a reproducible methodology. A well-defined review protocol, search strategy and inclusion and exclusion criteria reduce the risk of selective sampling of studies. A systematic, compared to a non-systematic, literature review also affords a greater degree of confidence that the literature has been exhaustively and systematically searched³⁷². However, systematic reviews are a lengthy process, and due to time constraints, non-systematic reviews were conducted for this thesis³⁷³. This approach gave greater scope to identify useful studies that may have fallen outside a search framework, such as older studies and those conducted in different population, i.e. international adoptees

3.2 Prevalence and co-occurrence of child maltreatment and household dysfunction

The prevalence of each form of child abuse and each indicator of neglect and household dysfunction were estimated in Chapter 4. Gender differences in prevalence estimates were compared using chi-squared tests. Latent Class Analyses (LCA) and logistic regression models for binary and multinomial response variables were applied to assess whether different forms of child maltreatment (abuse and neglect) and household dysfunction co-occurred. As described in Chapter 2, measures of child abuse, neglect and household dysfunction were reported at different ages and their response rates differed. The estimated prevalence of adverse childhood experiences could be biased when missing data are not completely at random (MNAR). Below I describe statistical approaches used to minimise the bias associated with missing data (§3.1.1) and identify patterns of co-occurrence of childhood maltreatment (§3.1.2).

3.2.1 Methods for missing data problems

Responses for child maltreatment and household dysfunction measures: Retrospective measures of child maltreatment and household dysfunction were collected at age 45y from 9,310 individuals. Participants of the 45y survey differed from non-participants with respect to prospective neglect and household dysfunction measures (as discussed in §2.6). Prospective indicators of neglect and household dysfunction were available from 11,202 to 15,583 participants. Among them, 6,294 had complete data for all 18 measures of child maltreatment. Different response rates may affect prevalence estimates as participants with complete data may differ in the outcome measure from those with missing data (selection bias).

To reduce the possible bias due to attrition and missing data, I applied multiple imputation and compared prevalence estimates in four different samples (Figure 3.1);

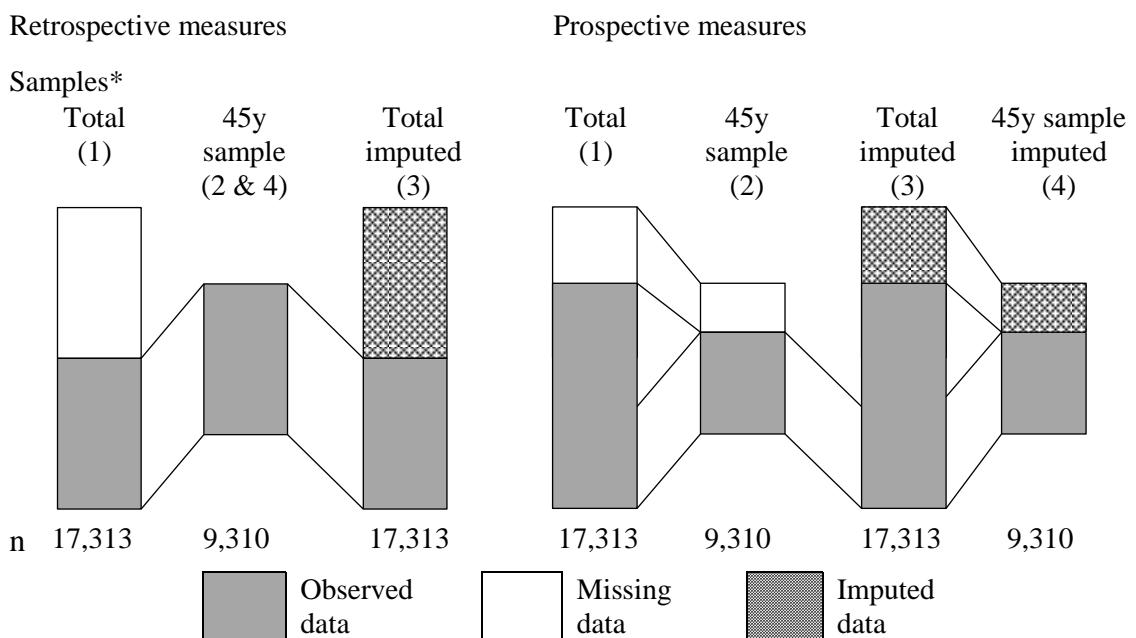
Sample 1: participants in the original birth cohort alive at age 45y (n=9,310 for retrospective measures and 11,202 - 15,583 for prospective measures);

Sample 2: participants of the 45y survey (n = 9,310 for retrospective measures and 6,852 – 8,868 for prospective measures);

Sample 3: participants in the original birth cohort alive at age 45y, missing data imputed (n=17,313);

Sample 4: participants of the 45y survey; missing data imputed (n = 9,310)

Figure 3.1: Data samples used to estimate prevalence and co-occurrence of child maltreatment and household dysfunction



Graphical representation of data in each sample; *Data samples; 1) participants alive at age 45y, 2) participants of the 45y survey, 3) participants alive at age 45y with imputed data, and 4) participants of the 45y survey with imputed data.

Multiple imputation; There are several missing data mechanisms (Box 3.1). In an imputation model all partially observed variables are treated as response variables and data are assumed to be missing at random (MAR), conditional on some given covariates. These covariates should include variables that predict the probability of missingness³⁷⁴ and also the values of response measures³⁷⁵. First, multiple copies of the dataset are generated, and missing values are replaced by imputed values using the chained equation method³⁷⁶. To account for the uncertainty in calculating missing values, the imputed figures are selected from their predictive distribution based on the observed data (average within-imputation variance). Second, the model of interest (i.e. the model to estimate prevalence of a maltreatment measure) is fitted to each imputed dataset, and results are combined using Rubins combination rules³⁷⁷. This accounts for the variability in results between the imputed datasets, and thus the uncertainty associated with the missing values (between-imputation variance)³⁷⁸.

Box 3.1: Missing data mechanisms

Missing completely at random (MCAR) assumes that the probability of an observation being missing is unrelated to both the unobserved value itself, and values of other variables in the dataset. Thus there are no systematic differences between the missing and observed values.

Missing at random (MAR) assumes that the probability of an observation being missing can be predicted by other observed measurements and is unrelated to the unobserved value itself after controlling for other variables in the analyses.

Missing not at random (MNAR) assumes that missing data are systematically different to the observed data, even after accounting for observed data. In such cases, the reason for values being missing is dependent on the unseen observations themselves.

Advantages and methodological issues of multiple imputation: The main advantages of multiple imputation are that it maximises power by retaining all observed data, whilst correcting for selection bias by including all the predictors of missing data in the imputation model³⁷⁹. Unlike other ad-hoc methods, or a single imputation model, multiple imputation accounts for the uncertainty associated with estimating missing values, thus increasing the precision of estimates³⁸⁰. Furthermore, multiple imputation has been shown to be robust in departures from normality assumptions, and provides adequate results for small sample sizes³⁷⁹.

However, it is not possible to verify the MAR assumption required by multiple imputation, although similar results in the complete and multiple imputation analyses

may indicate that the MAR assumption is likely to have been met³⁸⁰. Even when estimates obtained from the two analyses differ, multiple imputation is an improvement on complete data analyses as it adjusts for missing data patterns^{381;382}. There is a debate about the upper limit of missing data which can be imputed and still provide reliable estimates. Multiple imputation tends to give less biased results compared to complete data analyses, in studies where 50-80% of participants have missing observations³⁸³⁻³⁸⁵. The STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) Statement advises that if a large fraction of the data are imputed, observed and imputed values should be compared³⁸⁶.

In Chapter 4, I applied multiple imputation for child maltreatment and household dysfunction measures to a target sample of all participants alive at age 45y (n=17,313). Variables found to be associated with the probability of missing observations were identified previously by Atherton et al³³⁸. These measures were used in the imputation model; ethnicity, social class at birth, lone-mother household and reading ability at age 7y. Child maltreatment and household dysfunction measures were also incorporated in the imputation model, as they predicted missingness and were used in subsequent analyses. The relationship between child maltreatment and household dysfunction measures were assessed using complete and multiply imputed datasets. These results were compared to indicate if MNAR was present. Findings were similar, and analyses from the complete dataset are presented (Chapter 4).

3.2.2 *Latent class analysis*

In Chapter 4, I applied LCA to investigate the co-occurrence of child maltreatment measures and identify distinct groups. Unlike traditional data reduction methods, such as factor analysis, LCA identifies typologies of people, rather than a categorisation of variables³⁸⁷. In LCA, unobserved (latent) classes are ascertained by maximising the similarity of observed responses within classes, whilst optimising the difference in observed responses between classes³⁸⁸. Probability models are fitted and class parameters are estimated using the Maximum Likelihood method³⁸⁸. The Full Information Maximum Likelihood (FIML) is also used to estimate parameters so that participants with missing observations for some observed variables can be included in the model. The LCA provides estimates for 1) the latent class probability (proportion of

participants in a given class) and 2) the conditional response probability (probability of a positive response for an observed variable, i.e. physical abuse)³⁸⁹. Each participant is assigned a probability of belonging to each latent class (posterior membership probability), based on their response patterns. Individuals are allocated to the class with the highest membership probability. Models are fitted with the assumption that observed variables within the same latent class are correlated, each latent class is mutually independent within each model, and that data are MAR^{388;390;391}. A strength of LCA is that observed binary measures can be incorporated into the model, and a simple categorical measure can be derived and employed in subsequent analyses³⁹².

Model fit can be assessed using several diagnostic tests³⁹². Entropy, an aggregate of the posterior probabilities, assesses whether participants have been accurately classified into a latent class. A high entropy (i.e. >80%) indicates a large proportion of the sample were correctly classified given the specified model³⁸⁷. The log-likelihood (LL) Akaike Information Criteria (AIC) and Bayesian Information Criterion (BIC) test the fit of the model, accounting for number of parameters used and sample size (BIC only). The LL statistics assume data to be MAR, and a lower AIC and BIC indicate a better fit³⁹³. Class error estimates the probability of cohort members being categorised into the wrong latent class, with a value closer to 0 indicating better assignment of subjects to classes. To determine the optimal number of latent classes, the Bootstrapped Likelihood Ratio Test is used to compare models (i.e. three vs. two-class model). A significant test indicates that the more complex model (i.e. three-class) provides a superior fit to the data than a less complex model (i.e. two-class). Interpretation of the derived classes is also important, as those which identify only a small number of subjects are not meaningful. Thus each class in a given model should be comprised of at least 1% of the sample³⁹².

In Chapter 4, LCA models were fitted to all 15 child maltreatment measures to examine patterns of response. One-class to nine-class models were fitted to the data. The final model was selected based on the goodness-of-fit statistics.

Maltreatment (and household dysfunction) measures at all ages in childhood were used for assessing co-occurrence in Chapter 4. In Chapters 5 and 6, I used prospective neglect and household dysfunction measures that were collected prior to, or in

concurrence with height and puberty measurements. Therefore, an LCA model was also fitted to the seven retrospective maltreatment measures and eight indicators of neglect reported at age 7y only (Appendices 4.4 and 4.5).

3.2.3 *Generalised linear models*

Logistic regression models: In Chapter 4, the relationship between each binary child maltreatment (response) and household dysfunction measure (exposure) was investigated using logistic regression models. The association between the response and exposure variable is expressed in terms of odds ratio (OR); the odds of a positive response (outcome) for a unit increase in the exposure measure. The 95% confidence intervals (CI) are estimated, and a Wald test is used to determine whether there is a significant association.

Multinomial logistic regression: In Chapter 4, multinomial logistic regression models were used to examine the relationship between household dysfunction and the categorical latent class variable obtained from the LCA (3.1.2). Multinomial logistic regression is an extension of standard logistic regression by allowing more than two discrete outcomes. Thus, several $(k-1)$ logistic regression models are estimated simultaneously, each using a designated reference category (k is the number of categories of the response). Relative risk ratios (RRR) and 95% confidence intervals (CI) can be estimated.

In Chapter 4, I applied logistic and multinomial logistic regression models to examine the relationship between different forms of child maltreatment and household dysfunction. In all models, the interaction between each exposure and gender were examined. Potential confounding factors were included in the models to examine whether there was an independent association between the exposure and outcome.

3.3 Statistical methods for repeated height measurements

In Chapter 5, I investigated the association between adverse childhood experiences (child maltreatment and household dysfunction) and height trajectories. Issues surrounding the analysis of longitudinal measures for height are discussed in §3.2.1. The difference in height at each age between participants who were exposed to child maltreatment and household dysfunction, and those who were not, were estimated using multivariate response models (§3.2.2). The difference in adult leg length between exposed and unexposed cohort members was estimated using linear regression models (§3.2.3).

3.3.1 *Issues of longitudinal data*

In this study, height of each cohort member at four occasions was used; age 7, 11, 16y and adulthood. Longitudinal measures of height are highly correlated within individuals and these correlations need to be accounted for in the analyses. For example, height at age 16y is strongly correlated with height at age 11y ($r=0.83$ for males and 0.72 for females) and with final height ($r=0.73$ and 0.67, respectively).

In addition, the mean and standard deviation (SD) of height differed by age and gender. In the 1958 cohort, SD of height was greater in boys at age 16y (SD=6.9cm) compared to that in girls at age 16y (SD=6.2cm), and that in boys at age 7y (SD=5.8cm) (Table 5.8). To allow direct comparisons across age and gender, height at each age and adult leg length was standardised using age and gender-specific standard deviation scores (SDS) as shown in §2.3.1. For all ages and both genders, height SDS and adult leg length SDS had an approximate normal distribution with mean zero and SD of one.

3.3.2 *Multivariate response models*

Repeated height SDS measures were analysed using multivariate response models. In a multivariate response model, each outcome measure (i.e. height SDS at each age) is considered a response, and fitted with a regression function. All responses are modelled simultaneously. The correlations between responses are accounted for by specifying the covariance matrix. Model parameters are estimated using iterative generalised least square method (IGLS). Wald tests are used to determine whether there is a significant

association. As response models are jointly fitted, differences in the effect of the exposure on each response can be tested using a contrast test³⁹⁴.

As a multivariate response model accounts for the hierarchical structure of the data (i.e. within-individual correlations), it can also be considered a multi-level model, where response observations (height measurements) are level-one units, nested within individuals (level-two units). As with other multi-level models, estimates from a multivariate response model are statistically efficient even where some responses are missing on one or more occasions. The estimates of model parameters are unbiased when measurements are MAR³⁹⁴.

Alternative models: Other multi-level models used for repeated height measurements include growth models with random effects, which are useful when there are a sufficient number of observations for each individual. As in multivariate response models, observations (level-one units) are clustered within individuals (level-two units). The response measure are characterised by a linear function of age. Random effects are incorporated into models, so each individual has their own intercept and slope coefficients³⁹⁴. Unlike multivariate response models, which treat age as fixed discrete occasions, growth models consider age as a continuous variable.

In this study, height measurements for cohort members are widely spaced, with a maximum of four measures for each person throughout childhood and adulthood. Furthermore, the age at which final adult height was achieved is not known. Growth models, therefore, are not a practical approach, and multivariate response models are considered more appropriate.

In Chapter 5, multivariate response models were used to examine the associations between each measure of child maltreatment and household dysfunction and height at all ages, simultaneously. The four multiple response variables were height SDS at age 7, 11, 16y and adulthood. Participants with data on exposures (i.e. child maltreatment or household dysfunction) and height at one (or more) ages were included in the analysis. To assess if the association changed between different ages, the effect of each exposure on height between each two successive ages (between 7 and 11y, 11 and 16y,

and 16y and adulthood) and between childhood (age 7y) and adulthood were compared using contrast tests.

3.3.3 *Linear regression model*

In Chapter 5, linear regression models were also applied to investigate the effect of each child maltreatment and household dysfunction measure on adult leg length SDS. Linear regression models assume that the response measures are identically and independently distributed, and follow a normal distribution. Regression parameters are estimated using Ordinary Least Squares (OLS). T-tests are applied to determine whether there is a significant association between the exposure and response. With continuous exposure measures, linear regression estimates the effect of a one unit increase in the exposure on the response measure. For a binary or categorical exposure variable, linear regression estimates the difference in the response mean between groups.

3.4 Statistical methods for multiple categories of pubertal development

In Chapter 6, multinomial logistic regression models were used to assess the association between child maltreatment, household dysfunction and categorical pubertal development measures. Such a model was chosen as pubertal development measures were classified into categorical variables ('early', 'intermediate', or 'late').

In the preliminary analyses, pubertal measures were first treated as continuous variables (Tanner scores for pubic hair growth (for both genders), testicular (for boys) and breast (for girls) development at age 11y (range 1-5); facial hair growth at age 16y and age of voice change for boys (range age <11y to- \geq 15y), and age of menarche for girls (range age 9y to >16y)). Linear regression models were used to test for a trend between adverse childhood experiences and markers of puberty³⁹⁵. Thus, mean stage (or age) of pubertal development between exposed and unexposed cohort members were compared (Appendices 5.1-5.10). Few associations were found, thus categorical measures of pubertal development were adopted to examine whether adverse childhood experiences were associated with

an increased risk of early and later pubertal development ('U-shaped' relationship).

In Chapter 6, multinomial logistic regression model were applied to estimate the relative risk of 'late' and 'early' compared to 'intermediate' stage of pubertal development (RRR and 95% CI). Unadjusted relationships were initially examined. Potential confounding factors were then included in the models to establish whether associations were independent. Unadjusted and adjusted RRR for each puberty measure were estimated between individuals who experienced maltreatment or household dysfunction in childhood (versus those who did not).

3.5 Additional analyses

In Chapters 5 and 6, analyses were repeated using multiple imputation (§3.1.1) to examine whether attrition, as well as missing data on confounding factors, influenced the associations between adverse childhood experiences and child-to-adult height growth and pubertal development. Missing observations for child maltreatment, household dysfunction and confounding measures were imputed to a target sample of all participants alive at age 45y (males n=8,874; females n=8,439). As the relationships between adverse childhood experiences and height growth and pubertal development were examined separately for males and females, the imputation models were fitted for each gender. Variables incorporated into the multiple imputation models were: 1) measures associated with attrition and missing adverse childhood experience data (i.e. variables used in the previous multiple imputation model §3.1.1); 2) child maltreatment and household dysfunction measures at age 7, 11, 16 and 45y; 3) confounding factors used in Chapters 5 and 6 (§2.4) and; 4) height at ages 7, 11, 16y and adulthood and respective markers of pubertal development.

Using the imputed data, linear regression models were adopted to examine the relationship between adverse childhood experiences and height at age 7y and adult height. For pubertal development, multinomial logistic regression models were used to assess the association between adverse childhood experiences and testicular development at age 11y (for boys) and age of menarche (for girls). Exposures were limited to child maltreatment measures reported at age 45y, derived prospective neglect,

household dysfunction and adversity scores and maltreatment groups identified by LCA. Analyses were restricted to participants with data on the outcome measure of interest, e.g. height at age 7y or age of menarche for girls. Results were compared to findings from the complete data analyses to determine whether missing data may have influenced associations.

3.6 Issues relating to multiple testing

In life-course studies, a multiplicity of data, hypotheses and analyses leads to multiple testing on a set of data. The more tests performed, the greater the risk of rejecting a null hypothesis when it is true (a Type I error). If k independent associations are examined, the probability of not rejecting at least one of the k null hypotheses when all are true (false positive) increases as the number of independent tests increases³⁹⁶. It is expected that one in twenty comparisons would be statistically significant at the 0.05 level even when the null hypothesis is true³⁹⁷. Multiple statistical correction methods have been developed to correct for multiple testing. The Bonferroni correction is one approach based on the hypothesis that when testing k associations (independent or dependent) on the same data, a significance level $1/k$ of what would be considered a significant association if only one test was performed, should be reached³⁹⁸. For example, if k tests are performed, with statistical significance set at the 0.05 level, a p value of $\leq 0.05/k$ is considered a statistically significant association³⁹⁹.

However, statistical correction methods are not universally accepted and corrections such as Bonferroni may artificially increase the risk of falsely rejecting the null hypotheses (Type II error). The correction reduces the power to detect an association and increases the probability of producing false negatives⁴⁰⁰. Instead it has been recommended, that each association should be critically examined and interpreted in isolation⁴⁰¹. Such an approach has been adopted in this thesis.

3.7 Summary

The 1958 cohort has missing data and this has implications for reporting prevalence and co-occurrence estimates. In the study, multiple imputation was considered an appropriate approach to reduce the bias associated with non-response and attrition. Prevalence estimates in different complete and imputed data samples were compared to examine whether child maltreatment and household dysfunction were under-reported in the 45y sample (Chapter 4). As multiple measures of child maltreatment were available, LCA was a suitable data reduction method to assess whether different forms of child abuse and neglect co-occurred in the cohort.

Analysing child-to-adult height trajectories requires methods that take into account the high correlation amongst repeated height measures from the same individuals. The covariance structure needs to be considered to obtain efficient estimates of the parameters and to assess the within-individual and between-individual variation. As there were only three childhood and one adult height measure, age was treated as a fixed occasion in multivariate response models to examine the association between adverse childhood experiences and child-to-adult height trajectories (Chapter 5).

For analyses of pubertal development measures, continuous measures were initially adopted to assess whether the mean stage of pubertal development differed by each exposure. To examine whether there were threshold associations, categorical measures of puberty were used to assess whether child maltreatment and household dysfunction were associated with an increased risk of ‘early’ or ‘late’ development, versus intermediate development (‘U-shaped’ relationship). In Chapter 6 multinomial regression models were employed to examine the influence of child maltreatment and household dysfunction on several measures of pubertal development.

4 Co-occurrence of child maltreatment and household dysfunction

4.1 Background

Various prevalence estimates for child maltreatment and household dysfunction exist due to the use of multiple definitions of child abuse and neglect, data collection methods and study populations. In addition, few studies have information on a wide range of adverse childhood experiences. Thus there has been limited examination of the complex inter-relationships between different forms of child maltreatment, as well as household dysfunction measures. Establishing the extent to which child maltreatment co-occurs, and how they are associated with measures of household dysfunction, is important for understanding their long-term impact on later outcomes.

In this chapter, the prevalence of each form of child maltreatment and household dysfunction in the 1958 cohort is estimated, accounting for missing data issues. The relationship between different forms of abuse and neglect, and the extent to which they co-occur are explored. Distinct patterns of response to child maltreatment measures and their associations with measures of household dysfunction are investigated.

4.1.1 *Epidemiology of child maltreatment*

Three types of data sources are common in child maltreatment studies; self-report, parent-report and agency report (§1.5.3). In general, self and parent-reports have generated higher prevalence estimates of child maltreatment compared to agency reports. Overall, 1 in 10 children in developed countries are thought to experience some form of maltreatment during their childhood³⁰. Neglect, followed by psychological abuse, tend to be the most frequently reported forms of maltreatment, and physical and sexual abuse are the least.

Psychological (or emotional abuse) is the most common form of child abuse reported. In retrospective self-report studies, between 5.8%³⁴² and 22.0%⁴⁰² of participants report psychological abuse in childhood. Large UK and US self-report studies estimate that 3-

6.4% of all children are psychologically abused each year^{20;22}. Agency reports observe lower rates of psychological abuse in the population, however this is a probable consequence of agencies rarely referencing psychological abuse as a reason for referral until recently (Table 4.1)⁴⁰³.

Physical abuse: The prevalence of child physical abuse ranges considerably in parent and agency reports (Table 4.1). In the Avon Longitudinal Study of Parents and Children (ALSPAC), 1.8% of parents reported physical cruelty towards their child by themselves or their partner. In contrast, only 0.4% of children were referred to agencies for physical abuse¹⁹⁰. One UK systematic review showed that 9% of children are physically abused each year, and only 1 in 23 cases were reported to the police or social services⁴⁰⁴. Findings suggest that only a small proportion of cases of physical abuse are investigated by authorities.

The rate of physical abuse is higher in North American than in European countries. In the US, nearly a quarter of substantiated maltreatment cases are due to physical abuse, compared to 10% in the Netherlands^{25;24;33}.

Sexual abuse: A recent meta-analysis estimated that the global prevalence of child sexual abuse was 11.8%. Figures were shown to differ between data sources, with self or parent-reported studies producing a rate 30 times higher than agency reports (12.7% vs. 0.4%, respectively)⁴⁰⁵. Prevalence estimates are also dependent on the definition of sexual abuse used (i.e. the inclusion of penetrative or non-penetrative acts). There is some indication that the prevalence of non-penetrative sexual abuse is greater than that of penetrative sexual abuse⁴⁰⁶. Therefore, the discrepancy between self or parent-reports and agency reports may partly reflect a greater severity of experiences ascertained through agency reports.

Witnessed intimate-partner violence is often excluded from large child maltreatment studies. Within the UK, it has been estimated that 23.3-24.8% of women have experienced domestic abuse, the majority of whom have children⁴⁰⁷. This is consistent with findings from UK self-report studies, which suggest that nearly a quarter of all young adults have witnessed violence between their parents at least once during

childhood^{20:408}. In the same study, 4% of 11-17y olds were exposed to severe domestic violence, including a parent being kicked, choked or beaten up by their partner^{20:409}.

Table 4.1: Studies of the prevalence of child maltreatment

Study	Design; Year of birth; n	Maltreatment definition (age occurred)	Source	Prevalence			
				Psychological abuse	Physical abuse	Sexual abuse	Neglect*
Health & Development Study, New Zealand ³³³	National birth cohort 1977; 1,265	Own criteria (≤ 16 y)	Self (18y)		10.4%	6.1%	
Memphis study, US ²³	Random sample 1932-79; 967	Childhood Trauma Questionnaire (childhood)	Self (18-65y)	12.1%	18.9%	5.0%	E: 5.1% P: 17.9%
Australian PATH Through Life Project ³⁴²	Random sample 1975-82, 55-62, 35-42; 7,485	Parental Bonding Instrument; British National Survey of Health & Development; US National Comorbidity Survey (≤ 16 y)	Self (20-64y)	6.5-5.8%	5.2%	1.1%	1.6%
Quebec study ⁴⁰²	Random sample ≤ 1988 ; 1,002	Finkelhor 1990; Quebec health Survey questionnaire (≤ 18 y)	Self (≥ 18 y)	22.0%	19.4%	15.9%	
National Longitudinal Study of Adolescent Health (Add Health), US ⁴¹⁰	School sample 1978-83; 10,828	Finkelhor 1994; Gallup Questionnaire; Multidimensional Neglectful Behavioural Scale (≤ 18 y)	Self (20-36y)		28.4%	4.5%	S: 41.5% P: 11.8%
Adverse Childhood Experience (ACE) Study, US ^{32;182}	Healthcare provider sample, Unknown; 9,508	Parent-child Conflict Tactics Scale; modified Wyatt Sexual History Questionnaire (≤ 18 y)	Self (> 18 y)	11.1%	10.8%	22%	
Children in the Carolinas Study; US ^{293;411}	Random sample 1984-2002; 1,435	Parent-child Conflict Tactics Scale (≤ 18 y)	Parent		4.3%	1.1%	P: 15.4%
Attitudes & prevalence study, Portugal ⁴¹²	Population sample 1986-2004; 2,391	Inventory of Educational Practices (≤ 18 y)	Parent	22.4%	12.3%		

Study	Design; Year of birth; n	Maltreatment definition (age occurred)	Source	Prevalence			
				Psychological abuse	Physical abuse	Sexual abuse	Neglect*
Developmental Victimization Survey (DVS), US ²¹	Random sample 1985-2001; 2,030	Juvenile Victimization Questionnaire (2-17y)	Self (10-17y) Parent	13.0 (rate per 1,000 children)	8.0	3.0	5.0
National Survey of Children's Exposure to Violence (NatSCEV), US ²²	National sample 1990-2008; 4,549	Juvenile Victimization Questionnaire (<18y)	Self (10-17y) Parent	Lifetime rates 11.9% Past year rates (2007-8) 6.4%	9.1% 4.4%	1.2% 0.3%	3.6% 1.5%
National Society for the Prevention of Cruelty to Children Survey, UK ²⁰	Random sample 1985-2009; 6,196	Juvenile Victimization Questionnaire; National Survey of Children's Exposure to Violence; Mother & Father Parental Acceptance Questionnaire (<16y)	Self (10-24y) Parent	Lifetime rates <11y 3.7% 11-17y 6.8% 18-24y 6.9% Past year rates (2008-9) <11y 1.8% 11-17y 3.0%	1.3% 6.9% 8.4% 0.7% 2.4%	0.1% 0.1% 1.0% 0 0	3.7% 9.8% 9.0%
Canadian Incidence Study of Reported Child Abuse & Neglect (CIS) ²⁵	National sample 1983-98; 7,672	Modified Harm/Endangerment Standards (<15y)	Agency	3.6 (rate per 1,000 children)	2.5	0.9	4.5
US National Incidence Study (NIS) ²⁴	National sample 1988-2006; estimated for total population	Modified Harm (H)/ Endangerment (E) Standards (<18y)	Agency	(H) 2.0 (E) 4.1 (rate per 1,000 children)	4.4 6.5	1.8 2.4	10.5 30.6
Netherlands Prevalence study of Maltreatment of youth ³³	National sample 1987-2005; estimated for total population	Modified Harm/Endangerment Standards (<18y)	Agency	Past year rates (2005) 0.3%	0.6%	0.1%	0.8-0.9%

Study	Design; Year of birth; n	Maltreatment definition (age occurred)	Source	Prevalence			
				Psychological abuse	Physical abuse	Sexual abuse	Neglect*
Nebraska School Study ⁴¹³	State school sample 1976-90; 40,211	Modified Maltreatment Classification System (≤ 18 y)	Agency	11.2% maltreated			
Longitudinal Studies of Child Abuse & Neglect (LONGSCAN), US ^{34;323;414}	At-risk sample & matched controls 1986-94; 1,524	Modified Maltreatment Classification System; LONGSCAN questionnaire (≤ 18 y)	Self (12y) Agency	39% 6%	21% 3-5%	9% 2%	
Ontario Health Survey (OHS) ³²¹	Population probability sample ≤ 1985 ; 8,991	Child Maltreatment History Self-Report (≤ 16 y)	Self (≥ 15) Agency	25.3% 1.3%		9.0% 0.8%	
Avon Longitudinal Study of Parents & Children (ALSPAC), UK ¹⁹⁰	Birth cohort 1991-2; 14,138	Referrals of suspected maltreatment; Child Protection Register (CPS), ALSPAC questionnaire (≤ 3 & ≤ 6 y)	Parent Agency Referrals CPS	5.4% 0.3% 0.1%	1.8% 0.4% 0.5%	0.1% 0.6% 0.5%	0.4%

*E: emotional neglect; P: physical neglect; S: Supervision nelget, othewise summary measure of neglect

Neglect is not routinely collected in community child maltreatment studies, partly because there are many aspects of omission of care (§1.5.1). Prevalence estimates vary depending on the type of neglect investigated (i.e. physical, emotional or supervisory) and the definitions used. To illustrate, in the US National Longitudinal Study of Adolescent Health over a third of participants reported supervisory neglect, whilst just over 10% reported physical neglect (Table 4.1)⁴¹⁰. Most studies use a combined measure of neglect, and in large US and UK community samples, life time rates for 0-17y olds range from 3.6% to 9.8% (Table 4.1)^{20,22}.

Neglect is the most frequently referenced category of child maltreatment by agencies, with 45-61% of cases neglected^{24,25}. Neglect is often a secondary form of maltreatment noted, and therefore not the reason why the child came to the attention of the agency³⁴.

Gender and child maltreatment: There is substantial evidence, from both self and agency reports, which suggest a gender difference in child maltreatment experiences^{22-25,415}. It has been estimated that girls are 2.5 to 3 times at greater risk of child sexual abuse than boys⁴¹⁶, whereas boys are almost twice as likely to report physical neglect²³. There is some indication that women are also more likely to report childhood psychological or emotional abuse^{23,342}. Whether these findings are true differences in maltreatment experiences or the consequences of social and cultural norms is not fully understood. For example, research has indicated that mental health professionals rarely ask adult males about childhood sexual abuse⁴¹⁷ and males are less likely to disclose abuse experiences than females⁴¹⁸.

Age and child maltreatment: Victims of maltreatment include children of all ages, although the distribution of abuse and neglect by age group is highly skewed. In the US, population studies indicate that the highest incidence of psychological, physical and sexual abuse is amongst adolescents^{21,22,24,25,419}. Agency reports have found neglect to be highest amongst pre-school children compared to older children²⁴. Child maltreatment related hospital admissions are predominantly in children aged 0-6y, suggesting that more severe abuse and neglect occurs in this age group³²⁷. It is also possible that lower rates of child maltreatment at younger ages reflect some under-coverage in these age groups. Prior to school age, children are less observable to community professionals and therefore less likely to be reported to agencies.

4.1.2 *Multiple forms of child maltreatment*

Studies investigating the co-occurrence of child maltreatment have found that child abuse and neglect mostly occur in multiple forms. Where physical and sexual abuse have been examined, rates of co-occurrence have varied from 17% in a community sample of children⁴²⁰ to 71% in an adolescent female cohort of psychiatric patients⁴²¹. Studies of adolescents and college populations have reported co-occurrence rates of physical and sexual abuse at around 30%^{251;422}. Amongst 519 US agency reports of maltreatment, the majority of physical and sexual abuse cases involved other forms of maltreatment. Psychological abuse also rarely occurred in isolation³⁴. Population studies that have included psychological abuse in addition to physical and sexual abuse have found co-occurrence ranging from 10% to 43%^{423;424}. A recent American community survey showed that amongst participants who reported one form of maltreatment, the likelihood of them reporting another was 2 to 18 times greater than those who did not³².

Establishing whether maltreated children experience multiple forms of abuse and neglect is important as those that do may be at greater risk of subsequent adversity, compared to children that report a single form of maltreatment. In the UK, a greater proportion of children with substantiated mixed abuse (physical, sexual and psychological abuse and neglect) were re-referred to child protection services within 27 months compared to those identified as ‘only’ psychologically, physically or sexually abused or neglected⁴²⁵. Amongst those that report multiple forms of child maltreatment there is also a greater risk of adverse adult health outcomes, compared to those that report ‘only’ a single form^{426;427}. For example, an American survey found that increments in the number of different forms of child maltreatment reported was associated with an increase in the number of health risk factors (e.g. smoking and overweight status) physical symptoms and greater functional disability⁴²⁸. A full exploration of the interrelationships between a wide-range of child maltreatment is therefore necessary to identify those who are most at risk of adverse health outcomes.

Yet studies have a tendency to focus on physical and sexual abuse, often excluding measures of psychological abuse, neglect and witnessing intimate-partner violence. Consequently, children’s experiences are not fully represented and long-term outcomes

may be attributed to some forms of child maltreatment rather than others with which they co-occur. Most of the studies investigating the co-occurrence of child maltreatment are cross-sectional and rely on one data source, in particular retrospective self-reports^{23;32}. As discussed in §1.5.3, using one data source in isolation can provide unreliable estimates of the population prevalence³³³. In comparison, findings from longitudinal community studies which collect information from multiple sources produce a more accurate representation of child abuse and neglect³²⁴. For example, the US longitudinal Developmental Victimization Survey and National Longitudinal Study of Adolescent Health used self and parental reports to identify maltreated children^{21;410}. In ALSPAC, maltreated children were identified from referrals to social services and parent's responses to questions on potentially abusive behaviours¹⁹⁰. However, this is a regional sample, with no measure of witnessing intimate-partner violence and currently no self-report measures of child maltreatment^{29;429}. To date, there is no nationwide longitudinal study in the UK with information on all forms of child maltreatment, collected from both self-reports in adulthood and prospectively in childhood.

4.1.3 *Household dysfunction and child maltreatment*

Household dysfunction and child maltreatment are highly correlated. Children from dysfunctional family backgrounds are more likely to experience maltreatment and often in multiple forms. Several markers of household dysfunction have been associated with child maltreatment: parental substance abuse and mental health status, family conflict and harsh parenting practices, family contact with the police and time spent in institutional care, social isolation and high risk neighbourhoods^{45;46;64;65;68;77;94;298;313;430}. However, study findings vary and no form of household dysfunction has consistently been shown to predict maltreatment. For example, maternal substance abuse may increase the likelihood of maltreatment, but prospectively it does not clearly differentiate or predict those who will go on to be maltreated. More recently, emerging evidence indicates that the total level of risk is a more reliable predictor of maltreatment than any single exposure^{431;432}. In the prospective Stress, Social Support, and Abuse & Neglect in High Risk Infants Study, MacKenzie et al found that accumulation of risk factors, such as parental separation/divorce, receipt of social assistance, maternal depression and unsafe neighbourhood, had a greater power to predict later maltreatment than most single factors⁴³². However, the direction of the relationship between household dysfunction and child maltreatment remains uncertain. It is unclear whether

household dysfunction can be used to predict the likelihood of abusive or neglectful behaviour in the population, or whether child maltreatment occurs in families with functioning difficulties⁵⁹.

Accumulation of child abuse, neglect and household dysfunction has been associated with an increased risk of adverse outcomes in later life. In a study of ‘at risk’ American children, multiple forms of child maltreatment, family disruption and life stress were associated with an increase in the severity of behavioural problems in adolescence⁴³³. A similar US study found a cumulative effect of parenting styles and seven household dysfunction measures (including household member legal conviction and parent substance misuse) on risk of externalizing and internalizing problems in childhood⁴³⁴. The Adverse Childhood Experiences Study (ACE) has found a strong cumulative relationship between child maltreatment and household dysfunction, and cardiovascular disease^{182;188;432}, liver disease⁴³⁵ and lung cancer risk⁴³⁶, such that for each additional adverse childhood experiences, the risk of disease increases.

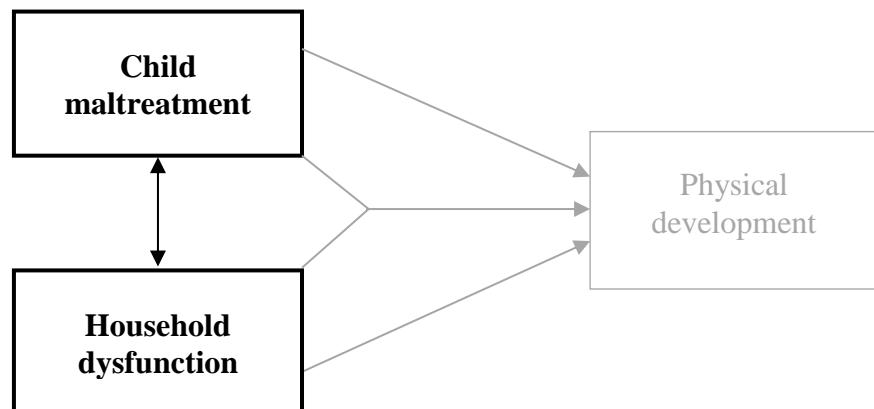
Few studies have investigated the association between different forms of child maltreatment and household dysfunction. The existing literature is restricted to either one form^{46;64;65;430;437}, or a summary measure of child maltreatment^{59;68;298}, and an isolated indicator of household dysfunction. Maltreated children are more likely to experience a wide range of adversities^{32;438} and these are not currently reflected in the established literature. Studies that have investigated the association between multiple measures of child abuse and neglect and household dysfunction, such as the ACE project, rely on retrospective data collection methods¹⁸². It is important to assess the inter-relationships between all forms of child maltreatment and household dysfunction in a large populations study, using a range of data collection methods, to fully understand children’s early life experiences.

4.2 Objectives

There are three main objectives in this chapter (illustrated in Figure 4.1):

1. Estimate the prevalence of child maltreatment (i.e. psychological, physical and sexual abuse, witnessing intimate-partner violence and neglect).
2. Establish the extent to which different forms of child maltreatment co-occur.
3. Assess associations between household dysfunction and each form of child maltreatment, and child maltreatment groups.

Figure 4.1: Relationships between household dysfunction, child maltreatment and physical growth*



*relationship addressed in this chapter highlighted in bold

4.3 Methods

4.3.1 *Study samples*

Samples used in the analyses in this chapter include;

- 1) 9,310 to 15,583 cohort members alive at age 45y, for whom data on child maltreatment and household dysfunction were available
- 2) 6,294 – 9,310 participants of the 45y biomedical survey, and
- 3) 17,313 cohort members alive at age 45y, for whom missing data were imputed.

4.3.2 *Measures*

As described in §2.2.1, psychological, physical and sexual abuse, witnessed abuse of a family member, neglect and two emotional indicators of neglect were retrospectively reported at age 45y. A further eight indicators of neglect were collected prospectively during childhood. For measures collected at multiple ages, i.e. 7 and 11y surveys, an indicator was classified as positive (or one) if it presented at any age (zero otherwise). A cumulative neglect score was derived by summing all eight prospective and three retrospective neglect measures (range 0-11), for cohort members with complete data. A binary variable was derived (≥ 3 indicators): $\approx 25\%$ of participants had a high neglect score.

All 18 household dysfunction measures, collected both in childhood and adulthood, were considered in this chapter: domestic tension (ascertained at ages 7 and 45y), parental separation/divorce by age 16y (ages 7, 11, 16 and 33y), alcohol/drug dependency (ages 7 and 45y), relationships with parents (age 16y), parental mental health/depression (ages 7, 11, 16 and 45y), parental contact with authority/institutional care (ages 7, 11 and 16y) and strict upbringing (age 45y). For variables collected in multiple surveys during childhood, a measure was classified as one if it presented at any age (zero otherwise).

Confounding factors: Ethnicity, reported at age 33 and 42y, was categorised into two groups; ‘white’ and ‘non-white’. Social class at birth, recorded in 1958 was classified into four groups; 1) professional/managerial (I/II), 2) skilled non-manual (IIInm), 3)

skilled manual (IIIm) and 4), semi-skilled/unskilled occupation (IV/V). Lone-mother households were identified with a separate variable.

4.3.3 Statistical analysis

Prevalence of maltreatment

To assess whether the prevalence of child maltreatment was under-estimated in the 45y sample due to attrition and missing data, multiple imputation was used. Data were assumed missing at random (MAR) and a multiple imputation model using all participants alive at age 45y (n=17,313) was used to reduce possible bias caused by missing data³⁸⁰. Ethnicity, lone-mother households, social class at birth, reading ability at age 7y, gender and all child maltreatment and household dysfunction measures were incorporated in the imputation model (§3.1.1). The chained equation method was used to create 30 complete datasets³⁷⁶. Overall estimates were attained by combining parameters from these datasets using Rubin's rules³⁷⁷.

Prevalence estimates using four different data samples were compared: 1) observed data of those alive at age 45y, 2) observed data of participants of the 45y survey, 3) imputed data of those alive at age 45y and 4) imputed data restricted to participants of the 45y survey.

Co-occurrence of maltreatment

Tetrachoric correlations were used to estimate the correlation between indicators of neglect. For each form of child abuse (psychological, physical, sexual and witnessed abuse) the proportion of abused participants who experienced other forms of abuse was calculated, as was the mean number of other maltreatment experiences. Associations between neglect score and child abuse were assessed using logistic regression models. For each form of abuse, an odds ratio (OR) and 95% confidence interval (CI) were estimated for a unit increase in neglect score (i.e. an additional neglect indicator).

As described in Chapter 3, Latent Class Analysis (LCA) was used to identify distinct patterns of co-occurrence amongst the 15 child maltreatment measures. Full

Information Maximum Likelihood (FIML) was applied, ensuring that participants with missing observations were included in the model and all available information was used to estimate parameters. Models that specified one through to nine latent classes (i.e. maltreatment groups) were sequentially fitted to the data. The most parsimonious model was chosen using the criteria of fit indices: low Akaike and Bayesian Information Criterion (AIC and BIC) values, low class error, high entropy and bootstrap likelihood ratio tests and its interpretability³⁸⁷. For each model, the size of each class (class probability) and the likelihood of a positive response for each maltreatment measure given class membership (item probability) were estimated. Posterior membership probability for each maltreatment group was estimated for each participant, and individuals were allocated to the class with the highest membership probability. Maltreatment groups were assigned to those with complete data on all child maltreatment measures (n= 6,294), although all available data were used to estimate the model, i.e. participants alive at age 45y with missing observations (n=17,313).

Multinomial logistic regression models were utilised to assess whether the distinct maltreatment groups obtained from the LCA were associated with each household dysfunction measure. Relative risk ratio (RRR) and 95% CI were estimated for each maltreatment group (vs. a low risk group). Logistic regression models were also fitted to each child maltreatment subtype (abuse or neglect score ≥ 3) to evaluate their association with each household dysfunction measure. Interactions between household dysfunction measures and gender were tested in all regression models. Where significant interactions were found (p<0.05), separate analyses for men and women were conducted, otherwise models were fitted for both genders combined. All regression models were adjusted for gender and social class at birth.

Additional analysis

Sensitivity analysis of the binary neglect variable was conducted using various thresholds (≥ 2 , ≥ 3 , or ≥ 4 (Appendix 3.1)). The relationship of neglect with abuse and household dysfunction measures were similar at these thresholds, and ≥ 3 was used here. All analyses were conducted using individuals with available data (complete data) and repeated for the imputed sample. The LCA analysis was completed prior to the multiple imputation, and missing posterior membership probabilities were imputed, with

participants subsequently categorised into maltreatment groups. Associations between household dysfunction measurements and each maltreatment type or maltreatment groups identified from LCA were similar in the complete dataset and imputed samples (Appendix 3.2). Thus, results from the LCA model and regression models using complete data are presented here.

4.4 Results

4.4.1 *Child maltreatment and demographic characteristic*

In the 1958 cohort a greater proportion of children from low socio-economic groups or overcrowded households reported abuse and neglect, compared to those from less deprived households, as shown in Table 4.2. Father's level of education was related to reporting of maltreatment at age 45y; fewer maltreated participants had fathers who remained in education after the minimum age than subjects who did not report abuse or neglect (77-85% vs. \approx 74%). In contrast, only sexual abuse and witnessed abuse were associated with level of maternal education. Disability diagnosed by age 16y was not associated with child maltreatment measures.

4.4.2 *Prevalence of child maltreatment*

Prevalence estimates of child maltreatment and household dysfunction varied slightly between the study samples (Tables 4.3 and 4.4). The frequency of retrospectively reported child abuse, neglect and household dysfunction was lower for participants of the 45y survey (n=9,310) compared to the imputed sample of those alive at age 45y (n=17,313). To illustrate, the prevalence of physical abuse was 6.1% in the observed 45y data compared to 9.0% in the imputed data. For prospectively collected measures, prevalence was lowest for participants of the 45y survey. For example, neglected appearance was reported for 5.8% of participants from the 45y survey compared to 7.4% of those alive at 45y. Restricting the imputed sample to those who completed the 45y survey did little to change the prevalence estimates of childhood measures. This finding suggests that individuals with adverse experiences in childhood were less likely to remain in the study and thus the extent of maltreatment and household dysfunction within the cohort was likely to be under-estimated in the participating sample at 45y.

Across all data samples, 10.0-12.5% of participants reported psychological abuse at age 45y, 6.1-9.0% physical abuse, 1.6-2.9% sexual abuse, 6.0-8.5% witnessed abuse and 2.7-4.4% reported being neglected as a child (Table 4.3). Childhood neglect measures related to education (i.e. low parental aspirations or 'mother/father little interest in education') were most prevalent (>30%), followed by father activity indicators ('hardly reads' and 'hardly ever any outings'). Approximately two-thirds of participants had at

least one indicator of neglect, with 25.9-32.1% having ≥ 3 indicators (Table 4.5). Gender differences were found, with significantly more females retrospectively reporting all forms of child maltreatment compared to males, except for physical abuse and father unaffectionate. In contrast, prospective neglect measures were more prevalent amongst males than females, with significant differences found for neglected appearance, 'mother hardly reads or takes on outings', 'mother/father little interest in education' and low parental aspirations (Table 4.4).

Table 4.2: Relationship between child maltreatment (reported at age 45y) and demographic measures

		Psychological abuse		Physical abuse		Sexual abuse		Witnessed abuse		Neglect		Mother unaffectionate		Father unaffectionate	
		No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Sex	Males	50.6	41.2	49.7	48.9	50.2	14.8	50.5	36.6	50.1	33.5	50.5	26.3	49.1	55.1
	Females	49.4	58.8*	50.3	51.2	49.8	85.2	49.5	63.4*	49.9	66.5*	49.5	73.7*	50.9	44.9*
	n	8,381	929	8,747	563	9,161	149	8,750	560	9,062	248	8,983	327	8,459	851
Social class at birth	I/II	19.6	14.6	19.6	11.3	19.3	7.0	19.6	11.2	19.3	11.1	19.4	11.4	19.6	14.4
	IIInm	10.0	10.0	10.0	10.0	10.0	9.2	10.0	10.3	10.0	11.1	10.2	6.0	10.2	8.3
	IIIm	48.7	48.9	48.6	50.4	48.7	46.5	48.9	46.4	48.7	48.3	48.6	51.0	48.3	52.5
	IV/V	21.7	26.5*	21.8	28.3*	21.9	37.3*	21.6	32.2*	22.0	29.5*	21.8	31.7*	21.9	24.9*
	n	8,144	888	8,502	530	8,890	142	8,497	535	8,798	234	8,716	316	8,211	821
Household crowding at 7y	No	88.7	85.3	88.8	81.0	88.5	80.0	89.1	77.5	88.5	80.4	88.5	83.7	88.9	83.0
	Yes	11.4	14.7*	11.2	19.0*	11.6	20.0*	11.0	22.5*	11.5	19.6*	11.5	16.3*	11.1	17.0*
	n	7,702	835	8,042	495	8,407	130	8,031	506	8,312	225	8,237	300	7,763	774
Disability diagnosed by age 16y	No	94.5	98.4	98.5	97.6	98.5	99.1	98.5	98.7	98.5	98.0	98.5	98.1	98.4	98.9
	Yes	1.5	1.6	1.5	2.4	1.5	0.9	1.5	1.3	1.5	2.0	1.5	1.9	1.6	1.1
	n	7,158	753	7,460	451	7,798	113	7,460	451	7,710	201	7,642	269	7,200	711
Fathers duration at school	>min age	26.1	22.8	26.2	18.7	26.0	14.8	26.4	16.1	25.9	22.6	26.0	20.7	26.3	21.1
	≤min age	73.9	77.2*	73.8	81.3*	74.0	85.2*	73.6	83.9*	74.1	77.4	74.0	79.3*	73.8	79.0*
	n	7,165	750	7,461	454	7,800	115	7,468	447	7,716	199	7644	271	7,207	708
Mothers duration at school	>min age	26.9	27.9	27.2	23.6	27.1	17.8	27.3	22.5	27.1	24.8	27.1	24.1	27.1	26.0
	≤min age	73.1	72.1	72.8	76.4	72.9	82.2*	72.7	77.5*	72.9	75.2	72.9	75.9	72.9	74.0
	n	7,934	858	8,283	509	8,657	135	8,272	520	8,566	226	8,489	303	8,000	792

*Chi-squared tests for difference between exposed and unexposed, p<0.05

Table 4.3: Prevalence (%) of childhood maltreatment measures collected at multiple ages in the 1958 British birth cohort

Child maltreatment	Observed; % (n)				Imputed [‡] ; %		
	Alive at 45y		Participants at 45y	n	Alive at 45y ¹	Participants at 45y ²	
	Males	Females		All			
Abuse							
Psychological abuse (45y)	8.3 (383)	11.7* (546)	10.0	9,310	-	12.5	-
Physical abuse (45y)	6.0 (275)	6.1 (288)	6.1	9,310	-	9.0	-
Sexual abuse (45y)	0.5 (22)	2.7* (127)	1.6	9,310	-	2.9	-
Witnessed intimate-partner violence							
Witnessed abuse of family members (45y)	4.4 (205)	7.6* (355)	6.0	9,310	-	8.5	-
Neglect							
Neglected (45y)	1.8 (83)	3.5* (165)	2.7	9,310	-	4.4	-
Physical neglect							
Neglected appearance (7,11y)	9.0 (605)	5.9* (406)	7.4	13,661	5.8	7.6	6.1
Emotional neglect							
Mother not affectionate at all (45y)	1.9 (86)	5.1* (241)	3.5	9,310	-	4.6	-
Father not affectionate at all (45y)	10.2 (469)	8.2* (382)	9.1	9,310	-	11.2	-
Mother hardly ever reads to child (7y)	16.8 (1,207)	15.3* (1,054)	16	14,099	15	16.3	15.2
Father hardly ever reads to child (7y)	29.1 (2,025)	27.6 (1,845)	28.4	13,641	27.5	29.2	28.1
Hardly ever takes outings with mother (7,11y)	7.6 (604)	5.0* (381)	6.3	15,583	5.6	6.5	5.7
Hardly ever takes outings with father (7,11y)	11.6 (903)	12.1 (902)	11.9	15,190	10.9	12.4	11.3
Mother little interest in education (7,11,16y)	32.5 (2,435)	28.9* (2,062)	30.8	14,626	26.4	30.8	26.7
Father little interest in education (7,11,16y)	36.4 (2,649)	32.9* (2,282)	34.7	14,222	30.3	34.7	30.5
Low parental aspirations (7,11,16y)	34.6 (2,510)	31.4* (2,188)	33.0	14,236	30.4	33.0	30.6
Total (n)	8,874	8,439		9,310	17,313	9,310	

*Chi-squared tests for gender difference, p<0.05; - same sample as those with data and alive at age 45y; [‡]Multiple imputation sample, ¹those alive at 45y, ²sample restricted to 45y participants

Table 4.4: Prevalence (%) of household dysfunction measures collected at multiple ages in the 1958 British birth cohort

Household dysfunction	Observed; % (n)					Imputed [‡] ; %	
	Males	Females	Alive at age 45y		Participants at 45y	Alive at 45y ¹	Participants at 45y ²
			All	n			
Domestic tension (7y)	5.4 (396)	4.9 (344)	5.2	14,239	4.4	5.4	4.5
A lot of conflict/tension in household (45y)	11.0 (510)	16.1* (755)	13.6	9,310	-	15.7	-
Parental separation/divorce by age 16y (33y)	13.4 (764)	13.6 (796)	13.7	11,694	10.6	14.9	10.9
Alcoholism (7y)	0.9 (62)	0.9 (63)	0.9	14,235	0.7	1.0	0.8
Mother drink/drug problems (45y)	3.4 (157)	5.4* (253)	4.4	9,310	-	4.4	-
Father drink/drug problems (45y)	9.5 (441)	11.2* (526)	10.4	9,310	-	11.4	-
Family mental health problems (7y)	4.6 (334)	4.7 (326)	4.6	14,243	3.8		
Mother mental health problem (11,16y)	2.6 (190)	2.6 (179)	2.6	14,353	2.4	2.6	2.4
Mother nervous trouble/depression (45y)	16.4 (759)	22.4* (1,052)	19.5	9,310	-	20.5	19.5
Father mental health problem (11,16y)	1.2 (86)	1.4 (95)	1.3	14,341	1.2	1.3	1.2
Father nervous trouble/depression (45y)	9.3 (431)	10.8* (507)	10.1	9,310	-	10.2	-
Did not get on well with mother (16y)	4.3 (252)	6.0* (339)	5.1	11,565	4.7	5.3	4.8
Did not get on well with father (16y)	6.7 (381)	9.2* (505)	8	11,124	7.6	8.4	7.7
Family contact police/probation services (7,11,16y)	5.9 (434)	6.2 (435)	6	14,394	5.2	5.9	5.1
Family contact children department/charity (7,11,16y)	7.9 (576)	7.6 (531)	7.7	14,364	6.1	8.0	6.5
In care by age 16y (7,11,16y)	4.4 (252)	3.5* (190)	4	11,202	2.9	3.9	2.9
Strict, authoritarian or regimented upbringing (45y)	24.7 (1,141)	27.9* (1,306)	26.3	9,310	-	29.1	26.3
Physical punishment (45y)	6.4 (296)	8.8* (413)	7.7	9,310	-	10.3	-
Total	8,874	8,439	17,313		9,310	17,313	9,310

*Chi-squared tests for gender difference, p <0.05; - same sample as those with data and alive at age 45y; [‡]Multiple imputation sample, ¹those alive at 45y, ²sample restricted to participants who completed the biomedical survey

For household dysfunction reported at 45y, ‘strict upbringing’ (26.3% - 29.1%) was most prevalent and ‘mother’s drink/drug problems’ (4.4%) was the least (Table 4.3). For prospective measures, ‘not getting on with the father’ (7.6-8.4%) was most prevalent and alcoholism (0.7–1.0%) was the least (Table 4.3). In addition, significantly more females retrospectively reported household dysfunction measures and not getting on with their parents at age 16y, compared to males. No gender differences were found for most forms of household dysfunction prospectively collected.

Table 4.5: Summary of neglect score (age 7, 11, 16y and adulthood)

Number of indicators of neglect (range 0-11)*	Observed [†]		Imputed [‡] (%)	
	(%)	n	Alive at 45y ¹	Participants at 45y ²
0	36.0	2,265	30.8	33.7
1	20.7	1,304	20.1	20.9
2	17.4	1,094	17.0	17.3
3	11.7	739	13.2	12.5
4	6.9	432	8.4	7.6
5	4.1	258	5.0	4.3
6-11	3.2	202	5.5	3.7
Total (n)		6,294	17,313	9,310

*Neglect score combines eight prospective (mother/father hardly read (7y); mother/father hardly any outings (7 & 11y); mother/father little interest in education (7, 11 & 16y); low parental aspirations (7, 11 & 16y); neglected appearance (7 & 11y)) and three retrospective measures (I was neglected; mother/father unaffectionate). [†]Cohort members with complete data for each measure were included;

[‡]Multiple imputation sample, ¹those alive at 45y, ²sample restricted to 45y participants

4.4.3 Co-occurrence of child maltreatment

Indicators of neglect were highly correlated, with the strongest correlations found between variables with shared measures than others, e.g. ‘mother/father hardly reads’ ($r=0.67$) and ‘mother/father little interest in education’ ($r=0.93$) (Appendix 3.3).

Neglect indicators were rarely reported in isolation: of those with a positive response to any indicator of neglect, 73.8-96.1% of participants reported a further measure of neglect. For each indicator of neglect, the average number of other neglect measures reported ranged from 2.0 (95% CI: 1.9, 2.1) for low parental aspirations, to 3.2 (3.0, 3.4) and 3.5 (3.3, 3.7) for neglected appearance and ‘hardly any outings with mother’.

Gender differences were found for unaffectionate mother and ‘father hardly ever reads’: a higher proportion of males reported other neglect measures, than females (Table 4.6).

Table 4.6: Proportion of other neglect measures and mean neglect score, by indicators of neglect

Neglect indicators	n	Cumulative neglect score†			
		% ¹		Mean (95% CI) ² *	
		Males	Females	Males	Females
Neglected	149	90.7	90.6	2.7 (2.1, 3.3)	2.9 (2.5, 3.3)
Physical neglect					
Neglected appearance	359	91.5	91.1	3.2 (2.9, 3.4)	3.2 (2.9, 3.6)
Emotional neglect					
Mother unaffectionate	206	91.3	77.5*	2.6 (2.2, 3.1)	2.3 (2.0, 2.6)
Father unaffectionate	551	76.3	79.7	2.2 (2.0, 2.4)	2.3 (2.1, 2.5)
Mother hardly ever reads	950	90.7	91.0	2.6 (2.4, 2.7)	2.5 (2.3, 2.6)
Father hardly ever reads	1,712	84.0	79.8*	2.2 (2.1, 2.3)	2.0 (1.9, 2.1)
Hardly ever takes outings	332	96.3	95.8	3.5 (3.2, 3.7)	3.6 (3.3, 4.0)
Hardly ever takes outings	688	94.2	92.8	3.1 (2.9, 3.3)	2.9 (2.7, 3.1)
Mother little interest in education	1,531	96.4	96.6	2.7 (2.6, 2.8)	2.6 (2.5, 2.8)
Father little interest in education	1,802	93.7	93.1	2.5 (2.4, 2.6)	2.4 (2.3, 2.5)
Low parental aspirations	1,782	73.8	73.8	2.0 (1.9, 2.1)	2.0 (1.8, 2.1)

†Cumulative neglect score calculated by excluding relevant neglect indicator (0-10).

¹Proportion of participants who reported relevant neglect indicator and at least one other, X² used to estimate significant gender difference. ²Mean number of other indicators of neglect experienced and 95% CI in parenthesis; no. of observations 6,294; *p <0.05

Among 14.2% of cohort members who reported any form of child abuse, the majority (62.0% males; 68.3% females) also reported another form of abuse and/or had a high neglect score (≥ 3) (Appendix 3.1.1). Neglect score was associated with an increased risk of each form of abuse (Appendix 3.2.2): for every unit increase in neglect score, the risk of psychological abuse increased by 28.0% (95% CI: 22%, 34%), physical abuse by 35.0% (28%, 42%), sexual abuse by 36.8% (23%, 52%) and witnessing abuse by 36% (29%, 44%).

Different forms of child maltreatment were also highly correlated (Appendix 3.4). The strongest correlations were between psychological and physical abuse ($r=0.83$), and

witnessed abuse and physical abuse ($r=0.76$) compared to a high neglect score (although correlations remained significant). Participants sexually abused reported, on average, the greatest number of other forms of child maltreatment (mean=2.1), compared to those neglected who reported the least (mean=0.4) (Appendix 3.1.2) than others.

LCA modelling of the five abuse and 11 neglect measures indicated that the 3-class model had an adequate fit compared to other class solutions (Table 4.7). Specifically, the 3-class model had the highest entropy, and relatively low class error and BIC compared to other models. The bootstrap likelihood ratio test indicated a better fit with increasing class numbers. However, the 3-class solution was selected because it had distinct classes with a good level of assignment of individuals, indicated by the high proportion of participants with a posterior class membership probability close to 0 and 1 (probabilities of ≤ 0.05 or ≥ 0.95 ; class 1 84.5%, class 2 87.0% and class 3 92.4%).

Table 4.7: Child maltreatment[#] fit indices for latent class models

Number of classes	LL †	BIC(LL)†	AIC(LL)†	Class Error†	Entropy R ² ‡	Boot -2LL Diff*	
						-2LL Diff	p-value
1	-30759.56	61650.32	61549.11	NA	NA	NA	NA
2	-28181.10	56633.37	56424.21	0.04	0.81	5156.90	0.00
3	-27091.73	54594.59	54277.47	0.05	0.84	2178.74	0.00
4	-26639.25	53829.59	53404.51	0.09	0.78	904.96	0.00
5	-26363.60	53418.24	52885.20	0.10	0.78	551.30	0.00
6	-26216.76	53264.52	52623.52	0.11	0.77	293.68	0.00
7	-26083.81	53138.58	52389.62	0.10	0.83	265.90	0.00
8	-26033.94	53178.79	52321.88	0.10	0.82	99.74	0.00
9	-26000.79	53252.46	52287.59	0.11	0.80	66.29	0.00

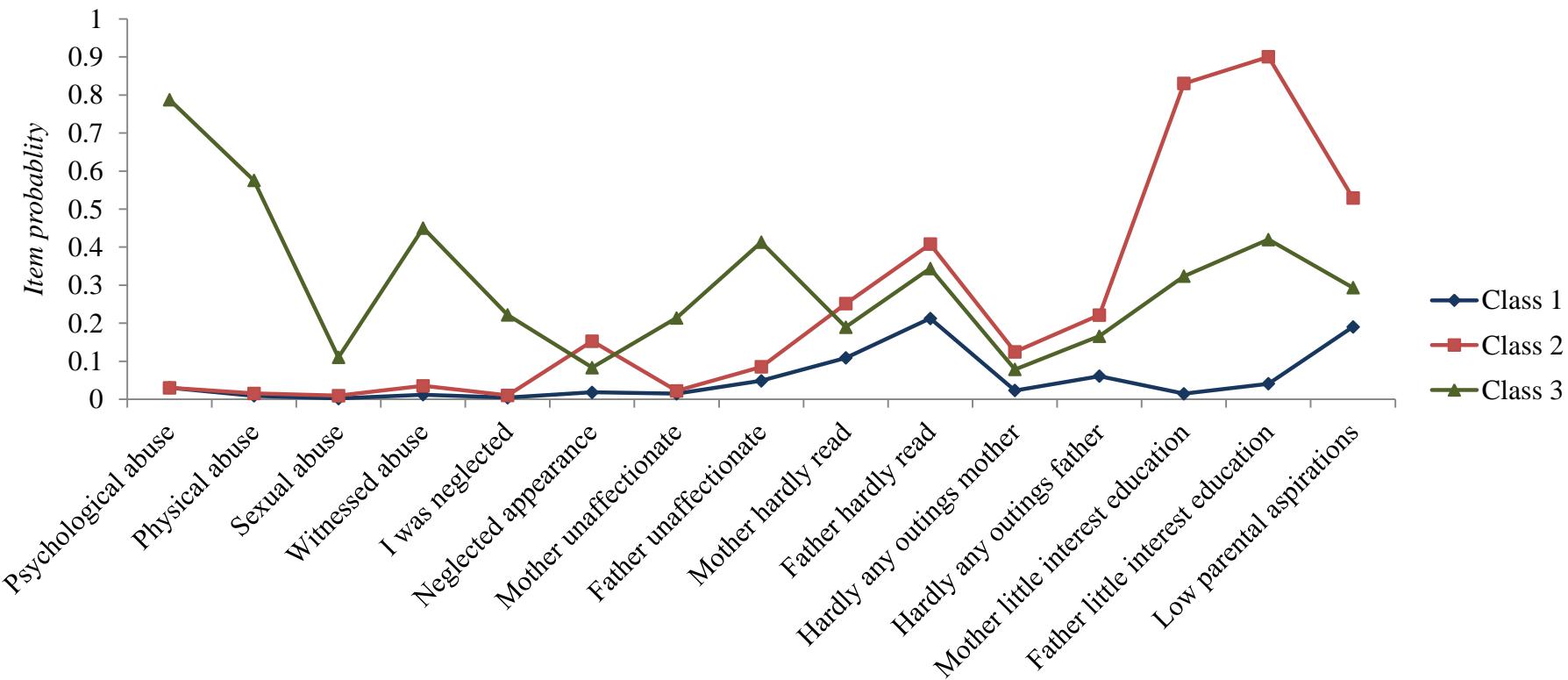
[#]5 abuse and 11 indicators of neglect. †Lower LL, BIC, AIC and class error values indicate better fit.

‡Entropy should be >0.7 , with values closer to 1 indicating a better fit. *Bootstrap likelihood ratio test indicates an improved fit compared to a model with $k-1$ latent classes. Significantly lower values indicate better fit.

Thus, three distinct child maltreatment groups were identified, as shown in Figure 4.2. The largest group (class 1, 66.9%) had the lowest risk of all maltreatment types, compared to the others, represented by the flat pattern. The second group (neglect 'only', 24.9%) is characterised by a low risk of abuse, but the highest risks for all prospective neglect measures, compared to group 1 and 3, indicating low parental support in childhood (71.2% with a neglect score ≥ 3). In Figure 3, the proportion of participants in each maltreatment group, stratified by abuse and neglect measures is shown. Of cohort members whose parents showed little interest in their education, or had a neglected appearance, 66.9–86.4% were grouped into neglect 'only' class (Figure 4.3). The smallest group (class 3, abuse and neglect, 8.2%) had the highest risk of abuse, compared to other groups, with 69.2–83.1% of those abused belonging to this group, and an increased risk of all indicators of neglect.

Maltreatment classes did not vary by gender, with the 3-class model an adequate fit for both males and females (Appendices 3.5 and 3.6).

Figure 4.2: Child maltreatment: Profiles of retrospective and prospective variables for three latent classes

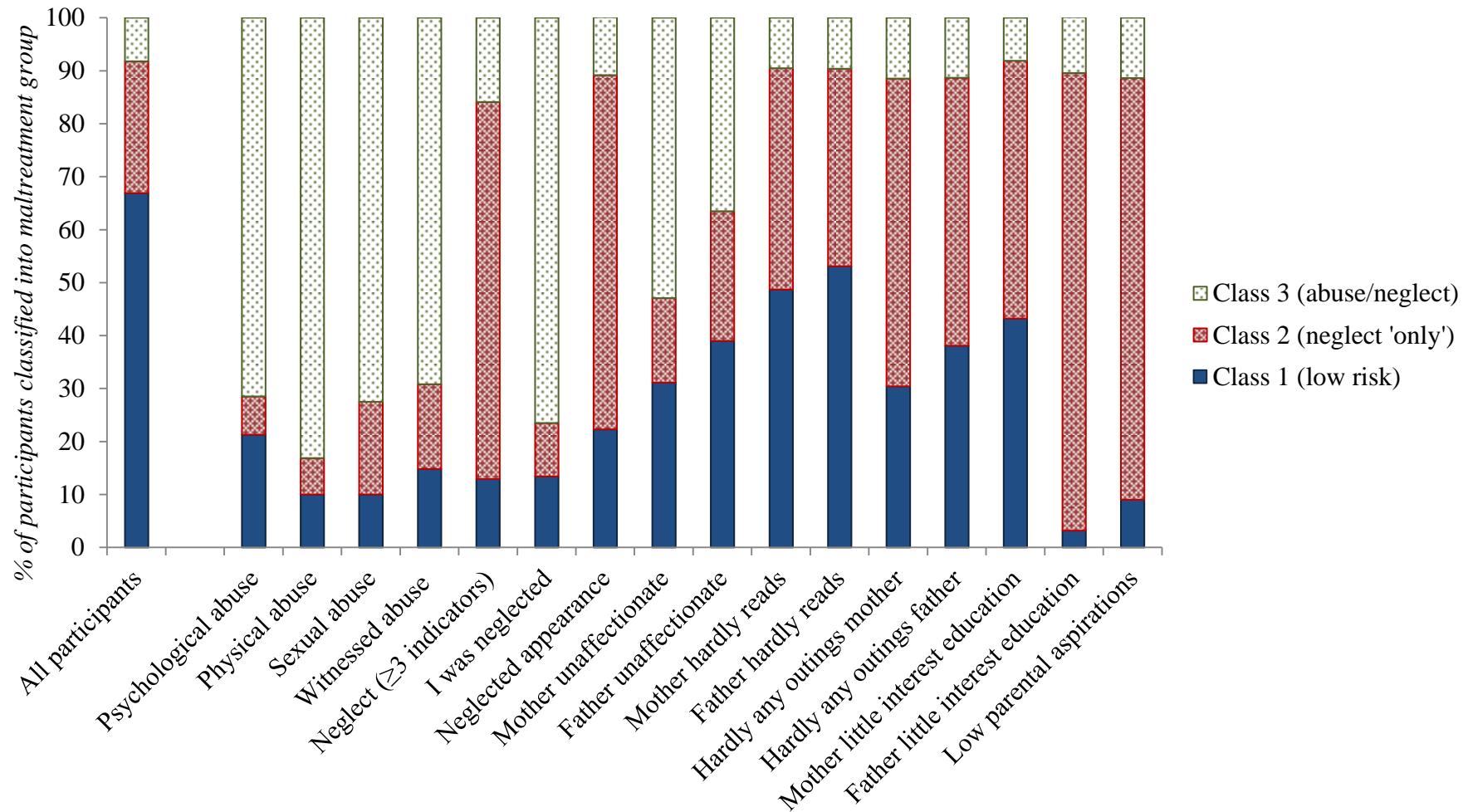


Class 1: Low risk of maltreatment (66.9%)

Class 2: Low risk of abuse and neglect reported retrospectively, but high risk of neglect measured prospectively (24.9%)

Class 3: High risk of abuse and neglect reported retrospectively, intermediate risk of neglect measured prospectively (8.2%)

Figure 4.3: Proportion of cohort members classified into each maltreatment group (identified by Latent Class Analysis: low risk, neglect 'only', abuse and neglect), by child maltreatment measure



4.4.4 *Household dysfunction and child maltreatment*

Household dysfunction measures were significantly associated with maltreatment groups. The association was stronger with class 3 (abuse and neglect) than class 2 (neglect ‘only’), especially for the retrospective measures of household dysfunction (Table 4.8). Family conflict and physical punishment, reported at 45y, were highly correlated with childhood abuse ($r=0.51-0.76$ and $0.52-0.88$ respectively), and were most strongly associated with the ‘abuse and neglect’ group ($RRR=26.3; 21.1, 33.0$ and $RRR=31.0; 26.6, 43.5$, respectively), than ‘neglect only’. Similar effect estimates were shown between each household dysfunction measure collected in childhood and the neglected ‘only’ group. Retrospective measures were weakly associated with the neglected ‘only’ group.

Associations of parental alcoholism, family contact with prison/probation and children’s department and strict upbringing with the neglect ‘only’ group were significantly stronger in females than males. For example, girls who grew up in a household affected by alcoholism were more likely to be neglected (not abused) than those who did not ($RRR=6.7$). No association was found in boys (Table 4.8)

Measures of household dysfunction were also associated with each form of child maltreatment (Table 4.9). In particular, family conflict and physical punishment were strongly related to all forms of abuse. Amongst other measures, strong relationships were found between parental nervous trouble/depression and psychological abuse, strict and authoritarian upbringing and physical abuse, parental separation or time in care and sexual abuse, and alcoholism and father drink/drugs and witnessing abuse of a family member. Domestic tension and alcoholism reported at age 7y were strongly associated with ≥ 3 indicators of neglect compared to other forms of household dysfunction.

There was no significant interaction with gender for most measures of household dysfunction. However, a stronger relationship in boys, than girls, was shown for mother drinking/drugs and physical abuse ($OR=4.5$ for boys vs. 2.3 for girls) and parental divorce and psychological abuse ($OR=4.4$ vs. 2.9). A significant relationship between father drinking/drugs and sexual abuse was shown for girls only (Table 4.9).

Table 4.8: Relative risk ratio (RRR: 95% CI) of distinct maltreatment classes (identified from LCA: neglect ‘only’, abuse and neglect) by household dysfunction measure

Household dysfunction	Class 2 † (neglect ‘only’)	Class 3 † (abuse/neglect)
	RRR (95% CI)	RRR (95% CI)
Domestic tension	3.43* (2.53, 4.66)	4.75* (3.24, 6.97)
Alcoholism	-	3.43* (1.32, 8.87)
Males	0.80 (0.26, 2.48)	-
Females	6.65* (1.73, 25.57)	-
Family member mental health problems	2.39* (1.76, 3.23)	2.75* (1.82, 4.15)
Mother mental health problems	2.37* (1.60, 3.52)	3.75* (2.30, 6.11)
Father mental health problems	2.02* (1.18, 3.44)	3.21* (1.65, 6.24)
Did not get on well with mother	1.61* (1.17, 2.21)	3.26* (2.25, 4.73)
Did not get on well with father	2.04* (1.58, 2.64)	4.17* (3.07, 5.66)
Family contact prison/probation services	-	5.53* (3.88, 7.90)
Males	2.91* (1.96, 4.32)	-
Females	5.46* (3.62, 8.24)	-
Family contact children’s department/charity	-	4.08* (2.89, 5.77)
Males	2.43* (1.63, 3.62)	-
Females	4.19* (2.92, 6.00)	-
In care by age 16y	2.88* (1.87, 4.43)	5.49* (3.31, 9.12)
A lot of conflict	1.43* (1.16, 1.76)	26.34* (21.05, 32.96)
Mother drink/drugs	1.52* (1.14, 2.04)	3.03* (2.14, 4.27)
Father drink/drugs	1.59* (1.30, 1.94)	5.95* (4.76, 7.45)
Mother nervous trouble/depression	1.15 (0.98, 1.35)	4.46* (3.66, 5.43)
Father nervous trouble/depression	0.95 (0.76, 1.17)	3.50* (2.78, 4.40)
Strict/authoritarian upbringing	-	4.86* (4.00, 5.90)
Males	0.88 (0.71, 1.08)	-
Females	1.19 (0.98, 1.45)	-
Physical punishment	1.07 (0.78, 1.47)	31.00* (26.56, 43.53)
Parental separation/divorce	2.74* (2.18, 3.45)	6.16* (4.71, 8.07)

† Multinomial logistic regression models were used, class 1 (low risk of maltreat) is reference category. All models were adjusted for social class at birth. For most household dysfunction measures, RRR (95%) was estimated for both genders combined, adjusting for gender. For some measures, there was a significant gender interaction, thus RRR was given for each gender * $p < 0.05$

Table 4.9: Odds ratios (OR: 95% CI) of childhood maltreatment by household dysfunction measure†

Household dysfunction	Child maltreatment; OR (95% CI)				
	Psychological abuse	Physical abuse	Sexual abuse	Witnessed abuse	≥3 indicators of neglect±
Domestic tension	2.49* (1.90, 3.26)	2.82* (2.07, 3.84)	3.04* (1.75, 5.26)	2.69* (1.96, 3.68)	4.44* (3.35, 5.87)
Alcoholism	1.77 (0.89, 3.52)	2.21* (1.04, 4.73)	4.96* (1.87, 13.15)	4.27* (2.28, 7.98)	4.43* (2.07, 9.47)
Did not get on well with mother	2.02* (1.51, 2.72)	2.21* (1.56, 3.14)	2.23* (1.20, 4.14)	2.00* (1.39, 2.88)	1.83* (1.38, 2.44)
Did not get on well with father	3.07* (2.45, 3.83)	3.51* (2.70, 4.55)	3.38* (2.12, 5.40)	3.15* (2.40, 4.13)	1.89* (1.49, 2.39)
Family member mental health problems	2.04* (1.51, 2.76)	1.84* (1.26, 2.68)	4.02* (2.38, 6.79)	2.10* (1.47, 3.00)	2.98* (2.25, 3.94)
Mother mental health problems	2.10* (1.47, 3.01)	1.82* (1.15, 2.86)	1.99 (0.91, 4.37)	2.01* (1.29, 3.12)	2.35* (1.64, 3.35)
Father mental health problems	1.84* (1.10, 3.09)	2.11* (1.17, 3.81)	1.68 (0.52, 5.44)	2.14* (1.18, 3.87)	2.41* (1.48, 3.90)
Family contact probation services	1.93* (1.49, 2.49)	2.06* (1.52, 2.80)	4.16* (2.67, 6.47)	3.36* (2.57, 4.40)	3.68* (2.86, 4.74)
Family contact children's department	2.59* (2.05, 3.26)	2.38* (1.79, 3.16)	5.26* (3.45, 8.02)	2.53* (1.92, 3.34)	3.56* (2.79, 4.53)
In care by age 16y	3.19* (2.29, 4.46)	3.52* (2.41, 5.14)	6.13* (3.50, 10.73)	2.76* (1.84, 4.12)	4.18* (2.83, 6.18)

Prospective variables

Household dysfunction	Child maltreatment; OR (95% CI)					≥ 3 indicators of neglect \pm
	Psychological abuse	Physical abuse	Sexual abuse	Witnessed abuse		
A lot of conflict	18.34* (15.71, 21.42)	13.10* (10.89, 15.76)	8.06* (5.76, 11.27)	18.08* (14.91, 21.91)		2.50* (2.13, 2.93)
Mother drink/drugs	3.40* (2.69, 4.28)	-	1.66 (0.91, 3.03)	3.84* (2.94, 5.02)		1.52* (1.16, 1.99)
Male	-	4.52* (3.01, 6.80)	-	-		-
Female	-	2.30* (1.54, 3.43)	-	-		-
Father drink/drugs	4.08* (3.47, 4.81)	3.80* (3.11, 4.63)	-	5.87* (4.86, 7.09)		2.16* (1.82, 2.57)
Male	-	-	0.44 (0.06, 3.30)	-		-
Female	-	-	4.06* (2.77, 5.95)	-		-
Mother nervous trouble/depression	4.72* (4.10, 5.44)	3.53* (2.96, 4.21)	3.37* (2.43, 4.68)	3.92* (3.29, 4.68)		1.50* (1.30, 1.73)
Father nervous trouble/depression	4.07* (3.44, 4.80)	2.64* (2.13, 3.28)	2.47* (1.66, 3.70)	3.77* (3.00, 4.52)		1.18 (0.98, 1.43)
Strict/authoritarian upbringing	4.56* (3.97, 5.25)	6.19* (5.16, 7.43)	3.64* (2.62, 5.07)	2.98* (2.50, 3.55)		1.30* (1.15, 1.48)
Physical punishment	27.45* (22.95, 32.83)	66.10* (53.15, 82.21)	8.96* (6.38, 12.58)	13.04* (10.75, 15.82)		2.32* (1.90, 2.82)
Parental separation/divorce	-	3.70* (3.00, 4.58)	5.80* (4.04, 8.31)	4.36* (3.55, 5.35)		2.69* (2.20, 3.30)
Male	4.37* (3.34, 5.71)	-	-	-		-
Female	2.87* (2.27, 3.64)	-	-	-		-

\dagger All models were adjusted for social class at birth. \pm three or more indicators of neglect (eight prospective and three retrospective measures). For most household dysfunction measures, OR (95%) was estimated for both genders combined, adjusting for gender. For some measures, there was a significant gender interaction, thus OR was given for each and gender * $p < 0.05$

4.5 Discussion

In the 1958 British birth cohort, the estimated prevalence of any form of childhood abuse was between 14.2% and 17.1%, (10-12.5% psychological, 6.1-9% physical, and 1.6-2.9% sexual abuse), whilst 25.9-31.6% had a high neglect score. There was a high level of co-occurrence amongst different forms of child maltreatment; of those reporting abuse, two thirds also reported other forms of abuse or had a high neglect score. For a unit increase in neglect score, the risk of each form of abuse increased incrementally by approximately 30%. The LCA model identified 8.2% of participants at risk of both abuse and neglect, and a further 24.9% at a high risk of neglect (without abuse). Measures of household dysfunction were strongly associated with all types of child maltreatment. However, associations were stronger with the abuse/neglect group than neglect 'only' group, suggesting participants from dysfunctional family backgrounds were most vulnerable to multiple forms of child maltreatment, and abuse in particular. These results provide evidence of the extent to which different forms of child maltreatment co-occur in a generation born fifty years ago.

4.5.1 *Methodological considerations*

A major strength of the study is in its longitudinal design, which has enabled identification of child maltreatment and household dysfunction from information collected in adulthood and also in childhood, from multiple informants. Measures used resonated with the conventional definition, although it is possible some may not reflect all aspects of the definition. For example, witnessing abuse was specific to physical or sexual abuse in this study, whereas the conventional definition also includes psychological, financial and emotional abuse. However, measures for child abuse and neglect in the 1958 cohort were in close agreement with the conventional definitions and reflected the lack of parental support to meet a child's emotional/educational needs²⁹. The wide range in retrospective and prospective measures provides a unique opportunity to examine child maltreatment and their associations with household dysfunction measures in a national cohort.

There are potential limitations to the study. Information on child abuse and some neglect and household dysfunction measures were self-reported at age 45y and may be affected by recall bias,^{330;333} possibly related to participants current emotional and

physical states³²⁰. High correlations among retrospective reports ($r=0.31$ to 0.83) may suggest a ‘response set’ effect, whereby individuals who reported one form of child maltreatment may have a tendency to report other adversities^{439;440}. However, the neglect score, which is composed predominantly of prospectively ascertained variables, was associated with increased risk of all abuse types, providing some validity for retrospective reports of abuse and neglect³⁶⁵.

Some dimensions of adverse childhood experience are not well recorded or represented in the study. Information on the severity of abuse experiences, including age of onset and frequency of abuse, are not known. It is also possible that there is overlap in concepts between some measures of child maltreatment and household dysfunction. For example, the definition of both child physical abuse and physical punishment (household dysfunction) includes a parent hitting the cohort member. The shared definition could account for the strong association found between physical abuse and physical punishment.

Sample attrition potentially affects the precision of prevalence estimates for the group remaining in a longitudinal study over time. In the 1958 cohort, those who had experienced neglect or household dysfunction in childhood were less likely to participate in the 45y follow-up. Thus, rates for those remaining in the study at 45y may be an under-estimate of the true prevalence. To allow for differential participation, estimates were calculated for an imputed sample of survivors at age 45y. The higher prevalence estimates from the imputed data (which accounts for missing patterns) are more likely to reflect the true extent of maltreatment and household dysfunction than complete cases. Sensitivity analyses showed that the strengths of association between household dysfunction and childhood maltreatment were similar for the sample remaining in the 45y survey and the imputed sample (Appendix 3.2).

4.5.2 *Characteristics and prevalence of child maltreatment*

As in previous studies, low socio-economic status and low parental educational achievement were associated with participants reporting abuse and neglect age 45y^{294;318}. Unlike other studies^{298;441}, level of maternal education was not associated with most child maltreatment measures, possibly as a consequence of fewer women

remaining in education in the mid-twentieth century, compared to contemporary populations. The established literature indicates that disabled children are more likely to be abused and neglected compared to able-bodied children⁴⁴². Disability was not associated with retrospective measures of child maltreatment in the 1958 cohort, potentially due to the small number of disabled participants in the cohort.

The prevalence of witnessing abuse, psychological and physical abuse in the 1958 cohort was within the range reported in a recent review²⁹, but the prevalence of sexual abuse was lower (1.6% - 2.9% versus 5-30%). The disparity in estimates possibly reflects differences in study populations, definition of childhood and sexual abuse, and methods of data collection (e.g. agency reports vs. parent or self-reports)^{39;429;430}. In a meta-analysis of worldwide studies, methodological factors accounted for nearly a quarter of the variance in prevalence estimates of child sexual abuse. Prevalence estimates were lower in: 1) community cohorts compared to college and general practitioner samples, 2) studies that used narrow rather than broad definitions of sexual abuse, 3) those that adopted one as opposed to multiple questions to assess sexual abuse and 4) male cohorts compared to females⁴⁴³. Thus, prevalence estimates may be low in the 1958 cohort because it is a general population study which adopted one question to ascertain child sexual abuse. The low prevalence of sexual abuse may have implications for the power to detect an effect on later outcomes, such as child-to-adult height growth and pubertal development.

Some emotional neglect measures collected in childhood were highly prevalent, e.g. ‘mother/father little interest in education’, such that two thirds of the cohort had ≥ 1 neglect indicator. This was possibly because most were derived from repeat measurements. It is likely that reliance on any single indicator of neglect may be misleading. However, the prevalence of neglect in the 1958 cohort (3.5-30.4%) is comparable to that reported in the NSPCC’s 1999 survey in which over a third of participants reported at least one form of emotional neglect⁴⁴⁴.

Consistent with previous studies, psychological and sexual abuse were retrospectively reported more frequently by females than males^{23;342;416}. Neglect measures at age 45y were also more commonly cited amongst females than males. In contrast, where gender differences were found for prospective indicators of neglect, a greater proportion of

boys were neglected compared to girls. The discrepancy between self and parent-reported neglect measures suggest that males were less likely to report maltreatment experiences at age 45y, than females. In a Canadian study, male participants known to have experienced sexual abuse were less likely to retrospectively report child maltreatment than female cohort members⁴¹⁸. Herbert et al concluded that male victims may be less likely, than females, to disclose their abuse experiences due to greater feelings of shame and self-blame. Therefore, by using both prospective and retrospective methods to ascertain cases of neglect, it is possible that fewer participants will have been misclassified.

4.5.3 *Co-occurrence of child maltreatment*

Co-occurrence of different forms of child maltreatment was common in the 1958 cohort, as shown elsewhere³⁹. In other community studies, the proportion of children who experienced multiple forms of abuse (psychological, physical and sexual abuse and witnessed abuse of family member) varies from 42.1–64.4%^{37;127;445}. Estimates from this study are at the upper end of this range: of those abused, 61.9% males and 68.3% females reported another form of maltreatment (including neglect).

The identification of two distinct maltreatment groups in this study was a novel finding. Although co-occurrence of child maltreatment measures was observed in the cohort, a distinct group of participants who had a high risk of neglect but a low risk of abuse was detected. Childhood abuse tended to co-occur with neglect, but less so vice versa. This is consistent with findings from LONGSCAN, where the majority of sexual and physical abuse cases involved multiple forms of maltreatment, whereas neglect cases rarely reported co-occurring abuse³⁴. Agency reports have found neglect to be the most common maltreatment reported^{18;99}, and community studies have shown that neglect is the most frequent form of maltreatment to occur in isolation⁴⁴⁶. Results from the 1958 cohort further support findings that indicate that abused participants are more likely to be neglected, whilst those neglected were not necessarily abused.

It is possible that the identification of a neglect ‘only’ group may be due to the high prevalence of prospectively reported indicators of neglect in the 1958 cohort. Over a third of cohort members reported individual childhood neglect measures, such as

interest in education and low parental aspirations, and over two thirds reported at least one indicator of neglect. In the LCA model, prospective and retrospective neglect measures distinctly clustered between the two maltreatment groups: 45y measures in the abuse and neglect group and childhood measures in neglect ‘only’. Furthermore, the correlation between retrospective and prospective measures of neglect was weaker compared to correlations between measures collected during the same period (Appendix 3.3). These differences suggest that indicators of neglect collected in childhood and at age 45y may be measuring different things. Instead, prospective neglect measures may be more reflective of socio-economic disadvantage, than retrospective variables. Comparing the relationship between different indicators of neglect and social class at birth, childhood measures are more strongly related to social class at birth than those reported in adulthood (Appendix 3.7). In addition, the strength of association between maltreatment groups and social class at birth is greater amongst participants classified as neglected ‘only’, compared to none maltreated and abuse and neglect. Thus, the LCA model may have identified participants who were at high risk of socio-economic disadvantage, as well as parental neglect.

4.5.4 Household dysfunction and child maltreatment

Evidence is substantial for both volatile family environment^{94;437;447} and physical punishment^{94;447;448} to be associated with child maltreatment. In the 1958 cohort, the relationship between these household dysfunction measures and child maltreatment was stronger than those presented elsewhere. The difference in findings may reflect methodological differences with prior studies mostly using agency reports to investigate the association⁴³⁰. Alternatively, the larger effect sizes found between certain measures could reflect a lack of distinctness of concepts between some measures. For example, the strong association between physical punishment and physical abuse may be because they are measuring the same thing. Likewise, ‘a lot of conflict’ and witnessing abuse may reflect similar constructs and thus were strongly related.

Overall, findings from the 1958 cohort indicate that household dysfunction measures were associated with a range of child maltreatment measures. Specific markers of household dysfunction may be particularly informative for predicting some forms of child maltreatment. For example, family contact with children’s department or charity

and time in care were more strongly associated with sexual abuse, than other forms of maltreatment. However, the strength of association between most forms of household dysfunction measure and child maltreatment were comparable. Thus a greater number of risk factors may be more predictive of later maltreatment, than any one individual risk factors¹⁹². In addition, the result of a stronger association for the abuse and neglect group, than neglect ‘only’ suggests that children from dysfunctional family backgrounds have a higher risk of being maltreated across a broad spectrum than those who are not. In the 1958 cohort, measures of child maltreatment and household dysfunction accumulated in participants. Such accumulation of adverse childhood experiences may have implications for the later health of cohort members.

4.5.5 *Conclusion*

Child maltreatment is common and likely to occur in multiple forms. Children from dysfunctional family backgrounds are most vulnerable to different forms of abuse and neglect. More attention to a wide range of measures is needed to identify distinct patterns of child maltreatment, in order to better understand the cumulative impact of childhood adverse experience on life-course outcomes. By understanding the inter-relationships between measures of adversity in early life, their potential influence on health outcomes in the contemporary adult population can be further examined.

5 Adverse childhood experiences and child-to-adult height trajectories

5.1 Background

Adverse childhood experiences (child maltreatment and household dysfunction) have been associated with short stature in children. Most existing studies investigated a specific form of child maltreatment (abuse or neglect) or household dysfunction and height at one particular age. Little is known about the influence of a range of adverse childhood experiences on child-to-adult height growth. It has been shown that some early life factors associated with tempo of growth are related to adult health outcomes. Therefore, establishing the impact of child maltreatment and household dysfunction on height trajectories will enable us to better understand the important pathways through which adverse childhood experiences influence risk of adult disease.

In this chapter I examine the associations between child maltreatment and household dysfunction on child-to-adult height trajectories.

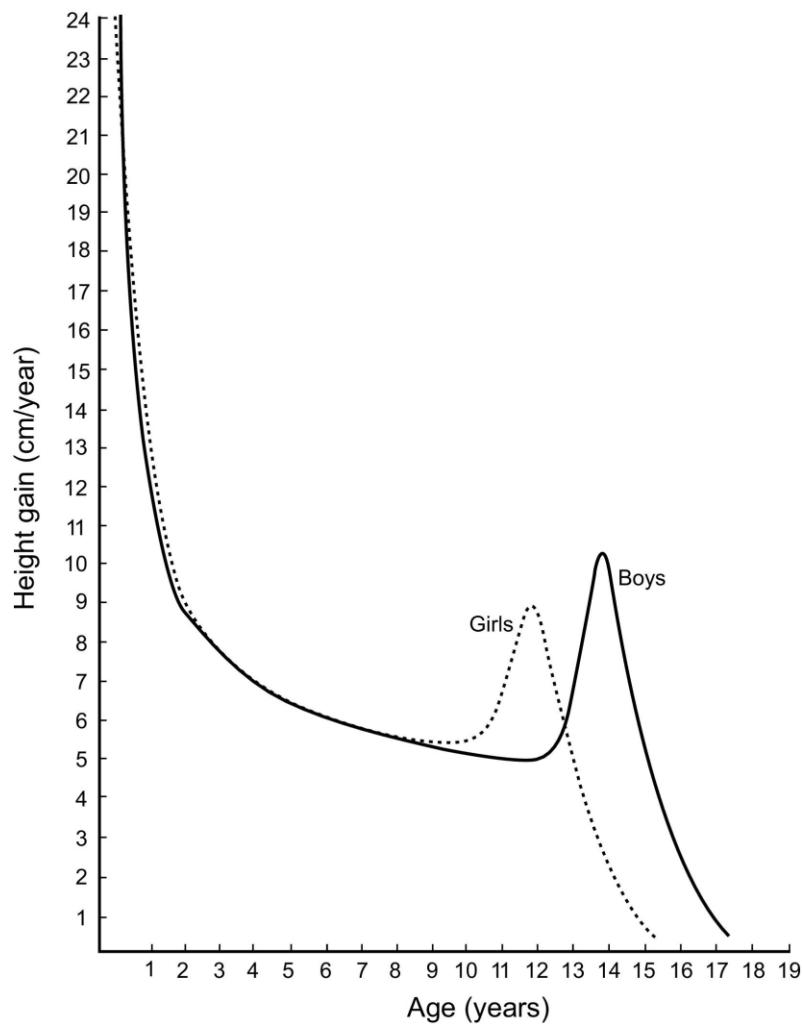
5.1.1 *Height growth*

Height growth occurs during infancy, childhood and adolescence. As shown in Figure 5.1, growth rate is high between birth and age 3y, with body length increasing by about 50% in the first year⁴⁴⁹. In childhood, growth velocity slowly declines and becomes relatively stable until the onset of puberty. An acceleration in growth rate marks the adolescent growth spurt, and occurs at around age 10-11y for girls and 12-13y for boys. Growth rate continues to accelerate until peak height velocity is reached (\approx age 12y for girls and \approx age 14y for boys) and is followed by a rapid decline in growth rate until final adult height is attained. By age 16-17y most girls have reached 98% of their final height, whereas boys reach the same stage at age 17-18y⁴⁴⁹.

Linear growth is regulated by growth hormones and sex steroids (testosterone in males and oestrogen in females), the latter regulating the growth spurt during adolescence. Individual components of height are characterised by growth at different periods. A

greater proportion of pre-pubertal growth is attributable to increases in leg length than in trunk length, whereas growth in trunk length is greater during the pubertal growth spurt⁴⁵⁰.

Figure 5.1: Height velocity curves for boys and girls from birth to age 18y; taken from Labarthe and adapted from Tanner^{451,452}



5.1.2 *Influences on height growth*

Factors found to influence height growth include genetics, prenatal and environmental circumstances. There is evidence to suggest that the effect of these factors on height may vary at different life stages. A summary of genetic and socio-economic influences on height growth are presented here.

Heritability of height; Genetics is a major factor in determining the body size of individuals. The heritability of adult height is estimated at between 0.89-0.93⁴⁵³. Height growth has been described as a classical quantitative trait. Genome-wide association studies have identified a total of 54 gene loci affecting height variation in the population⁴⁵⁴. Parental height has a strong association with their offspring's height growth^{455;456}. The association has been shown to increase with age of offspring, indicating that parental height is more strongly related to adult stature than childhood height^{457;152;458}. Though the strength of the association reflects genetic influences, it also reflects similarities in early life environment⁴⁵⁹.

Early life factors; Despite the high heritability of height, early environmental influences have also been shown to play an important role at each phase of linear growth. Birth weight is positively associated with childhood and adult stature^{460;207}. Factors associated with foetal growth (e.g. birth weight and length), such as maternal smoking during pregnancy and birth order, have been inversely related to childhood height^{14;152;210;461;462}. However, restricted prenatal growth is often followed by postnatal catch-up growth, i.e. lighter and shorter babies tend to grow faster during infancy than those born of average size^{152;458;463-467;468}.

It is well established that diet and nutritional status in early life influence height growth⁴⁶⁹. Breastfeeding has been linked to rates of growth in the first year of life^{152;206;212;462}. High calorie and protein rich supplements in early childhood increase body size^{204;470}. Deficiencies in some nutrients, including zinc, iron, iodine and vitamin D, have been associated with stunting in childhood⁴⁷¹. Population studies have shown increases in average adult height during periods of food surplus⁴⁷². It has been suggested that secular trends in adult height in the last century were due, in part, to improvements in quality of food intake^{205;473}.

Infection is a well-known influence on height growth, adversely affecting height through its interaction with nutritional status. For example, gastrointestinal damage caused by infection leads to malabsorption of micronutrients causing reductions in growth and leading to shorter adult stature²⁰⁵.

Socio-economic circumstances in early childhood have been associated with height growth^{152;154;211}. Low maternal education, manual occupation of the father, large family size and overcrowded accommodation have been associated with short stature, with stronger associations found with childhood compared to adult height^{207;460}. Individuals from socio-economic disadvantaged backgrounds tend to have delayed height growth in early childhood, mature later and grow at a faster rate or for a longer period, compared to those that are not. Therefore, differences in adult stature are smaller than in childhood^{152;214}.

It has been suggested that secular trends in adult height are attributable to increases in leg length rather than trunk length^{205;474}. Factors associated with leg length include childhood diet and socio-economic circumstances. For example, breastfeeding has been associated with longer legs²³¹, whilst overcrowding at age 7y has been related to disproportionately shorter legs in adulthood¹⁵⁴. In contrast, birth weight has been found to be positively associated with both leg and trunk length²³¹, whereas serious illness in childhood has been associated with short trunk length in adulthood¹⁵⁴.

5.1.3 Influence of child maltreatment on height growth

Child maltreatment and household dysfunction have been associated with poor height growth in childhood; however evidence is limited (Tables 5.1-5.3).

There is some indication that child abuse and neglect are associated with short stature and leg length in childhood (Table 5.1). In England, a clinical sample of 91 severely abused and/or neglected children were shorter by > 2 SD and had disproportionately shorter legs compared to matched non-maltreated peers¹⁴¹. Two Spanish studies found that children in foster care due to maltreatment to be below normal standards for height¹⁴², with height deficits being more evident among infants (age ≤ 2 y) compared to older children¹⁴⁵. An American study found that children in foster care were more likely to be at (or below) the 5th percentile for height than non-maltreated matched controls¹⁴³. After follow-up for at least one year, maltreated children in foster care tend to experience accelerated growth compared to those who remain in their natural homes^{144;145}, and the general population¹⁴².

Most studies of child maltreatment and height growth were based on foster care samples (Table 5.1). Poor growth has consistently been found in institutionalised children⁴⁷⁵. An effect of adverse emotional environments on height growth was first shown in a study of two German orphanages after World War II. Children aged 4-14y cared for by a cheerful woman gained more weight and height than those governed by a stern, strict matron over a year period, despite the latter receiving additional calories⁴⁷⁶. Recent studies of international adoptees also indicate that children who have experienced extreme emotional and physical deprivation often have retarded physical growth development at the time of adoption (Table 5.2)^{477;478}. Meta-analyses suggests that there is almost complete catch-up in height amongst adoptees during childhood⁴⁷⁹. Age at adoption may affect catch-up height growth, with older age at adoption being an important predictor of short stature in later life^{477;480;481}.

The evidence of a relationship between child maltreatment and height growth is mostly based on small and convenient samples. Maltreatment cases were identified by agency reports and most of these children have received some form of intervention, such as being placed into care or being hospitalised (Table 5.1). Thus the study samples are not representative of all those maltreated in the population³²⁴. Individual forms of child abuse and neglect may influence later health outcomes differently^{427;446;482-484}, yet most existing studies have adopted a summary measure of child maltreatment. Furthermore, multiple forms of maltreatment may have a cumulative effect on height growth, as it is associated with more severe health outcomes^{36;182;188;485}. Little attention has been given to the influence of multiple forms of child maltreatment on height growth. The current literature focuses on height at specific ages in infancy, or over short periods during adolescence. To date, no study has examined whether the effect of child maltreatment on height persists to adulthood at a population level.

5.1.4 Influence of household dysfunction on height growth

There is some evidence to suggest that family conflict, familial distress, parental substance abuse and parental divorce/separation, are associated with short childhood stature¹⁵¹⁻¹⁵⁴ and adult trunk length¹⁵⁴ (Table 5.3). Girls with prolonged experiences of family distress (due to parental death, separation, prolonged illness, alcoholism or criminal activity) prior to age 11y were found to be more likely to reach skeletal

maturity earlier and remain shorter adolescents and adults compared to others¹⁵¹. A previous study of the 1958 birth cohort found evidence of delays in growth amongst males whose parents had divorced/separated prior to age 4y, independent of early environmental factors¹⁵². In the 1946 British birth cohort, parental separation before age 6y was independently associated with adult trunk length, but not leg length¹⁵⁴. Both studies suggest that factors indicating household dysfunction in early life may be associated with height trajectories and also components of height.

Existing studies of household dysfunction and height are mostly based on specific measures of household dysfunction such as parental divorce (Table 5.3). Where multiple measures of household dysfunction have been investigated, analysis has been restricted to a summary measures (i.e. household dysfunction present or not)¹⁵¹. Children from dysfunctional family backgrounds are likely to experience a wide range of adversities^{32;438} and these are not currently reflected in the available literature. In addition, few studies have examined the influence of household dysfunction on growth patterns, as most focus on height at a specific age^{151;152}.

In Chapter 4, and elsewhere^{266;276}, household dysfunction has been shown to co-occur with child abuse and neglect, yet little is known about their joint influence on height growth. Accumulation of child maltreatment and household dysfunction has been associated with other aspects of childhood development, such as behaviour^{192;433}, mental health⁴⁸⁶ and academic outcomes⁴⁸⁷. However, the association between multiple forms of child maltreatment and household dysfunction and child-to-adult height trajectories has not been explored.

Table 5.1: Studies of the association between child maltreatment (agency reports) and height

Study	Design		Outcomes	Adjustment	Main findings
	Year of birth	N			
Sheffield child abuse study, England ^{141;144}	Cross-sectional unknown	Physical abuse & neglect <14y. 91 cases; 345 controls	Height & leg length (2mths-13.2y)	Fathers manual or none-manual classes, unemployed	Abuse & neglect associated with shorter stature & disproportionate lower limbs.
	Longitudinal (cases)	Abuse & foster care 260	Height & weight (0-14y)		Abuse associated with shorter stature & lower weight. Stay in foster care associated with catch-up growth.
Zaragoza City, Spain ¹⁴²	Longitudinal (cases) 1990-99 20 (boys only)	Physical neglect & emotional abuse (>6 months); >1 year in foster care	Height & weight at baseline (2-4y) & after 1 year in foster care.		Maltreatment associated with shorter stature & lower weight entering foster care. One year in foster care associated with catch-up growth.
Oregon study, USA ¹⁴³	Cross-sectional unknown 99 cases; 54 controls	Sexual, physical & emotional abuse & neglect & in foster care	Height (3-6y)		Neglect/emotional abuse associated with shorter stature in children in foster care. Number of maltreatment experienced was not associated with height.
Catalonia, Spain ¹⁴⁵	Longitudinal (cases) 1980-98 118	Battering, abandonment &/or neglect & in foster care for an average 229 days	Height (1mth-15y)		Foster care due to child maltreatment associated with shorter stature, stronger effect sizes in children aged ≤ 2 y. Stay in foster care associated with catch-up growth.
	31		Height (18mths-11y)		Foster care not associated with abnormal nutritional status

Table 5.2: Studies of the association between international adoption and height

Study	Design		Outcomes	Adjustment	Main findings
	Year of birth	N			
International adoptees†, USA ⁴⁸⁰	Longitudinal unknown 200 cases	Adopted & time in institutions (institutionalised vs. adopted early)	Height & weight for age at adoption (1-69mths) & in current assessment (8-11y)		At adoption: institutionalization associated with larger height & weight deficits compared to early adoption. At current assessment: adoption in general related to shorter stature.
English & Romanian Adoptees (ERA) study, England ^{477;478}	Longitudinal 1987-1992 165 cases; 52 controls	Age at adoption	Height for age at adoption (0– 42mths) & 4y.		Adoption from Romania associated with height deficits at baseline & at 4y. Younger age at adoption associated with catch-up growth
		≥ 6 month in institution & weight for age at adoption (under-weight 1.5 SD below U.K norm)	Height from age 6 to 15y	Deprivation- specific psychological pattern	≥ 6mths in institution associated with acceleration of growth between 6 to 11y & deceleration of growth between 11 & 15y. No association between weight at adoption & growth patterns.
International adoptees ⁴⁷⁹	Meta-analysis 33 studies	International adoption & duration in institutional care	Height for age at adoption (3mths- 11y) & later (18mths-18y).		International adoption & longer duration in institutional care associated with shorter stature at adoption & later.

† Adopted from Russia, Eastern Europe, South America and Asia

Table 5.3: Studies of the association between household dysfunction and height

Study	Design		Outcomes	Adjustment	Main findings
	Year of birth	N			
1946 British birth cohort, England, Scotland & Wales ¹⁵⁴	Cross-sectional 1946	3,262	Parental separation or divorce by 6y	Trunk & leg length at 43y	Parental height, birth weight, energy intake at 4y, childhood health, height & weight, fathers occupation, SEP
1958 British birth cohort, England, Scotland & Wales ^{153;152}	Cross-sectional 1958	6,574	Family conflict at 7y,	Height 7y	SEP & household crowding 7y; height 33y
	Longitudinal 16,835		Parental separation or divorce by 7y	Height 7, 11, 16, 23, 33y	Parental height, birth weight, family size & SEP
Wroclaw Growth Study, Poland ¹⁵¹	Longitudinal 1953	274 girls	Family distress at 11y (parental death, separation, prolonged illness, social deviations, e.g. alcoholism, criminal activity)	Height & subischial length yearly (8 to 18y) & age reach a)menarche b)Carpel score 1,000 c)RUS score 1,000 d)total bone score 995	Familial distress associated with earlier age of menarche, earlier advanced skeletal maturity & shorter stature at each age.
Swedish Level of Living Surveys, Sweden	Cross-sectional 1916 - 76	4,574	Family dissension & single parent families (up to 16y)	Short stature (1sd below mean height) (15-75y)	Age, gender, SEP, economic hardship & large family
					Dissension in the family & single parent families were not associated with height after adjustment for economic status.

'SEP' socio-economic position

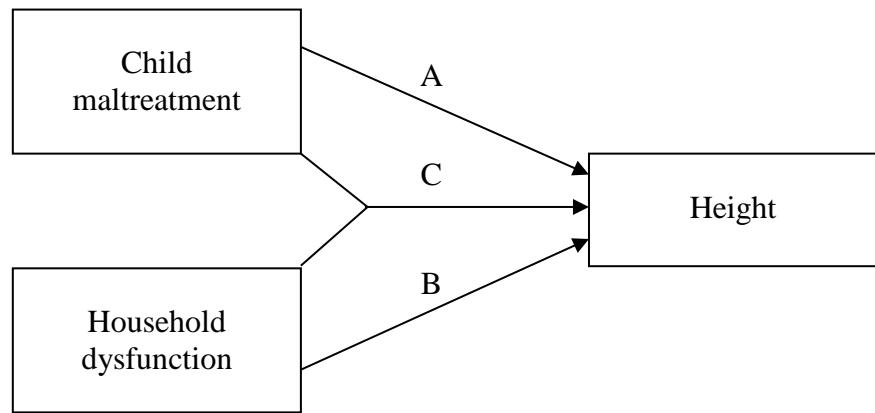
Based on research to date, I hypothesise that firstly, child maltreatment (abuse and neglect) is associated with child-to-adult height trajectories. The strength of association is greater for neglect reported at earlier ages compared to late childhood and that multiple forms of child abuse and neglect are more strongly related to height growth than any individual measure. Secondly, measures of household dysfunction in early life are associated with height trajectories. Thirdly, there is a cumulative effect of child maltreatment and household dysfunction on height growth (for each additional adverse childhood experience deficits in height at each age will increase).

5.2 Objectives

There are three main objectives in this chapter (illustrated in Figure 5.1).

1. Assess whether child maltreatment was associated with child and adult height and adult leg length, and whether the association persisted after adjustment for potential confounding factors (pathway A). The exposure measures include;
 - i. child abuse and neglect retrospectively reported at age 45y
 - ii. indicators of childhood neglect prospectively collected, and
 - iii. multiple forms of child maltreatment.
2. Determine whether household dysfunction in early life was associated to height growth, and whether the association persisted after adjustment for potential confounding factors (pathway B).
3. Establish whether there was a cumulative effect of child maltreatment and household dysfunction on height growth (pathway C).

Figure 5.5.2: Pathways between child maltreatment, household dysfunction and height



5.3 Methods

5.3.1 *Study samples*

The analysis in this chapter includes 14,025 cohort members for whom information on child maltreatment, household dysfunction and height at one age (at least) and leg length were available.

5.3.2 *Measures*

Response measures were height at ages 7, 11, 16y and adult height (§2.3.1). In order to compare the effect of an exposure on height across ages, and between males and females, internally derived, age and gender-specific standard deviation scores (SDS) were derived for height and adult leg length (§2.3.1).

Exposure measures were child maltreatment and household dysfunction collected in childhood and also in adulthood. Forms of child abuse retrospectively reported at age 45y were psychological, physical and sexual abuse, as well as witnessed abuse. For childhood neglect, three indicators were retrospectively reported at age 45y and eight were collected prospectively at ages 7, 11 and 16y (§2.2).

The established literature indicates that early childhood is a critical period for height growth, when exposures have a more important influence compared to those in later childhood (Figure 5.1)^{451;452}. Thus, I expected indicators of neglect at age 7y to be more strongly associated with stature than those reported at older ages (i.e. age 16y). I examined the relationship between indicators of neglect collected at each age in childhood, and subsequent height and adult leg length. A summary variable was derived for each neglect measure reported at one or several ages (e.g. age 7y 'only', 11y 'only' or 7 & 11y). The difference in mean height (SDS) and adult leg length (SDS) was compared between exposures at different ages; non-neglected used as reference category (presented in Appendices 4.1 and 4.2). Results suggest that indicators of neglect recorded at age 7y tended to be more strongly associated with subsequent height than exposures at later ages. Associations were stronger when neglect was reported at multiple ages including 7y (i.e. at age 7y and an additional age) than indicators reported at ages 11 and 16y. Thus in the subsequent analyses, I used prospective indicators of neglect collected prior to, or in concurrence with height measurements (Table 5.4).

In order to examine the cumulative effect of neglect a score was derived by summing all eight 7y indicators of neglect (unlike neglect score adopted in Chapter 4 which summed all neglect measures collected at ages 7, 11, 16 and 45y; range 0-11). Participants with complete data for each indicator at age 7y were included (range 0-8; n=9,245). As height of the child may affect teacher's assessment of neglected appearance (which included child undernourished), a second neglect score (range 0-7; n=13,112), excluding neglected appearance, was derived (Table 5.4). There was little difference in the influence of the neglect score with (range 0-8) and without (range 0-7) neglected appearance on child-to-adult height, and adult leg length. As the response rate for neglected appearance was lower than for other neglect indicators (Table 5.4), and the proportion of cohort members with neglect score would be improved when excluding neglected appearance (n=9,245 vs. n=13,112), results for neglect score using seven indicators are presented in this chapter. Results for neglect score including neglected appearance are given in Appendix 4.5.

Table 5.4: Summary of indicators of neglect at age 7y in the 1958 British birth cohort

Indicators of neglect; 7y	n (%)	Males; %	Females; %
Mother hardly reads to child	14,099 (16.0)	16.8	15.3
Father hardly reads to child	13,641 (28.4)	29.1	27.6
Mother hardly any outings with child	14,159 (1.6)	1.9	1.3
Father hardly any outings with child	13,731 (6.0)	5.7	6.2
Mother little interest in child's education	14,602 (14.8)	15.6	13.9
Father little interest in child's education	14,566 (15.5)	16.3	14.6
Low parental aspirations for child	14,262 (4.3)	4.4	4.2
Neglected appearance of child	10,338 (5.8)	6.9	4.7
0	5,145 (55.7)	54.7	56.6
1	1,746 (18.9)	18.4	19.4
2	1,397 (15.1)	15.4	14.9
Neglect score (range 0-8)	3	493 (5.3)	5.8
	4	265 (2.9)	3.1
	5-8	199 (2.2)	2.7
Total (n)		9,245	4,566
0	7,235 (55.2)	54.5	55.9
Neglect score excluding	1	2,587 (19.7)	19.5
neglected appearance	2	2,068 (15.8)	15.9
(range 0-7)	3	675 (5.2)	5.4
	4-7	547 (4.2)	4.7
Total (n)		13,112	6,694

The association between distinct patterns of child maltreatment and height growth was examined using a categorical measure obtained from responses to all 15 child maltreatment measures using latent class analysis (LCA); low risk, neglect 'only' and abuse and neglect.

As indicators of neglect at age 7y were shown to have the stronger effect on height compared to measures reported at ages 11 and 16y (Appendices 4.1 and 4.2), I repeated an LCA model using seven child maltreatment measures collected at age 45y and eight indicators of neglect reported at age 7y (not combined indicators at ages 7, 11 and 16y as used in Chapter 4). As in the previous LCA model in Chapter 4, the 3-class solution was also an adequate fit and the most parsimonious model according to the goodness of fit criteria (Appendix 4.3). The three distinct maltreatment groups are shown in Appendix 4.4 and were comparable to those found in Chapter 4. The largest group had a low risk of maltreatment (class 1), followed by a group with a low risk of abuse and a

high risk of neglect (class 2, neglect ‘only’) and the third a high risk of abuse and neglect (class 3, abuse and neglect). There was a small difference in the proportion of cohort members classified in the low risk group in the different LCA models (79.5% LCA model using indicators of neglect at age 7y vs. 66.9% childhood neglect LCA model). Fewer participants were also categorised as neglected ‘only’ in the 7y neglect LCA model (11.4%) compared to the childhood neglect LCA model (24.9%). The discrepancy in results possibly reflects the lower prevalence of indicators of neglect at age 7y compared to neglect measures at any childhood age used in Chapter 4. For example, the prevalence of the combined measure of low parental aspirations (ages 7, 11 and 16y) was 33% compared to 4.3% at age 7y only (Table 4.4 and 5.4).

Household dysfunction measures considered in this chapter include domestic tension, parental alcoholism, family member mental health problem, household contact with a probation officer or children’s department/charity, time in institutional care, and parental separation or divorce; all collected at age 7y (Table 5.5). A household dysfunction score was derived by summing all seven household dysfunction measures (n=12,464 individuals with complete data for each indicator were included; range 0-7).

Table 5.5: Summary of household dysfunction measures at age 7y in the 1958 British birth cohort

Household dysfunction; 7y	n (%)	Males; %	Females; %
Domestic tension family difficulty	14,239 (5.2)	5.4	4.9
Alcoholism family difficulty	14,235 (0.9)	0.9	0.9
Family member mental health problems	14,243 (4.6)	4.6	4.7
Family contact with probation officer	12,728 (1.9)	1.9	2.0
Family contact with children’s department/charity	13,267 (4.6)	4.8	4.3
Child in care by 7y	15,053 (2.0)	2.0	1.9
Parents divorced by 7y	13,613 (4.2)	4.4	4.0
Household dysfunction score (range 0-7)	0	10,999 (88.3)	88.0
	1	820 (6.6)	6.64
	2	387 (3.1)	3.3
	3-7	258 (2.1)	2.1
	Total (n)	12,464	6,342
			6,122

To examine whether there was a cumulative effect of childhood adverse experiences on height, neglect and household dysfunction scores were combined to create an overall adversity score at age 7y (i.e. sum of eight indicators of neglect and seven household dysfunction measures; range 0-15) (Table 5.6). Nearly half of children had at least one positive response to a neglect or household dysfunction measure at age 7y. A second adversity score was derived, excluding neglected appearance (range 0-14). There was little difference in results relating to adversity score with (range 0-14) and without (range 0-15) neglected appearance. In addition, as in neglect score, the number of cohort members with an adversity score would be improved when excluding neglected appearance (n=8,172 vs. n=11,548). Thus, results for adversity score excluding neglected appearance are presented in this chapter. Results for adversity score including neglected appearance can be found in Appendix 4.5.

Table 5.6: Summary of adversity score at age 7y in the 1958 British birth cohort

Adverse childhood experience; 7y	n (%)	Males; %	Females; %
0	4,375 (53.5)	52.9	54.2
1	1,568 (19.2)	18.3	20.0
2	1,227 (15.0)	15.4	14.6
Adversity score (range 0-15)			
3	439 (5.4)	5.9	4.8
4	270 (3.3)	3.6	3.0
5-15	293 (3.6)	3.9	3.3
Total (n)	8,172	4,023	4,149
0	6,105 (52.9)	52.2	53.5
1	2,307 (20.0)	19.5	20.5
2	1,773 (15.4)	15.7	15.0
Adversity score excluding			
neglected appearance			
3	621 (5.4)	5.8	5.0
4	411 (3.6)	4.0	3.1
5-15	331 (2.7)	2.8	2.9
Total (n)	11,548	5,879	5,669

Confounding factors; To reduce the likelihood that observed associations between adverse childhood experiences and height growth were related to the presence of a third factor, potential confounding factors were identified from the literature. Previous studies investigating the association between child maltreatment or household dysfunction and height growth have adjusted for parental height, birth weight, diet, childhood illness, SEP, household crowding and family size (Tables 5.1 and 5.3). Corresponding measures were ascertained from the 1958 cohort, and where available were included in the analyses (§2.4). Factors were considered as confounding factors if

they were shown to be associated with both adverse childhood exposures and height growth. Potential confounding factors considered in this chapter are shown in Table 5.7.

Table 5.7: Summary of confounding factors available in the 1958 British birth cohort

Potential confounding factors	N	Mean(SD)/%
Mid-parental height (SDS)	16,676	0.00 (0.84)
Smoking during pregnancy	15,985	33.1
Pre term (<38 weeks)	14,494	8.8
Birth weight (g)	15,649	3358.8 (527.2)
Breast fed	14,149	68.4
Social class at birth		
I/II	2,906	17.5
IIInm	1,569	9.5
IIIm	8,054	48.6
IV/V	4,042	24.4
Household crowding at 7y	15,053	13.0
Housing tenure at 7y		
Owner occupied	6,012	42.3
Council rented	5,646	39.8
Privately rented	1,757	12.4
Other	786	5.5
Household amenities score at 7y (sole/shared vs. none use of bathroom, indoor lavatory and hot water)		
0	11,533	81.6
1-2	984	7.0
3-4	827	5.9
5-6	790	5.6
Major disability at 7y	13,709	1.6

5.3.3 *Statistical analysis*

Multivariate response models were applied to examine each measure of child maltreatment or household dysfunction relationship with child-to-adult height trajectories (§3.2.2). Height (SDS) at ages 7, 11 and 16y and in adulthood were the response variables. Models for four response measures were fitted simultaneously by assuming that height (SDS) at all ages followed a multivariate normal distribution, thus accounting for correlations between height measures. Participants with at least one

height measurement were included in the model. The effect of exposures on height between successive ages (between 7 and 11y, 11 and 16y, 16y and adult) and between childhood (7y) and adulthood were compared using contrast tests. Linear regression models were applied to assess the relationship between child maltreatment, or household dysfunction, and leg length. T-tests were applied to determine whether there was a significant association.

For the association between maltreatment in childhood and height (pathway A), the exposure measures examined were;

1. each form of abuse and neglect reported at age 45y
2. each indicator of neglect reported at age 7y,
3. two neglect scores
 - a. sum of all indicators of neglect at age 7y (range 0-8)
 - b. sum of indicators of neglect at age 7y excluding neglected appearance (range 0-7)
4. three distinct maltreatment groups obtained from LCA of all fifteen measures of child maltreatment (at ages 7 and 45y); low risk of maltreatment adopted as reference category

For the association between household dysfunction and height growth (pathway B), the exposures examined were;

1. each household dysfunction measure reported at age 7y
2. a household dysfunction score (sum of all household dysfunction measures at age 7y; range 0-7)

Finally, I examined the association of adversity score with (range 0-15) and without (range 0-14) neglected appearance with height growth to examine the cumulative effect of neglect and household dysfunction at age 7y (pathway C).

For each exposure measure, unadjusted relationships with height were examined. Potential confounding factors were then included in the models. First, mid-parental height was added, followed by prenatal factors (maternal smoking during pregnancy,

pre-term birth and birth weight) and postnatal factors (social class at birth, breastfed, household crowding, tenure and amenities, and disability at age 7y). Age (in months) when height was recorded was included in all models (unadjusted and adjusted) to account for variations in the timing when measurements were taken. Unadjusted and adjusted differences in height SDS at each age and adult leg length SDS were estimated for participants who were maltreated, or had experienced household dysfunction in childhood, versus those who did not. The difference in height (cm) was derived as the difference in height SDS, multiplied by SD for height for each age and gender. All analyses were conducted for males and females separately due to the differences in growth trajectories and potential variation in associations.

The association between adverse childhood experiences and height growth was studied using different sample sizes, depending on the exposure measures.

Samples used for the analyses of childhood maltreatment and height (pathway A).

For analyses of the association between child maltreatment retrospectively reported at age 45y and height trajectories, all 9,310 participants at 45y had data on child abuse and neglect and height at one or more age, and therefore were included. Of the 9,310 cohort members, 9,078 had information on adult leg length.

For each of the eight indicators of neglect reported at age 7y (10,338-14,602 cohort members with data), 10,222-14,025 participants had at least one height measurement and 5,822-8,201 had a measure for adult leg length. Of those with a neglect score (range 0-8; n=9,245), 9,217 had height at one or more ages and 5,304 had a measure of leg length. Excluding neglected appearance, 13,057 participants with a neglect score (range 0-7; n=13,112) had at least one height measurement and 7,443 had a measure for leg length.

Maltreatment groups (obtained from LCA) were available for 5,386 participants, all of whom had at least one height measurement and 5,279 had data for adult leg length.

Samples used for the analyses of household dysfunction and height (pathway B)

For each of the seven 7y household dysfunction measure (13,267-15,053 with data), 14,756-12,483 cohort members had at least one height measurement and 7,215-8,412 had data for adult leg length. Of those with household dysfunction score (n=12,464), 12,398 had one or more height measurement and 9,180 had data for adult leg length.

Samples used for the analyses of cumulative childhood adversity and height (pathway C)

For analyses of the cumulative effect of neglect and household dysfunction at age 7y on height trajectories, 8,149 cohort members had data on adversity score (range 0-15; n=8,172) and height at one or more ages and 4,684 had a measure of adult leg length. Excluding neglected appearance, 11,502 participants with adversity score (range 0-14; n=11,548) had data on height at one or more ages and 6,597 had a measure of leg length.

Models were restricted to individuals with complete data on the exposure measure of interest (child maltreatment and household dysfunction) and one or more height measurements. Adjusted models were conducted using all available data and these are shown in Appendices 4.6 and 4.7. Analyses were repeated, limiting samples to participants with complete data on all confounding factors (i.e. maximum sample available in the adjusted model) and these are presented here (height n=4,744-11,613; leg length n=3,805-6,418).

Additional analyses

To assess whether the association between adverse childhood experiences and height growth was influenced by sample attrition, as well as missing observations, missing data were imputed (§3.4.1). Data were assumed missing at random (MAR), conditional on specific covariates, and a multiple imputation model was conducted for males and females separately. Variables included in both models were those associated with missing child maltreatment and household dysfunction observations (ethnicity, lone-mother households, social class at birth, reading ability at age 7y), each child maltreatment and household dysfunction measure at ages 7, 11, 16 and 45y and all confounding factors (§2.4.4). Height at ages 7, 11, 16y, adult height and leg length and

pubertal development measures (testicular development, pubic and facial hair growth and age of voice change for boys and breast development, pubic hair growth and age of menarche for girls) were also incorporated into the imputation models (§3.1.1). The chained equation method was used to create 20 complete datasets. Linear regression models were adopted to examine the association between adverse childhood experience and height at age 7y and adult height. Models were fitted to each imputed dataset and overall estimates were attained by combining parameters using Rubin's rules³⁷⁷. Analyses were restricted to participants with complete data on the outcome of interest (i.e. height at age 7y or adult height). Unadjusted and adjusted relationships were examined and results are presented in Appendices 4.8 and 4.9.

5.4 Results

5.4.1 Height measurements

A summary of height measures is given in Table 5.8. The greatest variation (SD) in height was at age 16y in males and age 11y in females, showing gender differences in tempo of growth. The correlation between height at different ages ranged from 0.70 to 0.85 for males and 0.67 to 0.93 for females (all $p < 0.001$), indicating strong correlations within individuals (Table 5.9).

Table 5.8: Summary of height measurements in the 1958 British birth cohort

Age (y)	Height (cm)			
	Males		Females	
	n	Mean (SD)	n	Mean (SD)
7	6,828	122.8 (5.8)	6,487	121.9 (6.4)
11	6,303	143.9 (6.9)	6,082	144.8 (7.5)
16	5,583	170.2 (7.9)	5,299	160.9 (6.2)
Adult	7,137	176.2 (6.8)	7,449	162.2 (6.4)
Adult leg length	4,565	84.0 (4.8)	4,615	76.3 (4.6)

Table 5.9: Correlation coefficients between height measures at age 7, 11 and 16y and adult height

Age	Males				Females			
	7y	11y	16y	Adult	7y	11y	16y	Adult
7y	1.00				1.00			
11y	0.85	1.00			0.81	1.00		
16y	0.75	0.83	1.00		0.74	0.72	1.00	
Adult height	0.70	0.73	0.77	1.00	0.71	0.67	0.93	1.00

All correlation coefficients were statistically significant ($P < 0.001$)

5.4.2 *Child maltreatment and height*

Child abuse and neglect reported at age 45y

Males who were physically abused, or had an unaffectionate father, tended to be shorter in childhood, but not in adulthood (Table 5.10). For females, witnessed abuse of a family member was associated with deficits in height at age 7y (Table 5.11). After adjustment for demographic and socio-economic factors, deficits in childhood height were no longer significant.

Sexual abuse tended to be associated with short stature in both genders. After adjustment, the strength of association did not weaken in males such that sexually abused boys were, on average, shorter in childhood by 0.14 to 0.21SDS (equivalent to 0.8-1.4cm) and adulthood by 0.24SDS (1.6cm), and had shorter legs by 0.32SDS (1.5cm) compared to those who were not sexually abused (Figure 5.3). However, these differences were not significant, possibly due to the small number of cases (n=22). Females who were sexually abused were significantly shorter at age 7y, compared to those who were not, but not thereafter. After adjustment, there was some indication that sexual abuse was associated with increases in height at ages 11 and 16y (≈ 0.10 SDS) and in adulthood (0.12SDS) as shown in Figure 5.3, but relationships were non-significant. Psychological abuse, 'I was neglected' and unaffectionate mother were not associated with height growth.

Table 5.10: Estimated effects (SE) of childhood abuse and neglect (reported at age 45y) on height SDS at age 7, 11 and 16y and in adulthood using multivariate response models, and adult leg length using linear regression models; males¹

Child maltreatment	Unadjusted					Adjusted				
	7	11	16	Adult	Leg	7	11	16	Adult	Leg
<i>Child abuse</i>										
Psychological abuse	-0.01 (0.06)	0.02 (0.07)	0.05 (0.07)	0.10 (0.06)	0.10 (0.07)	-0.06 (0.06)	-0.03 (0.06)	-0.01 (0.06)	0.03 (0.05)	0.04 (0.06)
Physical abuse	-0.17 ^a (0.07)	-0.18 ^a (0.08)	-0.12 (0.08)	-0.09 (0.08)	-0.07 (0.08)	-0.07 (0.06)	-0.09 (0.07)	-0.04 (0.07)	0.00 (0.06)	0.01 (0.07)
Sexual abuse	-0.13 (0.27)	-0.18 (0.30)	-0.12 (0.29)	-0.14 (0.28)	-0.29 (0.32)	-0.14 (0.24)	-0.21 (0.26)	-0.18 (0.26)	-0.24 (0.23)	-0.32 (0.28)
Witnessed abuse	-0.12 (0.09)	-0.11 (0.09)	-0.04 (0.09)	-0.02 (0.09)	-0.03 (0.09)	-0.04 (0.08)	-0.04 (0.08)	0.02 (0.08)	0.02 (0.07)	0.05 (0.08)
<i>Indicators of neglect</i>										
I was neglected	-0.13 (0.14)	-0.23 (0.15)	-0.02 (0.16)	0.04 (0.15)	-0.09 (0.15)	-0.07 (0.12)	-0.18 (0.13)	0.01 (0.14)	0.06 (0.12)	-0.03 (0.13)
Unaffectionate mother	0.09 (0.13)	0.01 (0.14)	0.08 (0.14)	0.11 (0.14)	0.10 (0.14)	0.17 (0.12)	0.08 (0.12)	0.15 (0.13)	0.18 (0.11)	0.17 (0.12)
Unaffectionate father	-0.11 ^a (0.06)	-0.08 (0.06)	-0.05 (0.06)	0.00 (0.06)	0.03 (0.06)	-0.08 (0.05)	-0.06 (0.05)	-0.04 (0.05)	0.02 (0.05)	0.06 (0.05)

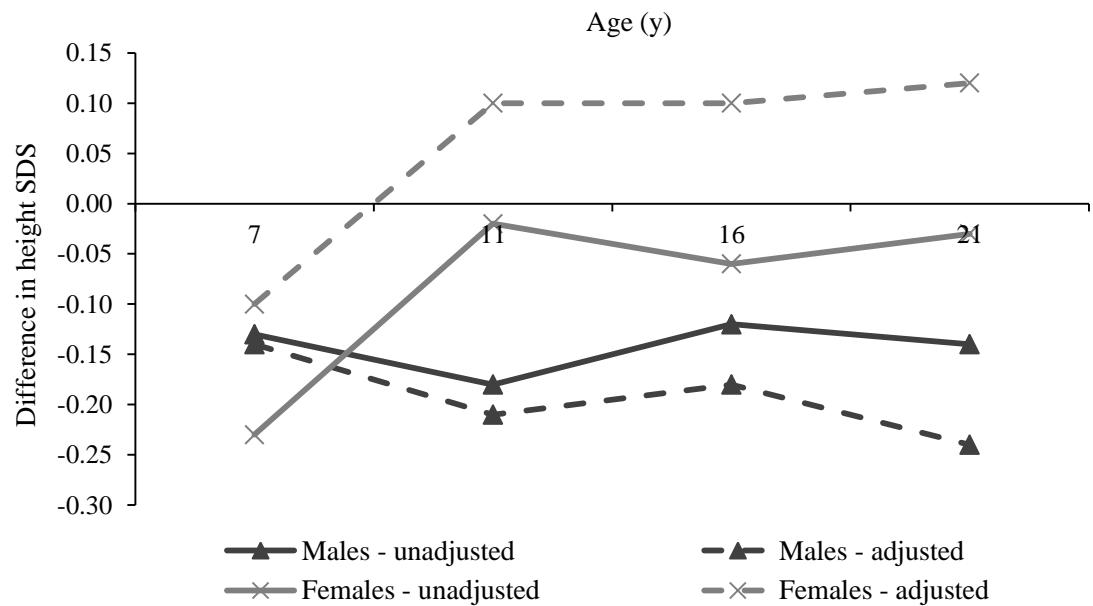
¹All values are differences in SDS. Unadjusted models include age height at age 7, 11 and 16y was recorded, adjusted models further include parental height, birth weight, prematurity, maternal smoking during pregnancy, social class at birth, breastfed, household crowding, disability, tenure of accommodation, amenity score; no. of observations 3,256 for height, 3,187 for leg length. ^ap<0.05.

Table 5.11: Estimated effects (SE) of childhood abuse and neglect (reported at age 45y) on height SDS at age 7, 11 and 16y and in adulthood using multivariate response models, and adult leg length using linear regression models; females¹

Child maltreatment	Unadjusted					Adjusted				
	7	11	16	Adult	Leg	7	11	16	Adult	Leg
<i>Child abuse</i>										
Psychological abuse	-0.07 (0.06)	-0.06 (0.06)	0.00 (0.06)	0.01 (0.06)	0.04 (0.06)	-0.02 (0.05)	-0.01 (0.05)	0.06 (0.05)	0.07 (0.04)	0.09 (0.05)
Physical abuse	-0.09 (0.08)	-0.07 (0.08)	-0.04 (0.08)	0.00 (0.08)	-0.03 (0.08)	-0.03 (0.07)	-0.01 (0.07)	0.03 (0.06)	0.07 (0.06)	0.02 (0.07)
Sexual abuse	-0.23 (0.12)	-0.02 (0.13)	-0.06 (0.13)	-0.03 (0.12)	-0.04 (0.13)	-0.10 (0.10)	0.10 (0.12)	0.10 (0.10)	0.12 (0.10)	0.07 (0.11)
Witnessed abuse	-0.17 ^b (0.07)	-0.11 (0.07)	-0.03 (0.07)	0.00 (0.07)	0.06 (0.07)	-0.09 (0.06)	-0.04 (0.06)	0.07 (0.06)	0.09 (0.06)	0.12 ^a (0.06)
<i>Indicators of neglect</i>										
I was neglected	0.14 (0.10)	0.07 (0.10)	0.04 (0.10)	0.11 (0.10)	0.14 (0.10)	0.17 (0.08)	0.10 (0.10)	0.06 (0.06)	0.13 (0.08)	0.14 (0.09)
Unaffectionate mother	0.03 (0.08)	-0.06 (0.08)	-0.06 (0.08)	-0.09 (0.08)	0.01 (0.08)	0.11 (0.07)	0.01 (0.07)	0.02 (0.07)	-0.01 (0.06)	0.07 (0.07)
Unaffectionate father	0.00 (0.06)	0.00 (0.07)	0.04 (0.07)	0.05 (0.06)	0.07 (0.07)	0.06 (0.06)	0.05 (0.06)	0.09 (0.05)	0.10 (0.05)	0.10 (0.06)

¹All values are differences in SDS. Unadjusted models include age height at age 7, 11 and 16y was recorded, adjusted models further include parental height, birth weight, prematurity, maternal smoking during pregnancy, social class at birth, breastfed, household crowding, disability, tenure of accommodation, amenity score; no. of observations 3,300 for height, 3,205 for leg length. ^ap<0.05.

Figure 5.3: Estimated effect of sexual abuse (reported at age 45y) on height SDS at ages 7, 11 and 16y and in adulthood using multivariate response models



Difference in mean height SDS; adult height was plotted at age 21y. Unadjusted models include age height measurement was recorded. Adjusted models further include parental height, birth weight, prematurity, maternal smoking during pregnancy, social class at birth, breastfed, household crowding, disability, tenure of accommodation, amenity score.

Indicators of childhood neglect (at age 7y)

All prospective indicators of child neglect ascertained at age 7y were associated with short stature at all ages (Tables 5.12 and 5.13). Cohort members who experienced childhood neglect were, on average, shorter at age 7y and remained shorter as adults, compared to those who were not neglected. For some indicators, effect sizes were smaller in adulthood than in childhood (i.e. neglected appearance). For males, neglect measures were associated with short adult leg length, except for 'father hardly reads' and low parental aspirations. For females, only 'mother little interest in education' and neglected appearance were related to deficits in adult leg length.

The influence of 7y neglect measures on height weakened substantially after adjustment for confounding factors. However, the effect of some neglect measures persisted. In the adjusted models, there were two patterns of association between indicators of neglect and child-to-adult height trajectories. First, for males 'father/mother little interest in education' and 'hardly any outings with mother' and for females, 'father hardly ever reads' and neglected appearance were associated with shorter child and adult height. The strength of association was significantly stronger in childhood (age 7y) than in adult height ($P < 0.05$ for contrast test comparing effect estimates at age 7y and in adulthood). For example, male cohort members whose father showed little interest in their education were, on average, shorter by 0.20SDS (95% CI; 0.13, 0.26) at age 7y (1.2cm) than others, the difference in height decreasing to 0.10SDS (0.03, 0.16) in adulthood (0.6cm). However, for some neglect measures the difference in height remained constant at each age. For example, female cohort members whose father hardly read to them, were, on average, between 0.05SDS (0.00, 0.10) and 0.08SDS (0.02, 0.13) shorter at each age (≈ 0.4 cm) compared to those whose father did read to them.

Second, in the adjusted models several indicators of neglect at age 7y remained associated with childhood height, but not adult height. For males, 'father hardly any outings' and neglected appearance were associated with shorter height at ages 7, 11 and 16y; thereafter the difference in height reduced and measures were not significantly associated with adult height. Females whose parents showed little interest in their education were, on average, significantly shorter at ages 7y (by 0.12SDS for mother and

0.09SDS for father) and 11y (0.14SDS and 0.11SDS, respectively), but not at age 16y and in adulthood compared to others.

Low parental aspirations, ‘father hardly reads’, ‘mother hardly ever reads’ (for males) and ‘hardly any outings with mother/father’ (for females) were not associated with height growth after adjustment for confounding factors. In addition, the relationship between all indicators of neglect and adult leg length attenuated, and were no longer significant.

There was a cumulative effect of indicators of neglect at age 7y, with increments in neglect score across the range 0-7 associated with a reduction in height at all ages (Figure 5.4). The strength of association was greater at age 7y than in adulthood. Neglect score was also related to deficits in adult leg length in both sexes. After adjustment for confounding factors, the association between neglect score and height at ages 7, 11 and 16y, though weakened, remained significant (Figure 5.3). For each additional neglect indicator childhood height, on average, decreased by 0.06 to 0.05SDS (\approx 0.3 to 0.4cm) in boys and 0.03 to 0.04SDS (\approx 0.2 to 0.3cm) in girls. By adulthood, the strength of association had decreased in both genders (significant only for males: P $<$ 0.05 for contrast test comparing effect sizes at age 7y and adulthood). However, a unit increase in neglect score remained associated with a decrease in adult height in both males (0.03SDS; 0.01, 0.05) and females (0.03SDS; 0.00, 0.05). In the adjusted models, adult leg length was no longer influenced by an accumulation of neglect measures.

Table 5.12: Estimated effects (SE) of childhood indicators of neglect (reported at age 7y) on height SDS at ages 7, 11 and 16y and in adulthood using multivariate response models, and adult leg length using linear regression models; males¹

Indicators of neglect; 7y	Unadjusted					Adjusted				
	7y	11y	16y	Adult	Leg	7y	11y	16y	Adult	Leg
Mother hardly reads†	-0.18 ^c (0.04)	-0.19 ^c (0.04)	-0.13 ^c (0.04)	-0.15 ^c (0.04)	-0.17 ^c (0.05)	-0.03 (0.03)	-0.04 (0.03)	0.01 (0.04)	-0.01 (0.03)	-0.04 (0.04)
Father hardly reads†	-0.10 ^c (0.03)	-0.09 ^c (0.03)	-0.09 ^b (0.03)	-0.05 (0.03)	-0.07 (0.04)	-0.03 (0.03)	-0.02 (0.03)	-0.03 (0.03)	0.00 (0.03)	-0.02 (0.04)
Mother hardly any outings†	-0.52 ^c (0.10)	-0.44 ^c (0.11)	-0.60 ^c (0.11)	-0.43 ^c (0.11)	-0.41 ^c (0.15)	-0.22 ^b (0.09)	-0.12 (0.10)	-0.33 ^c (0.10)	-0.15 (0.09)	-0.13 (0.13)
Father hardly any outings†	-0.26 ^c (0.06)	-0.32 ^c (0.06)	-0.27 ^c (0.06)	-0.22 ^c (0.06)	-0.28 ^c (0.09)	-0.08 (0.05)	-0.14 ^b (0.06)	-0.12 ^a (0.06)	-0.07 (0.05)	-0.13 (0.08)
Mother little in interest education†	-0.41 ^c (0.04)	-0.37 ^c (0.04)	-0.31 ^c (0.04)	-0.26 ^c (0.04)	-0.28 ^c (0.06)	-0.22 ^c (0.03)	-0.18 ^c (0.04)	-0.15 ^c (0.04)	-0.11 ^c (0.04)	-0.07 (0.05)
Father little interest in education†	-0.37 ^c (0.04)	-0.34 ^c (0.04)	-0.29 ^c (0.04)	-0.24 ^c (0.04)	-0.20 ^c (0.06)	-0.20 ^c (0.03)	-0.16 ^c (0.04)	-0.15 ^c (0.04)	-0.10 ^c (0.03)	-0.02 (0.05)
Low parental aspirations†	-0.23 ^c (0.07)	-0.24 ^c (0.07)	-0.24 ^c (0.07)	-0.13 (0.07)	-0.18 (0.11)	-0.03 (0.06)	-0.04 (0.06)	-0.09 (0.07)	0.03 (0.06)	-0.01 (0.09)
Neglected appearance‡	-0.58 ^c (0.07)	-0.52 ^c (0.07)	-0.43 ^c (0.07)	-0.29 ^c (0.07)	-0.35 ^c (0.10)	-0.28 ^c (0.06)	-0.23 ^c (0.06)	-0.16 ^b (0.07)	-0.04 (0.06)	-0.11 (0.09)
Neglect score excluding neglected appearance (range 0-7) ^Δ	-0.12 ^c (0.01)	-0.12 ^c (0.01)	-0.10 ^c (0.01)	-0.09 ^c (0.01)	-0.09 ^c (0.02)	-0.06 ^c (0.01)	-0.05 ^c (0.01)	-0.05 ^c (0.01)	-0.03 ^a (0.01)	-0.03 (0.02)

¹All values are differences in SDS. Unadjusted models include age height at age 7, 11 and 16y was recorded, adjusted models further include parental height, birth weight, prematurity, maternal smoking during pregnancy, social class at birth, breastfed, household crowding, disability, tenure of accommodation, amenity score.

†Emotional/education indicators of neglect no. of observations 5,541 – 5,712 for height, 3,112 – 3,201 for leg length; ‡Physical neglect indicator no. of observations 3,812 for height, 2,131 for leg length; ^Δsum of seven indicators, no. of observations 5,524 for height, 2,054 for leg length. ^ap<0.05; ^bp<0.01; ^cp<0.001.

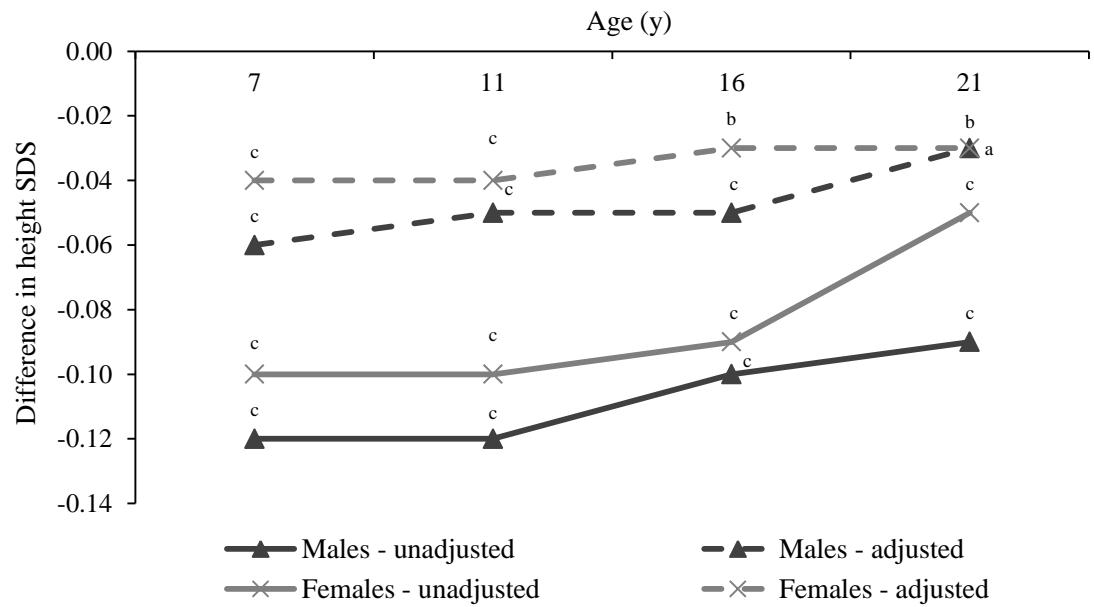
Table 5.13: Estimated effects (SE) of childhood indicators of neglect (reported at age 7y) on height SDS at ages 7, 11 and 16y and in adulthood using multivariate response models, and adult leg length using linear regression models; females¹

Indicators of neglect; 7y	Unadjusted					Adjusted				
	7y	11y	16y	Adult	Leg	7y	11y	16y	Adult	Leg
Mother hardly reads†	-0.13 ^c (0.04)	-0.11 ^c (0.04)	-0.11 ^c (0.04)	-0.09 ^b (0.04)	-0.08 (0.05)	-0.06 (0.03)	-0.05 (0.04)	-0.04 (0.03)	-0.03 (0.03)	-0.03 (0.04)
Father hardly reads†	-0.13 ^c (0.03)	-0.14 ^c (0.03)	-0.12 ^c (0.03)	-0.11 ^c (0.03)	-0.03 (0.04)	-0.07 ^b (0.03)	-0.08 ^b (0.03)	-0.06 ^a (0.03)	-0.05 ^a (0.03)	0.02 (0.04)
Mother hardly any outings†	-0.11 (0.13)	-0.18 (0.14)	-0.15 (0.14)	-0.02 (0.14)	-0.06 (0.21)	-0.04 (0.11)	-0.11 (0.12)	-0.09 (0.12)	0.06 (0.11)	-0.10 (0.19)
Father hardly any outings†	-0.20 ^c (0.06)	-0.20 ^c (0.06)	-0.21 ^c (0.06)	-0.19 ^c (0.06)	-0.10 (0.08)	-0.05 (0.05)	-0.05 (0.06)	-0.08 (0.05)	-0.07 (0.05)	0.01 (0.07)
Mother little in interest education†	-0.29 ^c (0.04)	-0.31 ^c (0.04)	-0.21 ^c (0.03)	-0.20 ^c (0.04)	-0.13 ^a (0.06)	-0.12 ^c (0.04)	-0.14 ^c (0.04)	-0.06 (0.04)	-0.06 (0.04)	0.01 (0.05)
Father little interest in education†	-0.25 ^c (0.04)	-0.26 ^c (0.04)	-0.19 ^c (0.04)	-0.15 ^c (0.04)	-0.09 (0.06)	-0.09 ^b (0.04)	-0.11 ^c (0.04)	-0.06 (0.04)	-0.03 (0.03)	0.01 (0.05)
Low parental aspirations†	-0.20 ^c (0.06)	-0.15 ^c (0.07)	-0.16 ^c (0.06)	-0.16 ^c (0.06)	-0.19 (0.10)	-0.09 (0.06)	-0.04 (0.07)	-0.07 (0.06)	-0.08 (0.06)	-0.10 (0.09)
Neglected appearance‡	-0.66 ^c (0.08)	-0.67 ^c (0.07)	-0.57 ^c (0.07)	-0.47 ^c (0.08)	-0.50 ^c (0.13)	-0.32 ^c (0.07)	-0.34 ^c (0.08)	-0.22 ^c (0.07)	-0.14 (0.07)	-0.18 (0.12)
Neglect score excluding neglected appearance (range 0-7) ^Δ	-0.10 ^c (0.01)	-0.10 ^c (0.01)	-0.09 ^c (0.01)	-0.08 ^c (0.01)	-0.05 ^b (0.02)	-0.04 ^c (0.01)	-0.04 ^c (0.01)	-0.03 ^b (0.01)	-0.03 ^b (0.01)	-0.01 (0.02)

¹All values are differences in SDS. Unadjusted models include age height at age 7, 11 and 16y was recorded, adjusted models further include parental height, birth weight, prematurity, maternal smoking during pregnancy, social class at birth, breastfed, household crowding, disability, tenure of accommodation, amenity score.

†Emotional/ education indicators of neglect no. of observations 5,241 - 5,437 for height, 3,120 – 3,212 for leg length; ‡ Physical neglect indicator no. of observations 3,907 for height, 2,323 for leg length; ^Δsum of seven indicators, no. of observations 5,555 for height, 3,160 for leg length. ^ap<0.05; ^bp<0.01; ^cp<0.001.

Figure 5.4: Estimated effect of a unit increase in neglect score (reported at age 7y; range 0-7) on height SDS at ages 7, 11 and 16y and in adulthood using multivariate response models



Difference in mean height SDS; adult height was plotted at age 21y adult height Unadjusted models include age height measurement was recorded. Adjusted models further include parental height, birth weight, prematurity, maternal smoking during pregnancy, social class at birth, breastfed, household crowding, disability, tenure of accommodation, amenity score. Neglect score sum of seven indicators. ^ap<0.05; ^bp<0.01; ^cp<0.001.

Maltreatment patterns

The relationship between maltreatment groups and child-to-adult height is shown in Table 5.14. Cohort members with a high risk of neglect ‘only’ were, on average, shorter at all childhood ages and in adulthood compared to cohort members in the low risk group for child maltreatment. Neglect ‘only’ was also associated with deficits in adult leg length in males but not in females. The maltreatment group abuse and neglect was not associated with height in either gender.

After adjustment for confounding factors, associations attenuated substantially, and were no longer significant in females. For males, neglect ‘only’ remained related to a \approx 1cm decrease in height at ages 7 and 11y compared to those with a low risk of maltreatment. The difference reduced thereafter, and was non-significant at age 16y and in adulthood.

Table 5.14: Estimated effects (SE) of maltreatment groups (identified by Latent Class Analyses: low risk, neglect ‘only’, abuse and neglect) and height SDS at age 7, 11 and 16y and adulthood using multivariate response models, and adult leg length using linear regression models¹

Maltreatment groups [†]	Unadjusted					Adjusted				
	7y	11y	16y	Adult	Leg	7y	11y	16y	Adult	Leg
Males (height:2,087; leg length: 2,045)										
Neglect ‘only’	-0.44 ^c (0.07)	-0.39 ^c (0.08)	-0.33 ^c (0.08)	-0.30 ^c (0.07)	-0.28 ^b (0.08)	-0.17 ^b (0.07)	-0.14 ^c (0.07)	-0.10 (0.07)	-0.05 (0.06)	-0.04 (0.07)
Abuse & neglect	-0.12 (0.08)	-0.12 (0.09)	-0.15 (0.09)	-0.09 (0.09)	-0.06 (0.09)	-0.03 (0.07)	-0.02 (0.08)	-0.09 (0.08)	-0.01 (0.07)	0.02 (0.08)
Females (height:2,657; leg length: 2,229)										
Neglect ‘only’	-0.23 ^c (0.07)	-0.25 ^c (0.07)	-0.23 ^c (0.07)	-0.20 ^c (0.07)	-0.13 (0.07)	-0.06 (0.06)	-0.07 (0.07)	-0.07 (0.06)	-0.05 (0.06)	0.02 (0.07)
Abuse & neglect	-0.13 (0.07)	-0.10 (0.07)	-0.07 (0.07)	-0.04 (0.07)	-0.01 (0.07)	-0.03 (0.06)	0.00 (0.07)	0.04 (0.05)	0.06 (0.05)	0.08 (0.06)

¹All values are differences in SDS. Unadjusted models include age height at age 7, 11 and 16y was recorded, adjusted models further include parental height, birth weight, prematurity, maternal smoking during pregnancy, social class at birth, breastfed, household crowding, disability, tenure of accommodation, amenity score. [†]latent class model includes all fifteen child maltreatment measures collected at ages 7y and 45y. ^b $p<0.01$; ^c $p<0.001$.

5.4.3 ***Household dysfunction and height***

Measures of household dysfunction were associated with short stature in childhood (except parents divorced/separated for females), but few were associated with adult height (Tables 5.15 and 5.16). Family contact with a probation officer, family member mental health problems (for males) and family contact with children's department or charity (for females) were related to a decrease in adult height. There was no significant association between household dysfunction and adult leg length, though large negative effect estimates were found for family contact with a probation officer for males and household member difficulty with alcoholism for females. The associations were substantially weakened after adjustment for confounding factors. Some household dysfunction measures remained associated with height at age 7y, but the strength of association significantly decreased by adulthood ($P < 0.01$ for contrast test comparing effect estimates at age 7y and in adulthood; except family contact with children's department/charity for males). For males, family member mental health problem and family contact with a children's department/charity were related to short stature at age 7y, by 0.14SDS (0.02, 0.25) and 0.15SDS (0.01, 0.28), respectively. Females from households where alcoholism was a family difficulty were, on average, shorter by 0.32SDS (0.05, 0.59) at age 7y (2cm) compared to others.

Household dysfunction score was inversely associated with height at each age; an increment in score, over the range 0-7, was related to a decrease in height. For example, for each additional household dysfunction measure, height at age 7y decreased, on average, by 0.9cm and 0.8cm for boys and girls respectively. After adjustment for confounding factors the effect estimates reduced, although a unit increase in score remained associated with an ≈ 0.4 cm decrease in stature at ages 7 (for males) and 11y (for females). Thereafter, the difference in height reduced, and household dysfunction score was not associated with height at age 16y and in adulthood ($P < 0.05$ for contrast test comparing effect estimates at age 7y and in adulthood). Household dysfunction score was not associated with adult leg length.

Table 5.15: Estimated effects (SE) of household dysfunction (reported at age 7y) on height SDS at ages 7, 11 and 16y and in adulthood using multivariate response models, and adult leg length using linear regression models; males¹

Household dysfunction at age 7y	Unadjusted					Adjusted				
	7y	11y	16y	Adult	Leg	7y	11y	16y	Adult	Leg
Domestic tension†	-0.21 ^c (0.06)	-0.23 ^c (0.07)	-0.21 ^c (0.07)	-0.12 (0.04)	-0.15 (0.09)	-0.07 (0.05)	-0.09 (0.06)	-0.09 (0.06)	0.00 (0.06)	-0.03 (0.08)
Alcoholism†	-0.30 ^a (0.15)	-0.37 ^a (0.16)	-0.35 ^a (0.17)	-0.04 (0.16)	-0.15 (0.22)	-0.11 (0.13)	-0.18 (0.14)	-0.18 (0.15)	0.13 (0.13)	0.01 (0.19)
Family member mental health problems†	-0.32 ^c (0.07)	-0.28 ^c (0.07)	-0.23 ^c (0.07)	-0.24 ^c (0.07)	-0.15 (0.10)	-0.14 ^a (0.06)	-0.08 (0.06)	-0.03 (0.07)	-0.05 (0.06)	-0.04 (0.09)
Contact with probation officer†	-0.42 ^c (0.11)	-0.29 ^b (0.12)	-0.20 (0.12)	-0.28 ^a (0.12)	-0.32 (0.19)	-0.15 (0.10)	-0.02 (0.10)	0.03 (0.11)	-0.04 (0.10)	-0.03 (0.17)
Contact with children's department/charity†	-0.36 ^c (0.08)	-0.29 ^c (0.08)	-0.18 ^a (0.09)	-0.14 (0.08)	-0.08 (0.12)	-0.15 ^a (0.07)	-0.07 (0.07)	0.03 (0.08)	0.04 (0.07)	0.06 (0.11)
In care†	-0.29 ^b (0.12)	-0.24 ^a (0.13)	-0.07 (0.13)	-0.13 (0.13)	0.06 (0.17)	0.01 (0.11)	0.08 (0.11)	0.22 (0.12)	0.16 (0.11)	0.33 (0.15)
Parents divorced/separated†	-0.21 ^c (0.07)	-0.19 ^b (0.08)	-0.15 (0.08)	-0.08 (0.08)	-0.15 (0.11)	-0.12 (0.06)	-0.09 (0.07)	-0.07 (0.07)	0.01 (0.07)	-0.06 (0.10)
Household dysfunction score (range 0-7) ^Δ	-0.15 ^c (0.02)	-0.13 ^c (0.03)	-0.08 ^c (0.03)	-0.07 ^b (0.03)	-0.07 (0.04)	-0.06 ^a (0.02)	-0.04 (0.02)	-0.01 (0.02)	0.00 (0.02)	0.00 (0.03)

¹All values are differences in SDS. Unadjusted models include age height at age 7, 11 and 16y was recorded, adjusted models further include parental height, birth weight, prematurity, maternal smoking during pregnancy, social class at birth, breastfed, household crowding, disability, tenure of accommodation, amenity score.

†No. of observations 5,112 - 5,715 for height, 2,883– 3,203 for leg length; ^Δsum of all seven household dysfunction measures at age 7y, no. of observations 5,018 for height, 2,834 for leg length. ^ap<0.05; ^bp<0.01; ^cp<0.001.

Table 5.16: Estimated effects (SE) of household dysfunction (reported at age 7y) on height SDS at ages 7, 11 and 16y and in adulthood using multivariate response models, and adult leg length using linear regression models; females¹

Household dysfunction at age 7y	Unadjusted					Adjusted				
	7y	11y	16y	Adult	Leg	7y	11y	16y	Adult	Leg
Domestic tension†	-0.22 ^c (0.06)	-0.24 ^c (0.07)	-0.13 ^a (0.07)	-0.10 (0.07)	0.05 (0.09)	-0.09 (0.06)	-0.12 (0.06)	0.03 (0.06)	0.00 (0.05)	0.14 (0.08)
Alcoholism†	-0.52 ^c (0.16)	-0.48 ^c (0.17)	-0.29 (0.17)	-0.13 (0.16)	0.38 (0.24)	-0.32 ^a (0.14)	-0.29 (0.15)	-0.12 (0.14)	0.04 (0.13)	0.39 (0.21)
Family member mental health problems†	-0.12 (0.07)	-0.17 ^a (0.07)	-0.12 (0.07)	-0.09 (0.07)	-0.10 (0.09)	0.03 (0.06)	0.00 (0.06)	0.05 (0.06)	0.07 (0.06)	0.07 (0.08)
Contact with probation officer†	-0.42 ^c (0.11)	-0.47 ^c (0.12)	-0.37 ^c (0.12)	-0.30 ^b (0.12)	-0.16 (0.16)	-0.15 (0.10)	-0.20 (0.11)	-0.11 (0.10)	-0.05 (0.10)	0.04 (0.14)
Contact with children's department/charity†	-0.34 ^c (0.08)	-0.39 ^c (0.09)	-0.29 ^c (0.09)	-0.21 ^b (0.09)	-0.02 (0.12)	-0.08 (0.07)	-0.14 (0.08)	-0.05 (0.07)	0.03 (0.07)	0.13 (0.11)
In care†	-0.26 ^a (0.12)	-0.29 ^a (0.13)	-0.22 (0.13)	-0.14 (0.13)	0.09 (0.17)	-0.05 (0.11)	-0.09 (0.12)	-0.05 (0.11)	0.02 (0.10)	0.19 (0.15)
Parents divorced/separated †	-0.07 (0.08)	-0.11 (0.08)	-0.12 (0.08)	-0.09 (0.08)	-0.02 (0.10)	0.03 (0.07)	0.00 (0.07)	0.01 (0.07)	0.04 (0.06)	0.11 (0.09)
Household dysfunction score (range 0-7) ^Δ	-0.13 ^a (0.02)	-0.15 ^a (0.03)	-0.09 ^a (0.03)	-0.08 ^a (0.03)	-0.01 (0.03)	-0.04 ^c (0.02)	-0.06 ^a (0.02)	-0.01 (0.02)	0.01 (0.02)	0.06 (0.03)

¹All values are differences in SDS. Unadjusted models include age height at age 7, 11 and 16y was recorded, adjusted models further include parental height, birth weight, prematurity, maternal smoking during pregnancy, social class at birth, breastfed, household crowding, disability, tenure of accommodation, amenity score.

†No. of observations 5,216 - 5,898 for height, 2,885 – 3,215 for leg length; ^Δsum of all seven household dysfunction measures at age 7y, no. of observations 4,811 for height, 2,845 for leg length. ^ap<0.05; ^bp<0.01; ^cp<0.001.

5.4.4 Cumulative adversity (child neglect and household dysfunction) and height

Adversity score (child neglect and household dysfunction at age 7y) was associated with height at each age and adult leg length, such that for each additional adversity measure, on average, height and adult leg length decreased significantly by 0.12SDS at age 7y (1cm) (Table 5.17). The effect of adversity score on height growth diminished after adjusting for confounding factors, but remained significantly associated with childhood and adult height (non-significant for females). A unit increase in adversity score was associated with a decrease in height of 0.06SDS (0.04, 0.08) and 0.04SDS (0.02, 0.06) for boys and girls, respectively ($\approx 0.3\text{cm}$). For males, adversity score was also associated with adult height in the adjusted models (0.02SDS; 0.00, 0.04). The effect of adversity score was greater in childhood than in adulthood for both genders ($P < 0.01$ for contrast test comparing effect estimates at age 7y and in adulthood). In the adjusted models, adversity score was not associated with adult leg length.

Table 5.17: Estimated effects (SE) of cumulative adversity (household dysfunction and neglect score reported at age 7y) on height SDS at age 7, 11 and 16y and in adulthood using multivariate response models, and adult leg length using linear regression models¹

Adversity score excluding neglected appearance (range 0-14) [†]	Unadjusted					Adjusted				
	7y	11y	16y	Adult	Leg	7y	11y	16y	Adult	Leg
Males	-0.12 ^c (0.01)	-0.11 ^c (0.01)	-0.08 ^c (0.01)	-0.08 ^c (0.01)	-0.08 ^c (0.02)	-0.06 ^c (0.01)	-0.05 ^c (0.01)	-0.03 ^a (0.01)	-0.02 ^c (0.01)	-0.02
Females	-0.09 ^c (0.01)	-0.09 ^c (0.01)	-0.06 ^c (0.01)	-0.06 ^c (0.01)	-0.04 ^a (0.02)	-0.04 ^c (0.01)	-0.04 ^c (0.01)	-0.02 (0.01)	-0.02 (0.01)	-0.01 (0.01)

¹All values are differences in SDS. Unadjusted models include age height at age 7, 11 and 16y was recorded, adjusted models further include parental height, birth weight, prematurity, maternal smoking during pregnancy, social class at birth, breastfed, household crowding, disability, tenure of accommodation, amenity score. [†]sum of seven indicators of neglect and seven household dysfunction measures at age 7y, no. of observations 4,892 for height, 2,669 for leg length for males; 4,673 for height, 2,688 for leg length for females. * $p < 0.05$

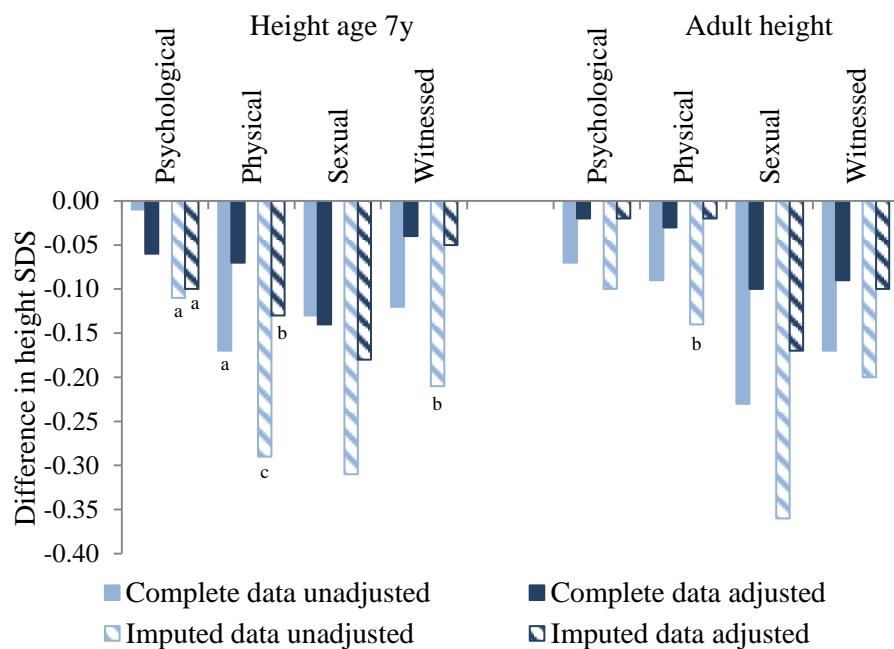
5.4.5 Additional analyses

Details of the association between adverse childhood experiences and height at age 7y and adult height using data from the multiple imputation models are presented in Appendices 4.8 (for males) and 4.9 (for females). The strength of the associations tended to be stronger in the imputed samples than in the complete data sets (Figures 5.5 to 5.7). However, similar patterns of association were found in both data sets.

Specifically, adverse childhood experiences were related to short stature, the strength of association was greater for child height compared to adult height and relationships weakened after adjustment for confounding factors.

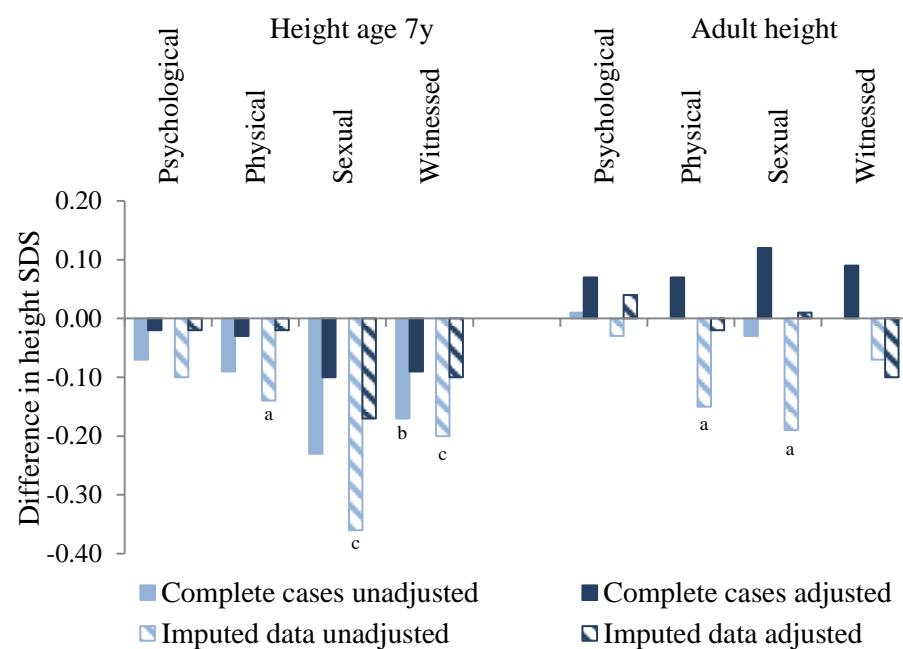
The strength of association between child abuse, or maltreatment groups, and height was greater in the imputed data set compared to the complete data models. Unlike in the complete data analyses, psychological, physical and sexual abuse and witnessing abuse were associated with deficits in height at age 7y in the imputed data (Figures 5.5 for males and 5.6 for females). Physical and sexual abuse were also related to shorter adult stature. In the imputed data, after adjustment for confounding factors relationships weakened, however some associations remained. Psychologically and physically abused boys were, on average, shorter by 0.10SDS (0.00, 0.20) and 0.13SDS (0.03, 0.23), respectively, at age 7y, compared to non-abused boys. As in the complete data analyses, sexual abuse was associated with large deficits in childhood and adult height in males, though the associations did not reach statistical significance in the adjusted models. The relationship between other forms of abuse and height attenuated and were no long significant after adjustment in the imputed data.

Figure 5.5: Estimated effect of child abuse (reported at age 45y) on height SDS at ages 7y and adult height using complete (multivariate response models) and imputed (linear regression models) data; males



Difference in mean height SDS. Unadjusted models include age height at age 7y was recorded, adjusted models further include parental height, birth weight, prematurity, mother smoked during pregnancy, social class at birth, breastfed, household crowding, disability, tenure of accommodation, amenity score. No. of observations height age 7y n=6,828 and adult height n=7,137. ^ap<0.05; ^bp<0.01; ^cp<0.001

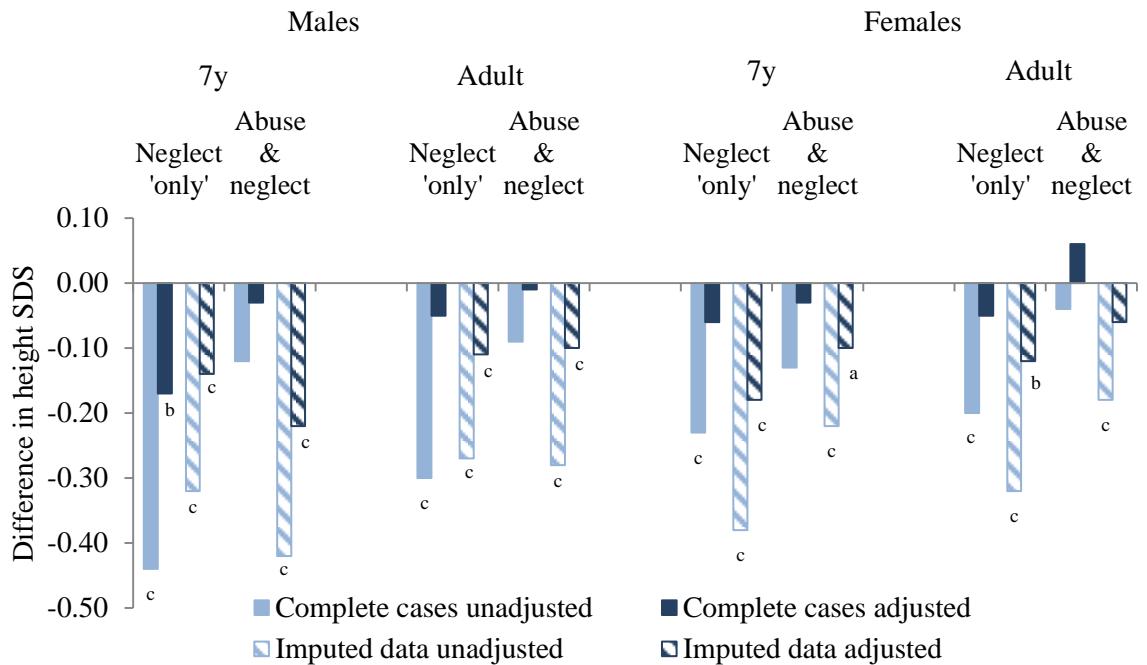
Figure 5.6: Estimated effect of child abuse (reported at age 45y) on height SDS at ages 7y and adult height using complete (multivariate response models) and imputed (linear regression models) data; females



Difference in mean height SDS. Unadjusted models include age height at age 7y was recorded, adjusted models further include parental height, birth weight, prematurity, mother smoked during pregnancy, social class at birth, breastfed, household crowding, disability, tenure of accommodation, amenity score. No. of observations height age 7y n=6,487 and adult height n=7,449. ^ap<0.05; ^bp<0.01; ^cp<0.001.

The relationship between maltreatment groups and height at age 7y and adult height using imputed and complete data are shown in Figure 5.7. In both datasets, neglect ‘only’ maltreatment group was associated with shorter stature at age 7y and in adulthood. The strength of association tended to be greater in the imputed compared to the complete data analyses (except for height at age 7y for males). After adjustment for confounding factors, effect estimates weakened, although for males neglect ‘only’ remained related to deficits in height at age 7y in both dataset. In addition, in the imputed data, males at high risk of neglect ‘only’ remained, on average, shorter in adulthood. The relationship between neglect ‘only’ and height at both ages also persisted in females (0.18SDS; 0.10, 0.26 age 7y and 0.12SDS; 0.04, 0.20 adult height) after adjustment in the imputed data. In contrast, the associations were no longer significant in the complete data analyses.

Figure 5.7: Estimated effect of maltreatment groups (identified by Latent Class Analyses: low risk, neglect ‘only’, abuse and neglect) on height SDS at age 7y using complete (multivariate response models) and imputed (linear regression models) data



Difference in mean height SDS; low risk of maltreatment used as reference category. Unadjusted models include age height at age 7y was recorded, adjusted models further include parental height, birth weight, prematurity, maternal smoking during pregnancy, social class at birth, breastfed, household crowding, disability, tenure of accommodation, amenity score. No. of observations n=6,828 for males and n=6,487 for females. ^ap<0.05; ^bp<0.01; ^cp<0.001.

In both complete and imputed data sets, the abuse and neglect maltreatment group was associated with short stature at age 7y. However, effect sizes were greater in the imputed compared to the complete data analyses, the relationships being non-significant in the complete data set. For adult height, no relationship was found for abuse and neglect maltreatment group in complete data models. In contrast, in the imputed data, participants with a high risk of abuse and neglect were also more likely to be shorter adults than those with a low risk of maltreatment (Figure 5.7). Associations attenuated after adjustment for confounding factors, however effects remained. In the imputed data set, participants with a high risk of abuse and neglect were, on average shorter by 0.22SDS (0.12, 0.32) for males and 0.10SDS (0.02, 0.18) for females at age 7y, compared to those with a low risk of maltreatment. The relationship between abuse and neglect maltreatment group and adult height persisted for males only (-0.10SDS; 0.04, 0.16).

There was little difference in the association between neglect, household dysfunction or adversity scores and height at age 7y and in adulthood in the imputed and complete data sets. In both datasets, for each additional indicator of neglect and/or household dysfunction, on average, height at both ages decreased. After adjustment for confounding factors effect sizes reduced, but neglect and adversity score remained significantly related to shorter stature at both ages. Household dysfunction score also remained associated with height at age 7y in the adjusted models in both datasets. In addition, in the imputed data a significant relationship between household dysfunction score and adult height in females persisted after adjustment; an increment in household dysfunction score was related to a 0.03SDS (0.01, 0.05) decrease in adult height (Appendix 4.9). No effect was found after controlling for potential confounding factors in the complete data analyses. In both datasets, household dysfunction score was not associated with adult height in males after adjustment (Appendix 4.8).

5.5 Discussion

Association found between adverse childhood experiences and child-to-adult height trajectories in the 1958 British birth cohort were mostly explained by demographic and socio-economic factors, although some effects remained. Several indicators of neglect at age 7y (e.g. ‘mother/father little interest in education’ for males and ‘father hardly reads’ for females) were related to shorter childhood stature (deficits ranging from 0.4 to 2.6cm). The strength of association decreased by adulthood, suggesting that there was catch-up growth. In addition, even after compensatory growth, possibly due to a longer period or a faster rate of growth, the relationship between some factors (‘parents little interest in education’ for males and ‘father hardly reads’ for females) and adult height persisted, with deficits in stature ranging from 0.4 to 0.6cm. A cumulative effect of child neglect on height also persisted after adjustment, such that an increment in neglect score was associated with a decrease of ≈ 0.3 cm in childhood height and a reduction of ≈ 0.1 cm in adult height.

Some household dysfunction measures (e.g. family contact with a probation officer, or children’s department/charity for boys and alcoholism for girls) remained significantly associated with shorter stature at age 7y (by 0.9 to 2.4 cm) in adjusted models, but not at subsequent ages. A cumulative effect of household dysfunction on childhood height was found; for each additional measure, height at ages 7 and 11y decreased, on average, by ≈ 4 cm. In addition, accumulation of child neglect and household dysfunction was associated with height growth, after adjustment for confounding factors. Stronger effects were found in childhood compared to adulthood (significant only for males).

Retrospective measures of child abuse and neglect and three maltreatment groups were not significantly associated with height growth after adjustment for confounding factors.

5.5.1 *Methodological considerations*

This study overcomes several limitations of research to date, such as the use of small samples^{141-143;145;151}, only a summary measure of adverse childhood experiences¹⁴¹⁻¹⁴⁵, and short-term follow-up of participants^{141-143;145;151;153;154}. In addition, the established literature is restricted to specialised cohorts, e.g. hospitalised children, children in foster

care, or international adoptees, and agency reports of child maltreatment. Thus, participants are likely to have received some form of intervention, i.e. medical treatment or removal from the natural home, which may have influenced height growth in these cohorts. For example, placement into foster care has consistently been associated with an increase in growth rate⁴⁷⁵. In contrast, the 1958 cohort is a national population sample which has used multiple informants to ascertain adverse childhood experiences, e.g. parent, teacher and self-reports. As maltreated participants and those from dysfunctional households were not identified using agency report they are less likely to have received some form of intervention. Therefore, results from this study may be more reflective of the long-term consequences of adverse childhood experiences on child-to-adult height trajectories.

As discussed in Chapter 2, a major strength of the 1958 cohort is the repeated measurements of height from early childhood through to adulthood. It is therefore an ideal sample in which to examine childhood experiences of abuse, neglect and household dysfunction influence on height growth. The data allowed the use of multivariate response models that account for the strong correlation of repeated height correlations (Table 5.8). These models have the flexibility to include participants with one or more height measures, therefore incorporating the majority of cohort members in the analyses.

There are some limitations of the study. The earliest height measurement in the cohort was at age 7y. The study is unable to examine the association between adverse childhood experiences and growth during critical periods in early childhood. In addition, retrospective measures of child maltreatment reflect any abuse or neglect up to age 16y. Thus it is not known whether maltreatment occurred prior to, or after childhood height measures.

The study's power to detect differences in outcome between unexposed and exposed cohort members may have been affected by the low prevalence of some measures, for example sexual abuse. In males, the strength of association between sexual abuse and height growth, though non-significant, was comparable to those found for childhood neglect measures, and greater for adult leg length (-0.32SDS vs. -0.01 to -0.11SDS, for sexual abuse and 7y indicators of neglect, respectively). Therefore, sexual abuse may

be related to height growth but the study did not have the power to detect an effect due to the small number of cases of sexual abuse (n=22).

As in all longitudinal studies, missing data are a potential issue for the 1958 cohort. Results from Chapter 4 suggest that attrition may have resulted in an under-estimation of child maltreatment experiences in cohort members alive at age 45y. In this chapter, missing data on confounding factors reduced sample size in the complete data analyses, potentially influencing coefficient estimates due to selection bias. A greater proportion of participants with missing data on confounding factors were maltreated, or from dysfunctional family backgrounds, compared to cohort members with complete information (Appendix 4.8). Results from the additional analyses using multiply imputed data indicate that the complete analyses may have under-estimated the true association between adverse childhood experiences and child-to-adult height trajectories. In the imputed data, a stronger relationship was shown between psychological, physical, sexual and witnessing abuse and height at age 7y and adult height, compared to the complete data models. The maltreatment group, abuse and neglect, was also associated with decreases in height at age 7y and adult height in the imputed analyses. In contrast, there was little difference in the strength of association between prospectively collected neglect, household dysfunction and adversity scores and height growth in the two datasets. Therefore, the relationship between indicators of neglect and household dysfunction collected at age 7y and child-to-adult height trajectories may be less affected by missing data issues.

Overall, a stronger relationship between child abuse and childhood height was found in the imputed data, compared to the complete data analyses. Nevertheless, similar patterns of association were found, such that greater effects were shown in childhood than adulthood and effects reduced after adjustment for confounding factors. However, it is likely that missing data assumptions required for multiple imputation are not met by the data. Thus, the true influence of adverse childhood experiences on height growth may be between estimates from the complete and imputed data analyses. Results from the complete data analyses are presented in this chapter as they are likely to be conservative estimates of the association between adverse childhood experiences and height growth.

5.5.2 *Comparison with previous work*

Unlike in the established literature, child abuse was not found to be significantly related to deficits in childhood height in the 1958 cohort¹⁴¹⁻¹⁴⁵. Though there was some indication, in both the complete and sensitivity analyses, that child abuse may be associated with deficits in height. The discrepancy in results could reflect methodological variations. In previous studies, the relationship has been examined using specialised cohorts, where cases of child maltreatment have been ascertained using agency reports. Whereas a large national sample was used in this study, and participants self-reported abuse retrospectively at age 45y. As the 1958 cohort is a population cohort, it is expected that there are fewer cases of child abuse and neglect than in targeted samples, such as foster care cohorts. In addition, findings from Chapter 4 suggest the child maltreatment may have been under-estimated in the 1958 cohort due to sample attrition. It is also possible recall bias could have affected the relationship, as abused participants may not have reported their maltreatment experiences and consequently were misclassified as not abused, therefore weakening the association^{323;330}.

In the 1958 cohort, indicators of neglect and household dysfunction at age 7y were associated with short stature at all ages. However, the association was largely explained by confounding factors. In particular, the strength of association weakened after adjustment for prenatal factors, such as birth weight, pre-term birth, maternal smoking during pregnancy and socio-economic circumstances, i.e. social class at birth and household crowding at age 7y. Previous studies have shown that the relationship between adverse childhood experiences and height growth attenuates after accounting for socio-economic disadvantage¹⁵². For example, a Swedish survey found that the association between parental divorce/separation and shorter adult stature was attributable to financial hardship associated with changes to the family structure, and not family conflict³⁵².

Nevertheless, an independent association was found between indicators of neglect at age 7y and deficits in childhood height after adjustment for demographic and socio-economic factors, with the effect persisting into adulthood for some measures. Effect estimates were smaller for individual indicators of neglect than those found in the

established literature: for example in the 1958 cohort neglect measures were associated with childhood (age 7, 11 and 16y) height deficits of 0.07-0.34 SD compared to ≥ 2 SD (age 0-14y) elsewhere^{141;142;144}. Differences in the strength of association may reflect variations in study samples (clinical/foster vs. population) and methods of case-ascertainment (agency vs. parent/teacher-reports). The severity of neglectful experiences may also have differed, as 7y measures in the 1958 cohort are indicator variables and do not directly measure neglectful behaviour. Severity of experiences has been shown to be an important moderator in the relationship between child maltreatment and behavioural outcomes⁴³³. Here, a cumulative effect of prospective neglect measures was found, suggesting that an increase in the number of neglectful experiences, and thus severity, was associated with greater deficits in height at each age.

Previous studies have found a cumulative effect of adverse childhood experiences on other aspects of child development¹⁹², including behavioural⁴³³ and emotional development⁴⁸⁶. No study has examined the cumulative effect of child maltreatment and household dysfunction on height growth. In the 1958 cohort, adversity score was negatively related to childhood and adult stature. For each additional neglect or household dysfunction measure at age 7y, height decreased by ≈ 0.3 cm in childhood and 0.1cm in adulthood. Researchers have suggested that a cumulative risk model may predict more variability in behavioural outcomes associated with adverse childhood experiences than agency reports of child maltreatment¹⁹². In the 1958 cohort, there was little difference in the cumulative effect of indicators of neglect at age 7y on height compared to adversity score at age 7y: increases in neglect and adversity score at age 7y were both associated with ≈ 0.3 cm deficit in childhood height in both genders. Therefore, the cumulative effect of neglect may be more strongly associated with deficits in height growth compared to the overall level of adversity (neglect and household dysfunction).

There are several possible mechanisms by which childhood neglect may influence child-to-adult height trajectories. The relationship between neglect and height growth may reflect the impact of socio-economic disadvantage, for which a relationship with height has been established^{152;207;231}. The relationship with short stature found for prospective neglect measures, but not for retrospective measures, suggests that indicators of neglect from various data sources may be measuring different exposures,

supporting findings from Chapter 4. Childhood neglect measures may have a stronger association with socio-economic disadvantage compared to those collected at age 45y. Indeed, the relationship between 7y neglect measures and child-to-adult height trajectories mirror findings from a previous study of the 1958 cohort which investigated the association between early socio-economic circumstances and height growth¹⁵². Li et al found that low social class at birth and household crowding at age 7y were related to deficits in childhood height. As with childhood neglect measures, the strength of association between socio-economic disadvantage and height decreased by adulthood, with catch-up growth following a period of early delay¹⁵². Child neglect may be an additional component of socio-economic disadvantage, alongside other aspects of material and social deprivation, which has an additional effect on height growth. Failures to provide adequate nutrition or medical treatment are important components of physical neglect, and are also related to socio-economic disadvantage²⁶⁵. Thus, deficits in height may represent the presence of chronic malnutrition or long-standing health issues associated with child maltreatment. There is also some evidence to suggest that a stress response to neglect may affect activation of the hypothalamic-pituitary-adrenal (HPA) axis. It has been hypothesised that cortisol, secreted in response to chronic stress, may inhibit pituitary growth hormone (GH) release, and decrease target tissue sensitivity to GH, somatomedin-C or other growth factors^{153;488;489;489;490;490;491}. However, physiological mechanisms by which neglect may influence height growth are not well understood.

It is also possible that the effects of material and social deprivation, such as an inadequate diet, may underlie the associations found between childhood indicators of neglect and height growth. The residual effect of neglect on height may be attributable to unmeasured confounding factors or other aspects of socio-economic disadvantage. For example, information on childhood diet was not collected in the 1958 cohort. In addition, it may not be possible to disentangle the separate effects of neglect and socio-economic disadvantage due to the complexity and overlap in constructs^{29;301;302}. Thus the results may reflect the impact of neglect and socio-economic disadvantage on child-to-adult height growth.

5.5.3 *Conclusion*

In summary, adverse childhood experiences were inversely associated with height growth. Although some of the associations were explained by demographic and socio-economic factors, an independent association persisted for some neglect and household dysfunction measures. A dose-response relationship indicates that the cumulative effect of neglect experiences was associated with child-to-adult height trajectories. Results from this study also highlight the importance of using a wide-range of adverse childhood experiences. A stronger association of adverse childhood experiences with childhood height compared to adult height indicates that growth deficits may diminish over time due to catch-up growth. Thus it is important to examine the influence on child-to-adult height trajectories as examining height at one age may fail to capture the full effect of the exposure. It is uncertain whether delays in growth may underlie the relationship between adverse childhood experiences and adult disease risk, but findings from this study suggest that it is a potential area for future research

6 Adverse childhood experiences and pubertal development

6.1 Background

Sexual abuse and household dysfunction, in particular parental divorce/separation, have been associated with early pubertal development in girls. Little is known about the influence of other forms of child maltreatment on pubertal development, or the associations in boys. It has been shown that the timing of maturation is related to a range of adult health outcomes^{197;198;198-202;240-243}. Therefore, establishing the impact of child maltreatment and household dysfunction on pubertal development will enable us to better understand the important pathways through which adverse childhood experiences influence risk of adult disease.

In this chapter I examine the associations between child maltreatment and household dysfunction on multiple markers of pubertal development.

6.1.1 *Pubertal development*

Puberty is a period of transition from childhood into adulthood when hormonal and physiological changes occur. These changes are triggered by the activation of two endocrine systems; the hypothalamic-pituitary-adrenal (HPA) and hypothalamic-pituitary-gonadal (HPG) systems, which regulate sexual maturation, reproductive capacity and lead to increases in body size. Activation of the HPA system, otherwise known as adrenarche, is characterised by rising levels of hormones which initiate puberty and bring about changes to pubic hair and body odour in the later stages of pubertal development. The maturation of the HPG system, or gonadarche, represents a second phase in puberty and is associated with the maturation of primary (ovaries and testes) and secondary sexual characteristics (e.g. breast (for girls) and testicular development (for boys), rapid growth and the initiation of the menstrual cycle (in girls). Tanner scores are commonly used to measure pubertal onset and development (Table 6.1)^{226;227}. The measures rate the stage of pubic hair growth, breast development in girls, and testicular development in boys from preadolescence (stage 1) to post-pubertal (stage 5). Other important markers of pubertal development are age of menarche for girls and voice change for boys, peak height velocity and skeletal maturation³⁶⁷.

In boys, the first physical manifestation of pubertal development is an increase in testicular volume (Tanner stage 2), which occurs at an average age of 11.5y³⁶⁷. Peak height velocity is reached within a year of testicular development attaining Tanner stage 3. Voice change occurs, on average, at age 14.2y⁴⁹² and signifies the end of puberty^{193;493}. For girls, the onset of puberty is characterised by an acceleration in growth, closely followed by the first signs of breast development (Tanner stage 2). Typically, girls attain Tanner stage 2 for breast development between ages 10.8 and 11.2y³⁶⁷. Peak height velocity occurs around one year later and is followed by menarche^{193;493}. In Europe, the average menarcheal age is between 12 and 13.5y³⁶⁷.

Table 6.1: Tanner standards for breast and testicular development and pubic hair growth^{226;227}

Tanner stage *	Breast development	Testicular development	Pubic hair growth
1	Elevation of papilla	Testes, scrotum, penis same size & proportion as early childhood.	No pubic hair growth
2	Elevation of breast & papilla, enlargement of areola diameter.	Scrotum & testes enlarge, change in texture & some reddening of scrotal skin.	Sparse growth of long, downy hair, straight/slightly curled, appearing on labia/base of penis.
3	Further enlargement of breast & areola, no separation of contours.	Penis growth in length, some increase in breadth. Further growth of testes & scrotum.	Darker, coarser, & more curled, spread sparsely over junction of pubes.
4	Projection of areola & papilla to form a secondary mound above level of breast.	Penis further enlarged in length & breadth with development of glands. Testes & scrotum further enlarged with darkening of scrotal skin.	Adult type hair, but area covered smaller than most adults.
5	Projection of papilla only, due to recession of areola to general contour of breast.	Genitalia adult size & shape. No further enlargement	Adult in type & coverage distributed as an inverse triangle & spread to medial surface of thighs.

*Tanner stage: 1=preadolescent, to 5=mature

6.1.2 *Influences on pubertal development*

Several factors are thought to influence the timing of pubertal development, such as genetic, diet and early environmental conditions.

Genetic factors are an important determinant of puberty. For example, the heritability of age of menarche has been estimated to be between 50 – 80%²²⁸⁻²³⁰. Twin studies suggest that both dominant (whereby one allele masks the effect of another allele on the same gene) and additive (multiple alleles have a cumulative impact on phenotype) genetic effects contribute to pubertal timing^{494;495}. In genome-wide association study, 30 gene loci have been found to effect age of menarche⁴⁹⁶. There is consistent evidence of a high correlation between mother and daughter's age of menarche, although this could partly be due to shared environments, as well as genetic factors⁴⁹⁶⁻⁴⁹⁸. Development of sexual characteristics also differ amongst ethnic groups²³⁷. Onset of puberty tends to be earlier in black children compared to white children²³³⁻²³⁵. In addition, black girls are more likely to develop pubic hair before, or in concurrence with breast development, whereas pubic hair growth is more likely to follow breast development in white girls²³³.

Early life factors; Although pubertal development is a highly heritable trait, early environmental conditions have been shown to influence pubertal maturation. Children born short and thin for gestational age are more likely to begin pubertal development later than others^{499;500}. Established influences of childhood growth have been related to puberty, such as socio-economic circumstances and diet^{207;231;232}. Socio-economic disadvantage has been linked to both earlier^{501;502} and later puberty^{151;503}, whereas malnutrition is associated with delays in maturation and onset of menses^{347;504;505}. Individual components of pre-pubertal diet are also important⁵⁰⁶. A high intake of animal fats and proteins is associated with early menarche^{507;508}, whereas an increase in carbohydrates, vegetable proteins and fats, thiamine and iron are related to delays in maturation⁵⁰⁷⁻⁵⁰⁹.

Pre-pubertal body growth has been associated with pubertal development, with taller pre-pubertal stature related to early onset of puberty⁵¹⁰⁻⁵¹³. Body composition and body fat may also be important. A recent review of American studies concluded that an

increase in pre-pubertal body mass index (BMI) was associated with an early age of menarche in girls. Such findings have led some researchers to suggest that a critical weight and height must be attained before sexual maturation is initiated⁵¹⁴. However, it remains unclear whether early pubertal onset is a consequence or an effect of increased body fat³⁴⁹. The evidence of an association between pre-pubertal BMI and early pubertal development in males is inconsistent^{492;515}.

6.1.3 Influence of child maltreatment on pubertal development

Adverse childhood experiences (child maltreatment and household dysfunction), and in particular sexual abuse and family structure, have been associated with early sexual maturation (Tables 6.2 and 6.3).

Several studies have shown a relationship between sexual abuse and early age of menarche (Table 6.2). A US longitudinal study found that girls who were sexually abused reached menarche at an average age of 11.5y compared with girls who were not sexually abused (average 12.5y)¹⁴⁶. In a large US cross-sectional study of black women, sexual abuse was associated with early menarche, with the strength of association increasing when a more stringent definition of early menarche was adopted (relative risk (RR)=1.27 age 12y vs. RR= 1.50 age \leq 11y)¹⁴⁷. Increased effect sizes have been related to an increase in the frequency^{147;238;354;516} and duration of abuse⁵¹⁶, attempted or completed intercourse and more than one abuser³⁵⁴.

Evidence of an association between physical abuse and age of maturation is inconsistent. In a longitudinal study, self-reports and/or substantiated cases of physical abuse were not associated with age of menarche or breast development²³⁸. Whereas a weak, but significant, relationship was found between self-reports of physical abuse and early age of menarche in the Black Women's Health Study¹⁴⁷. Where multiple forms of maltreatment have been investigated, the strength of association between physical abuse and early puberty weakens after accounting for sexual abuse. For example, in the Otago Woman's Health Child Sexual Abuse Survey, the relationship between severe physical punishment and early menarche attenuated, and was no longer significant, after adjustment for sexual abuse⁵¹⁶. Thus, sexual abuse may be more influential on puberty compared with physical abuse. The term 'trumping' has been coined to describe the

over-riding effect of sexual abuse on pubertal development over other forms of child maltreatment¹⁴⁶.

There is a lack of research investigating the relationship between child maltreatment and pubertal development in males, potentially due to challenges associated with collecting reliable measurements,⁵¹⁷ and less cultural awareness of maturation in males²³⁷. A US longitudinal study, ‘Children in the Community Project’, examined the influence of child maltreatment on puberty in boys. Results showed physical and sexual abuse, and physical neglect were related to an early age of voice change and beard growth. However, as with studies on multiple forms of maltreatment in females, physical abuse and neglect were not associated with early puberty after adjustment for sexual abuse²³⁸.

Evidence is limited for an association between other forms of child maltreatment, such as witnessing intimate-partner violence, psychological abuse and neglect, and pubertal development. However, there is some suggestion that parent-offspring relationships influence pubertal onset. Parental positivity and affectionate behaviour in early life has been shown to predict late puberty⁵¹⁸. Whereas, maternal harsh control and low levels of positive parental investment have been associated with early pubertal onset⁵¹⁷ and accelerated development of secondary sexual characteristics (in girls)¹⁵⁹. These findings suggest that a range of emotional and psychologically abusive and neglectful parenting may influence the timing of maturation.

There are several limitations to the existing literature on child maltreatment and pubertal development. As shown in Table 6.2, the majority of studies investigating the relationship between sexual abuse and age of menarche are cross-sectional and rely on retrospective self-reports of child abuse and menarcheal age; therefore are susceptible to recall bias. There is little research on the influence of other forms of child abuse or neglect, which are more common in the population, or whether multiple forms of child maltreatment have a cumulative effect on puberty. Markers of pubertal development have been restricted to age of menarche and there has been little investigation on other aspects of maturation. Finally, the relationship between child maltreatment and male pubertal development has largely been ignored in the literature, with only Brown et al investigating gender differences.

6.1.4 Influence of household dysfunction on pubertal development

Dysfunctional family environments have been shown to predict pubertal timing, as shown in Table 6.3. Children from households characterised by domestic conflict, or parental mental illness or drug use, are more likely to begin puberty at an earlier age than those who are not (Table 6.3). In particular, family structure has been shown to affect development. In a longitudinal Canadian study, the presence of a step-father increased the risk of adolescents entering puberty by age 13y by 69% compared to those who were not¹⁵⁶. Strong effects have been reported in girls, with those growing up in households without their biological father more likely to experience menarche at a young age, than those who do^{155;158;160;163}. The quality of the marital relationship, indicated by marital satisfaction and conflict, and emotional supportiveness, may also influence the onset of pubertal development in offspring^{162;159}. Father's contribution to the relationship appears to be especially important. Paternal affection and positive family relationships have been associated with delays in pubertal development, whilst increased paternal withdrawal, family conflict and increased duration of paternal absence have been related to early maturation^{159;162;516;518}. There is some indication that the quality of the father-daughter relationship has a unique contribution to the onset of puberty in girls. Ellis et al found that girls whose father spent more time with them, were more affectionate and positive at age 5-6y were less likely to have advanced pubertal development at age 12-13y compared to those whose father spent less time with them, and were less positive and affectionate⁵¹⁸. An additive effect of household dysfunction has also been found, such that for each additional exposure the age of menarche tends to decrease in girls³⁵⁴. There has been little investigation into the effect of family relationships on pubertal development in boys.

Some evidence exists, predominantly from observational studies, linking severe forms of childhood adversity (i.e. war) with later pubertal development^{519;520}. A study of girls living in the city of Šibenik, Croatia, during the Balkan war found a significant increase in mean menarcheal age, with greater delays in girls who had experienced personal tragedies compared to those who did not. These outcomes were seen despite no notable food shortages during the war or increases in the rates of infectious disease⁵²¹. These results are consistent with clinical observations of psychosocial dwarfism, whereby children who have suffered severe socio-emotional distress experience extreme retardation of growth and delays in pubertal development⁵²².

As in the child maltreatment literature, evidence of an association between household dysfunction and pubertal development is mostly from female cohorts, where age of menarche has been adopted as a marker of maturation. Little is known about household dysfunctions influence on pubertal development in males, or whether there is an association with other characteristics of puberty in females. Exposure measures have mostly been restricted to family structure, and less is known about other forms of household dysfunction, such as parental drug use or household contact with social services, e.g. police or institutional care.

In Chapter 4, I demonstrated that child maltreatment and household dysfunction co-occur. However, few studies have compared the effect of different forms of child maltreatment and household dysfunction, or examined their joint influence on pubertal development. Zabin et al found that the association between several household stressors (including drug use in household, time in care, arrest of household member and absence of mother) and earlier pubertal development disappeared after adjustment for sexual abuse, whereas sexual abuse remained associated with early menarcheal age³⁵⁴. In addition, levels of parental investment and supportiveness, independent of family-level measures (i.e. family structure), have been shown to influence pubertal timing in girls⁵¹⁷. These studies indicate that more proximal adverse experiences may have a greater influence on pubertal development, than those at a household level.

Three psychosocial models of pubertal timing have been developed to explain the association between adverse childhood experiences and pubertal development. Psychosocial acceleration theory supposes that familial and ecological stressors provoke early onset of pubertal development. Children growing up in highly stressful environments experience accelerated maturation, earlier sexual activity and are more likely to have unstable romantic relationships compared to children who experience high levels of support and stability, develop later and delay sexual activity and reproduction⁵²³. A variation of psychosocial acceleration theory is a paternal investment model, which suggests females are especially sensitive to a father's role in the family. Thus, early pubertal maturation is linked to unsupportive paternal investment⁵²⁴. Finally, the stress-suppression theory speculates that adverse physical or social conditions, including psychosocial stressors, cause delays in pubertal development and thus reproduction, until better times⁵²⁵.

Table 6.2: Studies of the association between child maltreatment and pubertal development

Study	Design Year of birth N	Exposure	Outcomes	Adjustment	Main findings
Children in the Community study, USA ²³⁸	Longitudinal 1965-74 816	Self-reports of physical & sexual abuse (≥ 18 y) & agency reports of physical & sexual abuse & neglect during childhood	Age of menarche & voice change; breast & beard development reported at 12-21y	Other maltreatment, gender, ethnicity, family SEP, father absent, mothers age at birth	2+ episodes of sexual abuse associated with early menarche, voice change & beard growth. No significant effect of physical abuse & neglect after adjustment for sexual abuse
Pacific Northwest foster study, USA ¹⁴⁶	Longitudinal 1993-6 100 (females)	Agency reports of physical & sexual abuse & physical neglect < 11 y	PDS† at 0, 6, 12 & 24mth follow-up & age of menarche	Age & age at first foster care placement & no. of placements	Physical abuse associated with rapid pubertal development; sexual abuse related to early development.
Otago Women's Health Child Sexual Abuse Survey, New Zealand ⁵¹⁶	Cross-sectional Unknown (< 65 y) 475 (females)	Self-reports of sexual (63% prior to menarche) & physical abuse	Early menarche	Family structure, relationship with parents	Father absence & child sexual abuse (particularly ≥ 12 mths), associated with early menarche (< 12 y)
South-western USA community study ³⁵³	Cross-sectional Unknown (18-56y) 623 (females)	Self-reports of sexual abuse before 14y	Age of menarche	Childhood SEP, family characteristics & personal traits	Sexual abuse associated with early age of menarche, by 6 months
Black Women's Health Study, USA ¹⁴⁷	Cross-sectional 1926-74 35,330 (females)	Self-reports of physical & sexual abuse before 11y	Early menarche	Age, mothers age at birth, height, education, income, foreign born status	Sexual & physical abuse associated with early menarche (< 12 y); risk increased with greater frequency of abuse

Study	Design Year of birth N	Exposure	Outcomes	Adjustment	Main findings
Baltimore study, USA ³⁵⁴	Cross-sectional Unknown (18- 41y) 323 (females)	Self-reports of sexual abuse prior to menarche	Age of menarche	SEP, family structure, household drug/ alcohol use, arrest of family member	Sexual abuse associated with early age of menarche; effect estimates increased with frequency of abuse, if perpetrators household/family member & if > 1 abuser
Youth and Family Relations Study, Canada ³³⁵	Cross-sectional Unknown (12- 19y) 66 (females)	Agency reports of sexual abuse	PDS† & age of menarche		Sexual abuse associated with early pubertal maturation (≤ 11 y)

†PDS – Pubertal Development Scale a self-reported measure of pubertal status³²⁶

Table 6.3: Studies of the association between household dysfunction and pubertal development

Study	Design Year of birth N	Exposure	Outcomes	Adjustment	Main findings
Wroclaw Growth Study, Poland ¹⁵¹	Longitudinal 1953 274 (females)	Prolonged family distress at 11y	Age of menarche		Familial distress associated with early age of menarche
Dunedin Health & Development Study, New Zealand ¹⁶⁰	Longitudinal 1972-3 416 (females)	Family conflict at age 7y & fathers absence between 3 – 11y	Age of menarche	SEP, weight at age 9y	Family conflict & father absence associated with early age of menarche (bottom 20%)
Canadian National Longitudinal Survey of Children & Youth ¹⁵⁶	Longitudinal Unknown 7,977	Living with a single or step-parent	Annual PDS† score (1994 – 2001)	Gender, SEP	Living with a step-father, but not mother or single parent, associated with early pubertal development
FinnTwin12, Finland ¹⁶¹	Longitudinal 1983-7 1891 twin pairs	Biological father absence at 14y	PDS† at 11 & 14y	Zygosity	Biological father's absence associated with accelerated pubertal development in both sexes
West coast study, USA ¹⁶²	Longitudinal Unknown 50 (females)	Parents marital satisfaction & emotional support; marital conflict 9-10y	PDS† at 11-12y	SEP & family structure	Low paternal marital satisfaction, emotional support & parental conflict associated with early pubertal development
Wisconsin Study of Families & Work, USA ¹⁵⁹	Longitudinal Unknown 120 children & 180 (females)	Parental depression; family attitude; marital compatibility & conflict; parental insecurity, authoritative parenting styles at 3-4y	Adrenarche at age 6-7y; breast & pubic hair Tanner score at 10-11y	Mothers age of menarche; BMI at 8-9y & 10-11y	Lower quality parental investment & increased father-reported marital conflict/depression associated with early adrenarche in both sexes & pubertal development in girls.

Study	Design Year of birth N	Exposure	Outcomes	Adjustment	Main findings
Montreal Study, Canada ⁵²⁷	Longitudinal 1977-9 131 (males)	Paternal alcoholism	PDS† at 11, 12, 13 & 14y		Alcoholic fathers associated with delayed pubertal development, by 7mths
Maternal depression & adolescent development study, USA ³⁵⁵	Longitudinal Unknown 87 (females)	Mothers psychiatric history at 11-12y	PDS† at 12- 13y	Fathers absence & dysfunctional relationships, SEP, ethnicity	Maternal mental health associated with early pubertal development & explained the relationship between discordant family relationships & earlier puberty
The National Survey of Family Growth, USA ³⁵⁶	Cross-sectional 1961-80 10,847 (female)	Parental separation (at 0-5, 6-11, 12-17y); no. changes to family structure; step-parent present	Age of menarche	Ethnicity, parent's education level, mothers age of first birth & at marriage	Parental separation at 0-5y, multiple changes to family structure & living with a step-father were associated with early menarche
Australian pregnant women study, Australia ¹⁵⁸	Cross-sectional Unknown 100 (females)	Early stress (witnessed domestic violence, parental separation, family relationships & parent absent by 10y)	Age of menarche	Ethnicity, participants education, family income	Early stress associated with early age of menarche; total early stress accounting for 10.9% of variance in age of menarche
New Zealand study ¹⁶³	Case-control Unknown 166 (sister pairs)	Family disruption/father absence whilst younger sibling pre- pubertal	Age of menarche	Father's warmth, psycho- pathology & dysfunction	Greater exposure to family disruption/father absence associated with early menarche by 3-4 months.
French student study ¹⁵⁵	Cross-sectional 1974-86 978	Family composition at 10-15y	Age of menarche & testosterone levels (n=75)		Father's absence & presence of step-father associated with early menarche; parental separation associated two-fold increase testosterone levels in females, not males.

Study	Design	Year of birth	Exposure	Outcomes	Adjustment	Main findings
		N				
South Italian school study ⁵²⁸	Cross-sectional	1975 – 8 380	Family stressful life indicators at 7y & 8-11y (marital conflict etc.)	Age of menarche & spermarche		Stressful family lives associated with early menarche; parental conflict at 7y associated with early spermarche

†PDS – Pubertal Development Scale a self-reported measure of pubertal status⁵²⁶

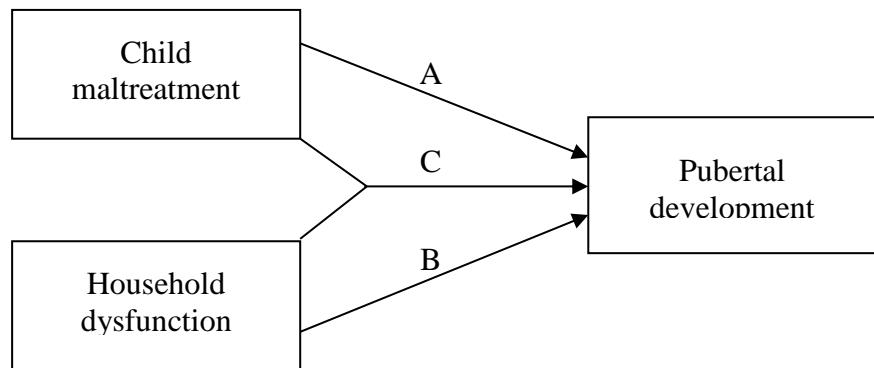
Based on evidence to date, I hypothesise that, first child maltreatment (abuse and neglect) is associated with early onset of puberty in both genders and that associations are stronger for sexual abuse compared to other forms of maltreatment. Second, measures of household dysfunction are also associated with early maturation. Finally, there is a cumulative effect of child maltreatment and household dysfunction on the risk of early pubertal development.

6.2 Objectives

There are three main objectives in this chapter (illustrated in Figure 6.1).

1. Assess whether child maltreatment was associated with the timing of pubertal development, and whether the association persisted after adjustment for potential confounding factors (pathway A). The exposure measures include;
 - a. child abuse and neglect retrospectively reported at age 45y,
 - b. indicators of childhood neglect prospectively collected, and
 - c. multiple forms of child maltreatment.
2. Determine whether household dysfunction in early life was associated with the timing of pubertal development, and whether the association persisted after adjustment for potential confounding factors (pathway B)
3. Establish whether there was a cumulative effect of child maltreatment and household dysfunction on pubertal development (pathway C).

Figure 6.1: Pathways between child maltreatment, household dysfunction and pubertal development



6.3 Methods

6.3.1 Study samples

Analyses in this chapter includes up to 11,638 cohort members for whom information on child maltreatment, household dysfunction and pubertal development was available.

6.3.2 Measures

Response measures were Tanner scores for pubic hair growth (for both genders), testicular (for boys) and breast (for girls) development at age 11y (range 1-5); facial hair growth at age 16y and age of voice change for boys (range age <11 to ≥ 15 y), and age of menarche for girls (range age 9 to >16 y). Continuous measures were used in the preliminary analyses (Appendices 5.1 and 5.2). For each marker of pubertal development, a categorical measure was also derived, indicating 'late', 'intermediate' and 'early' development (Box 6.1). A summary measure of pubic hair growth was created for males, combining Tanner score at age 11y and pubic hair rating at age 16y, as described in §2.3.2 (Table 2.5).

Box 6.1: Categorisation of pubertal development measures

Puberty measures	Stage of development		
	'Late'	'Intermediate'	'Early'
Males			
Testicular development; 11y Tanner scores	1	2	3-5
Pubic hair growth; 11y Tanner scores & 16y ratings	Late	Intermediate	Early
Facial hair growth; 16y	Absent	Sparse	Adult
Age of voice change; 16y	≥ 15y	13-14y	≤ 12y
Females			
Breast & pubic hair development; 11y Tanner scores	1	2	3-5
Age of menarche; 16y	≥ 14y	12-13y	≤ 11y

Exposure measures included child psychological, physical and sexual abuse and witnessed abuse retrospectively reported at age 45y. Eleven indicators of childhood neglect were used in this chapter; three retrospective and eight prospective. Initial examination of the exposure measures revealed that some cohort members had already commenced puberty by age 11y (Table 2.4). Thus, like in the analyses for height (Chapter 5), I used measures of childhood neglect at age 7y in the subsequent analyses to ensure that exposure variables were collected prior to pubertal development measures at ages 11 and 16y. As the physical appearance of the child may be related to pubertal development, two cumulative neglect scores were derived, one with (range 0-8) and the other without neglected appearance (range 0-7), by summing indicators of neglect collected at age 7y. Individuals with complete data for each indicator were included (Table 5.4). There was little difference in the results ascertained from both scores, thus neglect score without neglected appearance (range 0-7) is presented in this chapter.

The association between distinct patterns of child maltreatment and pubertal development was examined using maltreatment groups obtained from responses to all 15 child maltreatment measures (seven retrospective and eight prospective indicators of neglect at age 7y) using latent class analysis (LCA) reported in Chapter 5. The maltreatment groups included a low risk of maltreatment, neglect 'only', and abuse and neglect (Appendix 4.4).

As in Chapter 5, household dysfunction measures considered in this chapter were domestic tension, parental alcoholism, family member mental health problem, household contact with a probation officer or children's department/charity, time in

institutional care and parental separation or divorce; all collected at 7y (Table 5.5). Household dysfunction score was derived by summing all seven household dysfunction measures (individuals with complete data for each indicator were included; range 0-7).

To examine whether there was a cumulative effect of childhood adverse experiences on pubertal development, neglect and household dysfunction scores were combined to create an overall adversity score at age 7y (i.e. sum of eight indicators of neglect and seven household dysfunction measures; range 0-15). A second adversity score was created excluding the indicator of neglect, neglected appearance (range 0-14) (Table 5.6). The results for adversity score with and without neglected appearance varied little thus results for adversity score without neglected appearance (range 0-7) are presented in this chapter.

Confounding factors were identified from the literature, and where available were included in the analyses. Previous studies investigating the association between child maltreatment and household dysfunction and puberty have adjusted for ethnicity, socio-economic circumstances, level of parental education, mother's age of menarche, marriage and birth, and individual's BMI and height (Tables 6.2 and 6.3). Variables were considered as confounding factors if they were shown to be associated with both the risk of child maltreatment and also pubertal development (§2.4). Pre-pubertal BMI was not included, as the direction of the association has not been definitely established⁵¹⁵, and therefore may be on the causal pathway. Confounding factors considered in this chapter are shown in Table 6.4. Mother's age of menarche was only included in the adjusted models for females as a large proportion of male cohort members (65.4%) did not have information on maternal age of menarche.

Table 6.4: Summary of confounding factors available in the 1958 British birth cohort

Potential confounder	Total n	mean (SD)/%
Ethnicity (non-white)	16,298	9.4
Social class at birth	I/II	2,906 17.5
	III _{nm}	1,569 9.5
	III _{Im}	8,054 48.6
	IV/V	4,042 24.4
Household crowding at 7y	15,053	13.0
Mothers age of menarche (female cohort members only)	6,135	13.3(1.7)

6.3.3 *Statistical analysis*

Preliminary analyses

In the preliminary analyses, continuous measures of pubertal development were used to test for a trend between the exposure and outcome measures³⁹⁵. Linear regression models were adopted, and the difference in mean Tanner score at age 11y (for males and females), facial hair rating and onset of voice of change (for males) and age of menarche (for girls) was compared between participants who experienced maltreatment or household dysfunction and those who did not. T-tests were applied to determine whether there was a significant association. For most forms of child maltreatment and household dysfunction, there was no significant difference in mean stage of pubertal development between exposed and non-exposed groups (Appendices 5.1 and 5.2).

In addition, many puberty measures had skewed distributions (Table 2.8). Thus, categorical measures for each marker of puberty ('early', 'intermediate', or 'late') were derived, and analyses using these variables are presented in this chapter.

Regression models

Multinomial logistic regression models were applied to examine the association between child maltreatment and household dysfunction and each marker of pubertal development (§3.3). The 'intermediate' categories (i.e. boys whose voice broke between ages 13-14y, and girls whose menarcheal age was between 12-13y) were used as the reference groups. Relative risk ratios (RRR) and 95% confidence intervals (CI) of late and early development for exposed (vs. non-exposed to adverse childhood experiences) were estimated. A Wald test was used to determine whether there was a significant association.

For the association between maltreatment in childhood and puberty (pathway A), the exposure measures examined include;

1. each form of abuse and neglect reported at age 45y
2. each indicator of neglect reported at age 7y,
3. a neglect score (sum of all indicators of neglect at age 7y; range 0-8)

4. a neglect score excluding neglected appearance (range 0-7)
5. three distinct maltreatment groups obtained from LCA of all fifteen measures of child maltreatment (at ages 7 and 45y) ; low risk of abuse and neglect adopted as reference category

For the association between household dysfunction and puberty (pathway B), the exposures examined include;

1. each household dysfunction measure reported at age 7y
2. a household dysfunction score (sum of all household dysfunction measures at age 7y; range 0-7)

Finally, I examined the association between adversity score with (range 0-15) and without neglected appearance (range 0-14) and pubertal development to establish whether neglect and household dysfunction at age 7y have a cumulative effect (pathway C).

Initially, unadjusted relationships were examined. Confounding factors were then included in the models; ethnicity, socio-economic factors (household crowding and social class at birth) and maternal age of menarche (for females). Age (in months) when puberty characteristics were recorded was included in all models to account for variations in the timing when measurements were taken. In order to examine whether the relationship between neglect score and pubertal development was non-linear, a quadratic term was added to the models. Unadjusted and adjusted RRR for each puberty measure were estimated between individuals who experienced maltreatment or household dysfunction in childhood versus those who did not.

The association between adverse childhood experiences and pubertal development was studied using different sample sizes, depending on the exposure and outcome measure.

Samples used for the analyses of childhood maltreatment and pubertal development (pathway A)

For analyses to investigate the association between child abuse and neglect (retrospectively reported at age 45y) and puberty, of the 9,310 cohort members with data on child maltreatment information was available for:

- 3,718 males for testicular development (at age 11y)
- 3,687 males for pubic hair growth (at ages 11 and 16y)
- 3,382 males for facial hair growth (at age 16y)
- 3,635 males for age of voice change
- 3,802 females for breast development (at age 11y)
- 3,776 females for pubic hair growth (at age 11y)
- 3,010 females for age of menarche

For each indicator of neglect at age 7y (n=8), of the 10,338-14,602 cohort members with data on pubertal development was available for:

- 3,942-5,748 males for testicular development (at age 11y)
- 3,914-5,713 males for pubic hair growth (at ages 11 and 16y)
- 3,374-4,871 males for facial hair growth (at age 16y)
- 3,694-5,360 males for age of voice change
- 4,100-5,588 females for breast development (at age 11y)
- 4,081-5,553 females for pubic hair growth (at age 11y)
- 3,038-4,125 females for age of menarche

Of those with a neglect score with neglected appearance (range 0-8; n=9,245), information on puberty was available for:

- 3,614 males for testicular development (at age 11y)
- 3,590 males for pubic hair growth (at ages 11 and 16y)
- 3,088 males for facial hair growth (at age 16y)
- 3,379 males for age of voice change
- 3,744 females for breast development (at age 11y)
- 3,727 females for pubic hair growth (at age 11y)

- 2,762 females for age of menarche

For participants with a neglect score excluding neglected appearance (range 0-7; n=13,112), data on each marker of pubertal development were available for:

- 5,273 males for testicular development (at age 11y)
- 5,242 males for pubic hair growth (at ages 11 and 16y)
- 4,467 males for facial hair growth (at age 16y)
- 4,911 males for age of voice change
- 5,136 females for breast development (at age 11y)
- 5,107 females for pubic hair growth (at age 11y)
- 3,770 females for age of menarche

There was little difference in the results relating to neglect score with (range 0-8) or without (range 0-8) neglected appearance. Thus results presented in this chapter are for neglect score without neglected appearance, and others can be found in Appendices 5.8 and 5.9.

Maltreatment groups (obtained from LCA) were available for 5,386 participants, of which data on puberty measures was available for.

- 2,167 males for testicular development (at age 11y)
- 2,146 males for pubic hair growth (at ages 11 and 16y)
- 1,920 males for facial hair growth (at age 16y)
- 2,054 males for age of voice change
- 2,390 females for breast development (at age 11y)
- 2,378 females for pubic hair growth (at age 11y)
- 1,846 females for age of menarche

Samples used for the analyses of household dysfunction and pubertal development (pathway B)

For each 7y household dysfunction measure (n=7), of the 13,267-15,053 cohort members with data on pubertal development was available for:

- 5,308-5,894 males for testicular development (at age 11y)
- 5,098-5,859 males for pubic hair growth (at ages 11 and 16y)
- 4,307-5,017 males for facial hair growth (at age 16y)
- 4,711-5,511 males for age of voice change
- 4,978-5,744 females for breast development (at age 11y)
- 4,949-5,709 females for pubic hair growth (at age 11y)
- 3,670-4,229 females for age of menarche

Of those with household dysfunction score (n=12,464), pubertal measures were available for:

- 5,040 males for testicular development (at age 11y)
- 5,013 males for pubic hair growth (at ages 11 and 16y)
- 4,220 males for facial hair growth (at age 16y)
- 4,614 males for age of voice change
- 4,872 females for breast development (at age 11y)
- 4,844 females for pubic hair growth (at age 11y)
- 3,590 females for age of menarche

Samples used for the analyses of cumulative childhood adversity and pubertal development (pathway C)

For analyses to investigate the cumulative effect of neglect and household dysfunction at age 7y on pubertal development, of those with adversity score including neglected appearance (range 0-15; n=8,172), information on pubertal development was available for:

- 3,223 males for testicular development (at age 11y)
- 3,202 males for pubic hair growth (at ages 11 and 16y)
- 2,742 males for facial hair growth (at age 16y)
- 2,984 males for age of voice change
- 3,318 females for breast development (at age 11y)
- 3,303 females for pubic hair growth (at age 11y)
- 2,463 females for age of menarche

Of those with an adversity score without neglected appearance (range 0-14; n=11,548), information on puberty was available for:

- 4,693 males for testicular development (at age 11y)
- 4,666 males for pubic hair growth (at ages 11 and 16y)
- 3,942 males for facial hair growth (at age 16y)
- 4,314 males for age of voice change
- 4,531 females for breast development (at age 11y)
- 4,505 females for pubic hair growth (at age 11y)
- 3,347 females for age of menarche

Few differences were found between adversity score with (range 0-15) and without neglected appearance (range 0-15). Presented in this chapter are adversity score without neglected appearance (range 0-14), and others can be found in Appendices 5.8 and 5.9.

Analyses were limited to participants with complete data on the exposure measure of interest (child maltreatment and household dysfunction) and relevant pubertal development variable. Adjusted models were conducted using all available data and these are shown in Appendices 5.3-5.7. Presented in this chapter are models restricted to participants with complete data on all covariates (i.e. maximum sample available in the adjusted model). Where few associations are found between adverse childhood experiences and a particular marker of pubertal development, results are referred to in the text and tables are presented in the Appendix. Significant trends found in the preliminary analyses are also highlighted in the results and tables (in italics).

Additional analyses

To examine whether the association between adverse childhood experiences and pubertal development may have been affected by sample attrition, as well as missing data, missing observations were imputed. Details of the multiple imputation model have been described in §3.4 and §5.3.3. Multinomial logistic regression models were adopted to investigate the relationship between adverse childhood experiences and testicular development at age 11y in males, and age of menarche in females. Models were fitted to each imputed dataset and overall estimates were attained by combining

parameters from these datasets using Rubin's rules³⁷⁷. Exposure measures were restricted to child maltreatment measures reported at age 45y and neglect, household dysfunction and adversity scores and maltreatment groups. Participants with complete data on the outcome of interest (i.e. testicular development and age of menarche) were included in the analyses. Unadjusted and adjusted relationships were examined and are presented in Appendices 5.12 and 5.13. For males, maternal age of menarche was also included in the adjusted model (unlike in the complete cases analyses). There was little difference in models with and without maternal age of menarche, thus analyses without are presented in Appendix 5.12.

6.4 Results

6.4.1 *Pubertal development measures*

A summary of pubertal development measures is given in Table 6.5. A greater proportion of boys were at the pre-pubertal stage at age 11y (34.4% at Tanner stage 1 for pubic hair and testicular development), than girls (27.2% at Tanner stage 1 for pubic hair and breast development). By age 13y, over a quarter (26.8%) of boys voices had changed, whilst nearly three quarters (73.0%) of girls had started menarche (data not presented).

Table 6.5: Summary of pubertal development measures

Pubertal development measures	Stages of puberty; n (%)		
	‘Late’ [†]	‘Intermediate’	‘Early’ [‡]
<i>Males</i>			
Testicular development; 11y	2,409 (38.1)	2,855 (45.1)	1,066 (16.8)
Pubic hair growth; 11 & 16y	2,740 (43.5)	2,543 (40.4)	1,010 (16.1)
Facial hair growth; 16y	2,093 (37.4)	3,017 (53.9)	491 (8.8)
Age voice change	2,812 (45.8)	2,699 (44.0)	625 (10.2)
<i>Females</i>			
Breast development; 11y	2,220 (36.2)	2,199 (35.9)	1,707 (27.9)
Pubic hair growth; 11y	2,522 (41.4)	2,223 (36.5)	1,344 (22.1)
Age of menarche	1,256 (27.1)	2,640 (56.8)	750 (16.1)

[†] at early stage of development at given age, late developer

[‡] at late stage of development at given age, early developer

6.4.2 *Child maltreatment and pubertal development*

Child abuse and neglect reported at age 45y

The associations between retrospectively reported child maltreatment measures and pubertal development are presented in Table 6.6 and Appendix 5.14 (facial hair growth and age of voice change for boys) and Appendix 5.15 (breast and pubic hair development for girls). Sexual abuse tended to be associated with early pubertal development in both boys and girls. This is particularly evident in testicular development for boys and age of menarche for girls. Associations persisted after adjustment for ethnicity, socio-economic factors and maternal age of menarche (for girls). The RRR of early development of testicular development (vs. intermediate) was 5.50 (95% CI 1.00, 30.17) for sexually abused boys, compared to those who were not, and the RRR of early age of menarche was 2.41 (1.19, 4.88). Sexual abuse was also associated with early development of other pubertal markers (e.g. pubic hair growth), but relationships were non-significant. In the adjusted models, there was some indication that sexual abuse in childhood may be associated with late development of some pubertal markers (pubic hair growth, testicular development and facial hair growth (Appendix 5.14) for boys, and age of menarche for girls), suggesting a 'U' shaped relationship (increased risk of early and late puberty). However, these associations did not reach statistical significance. There was no significant association between other forms of abuse and pubertal development.

In contrast to sexual abuse, neglect was associated with a decreased risk of early puberty. In the adjusted models, neglected boys tended to mature later, and were less likely to develop earlier for testicular development at age 11y and pubic hair growth, than those not neglected (Table 6.6). 'I was neglected' was associated with a reduced risk of early pubic hair growth (RRR=0.11, 0.02, 0.83), and an increased risk of late maturation (RRR=1.37; 0.80, 2.32). A trend was shown between neglect and testicular development: males who retrospectively reported neglect were more likely to have a lower mean Tanner score for testicular development (-0.20; -0.39, 0.00) and pubic hair growth (-0.18; -0.33, -0.03) compared to those who did not (Appendix 5.1). For girls, retrospectively reporting an unaffectionate father was associated with an older mean average age of menarche (0.20y; 0.00, 0.40) (Appendix 5.2).

Table 6.6: Estimated effects (RRR) of child maltreatment (reported at 45y) on markers of pubertal development (reference category ‘intermediate’ development or age of menarche 12-13y)

Child maltreatment	Males				Females	
	Testicular [†] ; 11y		Pubic hair [‡] ; 11 & 16y		Age of menarche [‡]	
	Late (1)	Early (3-5)	Late	Early	Late (≥ 14)	Early (≤ 11)
<i>Child abuse</i>						
Psychological abuse	Unadjusted	0.91 (0.70, 1.20)	1.05 (0.75, 1.48)	1.25 (0.95, 1.63)	1.18 (0.82, 1.68)	1.33 (0.99, 1.78)
	Adjusted	0.90 (0.69, 1.18)	1.06 (0.75, 1.49)	1.24 (0.95, 1.62)	1.20 (0.83, 1.72)	1.32 (0.98, 1.78)
Physical abuse	Unadjusted	0.93 (0.68, 1.29)	1.01 (0.67, 1.52)	1.28 (0.93, 1.78)	1.09 (0.71, 1.69)	1.16 (0.78, 1.71)
	Adjusted	0.90 (0.65, 1.24)	1.01 (0.66, 1.52)	1.28 (0.93, 1.76)	1.19 (0.77, 1.84)	1.09 (0.73, 1.62)
Sexual abuse	Unadjusted	4.49 (0.95, 21.18)	5.48 ^a (1.00, 30.01)	1.66 (0.48, 5.68)	1.90 (0.42, 8.51)	1.43 (0.72, 2.86)
	Adjusted	4.32 (0.91, 20.42)	5.50 ^a (1.00, 30.17)	1.67 (0.49, 5.74)	2.11 (0.47, 9.50)	1.32 (0.65, 2.66)
Witnessed abuse	Unadjusted	1.28 (0.88, 1.85)	1.46 (0.93, 2.29)	1.14 (0.79, 1.62)	0.88 (0.53, 1.47)	1.23 (0.85, 1.79)
	Adjusted	1.21 (0.83, 1.76)	1.45 (0.92, 2.30)	1.10 (0.76, 1.57)	0.92 (0.55, 1.56)	1.14 (0.78, 1.66)
<i>Indicators of neglect</i>						
I was neglected	Unadjusted	1.35 (0.79, 2.32)	0.53 (0.20, 1.40)	1.37 (0.81, 2.32)	0.10 ^c (0.01, 0.75)	1.22 (0.74, 1.98)
	Adjusted	1.29 (0.75, 2.23)	0.53 (0.20, 1.38)	1.37 (0.80, 2.32)	0.11 ^c (0.02, 0.83)	1.17 (0.71, 1.93)
Unaffectionate mother	Unadjusted	0.92 (0.53, 1.59)	0.64 (0.28, 1.48)	1.32 (0.76, 2.29)	0.78 (0.33, 1.84)	1.04 (0.67, 1.63)
	Adjusted	0.89 (0.51, 1.54)	0.64 (0.28, 1.48)	1.32 (0.76, 2.30)	0.82 (0.36, 2.00)	0.95 (0.6, 1.49)
Unaffectionate father	Unadjusted	1.22 (0.95, 1.57)	1.24 (0.90, 1.71)	1.06 (0.83, 1.36)	0.91 (0.65, 1.28)	1.36 (0.97, 1.91)
	Adjusted	1.20 (0.93, 1.54)	1.25 (0.91, 1.72)	1.05 (0.82, 1.35)	0.94 (0.66, 1.32)	1.35 (0.96, 1.91)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis, [†]‘stage 2’, [‡]‘normal’ and [‡]age 12-13y used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity, social class at birth, household crowding and maternal age of menarche (for age of menarche only); no. of observations 3,073-3,613 males and 2,405-3,378 females; ^ap<0.05; ^bp<0.01; ^cp<0.001; italic indicates p<0.05 for linear trend (Appendix 5.1 and 5.2).

Indicators of childhood neglect (at age 7y)

Indicators of neglect at age 7y were associated with late pubertal development in both genders, as shown in Tables 6.8 and Appendix 5.16 (testicular development) for boys and Table 6.9 for girls. After adjustment for confounding factors, the association changed little and most relationships persisted. For boys, 'mother/father hardly read' and 'father hardly any outings' were associated with late age of voice change; 'mother hardly any outings' was associated with late testicular development and pubic hair growth; neglected appearance was associated with late pubic and facial hair development; and 'mother/father little interest in education' were related to late development of each puberty measure. For girls, 'mother hardly reads' was related to late breast development, and 'mother/father little interest in education' and neglected appearance were associated with late development of all markers of puberty.

In the adjusted analyses, a significant trend was found between most neglect measures and several puberty characteristics. Participants with a positive response to indicators of neglect had, on average, lower mean Tanner scores for pubic hair growth (for both genders) and breast development at age 11y (for girls) and facial hair ratings at age 16y (for boys) than those with a negative response. Neglected participants were also more likely to be older at onset of voice change (for boys) and menarche (for girls) than those not neglected (Appendices 5.3 and 5.4). For example, 'mother little interest in education' was associated with a decreased mean Tanner score for pubic hair growth (-0.05; -0.09, 0.00 for boys and -0.11: -0.19, -0.03 for girls) and breast development (-0.14; -0.22, -0.06 for girls), a lower facial hair rating at age 16y (-0.09; -0.14, -0.04 for boys) and older age of menarche (0.29y; 0.14, 0.43 for girls).

For boys, some neglect measures were only associated with an increased risk of late development; 'mother hardly any outings' was related to late testicular development at age 11y (RRR=1.60; 1.00, 2.56 (Appendix 5.24)), and 'father little interest in education' was associated with late pubic hair growth only (Table 6.8).

A few indicators of neglect were associated with earlier pubertal development (Tables 6.8 and 6.9). For boys, 'father hardly any outing' was associated with early testicular

development (Appendix 5.24). For girls, low parental aspiration was related to menarche at age ≤ 11 y.

Increments in neglect score were associated with late development of each pubertal marker. For boys, for each additional neglect indicator, the likelihood of late testicular development increased by 6% (95% CI; 1.00, 1.12), pubic hair growth by 8% (1.02, 1.14), facial hair growth by 9% (1.02, 1.15) and voice change at age ≥ 15 y by 11% (1.05, 1.17). For girls, an increment in neglect score was associated with a 11% (1.04, 1.19) increased chance of later breast development, 9% (1.02, 1.16) late pubic hair growth, and a 15% (1.06, 1.24) greater risk of menarche at age ≥ 14 y. After adjustment for confounding factors, the strength of association between neglect score and markers of puberty diminished, especially for girls. In contrast, there was little difference in the strength of association in adjusted models for boys (Table 6.8 and Figure 6.2).

Further analyses using a categorical neglect score suggested that the effect was greater for a high neglect score (≥ 4 for boys and ≥ 3 for girls), compared to a lower neglect score (Appendices 5.10 and 5.11). This result suggests that the relationship between neglect score and pubertal development was non-linear (although a significant quadratic term for neglect score was only found for facial hair growth at age 16y in boys ($P < 0.01$)). Cohort members with a high neglect score (≥ 4 for boys and ≥ 3 for girls) were at increased risk of later pubertal development compared to those with a low neglect score. After adjustment for confounding factors, a high neglect score remained associated with late pubic and facial hair growth and onset of voice change for boys and a reduced risk of early breast development for girls (Figures 6.2 and 6.3).

Table 6.7: Estimated effects (RRR) of neglect (reported at age 7y) on markers of pubertal development (reference category ‘intermediate’ development, or onset of voice change age 12-14y); males¹

Indicators of neglect; 7y	Pubic hair [‡] ; 11 & 16y			Facial hair [‡] ; 16y		Voice change [#]	
	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted
Mother hardly reads	Unadjusted	1.02 (0.88, 1.20)	0.97 (0.78, 1.20)	0.98 (0.84, 1.16)	0.89 (0.67, 1.19)	<i>1.27^c</i> (1.09, 1.48)	0.94 (0.72, 1.23)
	Adjusted	1.00 (0.86, 1.17)	1.02 (0.82, 1.27)	0.95 (0.80, 1.12)	0.88 (0.66, 1.19)	<i>1.25^b</i> (1.07, 1.47)	0.90 (0.69, 1.19)
Father hardly reads	Unadjusted	1.08 (0.95, 1.22)	0.93 (0.78, 1.11)	1.11 (0.97, 1.28)	1.02 (0.80, 1.29)	<i>1.36^c</i> (1.20, 1.55)	1.09 (0.88, 1.36)
	Adjusted	1.06 (0.93, 1.20)	0.97 (0.81, 1.16)	1.08 (0.94, 1.24)	1.03 (0.81, 1.31)	<i>1.34^c</i> (1.18, 1.53)	1.06 (0.85, 1.32)
Mother hardly any outings	Unadjusted	<i>1.73^a</i> (1.09, 2.76)	0.89 (0.43, 1.85)	1.03 (0.65, 1.62)	0.65 (0.26, 1.64)	1.15 (0.74, 1.78)	1.16 (0.58, 2.35)
	Adjusted	<i>1.63^a</i> (1.02, 2.60)	<i>1.03</i> (0.49, 2.14)	0.93 (0.59, 1.48)	0.63 (0.25, 1.60)	1.10 (0.71, 1.72)	1.08 (0.53, 2.19)
Father hardly any outings	Unadjusted	1.15 (0.88, 1.50)	1.22 (0.86, 1.72)	1.29 (0.99, 1.69)	1.40 (0.91, 2.16)	<i>1.55^c</i> (1.20, 2.00)	1.24 (0.81, 1.89)
	Adjusted	1.11 (0.85, 1.46)	1.35 (0.95, 1.91)	1.22 (0.93, 1.60)	1.38 (0.89, 2.15)	<i>1.51^c</i> (1.17, 1.96)	1.17 (0.76, 1.79)
Mother little interest education	Unadjusted	<i>1.33^c</i> (1.13, 1.56)	0.89 (0.70, 1.12)	<i>1.24^b</i> (1.05, 1.46)	0.65 ^b (0.46, 0.92)	1.22 ^b (1.04, 1.43)	1.22 (0.94, 1.57)
	Adjusted	<i>1.27^b</i> (1.08, 1.50)	0.97 (0.76, 1.23)	<i>1.19^a</i> (1.00, 1.41)	0.65 ^a (0.45, 0.92)	1.22 ^a (1.04, 1.44)	1.15 (0.88, 1.50)
Father little interest education	Unadjusted	1.29 ^c (1.10, 1.51)	0.90 (0.71, 1.12)	<i>1.20^a</i> (1.01, 1.41)	0.60 ^c (0.42, 0.85)	1.11 (0.95, 1.30)	1.29 ^a (1.01, 1.66)
	Adjusted	1.24 ^b (1.06, 1.46)	0.97 (0.77, 1.22)	<i>1.14</i> (0.96, 1.36)	0.59 ^c (0.41, 0.85)	1.10 (0.94, 1.30)	1.23 (0.95, 1.59)
Low parental aspirations	Unadjusted	1.13 (0.84, 1.52)	0.78 (0.50, 1.22)	1.32 (0.97, 1.78)	1.27 (0.76, 2.13)	1.28 (0.96, 1.71)	1.28 (0.81, 2.02)
	Adjusted	1.07 (0.80, 1.44)	0.86 (0.55, 1.35)	1.25 (0.92, 1.69)	1.27 (0.75, 2.15)	1.27 (0.95, 1.71)	1.21 (0.77, 1.92)
Neglected appearance	Unadjusted	<i>1.44^b</i> (1.09, 1.90)	0.77 (0.50, 1.19)	<i>1.44^b</i> (1.08, 1.93)	0.68 (0.36, 1.28)	1.17 (0.89, 1.54)	1.08 (0.69, 1.69)
	Adjusted	<i>1.38^a</i> (1.03, 1.83)	0.88 (0.56, 1.37)	<i>1.35^a</i> (1.00, 1.82)	0.66 (0.34, 1.25)	1.16 (0.87, 1.53)	1.01 (0.64, 1.60)
Continuous neglect score [‡]	Unadjusted	1.08 ^b (1.02, 1.13)	0.96 (0.90, 1.04)	<i>1.07^a</i> (1.02, 1.13)	0.92 (0.83, 1.02)	<i>1.12^c</i> (1.07, 1.18)	1.06 (0.98, 1.15)
	Adjusted	1.07 ^a (1.01, 1.12)	1.00 (0.93, 1.08)	<i>1.06^a</i> (1.00, 1.12)	0.92 (0.83, 1.02)	<i>1.11^c</i> (1.06, 1.18)	1.04 (0.95, 1.13)

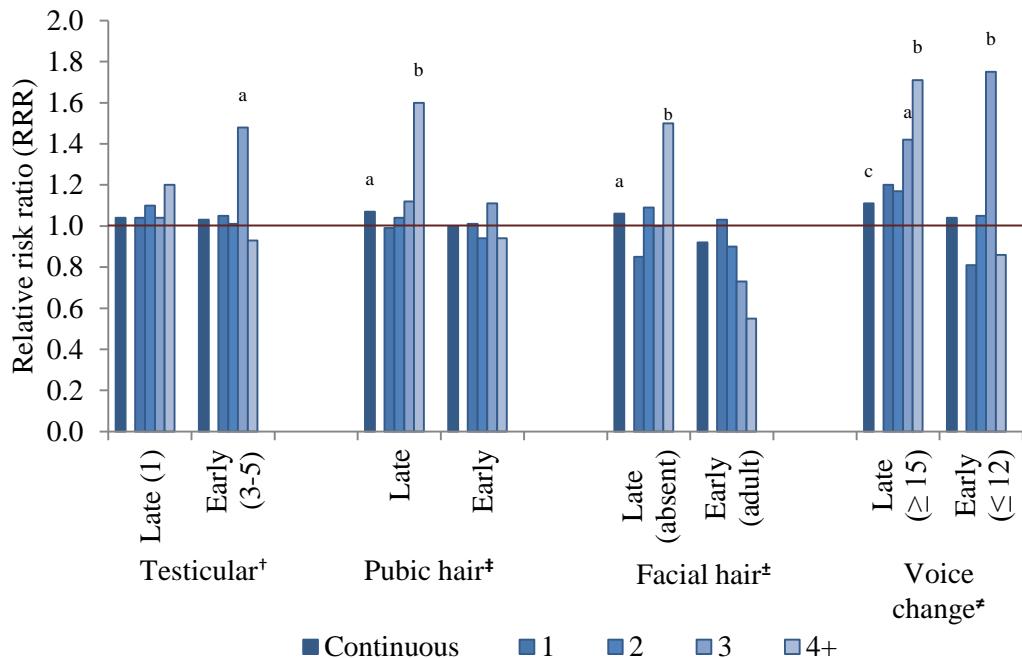
¹All values are relative risk ratio (RRR); 95% CI in parenthesis, [‡]‘normal’, [‡]‘sparse’ and [#]age 12-14y used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity, social class at birth and household crowding; no. of observations 3,362-5,710; [‡]sum of seven indicators excluding neglected appearance (range 0-7), no. of observations 4,465-5,271; ^ap<0.05; ^bp<0.01; ^cp<0.001; *italic* indicates p<0.05 for linear trend (Appendix 5.1)

Table 6.8: Estimated effects (RRR) of neglect (reported at age 7y) on markers of pubertal development (reference category 'intermediate' development, or age of menarche 12-13y); females¹

Indicators of neglect; 7y		Breast [†] ; 11y		Pubic hair [†] ; 11y		Age of menarche [‡]	
		Late (1)	Early (3-5)	Late (1)	Early (3-5)	Late (≥ 14)	Early (≤ 11)
Mother hardly reads	Unadjusted	<i>1.33^c (1.11, 1.60)</i>	<i>1.08 (0.89, 1.32)</i>	1.17 (0.98, 1.39)	1.06 (0.86, 1.30)	1.13 (0.91, 1.40)	0.97 (0.74, 1.26)
	Adjusted	<i>1.30^b (1.08, 1.56)</i>	<i>1.12 (0.92, 1.37)</i>	1.12 (0.94, 1.34)	1.09 (0.88, 1.35)	1.07 (0.86, 1.33)	0.97 (0.73, 1.27)
Father hardly reads	Unadjusted	1.04 (0.90, 1.21)	0.93 (0.79, 1.09)	1.14 (0.99, 1.31)	1.01 (0.85, 1.19)	1.19 ^a (1.00, 1.43)	1.08 (0.87, 1.34)
	Adjusted	1.03 (0.89, 1.20)	0.94 (0.80, 1.11)	1.11 (0.96, 1.28)	1.01 (0.85, 1.21)	1.14 (0.95, 1.37)	1.06 (0.85, 1.33)
Mother hardly any outings	Unadjusted	1.08 (0.63, 1.79)	0.57 (0.29, 1.14)	1.60 (0.92, 2.78)	0.80 (0.37, 1.72)	1.34 (0.63, 2.86)	1.19 (0.47, 3.02)
	Adjusted	0.99 (0.57, 1.70)	0.61 (0.30, 1.23)	1.49 (0.85, 2.59)	0.85 (0.39, 1.83)	1.14 (0.53, 2.45)	1.32 (0.51, 3.39)
Father hardly any outings	Unadjusted	1.22 (0.93, 1.61)	1.08 (0.80, 1.46)	1.12 (0.86, 1.45)	0.98 (0.71, 1.35)	1.30 (0.93, 1.82)	1.28 (0.85, 1.91)
	Adjusted	1.14 (0.86, 1.50)	1.22 (0.90, 1.65)	1.02 (0.78, 1.33)	1.07 (0.77, 1.48)	1.14 (0.81, 1.62)	1.30 (0.86, 1.96)
Mother little interest education	Unadjusted	<i>1.14 (0.94, 1.36)</i>	<i>0.72^c (0.58, 0.90)</i>	<i>1.09 (0.91, 1.31)</i>	<i>0.75^a (0.59, 0.95)</i>	<i>1.50^c (1.20, 1.89)</i>	<i>0.74 (0.53, 1.04)</i>
	Adjusted	<i>1.12 (0.93, 1.36)</i>	<i>0.75^a (0.60, 0.95)</i>	<i>1.04 (0.86, 1.25)</i>	<i>0.76^a (0.60, 0.98)</i>	<i>1.40^b (1.11, 1.78)</i>	<i>0.69^b (0.49, 0.98)</i>
Father little interest education	Unadjusted	<i>1.11 (0.92, 1.32)</i>	<i>0.77^c (0.62, 0.95)</i>	<i>1.16 (0.97, 1.39)</i>	<i>0.91 (0.73, 1.14)</i>	<i>1.45^c (1.16, 1.81)</i>	<i>0.96 (0.71, 1.29)</i>
	Adjusted	<i>1.09 (0.90, 1.32)</i>	<i>0.80^a (0.64, 1.00)</i>	<i>1.11 (0.92, 1.34)</i>	<i>0.94 (0.75, 1.19)</i>	<i>1.36^b (1.08, 1.71)</i>	<i>0.90 (0.67, 1.23)</i>
Low parental aspirations	Unadjusted	1.18 (0.85, 1.65)	1.05 (0.73, 1.52)	1.02 (0.75, 1.40)	0.83 (0.56, 1.24)	1.29 (0.83, 2.00)	1.94 ^b (1.22, 3.07)
	Adjusted	1.15 (0.82, 1.61)	1.11 (0.77, 1.61)	0.98 (0.71, 1.34)	0.86 (0.58, 1.29)	1.17 (0.74, 1.84)	1.96 ^b (1.22, 3.15)
Neglected appearance	Unadjusted	<i>1.89^c (1.32, 2.72)</i>	<i>0.66 (0.41, 1.07)</i>	<i>1.65^b (1.16, 2.34)</i>	<i>0.60 (0.35, 1.02)</i>	<i>1.70^a (1.11, 2.60)</i>	<i>0.83 (0.44, 1.57)</i>
	Adjusted	<i>1.94^c (1.34, 2.81)</i>	<i>0.70 (0.42, 1.14)</i>	<i>1.48^a (1.03, 2.12)</i>	<i>0.59 (0.34, 1.02)</i>	<i>1.52 (0.98, 2.37)</i>	<i>0.80 (0.41, 1.53)</i>
Continuous neglect score [‡]	Unadjusted	<i>1.07^a (1.01, 1.13)</i>	<i>0.94 (0.88, 1.01)</i>	<i>1.06^a (1.00, 1.12)</i>	<i>0.96 (0.89, 1.03)</i>	<i>1.13^b (1.05, 1.22)</i>	<i>1.01 (0.93, 1.11)</i>
	Adjusted	<i>1.06 (1.00, 1.13)</i>	<i>0.97 (0.90, 1.04)</i>	<i>1.04 (0.98, 1.10)</i>	<i>0.97 (0.90, 1.05)</i>	<i>1.10^a (1.02, 1.19)</i>	<i>1.00 (0.91, 1.10)</i>

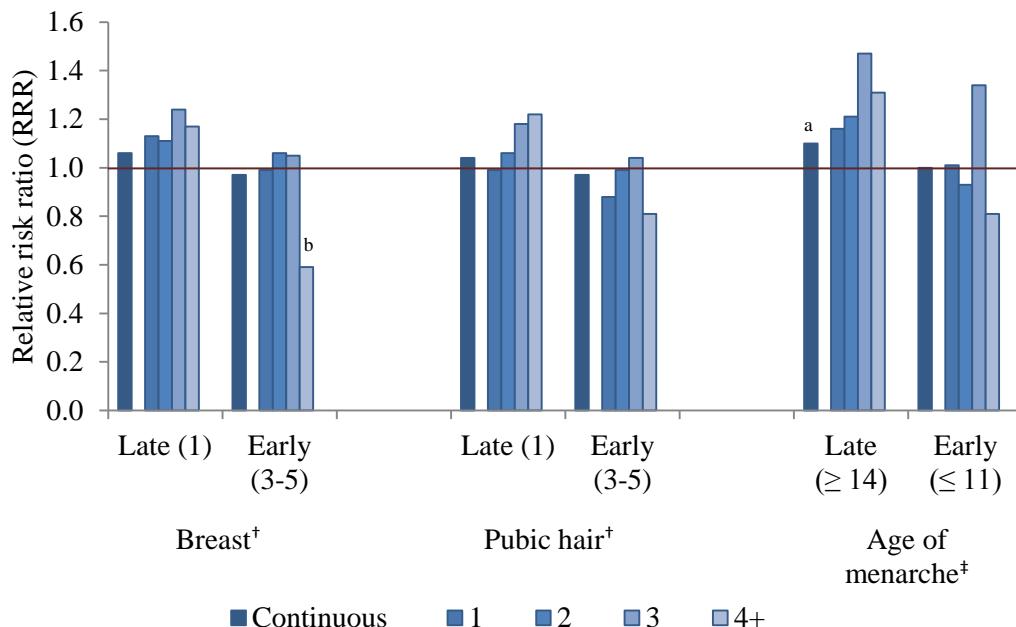
¹All values are relative risk ratio (RRR); 95% CI in parenthesis, [†]stage 2' and [‡]age 12-13y used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity, social class at birth, household crowding and maternal age of menarche; no. of observations 2,576-5198; [‡]sum of seven indicators excluding neglected appearance (range 0-7). no. of observations 3,227- 4,812; ^ap<0.05; ^bp<0.01; ^cp<0.001; italic indicates p<0.05 for linear trend (Appendix 5.2)

Figure 6.2: Adjusted estimated effects (RRR) of continuous and categorical neglect score (reported at age 7y; range 0-7) on markers of pubertal development (reference category ‘intermediate’ development, or onset of voice change age 12-14y); males¹



¹All values are relative risk ratio (RRR); 95% CI in parenthesis, [†]‘stage 2’, [‡]‘normal’, [‡]‘sparse’ and [‡]age 12-14y used as reference categories. Models adjusted for age pubertal measure was recorded, ethnicity, social class at birth and household crowding; Sum of seven indicators excluding neglected appearance (range 0-7), no. of observations 4,465-5,271; ^ap<0.05; ^bp<0.01; ^cp<0.001.

Figure 6.3: Adjusted estimated effects (RRR) of continuous and categorical neglect score (reported at age 7y; range 0-7) on markers of pubertal development (reference category ‘intermediate’ development, or age of menarche 12-13y); females



¹All values are relative risk ratio (RRR); 95% CI in parenthesis, [†]‘stage 2’ and [‡]age 12-13y used as reference categories. Models adjusted for age pubertal measure was recorded, ethnicity, social class at birth, household crowding and maternal age of menarche; sum of seven indicators excluding neglected appearance (range 0-7). no. of observations 3,227- 4,812; ^ap<0.05; ^bp<0.01; ^cp<0.001.

Maltreatment patterns

The association between maltreatment groups and markers of pubertal development are shown in Tables 6.10 and 6.11. There was no relationship between the abuse and neglect group and puberty. A high risk of neglect ‘only’ was related to an increased risk of later facial hair growth in boys and a reduced risk of earlier growth compared to those not maltreated. The strength of association weakened after adjustment for confounding factors, although neglect ‘only’ remained associated with early facial hair growth (RRR=0.40; 0.17, 0.95). A significant trend was also found between neglect ‘only’ and facial hair growth (-0.17; -0.26, -0.08). Neglect ‘only’ was not associated with other measures of pubertal development.

Table 6.9: Estimated effects (RRR) of maltreatment groups (identified by Latent Class Analysis: low risk, neglect ‘only’, abuse and neglect) on markers of pubertal development (reference category ‘intermediate’ development, or onset of voice change age 12-14y); males¹

Maltreatment groups [#]	Testicular [†] ; 11y		Pubic hair [‡] ; 11 & 16y		Facial hair [‡] ; 16y		Voice change [#]	
	Late (1)	Early (3-5)	Late	Early	Late (absent)	Early (adult)	Late (≥ 15)	Early(≤ 12)
Neglect ‘only’	Unadjusted	1.15 (0.85, 1.57)	0.96 (0.63, 1.46)	1.04 (0.76, 1.42)	0.80 (0.52, 1.24)	<i>1.46^a</i> (1.07, 1.98)	<i>0.41^a</i> (0.18, 0.96)	1.26 (0.93, 1.71)
	Adjusted	1.06 (0.77, 1.46)	0.98 (0.64, 1.50)	1.02 (0.74, 1.40)	0.87 (0.56, 1.35)	<i>1.38^a</i> (1.00, 1.90)	<i>0.40^a</i> (0.17, 0.95)	1.25 (0.91, 1.72)
Abuse & neglect	Unadjusted	0.95 (0.65, 1.37)	1.14 (0.72, 1.81)	1.01 (0.70, 1.46)	0.97 (0.52, 1.57)	1.03 (0.70, 1.52)	1.04 (0.53, 2.01)	1.01 (0.69, 1.47)
	Adjusted	0.90 (0.62, 1.31)	1.14 (0.71, 1.82)	0.97 (0.67, 1.40)	0.99 (0.60, 1.61)	0.98 (0.66, 1.49)	0.96 (0.49, 1.88)	1.01 (0.69, 1.48)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis; [#]latent class model includes all fifteen child maltreatment measures collected at ages 7y and 45y, ‘non-maltreated’ used as reference category, [†]‘stage 2’, [‡]‘normal’, ^a‘sparse’ and [#]age 12-14y used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity, social class at birth and household crowding; no. of observations 1,920-2,167; ^ap<0.05; ^bp<0.01; ^cp<0.001; *italic* indicates p<0.05 for linear trend (Appendix 5.1)

Table 6.10: Estimated effects (RRR) of maltreatment groups (identified by Latent Class Analysis: low risk, neglect ‘only’, abuse and neglect) on markers of pubertal development (reference category ‘intermediate’ development, or age of menarche 12-13y); females¹

Maltreatment groups [#]	Breast [†] ; 11y		Pubic hair [‡] ; 11y		Age of menarche [‡]	
	Late (1)	Early (3-5)	Late (1)	Early (3-5)	Late (≥ 14)	Early (≤ 11)
Neglect ‘only’	Unadjusted	0.95 (0.69, 1.30)	0.80 (0.56, 1.14)	1.18 (0.86, 1.62)	1.13 (0.78, 1.64)	1.43 (0.97, 2.11)
	Adjusted	0.88 (0.63, 1.22)	0.85 (0.59, 1.22)	1.03 (0.75, 1.43)	1.18 (0.80, 1.74)	1.27 (0.84, 1.90)
Abuse & neglect	Unadjusted	0.98 (0.70, 1.36)	1.12 (0.79, 1.58)	1.24 (0.90, 1.71)	1.18 (0.81, 1.73)	1.23 (0.85, 1.80)
	Adjusted	0.93 (0.63, 1.30)	1.17 (0.82, 1.67)	1.16 (0.84, 1.61)	1.22 (0.83, 1.79)	1.16 (0.79, 1.70)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis; [#]latent class model includes all fifteen child maltreatment measures collected at ages 7y and 45y, ‘non-maltreated’ used as reference category; [†]‘stage 2’ and [‡]age 12-13y used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity, social class at birth, household crowding and age of maternal menarche; no. of observations 1,611 – 2,253; ^ap<0.05; ^bp<0.01; ^cp<0.001; *italic* indicates p<0.05 for linear trend (Appendix 5.2)

6.4.3 *Household dysfunction and pubertal development*

A few measures of household dysfunction were associated with late pubertal development, as shown in Tables 6.12 (for boys) and 6.13 (for girls) and Appendix 5.17 (testicular development and pubic hair for boys and age of menarche for girls). For boys, parental divorce was significantly associated with late pubic hair growth; family alcoholism, contact with children's department/charity and time in care was associated with late facial hair growth; and domestic tension was linked to late onset of voice change. For girls, family contact with a probation officer or children's department/charity and time in care by age 7y were related to late breast development and/or pubic hair growth at age 11y. Family alcoholism, mental health problem and contact with a probation officer were also associated with a lower mean Tanner score for pubic hair growth at age 11y in girls (Appendix 5.2). Measures of household dysfunction were not associated with testicular development at age 11y in boys, and age of menarche in girls (Appendix 5.17).

Associations diminished after adjustment for confounding factors (Appendix 5.1 and 5.2), although some relationships persisted. For boys, an increase in the likelihood of absent facial hair growth at age 16y was associated with family alcoholism (RRR=3.17; 1.55, 6.49), contact with a children's department/charity (RRR=1.49; 1.10, 2.01) and time in care (RRR=1.55; 1.02, 2.35). A significant trend was also found between these measures and facial hair growth (Appendix 5.1). Girls whose family had been in contact with a children's department/charity or had spent time in care by age 7y were more likely to have a lower mean Tanner score for breast development (-0.21; -0.36, -0.06 and -0.30; -0.51, -0.08, respectively) and pubic hair growth at age 11y (-0.18; -0.33, -0.04 and -0.31; -0.53, -0.10, respectively) than those who had not (Appendix 5.2).

Accumulation of household dysfunction measures was associated with late facial hair growth at age 16y and voice change in boys. After adjustment for confounding factors the relationship between household dysfunction score and late voice change attenuated and was no longer significant. However, an association with facial hair growth persisted, such that for each additional measure of household dysfunction the risk of later facial hair growth increased by 13% (1.02, 1.25). Increments in household dysfunction score were not associated with pubertal development in girls.

Table 6.11: Estimated effects (RRR) of household dysfunction (reported at age 7y) on markers of pubertal development (reference category ‘intermediate’ development, or onset of voice change age 12-14y); males¹

Household dysfunction; 7y	Facial hair [‡] ; 16y		Voice change [‡]		
	Late (absent)	Early (adult)	Late (≥ 15)	Early (≤ 12)	
Domestic tension	Unadjusted	1.12 (0.84, 1.48)	0.78 (0.45, 1.35)	<i>1.50^b (1.16, 1.96)</i>	<i>1.18 (0.76, 1.84)</i>
	Adjusted	1.10 (0.83, 1.46)	0.79 (0.46, 1.37)	<i>1.48^b (1.13, 1.93)</i>	<i>1.13 (0.73, 1.77)</i>
Alcoholism	Unadjusted	<i>3.34^c (1.64, 6.80)</i>	<i>0.55 (0.07, 4.30)</i>	1.46 (0.75, 2.82)	1.46 (0.53, 4.04)
	Adjusted	<i>3.17^b (1.55, 6.49)</i>	<i>0.54 (0.07, 4.18)</i>	1.41 (0.73, 2.74)	1.38 (0.50, 3.82)
Mental health problems	Unadjusted	0.87 (0.65, 1.16)	0.43 ^a (0.22, 0.85)	1.26 (0.95, 1.66)	1.29 (0.83, 1.99)
	Adjusted	0.85 (0.63, 1.14)	0.43 ^a (0.22, 0.86)	1.23 (0.93, 1.63)	1.23 (0.79, 1.91)
Contact probation officer	Unadjusted	1.08 (0.65, 1.81)	1.31 (0.58, 2.99)	0.95 (0.60, 1.51)	1.17 (0.58, 2.37)
	Adjusted	1.04 (0.62, 1.73)	1.32 (0.58, 3.00)	0.93 (0.58, 1.49)	1.07 (0.53, 2.18)
Contact children’s department	Unadjusted	<i>1.55^b (1.15, 2.09)</i>	<i>0.97 (0.55, 1.73)</i>	1.14 (0.85, 1.52)	<i>1.56^a (1.03, 2.37)</i>
	Adjusted	<i>1.49^b (1.10, 2.01)</i>	<i>0.96 (0.53, 1.71)</i>	1.11 (0.83, 1.49)	1.44 (0.95, 2.20)
In care	Unadjusted	<i>1.61^a (1.06, 2.45)</i>	<i>0.43 (0.13, 1.38)</i>	1.11 (0.75, 1.66)	1.06 (0.54, 2.05)
	Adjusted	<i>1.55^a (1.02, 2.35)</i>	<i>0.42 (0.13, 1.35)</i>	1.10 (0.73, 1.65)	0.97 (0.50, 1.90)
Parental divorce	Unadjusted	1.28 (0.92, 1.74)	0.83 (0.44, 1.57)	1.10 (0.81, 1.48)	1.20 (0.75, 1.93)
	Adjusted	1.26 (0.92, 1.73)	0.84 (0.45, 1.60)	1.12 (0.82, 1.52)	1.18 (0.73, 1.89)
Continuous household dysfunction score ^Δ	Unadjusted	1.13 ^a (1.02, 1.25)	0.86 (0.69, 1.07)	1.10 ^a (1.00, 1.21)	1.11 (0.96, 1.29)
	Adjusted	1.12 ^a (1.01, 1.24)	0.85 (0.68, 1.07)	1.10 (0.99, 1.21)	1.08 (0.93, 1.25)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis, [‡]‘sparse’ and [#]age 12-14y used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity, social class at birth and household crowding; no. of observations 4,305-5,870; ^Δsum of all seven household dysfunction measures at age 7y, no. of observations 4,218-5,037; categorical household dysfunction score (range 0-7). ; ^ap<0.05; ^bp<0.01; ^cp<0.001; italic indicates p<0.05 for linear trend (Appendix 5.7)

Table 6.12: Estimated effects (RRR) of household dysfunction (reported at age 7y) on markers of pubertal development (reference category ‘intermediate’ development); females¹

Household dysfunction measures; 7y		Breast [†] ; 11y		Pubic hair [†] ; 11y	
		Late (1)	Early (3-5)	Late (1)	Early (3-5)
Domestic tension	Unadjusted	1.04 (0.77, 1.42)	1.05 (0.55, 2.01)	1.24 (0.92, 1.67)	1.07 (0.74, 1.54)
	Adjusted	1.04 (0.76, 1.42)	1.00 (0.71, 1.40)	1.21 (0.90, 1.64)	1.05 (0.72, 1.51)
Alcoholism	Unadjusted	1.00 (0.72, 1.39)	0.63 (0.28, 1.41)	<i>1.65 (0.86, 3.16)</i>	<i>0.69 (0.26, 1.81)</i>
	Adjusted	0.95 (0.50, 1.84)	0.69 (0.31, 1.57)	1.52 (0.79, 2.94)	0.73 (0.28, 1.94)
Mental health problems	Unadjusted	1.18 (0.86, 1.61)	0.98 (0.69, 1.38)	<i>1.24 (0.92, 1.67)</i>	<i>0.85 (0.57, 1.24)</i>
	Adjusted	1.14 (0.83, 1.56)	1.01 (0.71, 1.43)	1.20 (0.89, 1.62)	0.86 (0.58, 1.27)
Contact probation officer	Unadjusted	1.70 ^a (1.03, 2.8)	1.17 (0.66, 2.08)	<i>1.28 (0.81, 2.03)</i>	<i>0.67 (0.35, 1.28)</i>
	Adjusted	1.62 (0.97, 2.68)	1.24 (0.70, 2.22)	1.20 (0.75, 1.91)	0.70 (0.36, 1.35)
Contact children’s department	Unadjusted	<i>1.67^b (1.15, 2.41)</i>	<i>0.89 (0.57, 1.41)</i>	<i>1.26 (0.89, 1.79)</i>	<i>0.68 (0.42, 1.11)</i>
	Adjusted	<i>1.63^b (1.12, 2.38)</i>	<i>0.96 (0.61, 1.52)</i>	<i>1.17 (0.82, 1.67)</i>	<i>0.71 (0.43, 1.16)</i>
In care	Unadjusted	<i>1.61 (0.95, 2.71)</i>	<i>0.68 (0.34, 1.37)</i>	<i>1.18 (0.73, 1.92)</i>	<i>0.23^c (0.08, 0.65)</i>
	Adjusted	<i>1.56 (0.92, 2.66)</i>	<i>0.74 (0.36, 1.50)</i>	<i>1.09 (0.67, 1.78)</i>	<i>0.24^c (0.08, 0.68)</i>
Parents divorced	Unadjusted	1.15 (0.79, 1.67)	1.30 (0.88, 1.92)	1.23 (0.86, 1.76)	1.26 (0.83, 1.92)
	Adjusted	1.15 (0.79, 1.68)	1.31 (0.88, 1.95)	1.23 (0.85, 1.76)	1.26 (0.82, 1.93)
Continuous household dysfunction score ^A	Unadjusted	1.09 (0.98, 1.22)	0.95 (0.84, 1.09)	1.08 (0.97, 1.20)	0.87 (0.75, 1.01)
	Adjusted	1.07 (0.95, 1.19)	0.98 (0.86, 1.11)	1.05 (0.95, 1.17)	0.88 (0.76, 1.02)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis, ‘stage 2’ used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity social class at birth, household crowding and maternal age of menarche; no. of observations 3,125 – 5,329; ^Asum of all seven household dysfunction measures at age 7y, no. of observations 3,063-4,556; categorical household dysfunction score (range 0-7); ^ap<0.05; ^bp<0.01; ^cp<0.001; *italic* indicates p<0.05 for linear trend (Appendix 5.8)

6.4.4 Cumulative adversity (child neglect and household dysfunction) and pubertal development

There was a cumulative effect of neglect and household dysfunction at age 7y (adversity score) on all pubertal measures (except testicular development at age 11y for boys), such that for an increment in adversity score, the risk of late puberty, on average, increased (Tables 6.14 and 6.15). The effect of adversity score diminished slightly after adjustment for confounding factors, but most effects remained. In the adjusted models, for boys, for each additional adversity measure, the likelihood of late pubic hair growth increased by 6% (1.00, 1.12), facial hair growth by 6% (1.00, 1.12) and voice change at age ≥ 15 y by 9% (1.03, 1.15). For girls, an increment in adversity score was associated with a 7% (1.01, 1.14) increased risk of late breast development. A significant trend was also found between adversity score and some pubertal characteristics (Appendices 5.9 and 5.10). An increment in adversity was related to a lower mean facial hair rating (-0.02; -0.04, -0.01) and older average age of voice change (0.04y; 0.01, 0.06) for boys and a lower mean Tanner score for breast development (-0.03; -0.06, -0.01) and pubic hair growth at age 11y (-0.03; -0.06, -0.01) for girls (Appendices 5.1 and 5.2).

Table 6.13: Estimated effects (RRR) of cumulative adversity (household dysfunction and neglect reported at age 7y) on markers of pubertal development (reference category ‘intermediate’ development, or onset of voice change age 12-14y); males¹

Adversity score (range 0-14) [†]	Testicular [†] ; 11y		Pubic hair [‡] ; 11 & 16y		Facial hair [‡] ; 16y		Voice change [‡]	
	Late (1)	Early (3-5)	Late	Early	Late (absent)	Early (adult)	Late (≥ 15)	Early (≤ 12)
Unadjusted	1.04 (0.99, 1.09)	1.01 (0.95, 1.07)	1.07 ^a (1.02, 1.12)	0.98 (0.91, 1.04)	1.06 (1.01, 1.11)	0.91 (0.83, 1.01)	1.10 ^b (1.05, 1.15)	1.07 (0.99, 1.15)
Adjusted	1.02 (0.97, 1.07)	1.02 (0.96, 1.09)	1.06 ^a (1.00, 1.11)	1.01 (0.94, 1.08)	1.05 (1.00, 1.10)	0.91 (0.82, 1.00)	1.10 ^b (1.05, 1.16)	1.05 (0.97, 1.13)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis, [†]‘stage 2’, [‡]‘normal’, ^a‘sparse’ and ^bage 12-14y used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity social class at birth and household crowding; [†]sum of seven indicators of neglect (excluding neglected appearance) and seven household dysfunction measures at age 7y. no. of observations 3,940-4,691; ^ap<0.05; ^bp<0.01; ^cp<0.001; *italic* indicates p<0.05 for linear trend (Appendix 5.9)

Table 6.14: Estimated effects (RRR) of cumulative adversity (household dysfunction and neglect reported at age 7y) on markers of pubertal development (reference category ‘intermediate’ development, or age of menarche 12-13y); females¹

Adversity score (range 0-14) [†]	Breast [†] ; 11y		Pubic hair [†] ; 11y		Age of menarche [‡]	
	Late (1)	Early (3-5)	Late (1)	Early (3-5)	Late (≥ 14)	Early (≤ 11)
Unadjusted	1.05 (1.00, 1.11)	0.93 ^a (0.88, 0.99)	1.06 ^a (1.01, 1.11)	0.94 (0.88, 1.00)	1.10 ^a (1.03, 1.17)	1.00 (0.92, 1.09)
Adjusted	1.04 (0.98, 0.95)	0.95 (0.89, 1.01)	1.04 (0.98, 1.09)	0.95 (0.89, 1.02)	1.06 (0.99, 1.14)	0.99 (0.91, 1.08)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis, [†]‘stage 2’ and [‡]age 12-13y used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity, social class at birth, household crowding and maternal age of menarche; [†]sum of seven indicators of neglect and seven household dysfunction measures at age 7y. no. of observations 2,867-4,257; ^ap<0.05; ^bp<0.01; ^cp<0.001; *italic* indicates p<0.05 for linear trend (Appendix 5.10)

6.4.5 Additional analyses

Details of the association between adverse childhood experiences and markers of pubertal development using data from the multiple imputation models are presented in Appendices 5.12 (for boys) and 5.13 (for girls). Similar patterns of association were found in the imputed and complete data analyses. However, for some measures of maltreatment the strength of association was greater in the imputed data, than complete data. In contrast, the effect estimate of sexual abuse on early testicular development in boys was reduced in the imputed, compared to complete data models.

There was little difference in the strength of association between physical abuse, 'I was neglected' or unaffectionate mother reported at age 45y, and markers of pubertal development in the imputed and complete data analyses. In both data sets, no significant relationship was found between child abuse and neglect and testicular development in boys and age of menarche in girls. The relationship between sexual abuse and late age of menarche in girls also varied little. In both datasets, sexually abused girls had a \approx two-fold increased risk of menarche at age ≤ 11 y, compared to those who were not, after adjustment for confounding factors.

In addition, the association between neglect and household dysfunction scores and puberty was comparable in both data sets. In the imputed and complete data models, neglect score was associated with late pubertal development. For boys, the relationship weakened and was no longer significant after controlling for confounding factors. In contrast, the association between neglect score and late age of menarche persisted after adjustment in both data sets. Household dysfunction score was not associated with testicular development or age of menarche in either dataset.

For some measures, the strength of association between adverse childhood experiences and pubertal development was greater in the imputed compared to the complete data models. For boys, a significant relationship between witnessing abuse and unaffectionate father, and early testicular was found in the imputed data, whereas no effect was shown in the complete data models. In the imputed data, associations weakened after adjustment for confounding factors and were no longer significant. For girls, psychological and sexual abuse, witnessing abuse and unaffectionate father had a

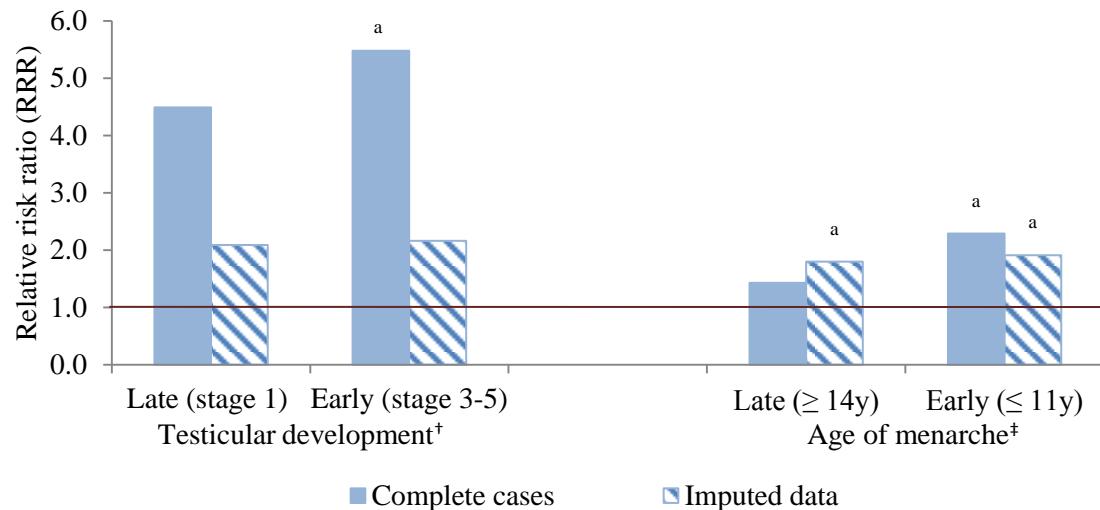
stronger relationship with late age of menarche in the imputed data, compared to the complete data analyses (Figure 6.4). In the imputed data, the association between psychological and sexual abuse and puberty remained significant after controlling for confounding factors. Psychologically and sexually abused girls were more likely to have menarche at age ≥ 14 y (RRR=1.40; 1.06, 1.84 and RRR=167; 1.03, 2.72, respectively), than those not abused (Appendix 5.23). The relationship between witnessed abuse and unaffectionate father and age of menarche attenuated, and were no longer significant after accounting for confounding factors in the imputed data set.

In the complete data analyses there was some indication that the maltreatment group neglect ‘only’ may be associated with late age of menarche, though the association was non-significant (Table 6.15). In comparison, in the imputed data, significant effects were found between maltreatment groups and pubertal development in girls, with associations persisting after adjustment for confounding factors. In adjusted models in the imputed data, participants categorised as neglected ‘only’ or abused and neglected were more likely to experience menarche at age ≥ 14 y (RRR=1.47; 1.17, 1.83 and RRR=1.33; 1.00, 1.78, respectively), compared to those with a low risk of maltreatment (Appendix 5.13).

Unlike in the complete data analyses, adversity score was also associated with late testicular development in the imputed models. The association attenuated and was no longer significant once accounting for confounding factors (Appendix 5.12). For girls, adversity score were related to late age of menarche in both data sets. In contrast to the complete data, the association persisted after adjustment in the imputed models, such that an increase in adversity score (range 0-14) was associated with 9% (1.04, 1.14) increased risk in late puberty (Appendix 5.13).

The strength of association between sexual abuse and early and late testicular development was weaker in the imputed compared to the complete data analyses, as shown in Figure 6.4. In the complete models, sexual abuse was independently associated with a five-fold increased risk of early testicular development, after controlling for confounding factors. Although sexually abused boys had an increased risk of early testicular development (RRR=1.98; 0.58, 6.79) after adjustment in the imputed data set, the relationship did not reach statistical significance (Appendix 5.22).

Figure 6.4: Estimated effects (RRR) of sexual abuse on testicular development at age 11y for boys (reference category ‘intermediate’ development) and age of menarche for girls (reference category age12-13y) in complete and imputed data¹



¹All values are relative risk ratio (RRR); 95% CI in parenthesis, [†]‘stage 2’ and [‡]age 12-13y used as reference categories. Models adjusted for age pubertal measure was recorded. no. of observations 6,330 for boys and 4,646 for girls; ^ap<0.05.

6.5 Discussion

This study found that associations between adverse childhood experiences and pubertal development weakened after adjustment for demographic and socio-economic factors, although some effects persisted. Childhood indicators of neglect remained related to late pubertal development in both boys and girls; the strength of association ranging from RRR=1.19 to 1.94. There was a cumulative effect of neglect on maturation, but results were more suggestive of a threshold effect. A neglect score of ≥ 4 for boys was related to an increased risk of late pubic hair (RRR=1.67) and facial hair growth (RRR=1.72) and onset of voice change (RRR=1.44). For girls, a score of ≥ 3 was associated with a greater risk of late breast development (RRR=1.52) compared to a low neglect score. The relationship between a few household dysfunction measures, such as family alcoholism, contact with children's department/charity and time in care, and late development (i.e. late facial hair growth in boys, and a low Tanner score for breast and pubic hair development in girls) persisted, although a cumulative effect was not found. An increment in adversity score was related to a 6% increased chance of late pubic and facial hair growth and a 9% greater risk of onset of voice change at ≥ 15 y for boys, whereas girls had a 7% increased risk of late breast development. For sexual abuse, an increased risk of early age of menarche for girls and advanced testicular development at age 11y for boys (borderline significant) also remained. Psychological and physical abuse, witnessing abuse of a family member and maltreatment groups were not related to the onset of puberty.

6.5.1 *Methodological considerations*

This study overcomes several limitations of research to date, such as the use of single measures of child abuse^{335;353;354} or household dysfunction^{160-162;527} and retrospective data collection of pubertal development measures^{147;353;354;516}. Most previous studies have been restricted to female participants, and there has been little investigation into the effects of adverse childhood experiences on pubertal development in males. In contrast, the 1958 cohort is a large longitudinal study, which has data on a wide range of childhood experiences, including child maltreatment and household dysfunction. A further strength of the study is the multiple markers of pubertal development collected for both genders, prospectively at multiple ages. Therefore, it is less likely that these measures are affected by recall bias, compared with retrospective measures of puberty.

Established methods were used to collect puberty data, such as medical examinations using the Tanner criteria which is considered the ‘gold standard’³⁶⁷. However, as measures were collected at fixed ages, the onset of puberty could not be established. In addition, age of menarche was recorded in years in the 1958 cohort, thus measurement error may affect the results. Categorical measures were adopted in the analyses to reduce the impact of measurement error in the study.

The retrospective nature of child abuse measures prevents the temporal relationship between abuse onset and pubertal development to be determined. It is not known if participants were pre-pubertal when maltreatment occurred. Reverse causation (i.e. menarche preceding abuse) would be a concern if children who matured faster were more likely to be victims of child maltreatment⁵²⁹. There is limited evidence for this hypothesis, although this is due to scant data investigating such a relationship.

However, there is some suggestion that sexual abuse tends to occur prior to the onset of puberty¹⁴⁰. An American study examining reverse causation in a health care sample of sexually abused women, found that the majority of sexual abuse in childhood occurred prior to the onset of puberty³⁵⁴. Thus, the available evidence supports the hypothesis that the direction of the association is from sexual abuse to pubertal development.

As discussed in Chapter 2, the 1958 cohort has been affected by missing data. Multiple imputation was used to determine whether attrition, and to a lesser extent missing covariate observations, influenced the relationship between adverse childhood experiences and pubertal development. A comparison of complete and imputed data found that missing data may have influenced the association between retrospective maltreatment measures and testicular development (for boys) and age of menarche (for girls). In the imputed data, although there was an indication that sexual abuse was associated with early testicular development, the strength of association was weaker than that in the complete cases analyses and did not reach statistical significance. In contrast, sexual abuse was independently related to an increased risk of both early and late age of menarche in girls, after adjustment for confounding factors. Stronger effects were also shown between witnessed abuse and early testicular development and late age of menarche, and psychological abuse and late age of menarche. In addition, maltreatment groups, neglect ‘only’ and abuse and neglect, were related to menarche at age ≥ 14 y in the imputed data. There was little difference in the association between

scores derived from prospective measures (neglect, household dysfunction and adversity) and markers of pubertal development in the complete and imputed data. It is unclear why the relationship between sexual abuse and early testicular development weakened in the imputed data set compared to the complete data models, whilst other relationships strengthened. The disparity in results relating to retrospective maltreatment measures indicate that missing data may not have been MAR. It is possible that selection bias may have influenced findings, as those maltreated may have been less likely to participate in the 45y survey. Thus, the relationship between sexual abuse and testicular development may have been over-estimated, whilst the association between other forms of child abuse and markers of puberty were underestimated in the complete analyses. Results from the complete data models are presented in this chapter, as in general, they are likely to be conservative estimates of the true association.

6.5.2 Comparison with previous work

Consistent with previous studies, sexual abuse was associated with early pubertal development in girls^{147;238}. In the 1958 cohort, sexually abused girls were more likely to experience menarche at age ≤ 11 y. Sexual abuse was also associated with an increased risk of advanced testicular development at age 11y in boys, although numbers were small. There was some indication that sexual abuse may be associated with other markers of puberty, such as pubic hair growth (for boys and girls), although relationships were not significant. It is possible that the timing of data collection may have influenced the relationship between sexual abuse and other measures of pubertal development. For example, age 11y may have been too late, or early, to detect variations in pubertal development. Alternatively, sexual abuse may have a unique impact on different stages of pubertal development. In the ‘Children in the Community’ study, sexual abuse was associated with age of menarche in girls, but not breast development, as in the 1958 cohort. However, unlike results from the 1958 cohort, sexually abused boys were more likely to develop facial hair and voice change earlier than others; testicular development was not examined²³⁸. Results may have differed in the 1958 cohort because of the small number of cases of sexual abuse, as well as variations in data collection methods (i.e. facial hair growth rating at age 16y vs. age experience first growth of beard).

Other forms of abuse were not associated with pubertal development. In the established literature there is limited evidence of a relationship between psychological and physical abuse and witnessing intimate-partner violence and pubertal development, especially after accounting for sexual abuse^{146;516}.

Indicators of neglect at age 7y were shown to be associated with late pubertal development, suggesting that neglectful experiences may delay maturation. A cumulative effect was shown between neglect score (at age 7y) and pubertal development, although there was stronger evidence of a threshold effect. Participants with a high neglect score (≥ 4 for boys and ≥ 3 for girls), thus more severe neglect, were more likely to have delayed pubertal development. Established literature on childhood sexual abuse suggests that females who experience more severe abuse, characterised by greater frequency, and penetrative vs. non penetrative experiences, are more likely to experience earlier menarche than victims of less severe abuse^{147;238;354;516}. Few studies have directly examined the impact of neglect on pubertal development, and those that have, have shown a weak association between neglect and the onset of puberty^{146;238}. However, this may be a consequence of different case-ascertainment methods, with previous studies identifying victims of child maltreatment using agency reports. Therefore, it is likely they will have experienced other forms of maltreatment, as neglect is often the secondary form of maltreatment noted, and therefore not the reason why the child came to the attention of child-protection services³⁴. In contrast, it is likely that neglected 1958 cohort members did not experience another form of maltreatment.

In contrast, neglect ‘only’ (ascertained from the LCA model in Chapter 5) was not associated with markers of pubertal development, although cohort members assigned to this maltreatment group reported, on average, ≈ 4 indicators of neglect at age 7y. However, fewer than 50% of participants categorised as having a high risk of neglect had a high neglect score (≥ 4 for boys and ≥ 3 for girls). Thus, the strength of association between neglect ‘only’ and pubertal development is weaker than that of a high neglect score.

A few measures of household dysfunction remained associated with later pubertal development after adjustment for potential confounding factors. In particular, household dysfunction influenced facial hair growth in boys and breast development

and pubic hair growth at age 11y in girls. This is in contrast with much of the established literature, which has found that household dysfunction, and in particular family structure, is linked to early pubertal development. The difference in findings may reflect methodological variations; previous studies tended to be small cohorts, cross-sectional and adopt retrospective data collection methods.

Results from the 1958 cohort suggest that different adverse childhood experiences were associated with distinct patterns of pubertal development; sexual abuse accelerating maturation whilst neglect and household dysfunction delays development. In addition, each adverse childhood experience was associated with different markers of puberty. For boys, sexual abuse was related to puberty measures at age 11y, whereas prospective indicators of neglect and household dysfunction were associated with puberty markers reported at age 16y. For girls, sexual abuse influenced age of menarche, whilst neglect and household dysfunction measures at age 7y were related to all three markers of pubertal development. Markers of pubertal development may measure different stages of pubertal development. Indeed, although puberty characteristics were significantly correlated, the strength of the correlation varied between measures (Appendices 5.18 (for males) and 5.19 (for females)). For example, testicular development at age 11y was more strongly correlated with pubic hair growth at age 11y ($r=0.48$) than voice change ($r=-0.10$) in boys, whereas breast development at age 11y was more strongly correlated with pubic hair growth at age 11y ($r=0.71$) compared with age of menarche ($r=-0.49$). Therefore, it is possible that sexual abuse, and neglect and household dysfunction, may influence different markers of puberty as they are more strongly associated with different stages of pubertal development.

It is also possible that neglect and household dysfunction may be more strongly associated with socio-economic disadvantage. Previous studies have linked material and environmental deprivation with delayed pubertal development^{151;503}. However, both retrospective and prospective neglect measures were associated with late puberty, and effects remained after adjustment for social class at birth and household crowding at age 7y. Thus, indicating that adverse childhood experiences may independently be associated with late pubertal development. In addition, neglect was more consistently related to markers of puberty compared to household dysfunction, suggesting that the parent-child relationship may be more important than household level factors.

The strength of association was greater between sexual abuse and early pubertal development compared with childhood neglect and household dysfunction measures and late maturation. These results were found despite a greater prevalence of neglect and household dysfunction measures, thus an increase in the study's power to detect differences between groups compared with sexual abuse. Therefore, the influence of sexual abuse on early pubertal development may be greater than the effect of neglect on later pubertal development. This finding is consistent with previous evidence, which suggests that sexual abuse has a particularly powerful effect on puberty, over and above that of other forms of child maltreatment and household dysfunction^{146;354}.

6.5.3 *Biological pathways*

Biological mechanisms through which child maltreatment may affect pubertal timing are not well understood, although there are possible theories which explain the association between neglect and late development and sexual abuse and early maturation.

Trickett and Putnam were the first to propose that physiological mechanisms associated with behavioural and psychiatric problems in sexually abused girls may be the cause of changes to the timing of pubertal development observed in this population^{530;531}. More recently, it has been hypothesised that sexual abuse may operate as a stressor that accelerates menarche by impacting on the HPA function and/or HPG function and/or other developmental processes. Stress-related hormones have been found to be higher in sexually abused girls, and there is evidence of deregulation of the HPA axis, with abused girls having significantly higher cortisol levels when exposed to minor stressors compared to those not abused⁵³². Activation of the HPA axis has been shown to suppress the release of gonadal hormones by the HPG axis, potentially altering physiological developments associated with puberty¹⁴⁰.

In contrast, the stress suppression psychosocial model of pubertal development hypothesises that adverse physical or social condition delay pubertal development and reproduction until predictably better times. Neurophysiological research provides a clearly articulated mechanism to support this theory, showing that when activation of the stress-response system is of sufficient duration and magnitude the functioning of the

HPG axis can be suppressed at several levels, including decreased GnRH pulsatility, disrupted GnRH surge secretion, reduction in pituitary responsiveness to GnRH, and alteration of stimulatory effects of gonadotropins on sex steroid production^{491;533}. However, there is little evidence of these effects in population studies. There is some indication that psychosocial stress, characterised by depressive symptoms and dysfunctional attitudes, induces reproductive dysfunction, including amenorrhea^{534;535}. Furthermore, psychosocial dwarfism has been shown to delay puberty development in adolescents who experience extreme psychosocial stress^{536;537}. Yet, no study has examined the stress response to adverse experiences in a population sample of pre-pubertal participants.

6.5.4 Conclusion

In conclusion, although the relationship between adverse childhood experiences and pubertal development diminished after adjustment, neglect and sexual abuse remained associated with markers of maturation. The finding that individual forms of maltreatment may influence tempo of pubertal development differently highlights the importance of separating each form of adverse childhood experience in research. This study provides important insight into the association between child maltreatment, household dysfunction and pubertal development, which may influence later health outcomes.

7 Discussion

There is growing evidence that adverse childhood experiences (child maltreatment and household dysfunction) are associated with an increased risk of adult disease^{184;185;538}.

Life-course study is an important approach to investigate how maltreatment (abuse and neglect) or household dysfunction in early life influence adverse outcomes in later life^{6;539}. A number of major developmental pathways have been recognised through which early life exposures may influence the risk of adverse health outcomes in adulthood, including physical, social, behavioural and cognitive development (Figure 1.1). In this thesis I have focused on physical development, an important pathway through which maltreatment and household dysfunction in childhood may potentially influence later health.

Shorter adult stature has been associated with an increased risk of adult mortality^{216;217} and cardiovascular morbidity^{194-196;218}. Adult height does not change once achieved, although shrinkage occurs from mid-adulthood⁵⁴⁰. Thus height is well accepted as a proxy measure for early life experiences. In addition, the timing of pubertal development has been associated with adult disease risks. Early pubertal onset has been related to an increased risk of total mortality,²³⁹ breast cancer in women²⁴⁰⁻²⁴³ and testicular cancer in men²⁴⁴⁻²⁴⁶, and an increased prevalence of cardiovascular disease risk factors, including adverse lipid levels^{194;221;222;541}, high blood pressure and insulin sensitivity in childhood and adulthood^{197-199;247}. There is some indication that late maturation may also be associated with higher disease risk in adulthood and mortality²⁴⁸. Examining whether early life exposures are associated with physical development, particularly child-to-adult height trajectories and pubertal development, will provide a better understanding of their long term effects on adult health.

There has been limited investigation of the association between adverse childhood experiences and physical development in population samples due to the methodological challenges associated with researching child maltreatment and household dysfunction. Few studies have information on a wide range of adverse childhood experiences and those that do often use summary measures of child abuse, neglect or household dysfunction. Little is known about the effect of different forms of child maltreatment

on physical development outcomes. There is sparse literature on the relationship between adverse childhood experiences and full growth trajectories for height, or pubertal maturation in boys. Instead, evidence has often been restricted to height at one age, or pubertal development in females. Furthermore, available data are frequently limited to specialised samples, such as children who are in foster care or hospitalised^{143;144}.

To my knowledge, this is the first study of a population sample in the UK to investigate the prevalence and co-occurrence of child maltreatment and household dysfunction. This study is also the first to examine the influence of a wide range of adverse childhood experiences on child-to-adult height trajectories and the timing of pubertal development in a population sample. Findings from these investigations will advance our understanding of the burden of adverse childhood experiences in Britain, and their long-term effect on physical development and adult health.

This chapter summarises major methodological issues relating to the strengths and weakness of the data, measures and statistical approach, the implications of the main findings and areas for future research.

7.1 Methodological considerations

Studying child maltreatment and household dysfunction and their association with physical development presents methodological challenges. These issues relate to the strengths and limitations of the available data with regard to: 1) defining and identifying appropriate exposure measures^{259;260}, 2) the adequacy of response measures, 3) the study sample and representativeness of the cohort and 4) missing data issues associated with longitudinal cohort studies. Advanced statistical methods were also used in this thesis due to the complexity of the data. These issues are discussed here.

7.1.1 *Strengths and limitations of the data*

Exposure measures in childhood: Difficulties in ascertaining cases of child maltreatment and household dysfunction may result in participants being misclassified, causing measurement bias^{259;542}. A major strength of the study was the wide range of measures on adverse childhood experiences from multiple data sources, potentially reducing the risk of participants being misclassified³²⁴. However, each method of data collection has strengths and weaknesses, and these need to be considered when interpreting results.

At age 45y, participants in the 1958 cohort retrospectively reported childhood abuse, neglect and household dysfunction. Several indicators of neglect and household dysfunction were ascertained at multiple ages in childhood, from multiple informants, including teachers, parents, health visitors, as well as cohort members. In this study, conventional definitions were used to identify measures of child abuse and neglect to reduce the effect of misclassification²⁹. Household dysfunction measures were based on recommendations from the WHO ‘Addressing adverse childhood experiences to improve public health’ expert consultation in May 2009 and also from the established literature²⁹¹. Child maltreatment and household dysfunction questions in the 45y survey were from established instruments^{340;341;543} and have been adopted by other national studies³⁴². Measures were in close agreement with the conventional definition, although it is possible some may not reflect all aspects of the definition, such as witnessed abuse. Information on age of onset, frequency or duration of abuse and neglect were not collected. Thus it was not possible to determine whether maltreatment occurred prior to the collection of the response measure. There is evidence to suggest that increases in severity, as indicated by frequency and duration of maltreatment, is linked to a greater risk of later adverse outcomes, such as poor mental health⁵⁴⁴ and cardiovascular events in adulthood⁵⁴⁵. As data on the severity of maltreatment was not collected, it was not possible to examine whether duration or frequency of abuse and neglect were related to physical development measures. Meta-analyses of multiple child maltreatment studies have also shown that the prevalence of abuse and neglect varies depending on the questions used to ascertain cases. Studies with multiple questions on each form of maltreatment tend to have higher frequencies compared to those with fewer questions^{546;547}. In the 1958 cohort, only one question was asked on most forms of

abuse which may partially explain why prevalence estimates for some forms of maltreatment, such as sexual abuse, were low²⁹.

As with all retrospective data collection, reporting of adverse early life experiences is dependent on subjects recall. Previous studies have found subjects with agency reports of child maltreatment do not always retrospectively report their experiences in adulthood^{323;330}. Recollection of childhood events may be influenced by experiences in early adulthood^{333;334}, as well as present-day factors, including an individual's physical and mental health, and socio-economic circumstances³²⁰. In adulthood, events at later ages are more likely to be recalled compared to those in early infancy. However, adverse childhood experiences are unlikely to occur in isolation. Children maltreated at older ages are more likely to have experienced maltreatment at younger ages compared to none-maltreated peers^{548;549}. Therefore, though participants who retrospectively report maltreatment may be recalling abusive or neglectful events in late childhood, they are also more likely to have experienced maltreatment events at earlier ages compared to those who did not. Prospective identification of abuse in childhood may be more accurate than retrospective methods, but this approach is not feasible in large population studies. Retrospective self-reports, although may under-estimate true levels of abuse due to recall bias, are a feasible and accepted method of data ascertainment. Such methods have the advantage of being able to collect information on childhood experiences from a group of participants that may be missed by prospective data collection methods³²⁴.

Neglect measures collected at ages 7, 11 and 16y did not directly measure recognised neglectful behaviour (e.g. frequently wearing dirty clothes, missing meals, being left home alone for several hours or not visiting the doctor when sick or injured). Instead, most variables indicate a possible failure in meeting the study child's emotional and educational needs, although they may be more representative of the parent-child relationship. Prospective indicators of neglect were also shown to be socially patterned. Contemporary conventional definitions, used to ascertain measures, have been criticised for reflecting middle-class values on parenting⁵⁵⁰. As a consequence, identified childhood indicators may be influenced by factors which are more common in low socio-economic households, e.g. level of parental education, amount of parental leisure time and low household income. Using these definitions may have biased

measurements as more deprived households may have been more likely to give a positive response compared to those of higher socio-economic status. Thus, it is possible that some materially deprived families may have been misclassified as neglectful in this study. Nevertheless, whilst professional bias may contribute to low-income families being more likely to be identified as neglectful, there is evidence that the problems associated with socio-economic disadvantage compromise the ability of parents to meet their children's needs adequately and increase the risk of neglect^{295;551;552}.

In my thesis, I have considered multiple prospective indicators of neglect and household dysfunction and derived cumulative scores that reflect the overall burden in the cohort. An increase in neglect score may indicate a greater risk of neglect, whilst a higher household dysfunction score suggests an increase in the severity of adversity. The creation of an overall adversity score, by the summation of neglect and household dysfunction score, combines different measures of adverse childhood experiences; neglect measures representing potential indicators of neglect, whereas household dysfunction measures record more objective measures of adversity. A disadvantage of the summary scores is that each measure was given equal weight, though individual variables may represent different aspects of neglect (emotional and physical), vary in their severity or were reported by different respondents (health authority visitor, parent and teacher). Thus participants with quite different experiences could receive scores that were relatively similar. However, by using summary scores participants' experiences were able to be summed on a continuous scale, reflecting the overall degree to which they reported indicators of neglect or household dysfunction in childhood. These continuous scores could then be used in sophisticated multivariate analyses.

Response measures: Most existing studies investigating the relationship between adverse childhood experiences and physical development have used height at one particular age, or pubertal development for girls (i.e. retrospective reports of age of menarche). I used repeated measures of height and pubertal development at multiple ages for both genders, a major strength of the 1958 cohort, to study the influence of adverse child experiences on child-to-adult height trajectories and several markers of pubertal development.

As ages of height measures were widely spaced, critical periods, such as the start of the pubertal growth spurt or peak height velocity, could not be explored. Nevertheless, the data allowed the effect of adverse childhood experiences on height in childhood, adolescence and adulthood to be estimated.

Markers of pubertal development were collected at fixed ages (11 and 16y). It was not possible to ascertain the exact age of pubertal onset (e.g. attainment of Tanner stage 2 for testicular development in boys), as this might have occurred between two ages. Some markers may be more appropriate measures of onset of pubertal development than others. In particular, age of voice change and facial hair growth in boys may not reflect age of pubertal onset but rather pubertal duration or progression, as they are characterised as late events in the development of boys⁵⁵³. There also may be different developmental patterns for certain pubertal characteristics amongst individuals. For example, for facial hair growth there are differences in the pace of development, as well as individual's self-awareness of their own development⁵⁵⁴. Nevertheless, secondary sex characteristics are frequently used to assess maturation because, unlike measures of somatic maturation, they do not require longitudinal observations, are easy to administer and are cost-effective⁵²⁶.

Here, each marker of pubertal development was modelled separately and the different timings of each maturity event were not accounted for in the analyses. It is possible that a participant may be classified as a 'late' developer for one marker and 'intermediate' for another. Such an approach was taken to examine whether the association with adverse childhood experiences was consistent amongst all pubertal markers. In the literature, several markers of pubertal development are often combined to provide an overall rating of maturation. Summary scores are a reliable way of portraying overall pubertal development, reflecting the sequencing and timing of pubertal events⁵⁵⁵. The next stage of this work would be to develop summary scores to assess the relationship between adverse childhood experiences and overall pubertal development at ages 11 and 16y.

Study sample and representativeness of the 1958 cohort: The 1958 cohort is a large population sample, followed up over 50 years. Sample sizes varied for different ages of follow-ups. For prospective indicators of neglect there were data for a substantial number of participants ($n \approx 14,000$). Most participants in the 45y survey had retrospective data on child abuse and neglect ($n=9,310$). As the study is a population sample, there was a low prevalence of some child maltreatment and household dysfunction measures. For example, only 0.5% of men retrospectively reported sexual abuse, 0.9% of participants were exposed to alcoholism at age 7y and 2% had spent time in care by age 7y. Thus, it is likely that the power to detect a small effect of some exposures on physical development was limited.

In general, participants remaining in the study at 45y were representative of those enrolled at birth, but for some purposes sample attrition may introduce bias (discussed below). Overall, the 1958 cohort is generally representative of current British adults³⁵⁸, although ethnic minorities were shown to be underrepresented (§2.5) ³³⁸. Thus, findings are still important for understanding how early life influences have affected height growth and pubertal development. The growth patterns identified, as well as their determinants, are expected to be relevant to disease risks in a contemporary adult population.

Missing data: Cohort members with a positive response to neglect and household dysfunction measures at ages 7, 11 and 16y were less likely to remain in the 45y survey. Therefore these adversity measures were under-represented in the 45y sample, as shown in Chapter 2. A range of demographic and socio-economic measures associated with adverse childhood experiences, as well as the probability of missingness (loss in follow-up), were used in multiple imputation models to adjust for the bias associated with missing data. The estimated prevalence of prospective neglect and household dysfunction measures in the imputed data analyses was higher than in the 45y sample, and thus was likely to be closer to the true prevalence (Chapter 4). This finding suggests that participants with a positive response to childhood indicators of neglect and household dysfunction were at increased risk of being lost to follow-up, thus adverse childhood experiences are likely to have been under-estimated in the participating sample at 45y.

In Chapters 5 and 6, additional analyses using multiple imputation models were undertaken to determine whether attrition, and to a lesser extent missing data, influenced the association between adverse childhood experiences and height at age 7y, adult height and pubertal development. There was little difference in the relationship between prospective measures of neglect and household dysfunction and physical development in the complete and imputed data. In contrast, the association between retrospective measures of child abuse and height growth, testicular development (for boys) and age of menarche (for girls) did differ in the two analyses. For height growth, the strength of association was greater in the imputed data for child abuse and the maltreatment group abuse and neglect with height at age 7y and adult height, compared to the complete analyses (§5.4.5). Thus the complete cases analyses may have underestimated the influence of child abuse and multiple forms of abuse and neglect on height growth. For pubertal development, stronger effects were found between psychological and early puberty (for boys), and sexual and witnessed abuse and late pubertal development (for girls) in the imputed data than the complete cases analyses (§6.5.4). In contrast, a weaker relationship was shown for sexual abuse and early testicular development in boys. It is possible that the complete analyses may have overestimated the association between sexual abuse and early pubertal development. However, the direction of the relationship remained constant and, compared to other forms of child maltreatment, a strong relationship was found.

7.1.2 *Statistical methods*

An advantage of the 1958 cohort was the availability of multiple measures of child maltreatment, which were found to be significantly correlated. A data reduction method, latent class analysis (LCA), was used to investigate the co-occurrence of all fifteen child abuse and neglect measures. Maltreatment groups identified using LCA were adopted to examine the association between distinct patterns of child maltreatment and physical development. In the LCA model, prospective and retrospective neglect measures distinctly clustered between the two maltreatment groups; 45y measures in the abuse and neglect group and childhood measures in the neglect ‘only’. Thus it is possible that instead of identifying patterns of maltreatment in the cohort, the grouping indicates a survey effect, whereby measures collected in childhood are highly correlated, as are those reported at age 45y. Identification of maltreatment groups may also have been confounded by socio-economic status. Childhood neglect measures are socially

patterned, with a strong association found between indicators of neglect collected at age 7y and low socio-economic status at birth. The neglect ‘only’ group could therefore be identifying a socio-economically deprived sub-group in the cohort. To further explore these relationships latent class regression could be used in future analyses, using data source as a covariate to account for correlations between measurement measures collected in the same survey³⁹⁰. Furthermore, demographic characteristics, such as socio-economic status, could be used to predict class membership in order to try and disentangle the association between neglect and socio-economic deprivation.

In this study, the association between adverse childhood experiences and child-to-adult height growth was investigated. Repeated height measurements are often analysed using growth models with random coefficients to provide estimates of growth curves for individuals or groups. Yet, growth models require a sufficient number of observations for each individual and reasonably small intervals between successive measures⁵⁵⁶. In the 1958 cohort, height measurements are sparse and widely spaced (childhood height at 7, 11 and 16y and adult height). It is also unclear at what age cohort members achieved final adult stature. Thus, multivariate response models were adopted to examine the association between adverse childhood experiences and child-to-adult height, assuming ages of measurements to be fixed occasions. The within individual correlation of height measurements was accounted for through the covariance structure (or matrix). As all height measures were modelled simultaneously, unlike in previous studies, it was possible to directly compare the strength of association between early life exposures and height at different ages using contrast tests³⁹⁴.

In multivariate response models (and also growth models) participants with one or more height measurement are included in the analyses. The model estimates should be efficient if data are missing at random (MAR) and missing data patterns do not affect the relationships under investigation. Although neglected participants or those from dysfunctional family backgrounds were less likely to be in the 45y sample (§2.6), there was no evidence to suggest that height differed between cohort members who were in the 45y sample and those who were not. Additional analyses did suggest that missing data may have influenced the association; under-estimating the effects of child abuse on child-to-adult height trajectories. There are more complex missing data models that can

be adopted in longitudinal studies, i.e. multiple imputation for multi-level data. However, such analysis is beyond the scope of this thesis and was not considered here.

Preliminary analyses, using continuous measures of pubertal development, found little difference in the mean puberty score amongst cohort members who experienced adversity in childhood compared to those who did not. To examine whether there was a threshold association, response measures were categorised as early, intermediate and late pubertal development. Multinomial logistic regression models were used to investigate the relationship between child maltreatment, and household dysfunction, and pubertal development (i.e. risk of early or late pubertal development compared with intermediate).

The availability of multiple exposure and outcome measures meant a large number of tests were conducted in this study; therefore multiple testing may be a concern. If an adjustment, such as the Bonferroni correction, were adopted here, some of the associations found would not reach the required p-value ($p < 0.001$) to indicate a significant relationship. For example, the relationship between sexual abuse and early testicular development in boys and early age of menarche in girls (p value < 0.05). However, sexual abuse had a consistent pattern of association across multiple markers of pubertal development, although the relationships did not reach statistical significance. In addition, the direction of the association with pubertal development was consistent across several prospective neglect measures, as well as derived cumulative prospective measures. Thus, suggesting that the relationships identified may not be a consequence of chance alone. Overall, it is unlikely that corrections for multiple testing would have altered the main findings of the study.

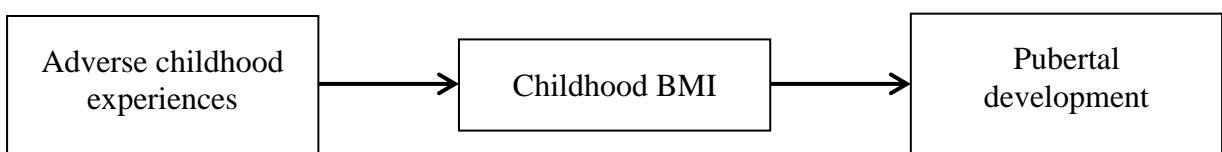
7.1.3 *Further methodological considerations*

In this study, markers of physical development investigated were height growth and pubertal development. Another important marker of physical development is weight-for-height growth, as characterised by body mass index (BMI). Child-to-adult BMI trajectories, height growth and maturation are highly correlated^{349;557;558}.

Adverse childhood experiences have been shown to be related to childhood BMI, with evidence of an increased risk of both being over and underweight. Studies of children born in the mid twentieth century show that severe maltreatment is associated with a lower BMI during childhood and adolescence^{142;144}. In particular, neglect has historically been considered a risk factor for being underweight or ‘failing to thrive’. Emotional deprivation may influence children’s eating behaviour or appetite, whereas physical neglect may lead to caregivers providing inadequate calories⁵⁵⁹. In contemporary cohorts, neglect, corporal punishment and sexual abuse have been linked to a greater risk of obesity amongst pre-school children^{149;560;561}. Excessive eating may occur in maltreated children as a consequence of poor parental supervision, or as a response to stress⁵⁶².

In this study, childhood BMI was not considered a potential confounding factor as it may be on the causal pathway between adverse childhood experiences and physical development. In particular, weight-for-height may be a potential mediator between adverse childhood experiences and pubertal development (Figure 7.1). For example, if childhood neglect measures were associated with lower BMI at age 7 (as has been shown in similar studies^{142;144}), weight-for-height growth may be a potential mechanism in delaying pubertal development. Examining the association between adverse childhood experiences and child and adult BMI was beyond the scope of this project, but is an important area for future research (further discussed §7.4)

Figure 7.1: Pathway between adverse childhood experiences and pubertal development



7.2 Main findings

The study identified six main findings, three of which were related to the prevalence and co-occurrence of adverse childhood experience. *First*, child maltreatment (abuse and neglect) was relatively common in this generation born in 1958, with 14-17% of participants reporting some form of abuse, and over a quarter having a neglect score ≥ 3 . *Second*, different forms of child maltreatment co-occurred. Three distinct maltreatment groups were identified: low risk of maltreatment, neglect ‘only’, and abuse and neglect. *Third*, household dysfunction was associated with child maltreatment, and more strongly with abuse than neglect measures. For example, participants whose father had an alcohol or drug problem were more likely to be in the abused and neglected group than the neglected ‘only’ group (relative risk ratio (RRR) 6.0 vs. 1.6).

The three findings relating to the association between child maltreatment, household dysfunction and physical development were: first, most associations between child maltreatment (psychological and physical abuse and witnessing abuse of a family member), household dysfunction and height and pubertal development attenuated, and were non-significant after adjustment for demographic and socio-economic factors. Second, the relationship between prospective indicators of neglect and delayed growth, though weakened, persisted after adjustment for confounding factors. Neglect at age 7y was related to height deficits of 0.8-2.0cm at age 7y and a smaller difference of 0.3-0.7cm in adult height, suggesting some catch-up growth. Neglect was also associated with late maturation, as indicated by a greater risk of pre-pubertal testicular development at age 11y (RRR=1.6), late pubic hair growth (RRR=1.2-1.6), adult facial hair growth at age 16y (RRR=1.2-1.4) and voice change at age ≥ 15 y (RRR=1.2-1.5) in boys, and prepubertal breast development and pubic hair growth at age 11y (RRR=1.3-1.9 and 1.5, respectively) and menarche at age ≥ 14 y (RRR=1.4) in girls. Third, child sexual abuse was independently associated with a two-fold increased risk of early menarche (≤ 11 y) in females, after controlling for confounding factors. There was also some indication that sexual abuse may be related to advanced testicular development at age 11y in males (RRR=5.50; 1.00, 30.17).

7.2.1 *Prevalence of child maltreatment and household dysfunction*

The established literature indicates that a substantial proportion of children in developed countries are maltreated¹¹⁸. Consistent with previous research, over 10% of participants in the 1958 cohort reported some form of abuse, whereas 25.9-32.1% had a neglect score ≥ 3 (out of eleven indicators of neglect collected at age 7, 11, 16 and 45y). Several UK and US national studies have consistently reported a higher prevalence of neglect compared to other forms of maltreatment^{20;24}. As shown elsewhere⁴³², different forms of maltreatment were found to co-occur in the 1958 cohort. Abused cohort members were more likely to report another form of maltreatment, and the risk of retrospectively reported abuse increased for each additional indicator of neglect. In addition, children from dysfunctional family backgrounds were at increased risk of maltreatment, especially abuse (Appendix 1.1).

7.2.2 *Child abuse and physical development*

Height growth: Previous studies investigating the relationship between child maltreatment and height growth tended to combine all forms of abuse (and neglect) and examine childhood height at one age^{141-145;479}. Few have explored the contribution of individual forms of abuse or height trajectories based on repeated measurements. Previous studies have been restricted to specialised cohorts, including children who had been hospitalised or placed into foster care as a consequence of child maltreatment^{141-145;479}. In this study, a population sample (the 1958 cohort) was adopted, to investigate the effect of physical, psychological and sexual abuse and witnessed intimate-partner violence on child-to-adult height. Unlike previous studies which found that child abuse was related to short stature in childhood^{141-145;479}, I found little evidence of an association between physical or psychological abuse, or witnessed abuse of a family member, and height growth, after adjustment for confounding factors. Sexual abuse was associated with large deficits in height at all ages (0.8cm at age 7y and 1.6cm in adulthood), and shorter adult leg length (1.5cm) in males, although the difference did not reach statistical significance, possibly due to the small number of men who reported sexual abuse at age 45y (n =22) and issues relating to missing data (§7.1.1).

Pubertal development: The literature indicates that sexual abuse is associated with early pubertal development, and that the effect of sexual abuse supersedes that of other forms of child maltreatment²³⁸. American longitudinal studies have found that the influence of other forms of abuse on pubertal development diminishes after adjustment for sexual abuse^{146;516}. Findings from the 1958 cohort provide further support for the association between sexual abuse and early puberty (menarche age ≤ 11 y for girls and more advanced testicular development at age 11 y for boys). Associations remained after adjustment for demographic and socio-economic factors, although relationships may be unstable due to the low prevalence of sexual abuse, especially in males. Other forms of child abuse were not related to puberty measures.

It is possible that an association was found between sexual abuse and early pubertal development as sexually abused participants may be a more homogenous group with regard to the severity of their experiences, than those who reported other forms of abuse. The severity of maltreatment experiences amongst sexually abused participants being more similar compared to others abused. In the Longitudinal Studies of Child Abuse and Neglect (LONGSCAN), the severity of experiences differed little in a group of sexually abused children compared to those physically abused⁵⁶³. It is possible that the severity of abuse may modify the relationship between child maltreatment and later outcomes⁵⁶⁴. Elsewhere, the severity of child abuse has been shown to be related to childhood behaviour problems and developmental and psychological functioning^{269;563}. Alternatively, sexual abuse may be the only form of maltreatment that influences pubertal development, or growth, by potentially triggering the hypothalamic-pituitary-adrenal (HPA) and hypothalamic-pituitary-gonadal (HPG) axis activation, as hypothesised by Trickett and Putnam (1993) and further discussed below¹⁴⁰. In contrast, other forms of abuse may not influence these physiological processes.

Several criteria have been identified to aid the judgement of whether the relationship between an exposure and outcome is causal, including strength of association, temporal relationship and biological credibility⁵⁶⁵. A significant relationship remained between sexual abuse and early pubertal development in girls after controlling for ethnic group, socio-economic disadvantage and maternal age of menarche (for girls). It is possible that the observed association could be due to unmeasured confounding factors, such as dietary quality and quantity. As these data were not recorded in the 1958 cohort, I used

proxy measures of dietary habits and lifestyles, including social class at birth and household crowding at age 7y⁵⁶⁶. The relatively large effect of sexual abuse on early age of menarche, compared to effect estimates of other adverse childhood experiences, indicates that it is less likely that the relationship is only due to an uncontrolled confounding variable in girls⁵⁶⁵. The relationship between sexual abuse and testicular development may be less consistent in males, due to small numbers.

The retrospective nature of the child abuse measures prevents the temporal relationship between sexual abuse and pubertal development from being determined; it is not known if participants were pre-pubertal when sexual abuse occurred. Reverse causation (i.e. puberty preceding abuse) would be a concern if children who matured earlier were more likely to be victims of child maltreatment⁵²⁹. However, an American study investigating reverse causation in a health care sample of sexually abused women showed that the majority of child sexual abuse events occurred before the onset of puberty³⁵⁴. Additionally, a study of recent US national data found that the peak onset of sexual abuse for girls is age 7-8y, suggesting that most sexual abuse is initiated prior to menarche¹⁴⁰. Evidence from America gives support to the hypothesis that the direction of the association is from sexual abuse to onset of menarche³⁵⁴.

Biological mechanisms through which sexual abuse may affect pubertal timing are not well understood. It has been hypothesised that sexual abuse may operate as a stressor that accelerates menarche by impacting on the HPA/HPG function and/or other developmental processes. Activation of the HPA axis has been shown to suppress the release of gonadal hormones by the HPG axis, potentially altering physiological developments associated with puberty¹⁴⁰. Stress-related hormones have been found to be higher in sexually abused girls, and there is evidence of deregulation of the HPA axis in this group, with abused girls having higher cortisol levels when exposed to minor stressors compared to those not abused⁵³². Therefore, it is possible that physiological reactions associated with sexual abuse may influence the age of onset of pubertal development.

This study provides further evidence of a relationship between sexual abuse and early pubertal development. Unlike many previous studies, a range of pubertal markers were available for both males and females. A novel finding from the 1958 cohort is the

borderline significant association between sexual abuse and early testicular development in boys. There is also some evidence to suggest that sexual abuse may be associated with deficits in height growth, suggesting delays in the tempo of growth may cause stunting in adulthood. Further evidence from prospective studies is required before there is strong evidence of a causal relationship between sexual abuse and early pubertal development.

7.2.3 *Child neglect and physical development*

The existing literature indicates that child neglect may be associated with: 1) deficits in childhood height and 2) earlier pubertal development^{142-145;147;238}.

Height growth: Results from the 1958 cohort found that neglect indicators reported at age 7y were associated with short stature in both genders, the strength of association greater for childhood height than adult height. The relationship between neglect and childhood height was weaker than those found in previous studies^{141;142;144}. The difference in effect sizes could be attributable to methodological variations, as the established literature have tended to use specialised cohorts and ascertained cases using agency reports. In the 1958 cohort, a cumulative effect of neglect score on height growth was shown: for each additional indicator of neglect, height decreased by 0.1-0.4cm for males and 0.2-0.3cm for females at each age. A dose-response association may also suggest that the severity of neglect experiences was related to height growth.

Pubertal development: A consistent relationship between neglect measures at age 7y and late pubertal development was also found. There was evidence of a trend, such that a positive response to some indicators of neglect was related to increased risk of late maturation and a decreased risk of early development. The strength of association between indicators of neglect and pubertal development were not as strong as that found for sexual abuse. However, findings of the association between indicators of neglect and height growth and puberty indicate that neglected participants (identified using 7y measures) were shorter in childhood, matured later and grew at a faster rate, or for a longer period than others, thus height deficits were smaller in adulthood than in childhood.

In contrast to indicators of neglect collected at age 7y, neglect measures reported at age 45y had a weak relationship with child-to-adult height growth and pubertal development. The variation in findings between prospective and retrospective measures of neglect may reflect the different informants used for each set of variables. Prospective indicators of neglect were reported by the study child's parent or teacher, whilst retrospective measures were self-reports of neglect. It has been suggested that using different data sources to ascertain child maltreatment cases may identify distinct sub-groups of maltreated participants within a cohort³²⁴. Previous studies have found that a proportion of participants identified by agency or parent-reports do not self-report maltreatment^{321;322} and a significant proportion of participants who retrospectively report abuse are not identified by agency reports^{323;330;331}. Thus findings may have differed because different cohort members will have been identified by retrospective and prospective measures.

The weak correlation between prospective and retrospective neglect measures (Appendix 3.3) and the distinct relationship between each type of measure (retrospective or prospective) and physical development indicate that the different neglect variables may have captured distinct constructs of neglect. Retrospective measures relied on cohort members own definition of neglect and unaffectionate parenting, and whether participants recognised their own experiences as neglectful. In contrast, prospective indicators of neglect may reflect contemporary conventional definitions of maltreatment, as these were used to identify measures in the dataset²⁹. However, prospective measures of neglect may not fully reflect the conventional definitions used to identify them. As exposure measures were restricted to those available in the 1958 cohort, prospective indicators of neglect tended to describe the parent-child relationship, rather than specific neglectful behaviour. The activities illustrated (e.g. reading or taking child on outings) were strongly related to social class at birth and material disadvantage, i.e. household overcrowding and few household amenities (Appendices 2.5, 2.6 and 3.7). Therefore, as well as identifying a level of neglect in the parent-child relationship, neglect measures collected at age 7, 11 and 16y may be more reflective of cohort members socio-economic circumstances in childhood than retrospective measures.

Disentangling the effects of neglect and socio-economic disadvantage is a major challenge in research. Parents' capacity to provide loving and nurturing care to their children is reflective of their social, educational and financial resources⁵⁶⁷. For example, the conventional definition of physical neglect refers to failures in providing adequate nutrition, hygiene, and shelter²⁹. Meeting such requirements may be more challenging for parents with restricted financial capabilities and who live in neighbourhoods that lack social and welfare support systems³¹⁴. Family characteristics and behaviours that are known to increase the risk of neglect, such as parental mental illness, substance abuse and inadequate stress-coping skills, are also associated with socio-economic disadvantage⁹⁴. Thus neglect may be another aspect of socio-economic disadvantage, alongside material and social deprivation, which influence physical growth. As neglect is socially patterned, it may not be possible to separate the effects of neglect and socio-economic disadvantage on later outcomes.

In this study, models were adjusted for socio-economic disadvantage and although the strength of association decreased, some 7y indicators of neglect remained associated with delays in physical development. Several childhood neglect measures ('father hardly reads', 'mother/father hardly any outings', 'mother/father little interest in education' and neglected appearance) continued to have a negative effect on height at each age, for both genders. In addition, a dose-response relationship between cumulative neglect score and differences in height at each age persisted. For pubertal development, most indicators of neglect at age 7y continued to be related to late development of one or more puberty markers after adjustment. For example, neglected appearance was related to late pubic hair development and adult facial hair growth at age 16y in boys, and pre-pubertal breast and pubic hair development at age 11y in girls. The association strengthened with increasing neglect score: a neglect score of ≥ 4 was related to late pubic and facial hair growth and onset of voice change at age ≥ 15 y for boys, whilst a neglect score of ≥ 3 was associated with late breast development for girls. These results suggest that child neglect may be associated with physical development independent of socio-economic disadvantage.

However, confounding factors used in the analyses may not have captured all aspects of socio-economic disadvantage. Thus the remaining effect of neglect on physical development may reflect the combined effect of neglect and socio-economic

disadvantage. Growth patterns associated with childhood neglect are comparable to those linked to socio-economic disadvantage. Children from disadvantaged socio-economic households tend to be shorter in pre-pubertal years, mature later, continue to grow for a longer period and are of average adult height^{152;205}. The observed associations between prospective neglect measures and physical development may therefore reflect the collective influence of child neglect and socio-economic disadvantage on physical development.

Potential mechanisms by which childhood neglect could influence child-to-adult height growth and pubertal development, such as adequate nutrition or access to medical treatment, are associated with socio-economic disadvantage^{265;347;504;505}. It is also possible that neglect may influence the stress-response system, in particular the hypothalamic-pituitary-adrenal (HPA) and hypothalamic-pituitary-gonadal (HPG) axis, which in turn may impact upon physical growth^{153;488-491;533}. Cortisol, secreted in response to chronic stress associated with neglect, may affect height growth by inhibiting pituitary growth hormone (GH) release, and decreasing target tissue sensitivity to GH, somatomedin-C or other growth factors⁴⁸⁹⁻⁴⁹¹. Activation of the stress-response system has been found to influence the functioning of the HPG axis, decreasing GnRH pulsatility, disrupting GnRH surge secretion and reducing pituitary responsiveness to GnRH, thus impacting on pubertal development^{491;533}. However, pathways through which the stress-response system could influence height growth are poorly understood, and there is little evidence of suppression of the HPA or HPG axis due to stress-response in populations studies⁵⁶⁸.

Results from this study indicate that neglect in early life is associated with child-to-adult height growth and pubertal development, in both males and females. After adjustment for a range of demographic and socio-economic factors, effects remained, suggesting that neglect may independently influence physical growth. However, the strong association between neglect and socio-economic disadvantage may mean that it is not possible to disentangle the effects of both on physical development. Instead, neglect may be another aspect of socio-economic deprivation that influences physical development. Further research is required on the biological mechanisms through which neglect may influence height growth and pubertal development, before there is strong evidence of an independent association.

7.3 Implications of findings

7.3.1 *Implications for research*

Findings from these analyses of the 1958 cohort support the inclusion of a range of measures of child abuse and neglect in future studies to fully capture the accumulation of maltreatment. Different forms of child abuse and neglect are rarely experienced in isolation, and co-occurring forms of maltreatment need to be accounted for when investigating risk factors and associated outcomes. Recognition must also be given to children's household environment due to its strong association with maltreatment, particularly severe forms, such as physical and sexual abuse.

The distinct relationships between sexual abuse and neglect and physical development highlight the importance of examining the independent effect of each form of child maltreatment on later outcomes. Combined measures of child maltreatment simplify the exposure and could potentially miss or under-estimate important relationships.

Sexual abuse and neglect in childhood have a distinct relationship with child-to-adult height growth and pubertal development. Sexual abuse in childhood was related to early pubertal development both in boys and girls. It is possible that sexual abuse has an important effect on specific physiological mechanisms that regulate the onset of puberty compared to other forms of abuse. Changes to the onset of pubertal development have been shown to influence adult disease risk. The strong effects reported here suggest that pubertal development may be a potential pathway through which sexual abuse could influence adult health.

Neglect during early life may delay physical development in childhood, influencing child-to-adult growth patterns as well as the timing of pubertal development. As neglect is socially patterned, it is important to recognise the combined effect of neglect and socio-economic disadvantage on physical growth. Children from disadvantaged backgrounds are more likely to be victims of child neglect, and childhood height and pubertal development have been shown to be particularly sensitive to early environment. All forms of adversity in childhood (neglect and socio-economic

disadvantage) may have an influence on physical development, and thus an impact on later health outcomes.

Other forms of abuse and household dysfunction were unrelated to physical development in the general population after adjustment for demographic and socio-economic factors. Therefore, it is unlikely that they influence adult disease risk through their effect on child-to-adult height growth or physical maturation.

7.3.2 *Implications for public health*

Findings from this study further highlight the importance of early family environments to the health and optimal development of children. Known determinants of height growth and maturation, such as socio-economic deprivation, were found to explain most of the association between adverse childhood experiences and physical development. However, there may be an additional effect of some forms of child maltreatment. In particular, neglect, especially at younger ages, was associated with delays in height growth and physical maturation. Neglect was also the most frequent form of child maltreatment identified in the cohort. In agency reports, neglect is often a subsidiary to another form of maltreatment, yet there is growing evidence that childhood neglect can be as damaging—or perhaps even more damaging—to a child than abuse. There needs to be greater awareness of the potential consequences of neglect, and these should be considered when identifying and responding to potential cases. Whether the association is causal is difficult to address due to the challenges in disentangling the relationship between neglect and socio-economic disadvantage. There is wide-range of evidence that the burden associated with poverty may affect parent's ability to adequately meet their child's needs. Neglect may be additional component of material and social deprivation that influences a child's development. Thus, addressing the causes and consequences of poverty may be more important for healthy child development than targeting neglect.

The generalizability of findings from this study may be limited due to social and economic development over the last fifty years. Changes to economic and welfare policy, legislation against corporal punishment and initiatives to improve child wellbeing and parent functioning may mean subsequent cohorts have very different

early life experiences compared to participants of the 1958 cohort. However, associations between early life experiences and child development in contemporary adult populations are important for identifying those at potential increased risk of ill health, such as cardiovascular disease. Awareness of associations between child maltreatment and physical development may potentially identify those at greater risk and inform early intervention strategies. Collecting information on patient's maltreatment history may assist practitioners and clinicians in monitoring and managing adult's risk of later adverse health outcomes

7.4 Potential areas for future research

This thesis investigated the prevalence and co-occurrence of child maltreatment and household dysfunction in a large British birth cohort, and examined the relationship between adverse childhood experiences and physical development, including child-to-adult height trajectories and the timing of pubertal development. Associations were estimated using multiple measures of child maltreatment and household dysfunction and prospectively collected measurements of physical development, in both males and females. To validate findings from this study, results need to be replicated in other cohorts to ascertain whether similar associations are found in contemporary populations.

The large effects of sexual abuse on early pubertal development, and the delays in height growth associated with neglect, suggest that physical development may be a potential pathway through which these forms of child maltreatment may influence later health outcomes. In the 1958 cohort, health outcomes, including vascular disease risk factors, were measured at age 45y. Thus, whether adverse childhood experiences and their associated growth patterns (e.g. delayed growth, later/early puberty and catch-up growth) are related to an increased risk of disease can be explored. In addition, repeated weight measurements are available, which would allow the relationship between adverse childhood experiences and BMI trajectories to be investigated. Simultaneous investigation of height and BMI trajectories and tempo of growth (pubertal development) would enhance knowledge of the causal pathways and underlying mechanisms linking adverse childhood experiences and adult disease.

Another potential area for future development would be to investigate the association between adverse childhood experiences and other developmental pathways in the 1958 cohort. Child maltreatment and household dysfunction may influence adult health through acting on behavioural, cognitive and social development in childhood. By exploring how adverse childhood experiences affect other areas of development, a full life-course perspective can be attained.

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Appendix 1: Publication

Appendix 1.1: Child maltreatment and household dysfunction in a British birth cohort;
Rachel Denholm¹, Chris Power¹, Claudia Thomas², Leah Li¹, Child Abuse Review (in
press)

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Key Words: Child maltreatment; Household dysfunction; Co-occurrence

Appendix 2: Additional information for Chapter 2

Appendix 2.1: Proportion (%) of child maltreatment measures coded ‘can’t say’ or ‘don’t know’ (‘NK’)

Year	Informant	Child maltreatment measures	NK	
			n	%
45y	Cohort member	Verbally abused	175	1.9
		Suffered humiliation, ridicule, bullying or mental cruelty	170	1.8
		Physically abused	87	0.9
		Sexually abused	42	0.5
		Witnessed physical or sexual abuse of others in my family	67	0.7
		I was neglected	220	2.4
		How affectionate was your mother	70	0.8
		How affectionate was your father	158	1.7
7y	Parent	Does the mother read to, or with, the child	151	1.0
		Does the father read to, or with, the child	606	3.9
		Does the mother take child out	92	0.6
		Does the father take child out	520	3.4
		Would the parents like the child to be able to stay on at secondary school after the minimum school leaving age	1,435	9.3
11y	Teacher	Mother interest in child’s education; 7y	1,064	6.9
		Father interest in child’s education; 7y	5,425	35.2
11y	Parent	Does the mother go out with the child for walks, outings, picnics, visits (other)	56	0.4
		Does the father go out with the child for walks, outings, picnics, visits (other)	96	0.6
		Would you like (child’s name) to leave school as soon as possible or stay on longer?	2,617	17.1
16y	Teacher	Mother interest in child’s education; 11y	1,595	10.4
		Father interest in child’s education; 11y	3,311	21.6
16y	Parent	Which of the following would the parent like the study child to do? (uncertain)	718	4.9
16y	Teacher	Mother interest in child’s education; 16y	1,519	10.4
		Father interest in child’s education; 16y	1,816	12.4

Appendix 2.2: Sensitivity analyses for ‘father little interest in child’s education’ (reported at age 7y); ‘can’t say’ or ‘don’t know’ (‘NK’) coded missing

Appendix 2.2.1: Prevalence (%) of ‘father little interest in child’s education’ (age 7y) in the 1958 Birth cohort

Father little interest in child’s education; 7y				
	NK=no		NK=missing	
	n	%	n	%
Males	7,435	16.3	4,986	25.1
Females	7,131	14.6	4,514	23.6

Appendix 2.2.2: Estimated effects (SE) of ‘father little interest in child’s education’ (age 7y; NK coded missing) on height SDS at ages 7, 11 and 16y and in adulthood using multivariate response models, and adult leg length using linear regression models¹

‘Father little interest in education’; 7y	Unadjusted					Adjusted				
	7y	11y	16y	Adult	Leg	7y	11y	16y	Adult	Leg
Males†	-0.44*	-0.40*	-0.35*	-0.28*	-0.27*	-0.21*	-0.16*	-0.15*	-0.10*	-0.09
	(0.03)	(0.03)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)
Females‡	0.34*	-0.34*	-0.30*	-0.26*	-0.19*	-0.11*	-0.13*	-0.07	-0.03	-0.01
	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)

¹All values are differences in SDS, SE in parenthesis. Adjusted models include parental height, birth weight, prematurity, maternal smoking during pregnancy, social class at birth, breastfed and household crowding, major disability, tenure of accommodation and amenity score at age 7y. †Males no. of observations 3,645-4,784 for height, 2,059-2,661 for leg length. ‡Females no. of observations 3,306-4,381 for height, 1,967-2,561 for leg length. * p<0.05

Appendix 2.2.3: Estimated effects (RRR) of 'father little interest in child's education' (age 7y; NK coded missing) on pubertal development; males¹

'Father little interest in education'; 7y	Testicular development [†] ; 11y		Pubic hair growth [‡] ; 11 & 16y		Facial hair growth [‡] ; 16y		Voice change [§]	
	Late (1)	Early (3-5)	Late	Early	Late (absent)	Early (adult)	Late (≥ 15)	Early (≤ 12)
Unadjusted	1.21* (1.03, 1.43)	1.04 (0.84, 1.29)	1.33* (1.13, 1.57)	0.84 (0.69, 1.11)	1.20* (1.01, 1.43)	0.59* (0.41, 0.84)	1.14 (0.97, 1.35)	1.29* (1.00, 1.68)
Adjusted	1.14 (0.96, 1.36)	1.06 (0.84, 1.33)	1.28* (1.08, 1.53)	0.98 (0.76, 1.25)	1.13 (0.94, 1.36)	0.56* (0.38, 0.81)	1.11 (0.93, 1.33)	1.22 (0.92, 1.61)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis, [†]'stage 2', [‡]'normal', [‡]'sparse' and [§]age 12-14y used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity, social class at birth and household crowding; no. of observations 3,206-3,746. *p<0.05

Appendix 2.2.4: Estimated effects of 'father little interest in child's education' (age 7y; NK coded missing) on pubertal development; females¹

'Father little interest in education'; 7y	Breast development [†] ; 11y		Pubic hair growth [†] ; 11y		Age of menarche [‡]	
	Late (1)	Early (3-5)	Late (1)	Early (3-5)	Late (≥ 14)	Early (≤ 11)
Unadjusted	1.21* (1.01, 1.46)	0.77* (0.62, 0.95)	1.26* (1.05, 1.51)	0.88 (0.70, 1.10)	1.54* (1.25, 1.91)	1.01 (0.76, 1.32)
Adjusted	1.13 (0.92, 1.38)	0.82 (0.65, 1.03)	1.18 (0.96, 1.44)	0.96 (0.75, 1.23)	1.43* (1.11, 1.84)	0.88 (0.64, 1.22)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis, [†]'stage 2' and [‡]age 12-13y used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity, social class at birth and household crowding; no. of observations 2,169-3,479. *p<0.05

Appendix 2.3: Proportion (%) of household dysfunction measures coded ‘can’t say’ or ‘don’t know’ (‘NK’)

Year	Informant	Household dysfunction measures	NK	
			n	%
45y	Cohort member	I had a strict, authoritarian or regimented upbringing	460	4.9
		I received too much physical punishment: smacking, hitting etc.	228	2.5
7y	Health visitor	Alcoholism	1,997	13.0
		Mental illness or neurosis	1,159	7.5
		Family visits psychiatric social worker	1,442	9.4
		Family required the services of a probation officer	1,563	10.1
		Divorce, separation or desertion	644	4.2
		Domestic tension	1,958	12.7
		Family required the services of the Children’s Department	1,225	7.9
		Family required the services of Dr Barnardo’s or other children’s society	1,232	8.0
		Family required the services of the NSPCC or RSSPCC	1,442	9.4
11y	Parent	In care	28	0.2
		In the care of the Local Authority	33	0.2
16y	Parent	In care of a Voluntary Society	38	0.3
		In the care of the Local Authority	45	0.3
		In care of a Voluntary Society	52	0.4

Appendix 2.4: Classification of pubertal development in previous studies

Puberty measure	Derived measures	Study
Tanner score (range 1-5)	Stages 1, 2, 3, 4 or 5	1958 British birth cohort ³⁴⁹ ALSPAC ⁵⁶⁹
	Stages 1 or 2-5	1958 British birth cohort ⁵⁷⁰ 1958 British birth cohort, ALSPAC, EPIC-Norfolk & EYHS ⁵⁷¹
	Stages 1-2 or 3-5	Great Smoky Mountains Study, US ⁵⁷²
	Age of transition from stage 1 to 2, and from stage 2 to 3	ALSPAC ⁵⁶⁹
Age of menarche	Continuous	1958 British birth cohort ³⁴⁸ 1946 British birth cohort ^{197;573;574} ALSPAC ⁵⁶⁹
	9-11, 12, 13, 14, 15, or 16y	1958 British birth cohort ³⁴⁹
	<11, 11, 12, 13, 14 or >14y	1958 British birth cohort & Newcastle upon Tyne study ³⁴⁶
	≤ 12y 3m, 12y 4m-13y 4m, 13y 5m- 14y 6m' or ≥14y 7m	1946 British birth cohort ¹⁹⁷
	Continuous and fifths of distribution	1946 British birth cohort ⁵⁷⁶
	≤ 11, 12, 13 or ≥ 14y	1946 British birth cohort ⁵⁷⁷
	<12, 12, 13, 14 or ≥15y	Aberdeen Children of the 1950s ⁵⁷⁸

ALSPAC ‘Avon Longitudinal Study of Parents and Children’; EPIC-Norfolk ‘The European Prospective Investigation of Cancer, Norfolk’; EYHS ‘European Youth Heart Study’

Appendix 2.5: Child maltreatment %/mean difference (n) by demographic characteristics; exposed vs. non-exposed

Demographic characteristics		n	Psychological abuse	Physical abuse	Sexual abuse	Witnessed abuse	Neglected	Father unaffectionate	Mother unaffectionate
Ethnicity	White	9,108	9.8	5.8	5.9	1.6	2.6	9.1	3.5
	Non-white	201	16.9*	15.9*	11.0*	3.5*	5.0*	12.4	5.5*
Smoking during pregnancy	Non smoker	5,901	9.3	5.1	5.1	1.3	2.2	8.0	3.0
	Smoker	2,806	10.9*	7.3*	7.5*	2.0*	3.3*	11.2*	4.5*
GA <38wks	No	7,338	9.2	5.4	5.6	1.4	2.4	8.7	3.3
	Yes	643	12.0*	7.6*	6.1	2.0	2.6	9.6	4.2
Social class at birth	I/II	1,726	7.5	3.5	3.5	0.6	1.5	6.8	2.1
	IIInm	904	9.9	5.9	6.1	1.4	2.9	7.5	2.1
	IIIm	4,399	9.9	6.1	5.6	1.5	2.6	9.8	3.7
	IV/V	2,003	11.7*	7.5*	8.6*	2.7*	3.4*	10.2*	5.0*
Breast fed	No	2,421	9.9	147	6.3	1.7	3.4	9.3	3.9
	Yes	5,697	9.5	319	5.5	1.3	2.2*	8.9	3.2
Major disability	No	7,818	9.5	5.7	5.7	1.4	2.5	9.0	3.4
	Yes	84	7.1	7.1	3.6	0.0	2.4	7.1	4.8
Overcrowded household	No	7,540	9.4	5.3	5.2	1.4	2.4 •	8.5	3.3
	Yes	997	12.3*	9.4*	11.4*	2.6*	4.4*	13.2*	4.9*
Accommodation Tenure	Owned	3,632	8.6	4.5	3.7	0.8	2.1	7.7	3.1
	Council rented	3,067	10.0	6.6	7.3	1.9	2.9	9.8	3.9
	Private rented	972	12.1	7.2	8.8	2.4	3.4	10.8	3.3
	Other	478	9.4*	7.5*	4.8*	2.1*	2.3*	10.0*	2.9
Amenity score	0	6,741	9.1	5.5	5.3	1.4	2.3	8.4	3.3
	1	540	11.3	5.7	5.6	1.5	3.1	10.9	3.7
	2	429	11.4	7.5	9.6	1.6	3.5	11.7	4.2
	3	396	12.6*	8.3*	10.6*	2.5	4.3*	12.9*	4.3

Demographic characteristics	n	Psychological abuse	Physical abuse	Sexual abuse	Witnessed abuse	Neglected	Father unaffectionate	Mother unaffectionate
Mid-parental height (SDS)†	9,094	0.01	-0.10*	-0.11	-0.06	0.00	-0.05	-0.11*
Maternal age of menarche (age)†‡	3,783	-0.02	0.20*	0.20	0.2	0.14	0.02	0.43*
Birth weight (grams)†	8,531	-26.06	-65.92*	-179.35*	-39.65	-45.96	1.92	-60.21*
<i>BMI at age 7y</i> †	7,522	<i>-0.02</i>	<i>-0.04</i>	<i>-0.11</i>	<i>-0.14</i>	<i>-0.29*</i>	<i>-0.03</i>	<i>-0.10</i>

Proportion exposed and unexposed, chi-squared test used determine if significant difference, n in parenthesis; †mean difference between exposed and unexposed, t-tests used to determine if significant difference; ‡analyses restricted to females only. *p<0.05, *italic* signifies that measure was not included in subsequent adjusted models as a confounding factor

Appendix 2.6: Indicators of neglect at age 7y %/mean difference (n) by demographic characteristics; exposed vs. non-exposed

Demographic characteristics		Mother hardly reads	Father hardly reads	Mother hardly any outings	Father hardly any outings	Mother little interest in education	Father little interest in education	Low parental aspirations	Neglected appearance
Ethnicity	White	15.9 (1,2765)	27.9 (12,371)	1.5 (12,818)	5.8 (12,456)	14.2 (13,146)	14.9 (13,113)	4.2 (12,904)	5.5 (9,357)
	Non-white	17.6 (958)	34.4* (907)	3.1* (965)	9.4* (912)	23.2* (1,028)	23.8* (1,025)	6.5* (977)	10.2* (694)
Smoking during pregnancy	Non smoker	14.7 (9,046)	27.5 (8,795)	1.2 (9,082)	4.8 (8,859)	11.8 (9,325)	12.8 (9,301)	3.6 (9,136)	4.3 (6,662)
	Smoker	18.5* (4,425)	30.3* (4,255)	2.3* (4,445)	8.0* (4,277)	20.3* (4,601)	20.7* (4,589)	5.8* (4,487)	9.0* (3,218)
GA <38wks	No	15.7 (11,188)	27.7 (10,864)	1.4 (11,231)	5.4 (10,939)	13.3 (11,550)	14.1 (11,519)	4.0 (11,303)	5.0 (8,219)
	Yes	15.4 (1,053)	30.6 (1,005)	1.7 (1,062)	6.2 (1,012)	18.4* (1,095)	18.8* (1,094)	4.7 (1,068)	8.1* (752)
Social class at birth	I/II	11.1 (2,445)	22.2 (2,398)	0.9 (2,458)	2.9 (2,416)	4.4 (2,502)	5.2 (2,500)	2.0 (2,465)	1.6 (1,852)
	III _{nm}	15.3 (1,352)	24.7 (1,317)	0.8 (1,361)	3.8 (1,328)	7.7 (1,382)	8.9 (1,378)	1.5 (1,372)	3.4 (991)
	III _{Im}	15.8 (6,889)	28.2 (6,707)	1.4 (6,919)	5.6 (6,753)	15.3 (7,126)	16.2 (7,109)	4.1 (6,966)	5.3 (5,044)
	IV/V	20.2* (3,399)	34.8* (3,208)	2.8* (3,407)	10.0* (3,223)	23.7* (3,510)	23.6* (3,497)	7.4* (3,444)	10.8* (2,399)
Breast fed	No	18.1 (4,403)	29.4 (4,235)	1.9 (4,423)	6.9 (4,257)	17.3 (4,337)	17.5 (4,332)	5.5 (4,458)	6.6 (3,081)
	Yes	15.1* (9,599)	27.9 (9,312)	1.5* (9,632)	5.5* (9,375)	13.1* (9,425)	14.2* (9,394)	3.7* (9,660)	5.2* (6,651)
Major disability	No	15.8 (13,321)	28.1 (12,899)	1.5 (13,373)	5.7 (12,983)	13.8 (13,171)	14.7 (13,134)	4.0 (13,453)	5.2 (9,334)
	Yes	13.9 (208)	32.5 (197)	1.4 (211)	9.9* (202)	21.3* (188)	21.3* (188)	9.4* (213)	16.0* (144)
Overcrowded household	No	14.4 (12,148)	26.6 (11,767)	1.2 (12,206)	4.6 (11,845)	12.6 (12,708)	13.2 (12,675)	3.5 (12,305)	4.2 (9,007)
	Yes	26.2* (1,951)	39.4* (1,874)	4.2* (1,953)	14.3* (1,886)	29.4* (1,894)	30.5* (1,891)	9.0* (1,957)	16.2* (1,331)
Accommodation tenure	Owned	12.5 (5,958)	23.8 (5,833)	0.7 (5,986)	3.0 (5,881)	6.8 (5,827)	7.5 (5,821)	1.9 (6,004)	2.3 (4,219)
	Council rented	19.4 (5,583)	32.4 (5,366)	2.3 (5,603)	8.8 (5,391)	21.3 (5,522)	22.4 (5,502)	6.7 (5,640)	9.1 (3,863)
	Private rented	17.4 (1,739)	31.2 (1,653)	1.9 (1,747)	7.0 (1,661)	16.3 (1,682)	17.3 (1,673)	5.3 (1,756)	6.6 (1,165)
	Other	16.7* (780)	29.2* (754)	2.2* (782)	6.6* (762)	17.4* (766)	17.9* (765)	2.7* (783)	4.2* (522)
Amenity score	0	15.3 (11,421)	27.2 (11,085)	1.4 (11,472)	5.1 (11,166)	12.6 (11,225)	13.5 (11,201)	3.7 (11,518)	4.7 (7,997)
	1	19.7 (973)	32.6 (941)	1.7 (975)	8.0 (941)	20.9 (953)	20.7 (950)	5.4 (984)	8.3 (654)
	2	16.9 (821)	30.8 (785)	3.4 (822)	9.4 (790)	19.6 (797)	20.3 (792)	7.5 (826)	7.6 (539)
	3	20.4* (784)	36.5* (735)	2.3* (785)	11.8* (736)	26.5* (762)	27.8* (758)	7.8* (790)	13.4* (529)

Demographic characteristics	Mother hardly reads	Father hardly reads	Mother hardly any outings	Father hardly any outings	Mother little interest in education	Father little interest in education	Low parental aspirations	Neglected appearance
Mid-parental height (SDS)†	-0.14* (13,918)	-0.05* (13,473)	-0.25* (13,977)	-0.17* (13,562)	-0.18* (14,388)	-0.15* (14,352)	-0.18* (14,082)	-0.30* (10,190)
Maternal age of menarche (age)†‡	0.13* (5,511)	0.03 (5,318)	0.56* (5,535)	0.37* (5,364)	0.13* (5,612)	0.10 (5,600)	0.15 (5,546)	-0.07 (4,117)
Birth weight (grams)†	11.7 (13,175)	-0.93 (12,756)	-10.01 (13,228)	-25.48 (12,836)	-45.96* (13,619)	-40.7* (13,582)	-61.08* (13,326)	-152.54* (9,666)
<i>BMI at age 7y</i> †	<i>0.02 (12,825)</i>	<i>0.01 (12,420)</i>	<i>-0.15 (12,879)</i>	<i>-0.06 (12,502)</i>	<i>0.03 (12,656)</i>	<i>0.01 (12,619)</i>	<i>-0.07 (12,956)</i>	<i>-0.38* (8,969)</i>

Proportion exposed and unexposed, chi-squared test used determine if significant difference, n in parenthesis; †mean difference between exposed and unexposed, t-tests used to determine if significant difference; ‡analyses restricted to females only. *p<0.05, *italic* signifies that measure was not included in subsequent adjusted models as a confounding factor

Appendix 2.7: Household dysfunction at age 7y %/mean difference (n) by demographic characteristics; exposed vs. non-exposed

Demographic characteristics		Domestic tension	Alcoholism	Mental health problem	Contact probation services	Contact children's department	In care	Parents divorced
Ethnicity	White	5.0 (12,880)	0.9 (12,875)	4.5 (12,883)	1.8 (11,519)	4.3 (11,994)	1.9 (13,523)	3.9 (12,316)
	Non-white	7.8* (976)	1.3 (977)	6.6* (977)	3.8* (862)	8.0* (912)	3.6* (1,073)	7.2* (931)
Smoking during pregnancy	Non smoker	4.2 (9,116)	0.7 (9,118)	4.2 (9,120)	1.5 (8,216)	3.4 (8,511)	1.5 (9,605)	3.3 (8,726)
	Smoker	7.1* (4,484)	1.3* (4,478)	5.2* (4,484)	2.6* (3,933)	6.5* (4,152)	2.8* (4,746)	5.4* (4,273)
GA <38wks	No	4.6 (11,280)	0.8 (11,279)	4.2 (11,285)	1.6 (10,124)	3.5 (10,505)	1.5 (11,886)	3.7 (10,794)
	Yes	6.5* (1,069)	0.5 (1,069)	5.0 (1,068)	2.0 (933)	7.1* (986)	3.0* (1,141)	5.3* (1,018)
Social class at birth	I/II	2.8 (2,457)	0.3 (2,457)	2.7 (2,455)	0.2 (2,268)	0.9 (2,306)	0.4 (2,587)	2.1 (2,374)
	IIInm	4.6 (1,370)	0.7 (1,369)	4.2 (1,370)	0.9 (1,222)	2.1 (1,263)	1.0 (1,429)	3.6 (1,295)
	IIIm	4.8 (6,960)	0.7 (6,958)	4.2 (6,966)	1.8 (6,247)	3.8 (6,496)	1.5 (7,302)	3.8 (6,686)
	IV/V	7.9* (3,435)	1.8* (3,434)	7.0* (3,435)	3.8* (2,978)	9.4* (3,187)	4.4* (3,650)	6.5* (3,244)
Breast fed	No	5.6 (4,448)	1.0 (4,447)	5.5 (4,451)	2.4 (3,970)	5.5 (4,146)	2.2 (4,466)	5.1 (4,254)
	Yes	5.0 (9,646)	0.8 (9,643)	4.2* (9,647)	1.7* (8,658)	3.3* (8,990)	1.4* (9,683)	3.5* (9,231)
Major disability	No	4.9 (13,424)	0.8 (13,418)	4.2 (13,425)	1.9 (12,053)	4.1 (12,525)	1.9 (13,489)	4.0 (12,847)
	Yes	11.2* (214)	1.9 (214)	23.8* (214)	2.1 (192)	13.9* (202)	5.0* (220)	5.3 (209)
Overcrowded household	No	4.6 (12,284)	0.7 (12,281)	4.2 (12,290)	1.5 (11,021)	3.8 (11,447)	1.7 (13,095)	4.2 (11,740)
	Yes	8.7* (1,955)	1.9* (1,954)	7.5* (1,953)	4.6* (1,707)	9.1* (1,820)	4.0* (1,958)	4.3 (1,873)
Accommodation tenure	Owned	2.9 (5,984)	0.4 (5,983)	3.0 (5,983)	0.4 (5,454)	2.2 (5,567)	0.9 (6,012)	2.0 (5,740)
	Council rented	7.6 (5,627)	1.4 (5,625)	6.2 (5,628)	3.6 (4,953)	6.0 (5,255)	2.4 (5,646)	5.3 (5,373)
	Private rented	6.0 (1,753)	1.0 (1,753)	4.6 (1,755)	1.9 (1,537)	6.2 (1,619)	3.0 (1,757)	6.9 (1,670)
	Other	2.7* (782)	0.5* (782)	4.1* (782)	1.1* (719)	2.8* (739)	1.3* (786)	3.1* (746)
Amenity score	0	4.5 (11,488)	0.7 (11,487)	4.2 (11,488)	1.5 (10,321)	3.7 (10,699)	1.6 (11,533)	3.4 (10,976)
	1	7.3 (984)	1.4 (983)	6.4 (984)	3.1 (865)	5.3 (923)	1.5 (984)	5.3 (945)
	2	6.4 (826)	0.6 (826)	4.7 (826)	2.5 (728)	5.3 (769)	2.5 (827)	6.9 (795)
	3	9.6* (785)	2.2* (786)	6.7* (788)	4.8* (691)	10.4* (730)	5.3* (790)	8.6* (758)

Demographic characteristics	Domestic tension	Alcoholism	Mental health problem	Contact probation services	Contact children's department	In care	Parents divorced
Mid-parental height (SDS)†	-0.11* (14,056)	-0.25* (14,052)	-0.17* (14,059)	-0.24* (12,568)	-0.18* (13,096)	-0.13* (14,831)	-0.08* (13,441)
Maternal age of menarche (age)†‡	-0.21* (5,541)	0.39 (5,540)	0.10 (5,543)	0.10 (4,983)	0.05 (5,175)	0.15* (5,762)	0.01 (5,316)
Birth weight (grams)†	-74.71* (13,302)	-4.89 (13,298)	-57.8* (13,306)	-65.37 (11,885)	-139.56* (12,390)	-156.88* (14,037)	-89.68* (12,717)
<i>BMI at age 7y</i> †	<i>-0.10 (12,927)</i>	<i>-0.09 (12,921)</i>	<i>-0.16* (12,929)</i>	<i>-0.08 (11,601)</i>	<i>-0.07 (12,048)</i>	<i>-0.08 (12,985)</i>	<i>0.06 (12,363)</i>

Proportion exposed and unexposed, chi-squared test used determine if significant difference, n in parenthesis; †mean difference between exposed and unexposed, t-tests used to determine if significant difference; ‡analyses restricted to females only. *p<0.05, *italic* signifies that measure was not included in subsequent adjusted models as a confounding factor

Appendix 2.8: Height at 7, 11 and 16y and adulthood, and adult leg length, mean difference by demographic characteristics; exposed vs. non-exposed¹

Demographic characteristics	Height (SDS)										
	7y		11y		16y		Adult		Leg		
	n	SDS	n	SDS	n	SDS	n	SDS	n	SDS	
Smoking during pregnancy	12,731	-0.18*	11,654	-0.17*	10,020	-0.13*	13,556	-0.12*	8,528	-0.13*	
GA <38wks	11,595	-0.18*	10,652	-0.19*	9,154	-0.12*	12,325	-0.07*	7,816	-0.11*	
Social class at birth	I/II	-	-	-	-	-	-	-	-	-	
	IIInm	-0.16*	-	-0.19*	-	-0.18*	-	-0.21*	-	-0.13*	
	IIIm	-0.28*	-	-0.29*	-	-0.31*	-	-0.26*	-	-0.22*	
	IV/V	-0.40*	12,117	-0.41*	10,407	-0.45*	14,050	-0.39*	8,848	-0.28*	
Breast fed	13,179	0.14*	11,092	0.15*	9,389	0.14*	12,508	0.13*	7,816	0.06*	
Major disability	13,238	-0.48*	10,890	-0.58*	9,207	-0.47*	12,149	-0.44*	7,735	-0.14	
Overcrowded household	13,315	-0.51*	11,571	-0.47*	9,826	-0.39*	13,209	-0.31*	8,361	-0.29*	
Accommodation Tenure	Owned	-	-	-	-	-	-	-	-	-	
	Council rented	-0.35*	-	-0.35*	-	-0.30*	-	-0.26*	-	-0.23*	
	Private rented	-0.14*	-	-0.19*	-	-0.16*	-	-0.21*	-	-0.14*	
	Other	13,226	-0.08*	11,131	-0.04	9,434	0.00	12,555	-0.04	7,980	-0.02
Amenity score	0	-	-	-	-	-	-	-	-	-	
	1	-	-0.13*	-	-0.17*	-	-0.13*	-	-0.15*	-	
	2	-	-0.12*	-	-0.13*	-	-0.18*	-	-0.16*	-	
	3	13,167	-0.25*	11,077	-0.26*	9,382	-0.29*	12,490	-0.27*	7,938	-0.29*
Mid-parental height (SDS)	13,154	0.52*	12,351	0.56*	10,518	0.61*	14,149	0.64*	8,910	0.55*	
Birth weight (grams)	12,462	0.0004*	11,407	0.0005*	9,829	0.0005*	13,275	0.0005*	8,356	0.0004*	

¹All values are differences in SDS between exposed and unexposed; - used as reference category, *p<0.05

Appendix 2.9: Markers of pubertal development % difference by demographic characteristics for males; exposed vs. non-exposed

		Testicular; 11y				Pubic hair; 11 & 16y				Facial hair; 16y				Voice change			
		n	Late (1)	2	Early (3-5)	n	Late	Inter-mediate	Early	n	Late (absent)	Sparse	Early (adult)	n	Late (≥15)	13-14	Early (≤12)
Ethnic group	White	5,917	38.1	45.5	16.4	5,881	42.7	41.0	16.3	5,399	37.4	54.1	8.5	5,759	46.4	43.6	10.0
	Non-white	415	37.4	39.3	23.4*	412	55.3	32.8	11.9*	202	37.6	47.5	14.9*	377	37.4	49.9	12.7*
GA <38wks	No	4,976	38.3	44.9	16.8	4,950	43.3	40.5	16.2	4,286	8.3	54.6	37.0	4,704	9.7	45.4	44.9
	Yes	507	35.7	49.5	14.8	501	44.5	41.7	1.8	418	11.5	51.9	36.6	465	11.8	38.3	49.9*
Social class at birth	I/II	1,085	34.9	46.7	18.3	1,079	42.3	39.9	17.9	959	35.1	55.2	9.7	1,027	46.5	45.7	7.8
	IIInm	620	36.9	45.7	17.4	616	43.2	39.6	17.2	544	35.7	56.3	8.1	589	43.0	46.9	10.2
	IIIm	3,011	38.1	45.6	16.3	2,991	42.9	41.2	15.9	2,580	38.3	53.1	8.6	2,842	44.4	45.1	10.5
	IV/V	1,473	41.1	43.1	15.8*	1,466	46.5	40.0	13.5*	1,249	39.1	53.2	7.7	1,396	47.5	41.7	10.8*
Overcrowded household	No	5,149	37.5	45.6	16.9	5,119	42.5	40.9	16.6	4,394	36.7	54.5	8.8	4,787	45.1	44.9	10.0
	Yes	747	42.2	42.3	15.5*	742	48.9	39.8	11.3*	623	42.5	48.8	8.7*	724	47.0	42.1	10.9*
Father duration of school	>Statutory age	1,291	33.4	49.8	16.8	1,285	40.3	41.2	18.5	1,134	8.6	55.7	35.6	1,207	9.9	43.9	46.2
	≤ Statutory age	4,212	39.8	43.5	16.7	4,186	44.2	40.7	15.2	3,517	8.8	53.2	38.0	3,907	10.3	45.0	44.6
Mother duration of school	>Statutory age	1,541	36.7	46.8	16.5	1,531	43.2	38.8	18.0	1,371	8.3	54.9	36.8	1,452	7.6	46.2	46.1
	≤ Statutory age	4,475	38.9	44.5	16.7	4,449	44.1	41.1	14.8	3,814	8.4	53.4	38.1	1,919	10.9	43.9	45.2
Maternal age at birth (y)†		6,030	0.03	1.00	0.05	5,994	-0.06	1.00	0.12	5,199	-0.09	1.00	-0.09	5,714	-0.35	1.00	-0.07
Birth weight (grams)†		5,824	-25.3	1.00	39.9*	5,789	-11.3	1.00	13.6	5,023	-17.3	1.00	-40.9*	5,509	13.7	1.00	-4.1

Proportion exposed and unexposed, chi-squared test used determine if significant difference, n in parenthesis; † mean difference between exposed and unexposed, t-tests used to determine if significant difference; *p<0.05, italic signifies that measure was not included in subsequent adjusted models as a confounding factor

Appendix 2.10: Markers of pubertal development % difference by demographic characteristics for females; exposed vs. non-exposed

		Breast; 11y				Pubic hair; 11y				Age of menarche			
		n	Late (1)	2	Early (3-5)	n	Late (1)	2	Early (3-5)	n	Late (≥ 14)	12-13	Early (≤ 11)
Ethnic group	White	5,784	36.6	35.9	27.5	5,749	41.7	36.5	21.8	4,486	27.0	57.1	15.9
	Non-white	342	30.7	35.4	33.9*	340	36.5	36.2	27.4*	160	28.8	49.4	21.9
GA <38wks	No	4,815	35.7	36.1	28.3	4,783	41.3	36.8	22.0	3,592	16.3	57.6	26.1
	Yes	421	39.9	35.6	24.5	419	43.0	34.6	22.4	311	14.5	55.6	29.9
Social class at birth	I/II	1,059	34.6	35.3	30.1	1,051	40.2	36.2	23.7	832	25.5	60.5	14.1
	IIInm	597	36.2	35.5	28.3	594	40.1	35.7	24.2	398	23.9	61.3	14.8
	IIIm	2,895	36.3	36.3	27.4	2,875	42.1	37.0	21.0	2,130	27.8	56.4	15.9
	IV/V	1,450	37.5	35.7	26.8	1,445	42.2	35.9	22.0	1,113	27.3	54.7	18.0*
Overcrowded household	No	4,984	35.1	36.0	28.9	4,951	40.1	36.9	23.1	3,674	25.5	58.0	16.5
	Yes	760	43.6	35.7	20.8*	759	50.9	33.2	15.9*	555	33.0	55.5	11.5*
Father duration of school	>Statutory age	1,290	34.3	37.6	28.1	1,282	39.1	38.3	22.6	978	15.6	60.2	24.1
	\leq Statutory age	4,054	36.8	35.3	27.9	4,030	42.4	35.5	22.1	2,947	16.2	56.9	26.9
Mother duration of school	>Statutory age	1,521	35.9	35.0	29.1	1,511	40.8	36.4	22.8	1,164	14.4	58.9	26.6
	\leq Statutory age	4,299	36.3	36.3	27.3	4,273	41.8	36.7	21.5	3,186	16.5	56.5	26.9
Maternal age of menarche (y)†		5,674	0.36*	1.00	-0.34*	5,639	0.17*	1.00	-0.34*	3,775	0.57*	1.00	-0.47*
Maternal age at birth (y)†		5,831	-0.14	1.00	0.27	5,795	-0.40*	1.00	0.17	4,355	0.09	1.00	-0.06
Birth weight (grams)†		5,655	-27.3	1.00	25.9	5,618	-17.1	1.00	-6.9	4,237	18.0	1.00	19.6

Proportion exposed and unexposed, chi-squared test used determine if significant difference, n in parenthesis; †mean difference between exposed and unexposed, t-tests used to determine if significant difference. *p<0.05, italic signifies that measure was not included in subsequent adjusted models as a confounding factor

Appendix 2.11: Further demographic characteristics

Social class at birth was re-classified as non-manual (I/II and III_{nm}), manual (III_m, IV, V) and lone-mother households.

Hospital admission, for any reason, was ascertained in the medical examination at age 7y, and a binary variables measure was derived.

Teachers rated cohort member's behaviour using the Bristol Social Adjustment Guide at age 7y. *Internalising and externalising behaviour scores* were transformed (square root), and categorised into normal (lowest 50% of scores), problem (top 13% of scores) and intermediate (remainder) groups⁵⁷⁹.

Reading score at age 7y assessed cohort members ability in recognise and comprehend words using the Southgate Reading Test (score 0-30)^{580,581}. Those in lowest 10% of scores were defined as poor readers.

Maths score at age 7y assess cohort members cognitive ability using the Problem Arithmetic Test⁵⁸⁰. Those in the lowest 10% of scores were defined as having poor mathematical ability.

Low birth weight was classified as <2,500g and a binary measure was derived.

Short stature at age 7y was categorised as height below the fifth centile (1.15 m for boys and 1.12 m for girls).

Cohort member's weight, in underclothes, to the nearest pound was recorded by trained medical personnel at age 7y, and later converted to kilograms (kg). *Overweight* was defined as a BMI (kg/m²) of 17.92 kg/m² or greater for boys and 17.75 kg/m² or greater for girls, according to International Obesity Task Force recommendations⁵⁸².

Appendix 2.12: Demographic and childhood (birth and age 7ys) characteristics of 11y indicators of neglect

Demographic and social characteristics		11y indicators of neglect (% bias)						
		Total* (%) (n=14,956)	Mother hardly outings	Father hardly outings	Low parental aspirations	Mother little interest in education	Father little interest in education	Neglected appearance
Gender	Male	7,643 (51.1)	-0.4	-0.1	-0.3	-0.2	0.1	-8.5
	Female	7,313 (48.9)	0.4	0.1	0.3	0.2	-0.1	8.9
Ethnicity	White	13,723 (91.8)	1.4	1.7	1.5	0.3	0.5	0.3
	Non-white	1,233 (8.2)	-16.1	-18.9	-16.4	-3.5	-5.6	-3.5
Social class at birth	Non-manual	4,049 (31.0)	1.2	3.0	1.0	0.2	2.3	3.1
	Manual	8,658 (66.2)	-0.4	1.6	-0.3	-0.1	1.4	-1.3
	Lone-mother	375 (2.9)	-2.7	-67.0	-3.0	0.8	-55.7	-2.7
Mothers duration on schooling	>Statutory age	3,550 (25.1)	2.0	3.0	1.8	0.0	1.0	3.8
	≤ Statutory age	10,611 (74.9)	-0.7	-1.0	-0.6	0.0	-0.3	-1.3
House tenure (7y)	Owned	5,535 (42.2)	0.9	2.0	0.6	-0.3	1.4	1.0
	Rented	7,575 (57.8)	-0.6	-1.5	-0.4	0.2	-1.0	-0.7
Hospitalisation (7y)	No	7,045 (54.1)	0.4	0.5	0.2	0.5	0.6	0.2
	Yes	5,989 (46.0)	-0.4	-0.6	-0.2	-0.5	-0.7	-0.3
Period of social care (7y)	No	13,511 (98.0)	0.2	0.2	0.1	0.1	0.3	-0.1
	Yes	274 (2.0)	-7.4	-11.5	-6.9	-5.9	-15.5	3.6
Internalising problems at 7y	Normal	7,262 (54.3)	1.4	1.8	1.2	0.8	1.1	4.2
	Borderline	4,260 (31.9)	-1.1	-1.1	-0.9	-0.4	-0.3	-4.4
	Problem	1,844 (13.8)	-2.9	-4.3	-2.8	-2.2	-3.7	-6.4
Externalising problems at 7y	Normal	5,936 (44.4)	1.1	1.7	1.2	1.2	1.8	4.5
	Borderline	5,696 (42.6)	-0.8	-1.1	-1.1	-0.6	-1.1	-2.0
	Problem	1,733 (13.0)	-1.2	-2.4	-0.6	-2.0	-2.6	-9.1

Demographic and social characteristics		11y indicators of neglect (% bias)						
		Total* (%) (n=14,956)	Mother hardly outings	Father hardly outings	Low parental aspirations	Mother little interest in education	Father little interest in education	Neglected appearance
Reading score (7y)	Normal	13,694 (91.6)	0.4	0.4	0.3	0.1	0.3	0.7
	Low	1,262 (8.4)	-3.8	-3.8	-3.5	-1.0	-2.9	-7.3
Maths score (7y)	Normal	11,948 (89.6)	-0.1	-0.3	-0.1	0.0	-0.3	-0.8
	Low	1,389 (10.4)	0.9	2.8	0.9	0.1	2.2	6.5
Birth weight	Normal	14,291 (95.6)	0.1	0.3	0.1	0.1	0.1	0.2
	Low (<2500g)	665 (4.5)	-1.9	-6.2	-1.7	-1.5	-2.8	-5.1
Short stature (7y)	No	11,292 (91.8)	0.2	0.0	-0.2	-0.1	-0.1	0.0
	Yes	1,012 (8.2)	-1.6	-0.4	1.6	1.0	1.2	-0.2
Overweight (7y)	No	11,084 (87.8)	-0.1	0.1	0.0	0.0	0.1	-0.1
	Yes	1,546 (12.2)	0.5	-0.4	0.0	0.1	-0.9	0.9
Smoking in pregnancy	No	9,349 (66.7)	0.5	1.1	0.3	0.9	1.0	0.8
	Yes	4,683 (33.4)	-0.9	-2.2	-0.5	-1.7	-2.1	-1.5
Breast fed (7y)	≥ 1 month	4,097 (31.4)	-1.0	-2.3	-0.8	-0.9	-1.5	-0.3
	< 1 month	8,965 (68.6)	0.5	1.0	0.4	0.4	0.7	0.1

Percentage bias ((sample with complete indicator of neglect % - total 11y cohort%)/total 11y cohort%); positive bias represents an overrepresentation of the characteristic in the sample relative to the total cohort, negative bias an underrepresentation). *Total includes participants of 11y survey and alive at age 45y.

Appendix 2.13: Demographic and childhood (birth and age 7y) characteristics of 16y indicators of neglect

Demographic and social characteristics		16y indicators of neglect (% bias)			
		Total* (%) (n=14,331)	Low parental aspirations	Mother little interest in education	Father little interest in education
Gender	Male	7,339 (51.2)	-0.4	-0.9	0.6
	Female	6,992 (48.8)	0.5	1.0	-0.6
Ethnicity	White	13,085 (91.3)	2.6	0.8	1.0
	Non-white	1246 (8.7)	-27.4	-8.2	-10.3
Social class at birth	Non-manual	3,776 (30.9)	1.6	2.2	5.3
	Manual	8,112 (66.3)	-0.4	-0.8	-0.5
	Lone-mother	353 (2.9)	-8.5	-5.0	-45.2
Mothers duration of schooling	>Statutory age	3,341 (25.0)	0.7	2.2	-3.7
	≤ Statutory age	10,016 (75.0)	-0.2	-0.7	-1.2
House tenure (7y)	Owned	5,134 (41.8)	0.1	0.3	2.9
	Rented	7,139 (58.2)	-0.1	-0.2	-2.1
Hospitalisation (7y)	No	6,592 (54.0)	-0.1	0.2	0.5
	Yes	5,613 (46.0)	0.2	-0.2	-0.6
Period of social care (7y)	No	12,656 (98.0)	0.2	0.3	0.4
	Yes	254 (2.0)	-8.0	-13.1	-17.7
Internalising problems at 7y	Normal	6,812 (54.4)	1.0	1.2	1.9
	Borderline	3,971 (31.7)	-0.8	-1.0	-1.8
	Problem	1,735 (13.9)	-2.0	-2.3	-3.3
Externalising problems at 7y	Normal	5,528 (44.2)	0.7	1.3	1.4
	Borderline	5,381 (43.0)	0.2	-0.4	-0.4
	Problem	1,608 (12.9)	-2.9	-3.2	-3.6
Reading score (7y)	Normal	13,142 (91.7)	0.6	0.4	0.8
	Low	1,189 (8.3)	-6.6	-4.2	-9.0
Maths score (7y)	Normal	11,206 (89.8)	-0.7	-0.4	-0.5
	Low	1,279 (10.2)	0.5	3.2	4.4
Birth weight	Normal	13,694 (95.6)	0.1	-0.1	0.1
	Low (<2500g)	637 (4.4)	-2.6	1.2	-2.4
Short stature (7y)	No	10,564 (91.6)	0.3	0.4	0.5
	Yes	971 (8.4)	-3.4	-3.8	-5.9
Overweight (7y)	No	10,407 (88.0)	0.4	0.3	0.0
	Yes	1,422 (12.0)	-2.8	-2.3	-0.2
Smoking in pregnancy	No	8,761 (66.2)	1.3	0.8	1.4
	Yes	4,469 (33.8)	-2.5	-1.5	-2.8
Breast fed (7y)	≥ 1 month	3,822 (31.3)	-1.2	-0.7	-1.2
	< 1 month	8,402 (68.7)	0.6	0.3	0.5

Percentage bias ((sample with complete indicator of neglect % - total 16y cohort%)/total 16y cohort%); positive bias represents an overrepresentation of the characteristic in the 16y sample relative to the total cohort, negative bias an underrepresentation). *Total includes participants of 16y survey and alive at age 45y

Appendix 2.14: Demographic and childhood (birth and age 7ys) characteristics of 16y household dysfunction measures

Demographic and social characteristics		16y household dysfunction measures (% bias)			
		Total* (%) (n=14,331)	Did not get on with mother	Did not get on with father	In care
Gender	Male	7,339 (51.2)	-0.6	-0.7	-0.3
	Female	6,992 (48.8)	0.6	0.7	0.4
Ethnicity	White	13,085 (91.3)	1.3	1.6	2.6
	Non-white	1,246 (8.7)	-13.9	-16.7	-27.8
Social class at birth	Non-manual	3,776 (30.9)	3.7	5.2	1.5
	Manual	8,112 (66.3)	-1.2	-0.1	-0.4
	Lone-mother	353 (2.9)	-11.2	-52.8	-7.8
Mothers duration on schooling	>Statutory age	3,341 (25.0)	3.4	4.6	0.2
	≤ Statutory age	10,016 (75.0)	-1.1	-1.5	-0.1
House tenure (7y)	Owned	5,134 (41.8)	2.6	3.8	-0.2
	Rented	7,139 (58.2)	-1.9	-2.7	0.1
Hospitalisation (7y)	No	6,592 (54.0)	0.0	0.2	-0.1
	Yes	5,613 (46.0)	-0.0	-0.2	0.1
Period of social care (7y)	No	12,656 (98.0)	0.3	0.4	0.1
	Yes	254 (2.0)	-14.1	-19.7	-7.0
Internalising problems at 7y	Normal	6,812 (54.4)	2.7	3.0	0.9
	Borderline	3,971 (31.7)	-1.9	-1.9	-0.7
	Problem	1,735 (13.9)	-6.3	-7.3	-2.0
Externalising problems at 7y	Normal	5,528 (44.2)	2.7	3.0	0.5
	Borderline	5,381 (43.0)	-0.7	-1.1	0.2
	Problem	1,608 (12.9)	-7.0	-6.6	-2.3
Reading score (7y)	Normal	13,142 (91.7)	1.2	1.3	0.6
	Low	1,189 (8.3)	-13.1	-14.5	-6.7
Maths score (7y)	Normal	11,206 (89.8)	-0.6	-0.7	0.2
	Low	1,279 (10.2)	5.3	5.9	-0.7
Birth weight	Normal	13,694 (95.6)	0.1	0.1	0.2
	Low (<2500g)	637 (4.4)	-2.4	-3.0	-3.7
Short stature (7y)	No	10,564 (91.6)	0.5	0.8	0.2
	Yes	971 (8.4)	-5.8	-8.2	-1.6
Overweight (7y)	No	10,407 (88.0)	0.2	0.3	0.4
	Yes	1,422 (12.0)	-1.7	-2.0	-2.7
Smoking in pregnancy	No	8,761 (66.2)	1.5	2.0	1.1
	Yes	4,469 (33.8)	-2.9	-3.9	-2.2
Breast fed (7y)	≥ 1 month	3,822 (31.3)	-1.3	-1.6	-1.1
	< 1 month	8,402 (68.7)	0.6	0.7	0.5

Percentage bias ((sample with complete household dysfunction measure% - total 16y cohort%)/total 16y cohort%); positive bias represents an overrepresentation of the characteristic in the sample relative to the total cohort, negative bias an underrepresentation). *Total sample includes participants of 16y survey and alive at age 45y

Appendix 3: Additional information for Chapter 4

Appendix 3.1: Sensitivity analyses for high neglect score

Results associated with different thresholds (≥ 2 , ≥ 3 and ≥ 4 indicators of neglect) used to define a high neglect score (retrospective and prospective measures; range 0-11) varied little. In Chapter 4, a high neglect score was defined as ≥ 3 indicators of neglect.

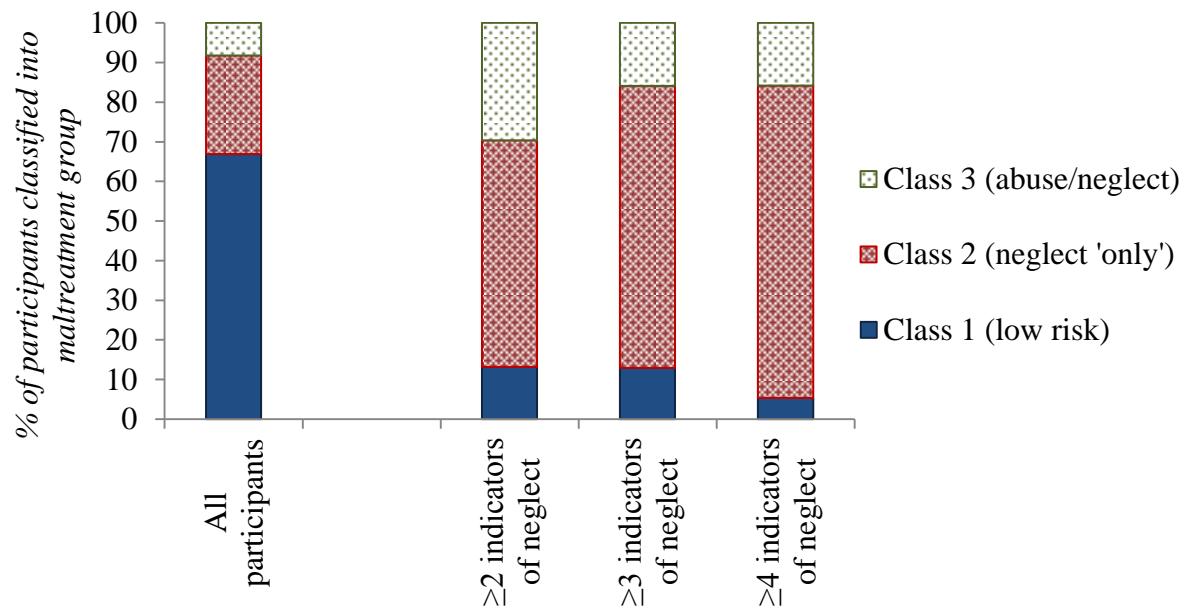
Appendix 3.1.1: Proportion of participants abused experienced other forms of abuse and/or high neglect score; n=6,294

High neglect score	%	Males (%)	Females (%)
≥ 2 indicators	43.3	73.1	77.7
≥ 3 indicators	25.9	62.0	68.3
≥ 4 indicators	14.2	53.8	55.8

Appendix 3.1.2: Mean (95% CI) number of other forms of maltreatment experienced; n=6,294

Child maltreatment	Mean number of other forms of maltreatment (95% CI)		
	≥ 2	≥ 3	≥ 4
Psychological abuse	1.4 (1.4, 1.5)	1.3 (1.2, 1.4)	1.1 (1.0, 1.1)
Physical abuse	2.0 (1.9, 2.1)	1.8 (1.7, 2.0)	1.7 (1.5, 1.8)
Sexual abuse	2.3 (2.0, 2.6)	2.1 (1.7, 2.4)	2.0 (1.7, 2.3)
Witnessed abuse	1.9 (1.7, 2.0)	1.7 (1.6, 1.8)	1.5 (1.3, 1.6)
Neglect	0.3 (0.3, 0.4)	0.4 (0.4, 0.4)	0.4 (0.4, 0.5)

Appendix 3.1.3: Proportion of cohort member classified into distinct maltreatment group (identified by LCA: low risk, neglect 'only', abuse and neglect), by high neglect score



Latent class model includes all seven retrospective measure of child maltreatment at age 45y, and eight indicators of neglect collected at ages 7, 11 and 16y

Appendix 3.1.5: Odds ratios (OR: 95% CI) of high neglect score by household dysfunction measure

Household dysfunction	High neglect score; OR (95% CI)		
	≥2 indicators	≥3 indicators	≥4 indicators
Domestic tension	3.91* (2.87 ,5.33)	4.44* (3.35 ,5.87)	4.02* (3.03 ,5.34)
Alcoholism	-	4.43* (2.07 ,9.47)	-
Male	1.38 (0.47 ,4.09)	-	1.26 (0.38 ,4.23)
Female	9.11* (2.03 ,40.84)	-	6.62* (2.54 ,17.21)
Did not get on well with mother	1.70* (1.29 ,2.24)	1.83* (1.38 ,2.44)	1.58* (1.12 ,2.23)
Did not get on well with father	1.83* (1.46 ,2.29)	1.89* (1.49 ,2.39)	-
Male	-	-	3.08* (2.05 ,4.62)
Female	-	-	1.50* (1.03 ,2.18)
Family member mental health problems	2.64* (1.96 ,3.54)	2.98* (2.25 ,3.94)	2.41* (1.77 ,3.28)
Mother mental health problems	2.20* (1.52 ,3.17)	2.35* (1.64 ,3.35)	2.10* (1.41 ,3.13)
Father mental health problems	2.74* (1.63 ,4.61)	2.41* (1.48 ,3.9)	1.88* (1.10 ,3.22)
Family contact probation services	3.82* (2.88 ,5.08)	3.68* (2.86 ,4.74)	3.86* (2.98 ,5.01)
Family contact children's department	3.44* (2.63 ,4.49)	3.56* (2.79 ,4.53)	4.00* (3.11 ,5.14)
In care by age 16y	4.92* (3.08 ,7.87)	4.18* (2.83 ,6.18)	4.27* (2.90 ,6.30)
A lot of conflict	2.24* (1.92 ,2.62)	2.50* (2.13 ,2.93)	2.40* (2.00 ,2.88)
Mother drink/drugs	1.57* (1.21 ,2.02)	1.52* (1.16 ,1.99)	1.57* (1.15 ,2.16)
Father drink/drugs	2.00* (1.69 ,2.37)	2.16* (1.82 ,2.57)	2.29* (1.88 ,2.79)
Mother nervous trouble/depression	1.46* (1.28 ,1.66)	1.50* (1.30 ,1.73)	1.35* (1.14 ,1.61)
Father nervous trouble/depression	1.25* (1.06 ,1.48)	1.18 (0.98 ,1.43)	1.01 (0.80 ,1.29)
Strict/authoritarian upbringing	1.26* (1.12 ,1.42)	1.30* (1.15 ,1.48)	1.40* (1.20 ,1.65)
Physical punishment	2.04* (1.68 ,2.48)	2.32* (1.90 ,2.82)	2.19* (1.75 ,2.75)
Parental separation/divorce	3.08* (2.50 ,3.80)	2.69* (2.20 ,3.30)	2.97* (2.36 ,3.72)

All values are odds ratios (OR); 95% CI in parenthesis. All models adjusted for social class at birth. For most household dysfunction measures, OR (95%) was estimated for both genders combined, adjusting for gender. For some measures, there was a significant gender interaction, thus OR was given for males and females separately; *p<0.05

Appendix 3.2: Sensitivity analyses using imputed datasets; participants alive at age 45y (n=17,313) and participants of the 45y survey (n=9,310)

Appendix 3.2.1: Proportion of other neglect measures and mean neglect score, by indicators of neglect using imputed datasets

Neglect indicators	Cumulative neglect score†							
	Alive at 45y ¹				Participants at 45y ²			
	% [‡]		Mean (95% CI) ^{¶*}		% [‡]		Mean (95% CI) ^{¶*}	
	Males	Females	Males	Females	Males	Females	Males	Females
Neglected	98.4	97.5	4.1 (3.7, 4.4)	3.8 (3.5, 4.0)	97.7	96.4	2.9 (2.5, 3.4)	3.0 (2.7, 3.4)
Physical neglect								
Neglected appearance	97.8	97.5	3.6 (3.5, 3.8)	3.6 (3.4, 3.9)	97.2	96.9	3.3 (3.0, 3.5)	3.3 (3.1, 3.6)
Emotional neglect								
Mother not affectionate at all	97.2	95.1	3.5 (3.1, 4.0)	3.1 (2.9, 3.4)	96.1	93.1	2.6 (2.3, 3.0)	2.5 (2.2, 2.8)
Father not affectionate at all	94.1	95.1	2.8 (2.6, 2.9)	3.0 (2.8, 3.2)	92.5	93.5	2.3 (2.1, 2.4)	2.4 (2.2, 2.6)
Mother hardly ever reads to child	97.2	96.9	3.0 (2.9, 3.1)	2.7 (2.6, 2.8)	97.0	96.9	2.7 (2.6, 2.9)	2.6 (2.4, 2.7)
Father hardly ever reads to child	95.1	94.2	2.6 (2.5, 2.7)	2.4 (2.3, 2.5)	94.5	93.2	2.3 (2.2, 2.4)	2.1 (2.0, 2.2)
Hardly ever takes outings with mother	99.1	98.5	4.0 (3.8, 4.2)	4.0 (3.7, 4.2)	98.8	98.4	3.6 (3.4, 3.8)	3.7 (3.4, 4.0)
Hardly ever takes outings with father	98.3	97.9	3.7 (3.5, 3.8)	3.3 (3.2, 3.5)	97.8	97.6	3.2 (3.1, 3.4)	3.0 (2.8, 3.2)
Mother little interest in education	99.0	98.8	2.9 (2.8, 3.0)	2.8 (2.8, 2.9)	98.8	98.7	2.7 (2.6, 2.8)	2.7 (2.6, 2.8)
Father little interest in education	98.3	97.9	2.8 (2.7, 2.8)	2.7 (2.6, 2.7)	98.1	97.6	2.6 (2.5, 2.7)	2.5 (2.4, 2.6)
Low parental aspirations	93.1	92.6	2.4 (2.3, 2.5)	2.3 (2.2, 2.4)	91.8	91.5	2.1 (2.0, 2.2)	2.1 (2.0, 2.3)

†Cumulative neglect score calculated by excluding relevant neglect indicator (range 0-10); ¹those alive at 45y n=17,313, ²sample restricted to participants who completed the biomedical survey n=9,310. [‡]Proportion of participants who reported relevant neglect indicator and at least one other, χ^2 used to estimate significant gender difference [¶]Mean number of other indicators of neglect experienced and 95% CI in parenthesis; *chi-squared tests for gender difference, p<0.05

Appendix 3.2.2: Odds ratio (OR; 95% CI) of child abuse by cumulative neglect score†, using imputed datasets

Abuse measures	Cumulative neglect score†; OR (95% CI)		
	Observed (n=6,294)	Imputed	
		Alive at 45y ¹	Participants at 45y ²
Psychological abuse	1.28* (1.22, 1.34)	1.40* (1.35, 1.45)	1.27* (1.23, 1.32)
Physical abuse	1.35* (1.28, 1.42)	-	1.33* (1.27, 1.39)
Male		1.42* (1.33, 1.51)	
Females		1.54* (1.47, 1.62)	
Sexual abuse	1.37* (1.23, 1.52)	1.50* (1.37, 1.65)	1.34* (1.24, 1.45)
Witnessed abuse	1.36* (1.29, 1.44)	1.47* (1.40, 1.53)	1.33* (1.27, 1.39)

All values are odds ratios (OR); 95% CI in parenthesis. †Cumulative neglect score calculated by excluding relevant neglect indicator (0-11). ¹those alive at 45y n=17,313, ²sample restricted to participants who completed the biomedical survey n=9,310. Estimates are for males and females, unless significant interaction was found and thus OR given for each gender separately. *p<0.05

Appendix 3.2.3: Relative risk ratio (RRR: 95% CI) of distinct maltreatment groups (identified from LCA: neglect 'only', abuse and neglect) by household dysfunction measure using imputed datasets

Household dysfunction	Maltreatment classes [†] ; RRR (95% CI)			
	Alive at 45y ¹		Participants at 45y ²	
	Class 2 (neglect 'only')	Class 3 (abuse/neglect)	Class 2 (neglect 'only')	Class 3 (abuse/neglect)
Domestic tension	2.62* (2.17, 3.17)	5.61* (4.30, 7.32)	3.00* (2.31, 3.91)	4.68* (3.38, 6.48)
Alcoholism	2.90* (1.70, 4.94)	6.24* (3.22, 12.08)	2.48* (1.26, 4.89)	4.55* (2.01, 10.28)
Males	-	-	-	4.17* (2.39, 5.04)
Females	-	-	-	5.23* (3.45, 7.92)
Family member mental health problems	1.97* (1.59, 2.45)	3.11* (2.45, 3.94)	2.09* (1.60, 2.75)	2.97* (2.09, 4.20)
Mother mental health problems	1.94* (1.46, 2.58)	3.20* (2.17, 4.73)	2.21* (1.59, 3.09)	3.54* (2.39, 5.23)
Father mental health problems	2.13* (1.46, 3.12)	4.66* (3.05, 7.13)	1.90* (1.19, 3.03)	3.27* (1.93, 5.55)
Did not get on well with mother	1.42* (1.15, 1.75)	3.59* (2.72, 4.74)	1.49* (1.15, 1.94)	3.19* (2.21, 4.59)
Did not get on well with father	1.52* (1.23, 1.89)	4.03* (3.22, 5.05)	1.77* (1.43, 2.19)	4.00* (3.13, 5.10)
Family contact prison/probation services	3.13* (2.62, 3.73)	-	3.48* (2.75, 4.41)	5.40* (4.10, 7.12)
Males	-	4.71* (3.48, 6.39)	-	4.06* (2.65, 6.21)
Females	-	6.87* (5.10, 9.26)	-	6.85* (4.70, 9.99)
Family contact children's department/charity	2.15* (1.79, 2.58)	4.96* (4.10, 6.01)	2.35* (1.84, 2.99)	3.98* (3.09, 5.13)
In care by age 16y	2.02* (1.53, 2.66)	5.65* (3.99, 8.00)	2.26* (1.60, 3.21)	5.15* (3.40, 7.80)

Prospective variables

Household dysfunction	Maltreatment classes [†] ; RRR (95% CI)				
	Alive at 45y ¹		Participants at 45y ²		
	Class 2 (neglect 'only')	Class 3 (abuse/neglect)	Class 2 (neglect 'only')	Class 3 (abuse/neglect)	
Retrospective variables	A lot of conflict	1.91* (1.66, 2.19)	22.40* (19.00, 26.42)	1.85* (1.56, 2.19)	20.82* (17.29, 25.07)
	Mother drink/drugs	1.58* (1.31, 1.91)	3.83* (2.99, 4.91)	1.71* (1.34, 2.20)	3.54* (2.67, 4.68)
	Father drink/drugs	1.59* (1.34, 1.88)	5.91* (4.85, 7.22)	1.59* (1.34, 1.89)	5.29* (4.36, 6.41)
	Mother nervous trouble/depression	1.18* (1.05, 1.34)	4.39* (3.84, 5.02)	1.27* (1.10, 1.46)	4.03* (3.41, 4.76)
	Father nervous trouble/depression	1.01 (0.84, 1.22)	3.08* (2.53, 3.74)	0.98 (0.81, 1.19)	3.12* (2.57, 3.79)
	Strict/authoritarian upbringing	1.06 (0.93, 1.20)	4.68* (4.00, 5.46)	-	4.30* (3.65, 5.06)
	Males	-	-	0.96 (0.79, 1.16)	-
	Females	-	-	1.25* (1.05, 1.49)	-
	Physical punishment	1.80* (1.35, 2.39)	37.47* (30.35, 46.26)	1.58* (1.20, 2.07)	31.79* (25.47, 39.68)
	Parental separation/divorce	2.07* (1.80, 2.38)	8.09* (6.95, 9.42)	2.49* (2.07, 2.99)	6.08* (4.88, 7.57)

All values are relative risk ratios (RRR); 95% CI in parenthesis, class 1 (low risk of maltreatment) used as reference category. ¹those alive at 45y n=17,313, ²sample restricted to participants who completed the biomedical survey n=9,310. All models were adjusted for social class at birth. For most household dysfunction measures, RRR (95%) was estimated for both genders combined, adjusting for gender. For some measures, there was a significant gender interaction, thus RRR was given for each and gender; *p<0.05

Appendix 3.2.4: Odds ratios (OR: 95% CI) of childhood maltreatment by household dysfunction measure[†], using imputed data for participants alive at age 45y (n=17,313)

Household dysfunction	Child maltreatment; OR (95% CI)				
	Psychological abuse	Physical abuse	Sexual abuse	Witnessed abuse	≥3 indicators of neglect
Domestic tension	3.75* (2.98, 4.71)	4.05* (3.15, 5.20)	4.37* (2.58, 7.41)	4.20* (3.38, 5.23)	4.20* (3.55, 4.98)
Alcoholism	2.32* (1.22, 4.41)	2.52* (1.32, 4.80)	4.42* (1.67, 11.72)	4.27* (2.38, 7.66)	4.87* (2.99, 7.93)
Did not get on well with mother	2.61* (2.05, 3.33)	2.92* (2.29, 3.72)	2.75* (1.66, 4.55)	2.66* (1.94, 3.65)	1.91* (1.62, 2.26)
Did not get on well with father	3.67* (3.01, 4.47)	4.33* (3.48, 5.38)	3.94* (2.62, 5.90)	3.90* (3.14, 4.84)	2.05* (1.74, 2.42)
Family member mental health problems	2.12* (1.70, 2.65)	2.14* (1.63, 2.81)	3.14* (2.04, 4.84)	2.30* (1.76, 3.01)	2.88* (2.39, 3.47)
Mother mental health problems	2.18* (1.54, 3.07)	1.91* (1.22, 2.98)	1.76* (0.81, 3.84)	2.10* (1.35, 3.29)	2.12* (1.66, 2.71)
Father mental health problems	2.90* (1.89, 4.47)	2.98* (1.77, 5.01)	2.22* (0.84, 5.86)	3.12* (1.90, 5.14)	2.58* (1.81, 3.67)
Family contact probation services	2.72* (2.19, 3.38)	2.99* (2.38, 3.74)	5.35* (3.60, 7.97)	4.14* (3.27, 5.25)	4.03* (3.48, 4.67)
Family contact children's department	3.36* (2.80, 4.04)	3.08* (2.46, 3.85)	5.52* (3.92, 7.76)	3.26* (2.66, 4.00)	3.69* (3.20, 4.25)
In care by age 16y	3.80* (2.87, 5.02)	3.96* (3.00, 5.23)	6.46* (4.01, 10.43)	3.24* (2.41, 4.34)	3.65* (2.89, 4.60)

Household dysfunction	Child maltreatment; OR (95% CI)				
	Psychological abuse	Physical abuse	Sexual abuse	Witnessed abuse	≥3 indicators of neglect
Retrospective variables	24.31* (20.53, 28.79)		- 14.57* (10.44, 20.34)	24.76* (20.33, 30.15)	3.03* (2.67, 3.44)
	Male	- 16.79* (13.01, 21.67)		-	-
	Female	- 24.09* (19.08, 30.4)		-	-
	Mother drink/drugs	3.57* (2.71, 4.70)	3.23* (2.23, 4.66)	1.76 (0.90, 3.44)	3.85* (2.86, 5.17)
	Father drink/drugs	5.01* (4.12, 6.10)	4.83* (3.89, 5.99)	4.42* (3.11, 6.27)	6.65* (5.48, 8.08)
	Mother nervous trouble/depression	5.47* (4.65, 6.42)	4.49* (3.67, 5.49)	4.63* (3.32, 6.47)	4.84* (4.06, 5.78)
	Father nervous trouble/depression	4.18* (3.53, 4.94)	2.93* (2.34, 3.67)	2.79* (1.77, 4.42)	3.81* (3.10, 4.68)
	Strict/authoritarian upbringing	5.87* (5.17, 6.65)	8.08* (6.85, 9.53)	5.86* (3.86, 8.90)	4.27* (3.63, 5.04)
	Physical punishment	38.98* (32.59, 46.62)	83.06* (67.19, 102.68)	15.85* (11.27, 22.28)	20.53* (16.85, 25.01)
	Parental separation/divorce	5.85* (4.99, 6.87)	7.21* (6.04, 8.62)	11.12* (7.94, 15.57)	7.42* (6.14, 8.98)

All values are odds ratios (OR); 95% CI in parenthesis. All models were adjusted for social class at birth. For most household dysfunction measures, RRR (95%) was estimated for both genders combined, adjusting for gender. For some measures, there was a significant gender interaction, thus RRR was given for each gender; *p<0.05

Appendix 3.2.5: Odds ratios (OR: 95% CI) of childhood maltreatment by household dysfunction measure[†], using imputed data for participants of 45y survey (n=9,310)

Household dysfunction	Child maltreatment; OR (95% CI)				
	Psychological abuse	Physical abuse	Sexual abuse	Witnessed abuse	≥3 indicators of neglect
Domestic tension	2.56* (1.97, 3.32)	2.69* (1.96, 3.68)	2.81* (1.64, 4.81)	2.84* (2.09, 3.86)	4.16* (3.36, 5.15)
Alcoholism	1.84 (0.94, 3.59)	2.00 (0.96, 4.18)	4.41* (1.7, 11.43)	4.34* (2.36, 7.97)	3.89* (2.14, 7.10)
Did not get on well with mother	2.01* (1.51, 2.69)	2.22* (1.59, 3.09)	2.16* (1.19, 3.92)	2.04* (1.41, 2.94)	1.83* (1.46, 2.29)
Did not get on well with father	2.98* (2.41, 3.68)	3.54* (2.72, 4.61)	3.27* (2.07, 5.16)	3.12* (2.41, 4.05)	1.90* (1.59, 2.26)
Family member mental health problems	2.04* (1.51, 2.76)	1.84* (1.26, 2.68)	4.05* (2.40, 6.84)	2.12* (1.48, 3.03)	2.84* (2.21, 3.64)
Mother mental health problems	2.12* (1.49, 3.03)	1.84* (1.18, 2.89)	2.00 (0.93, 4.29)	2.00* (1.29, 3.10)	2.05* (1.50, 2.80)
Father mental health problems	2.08* (1.23, 3.50)	2.31* (1.29, 4.13)	2.15* (0.70, 6.59)	2.35* (1.28, 4.30)	2.06* (1.34, 3.18)
Family contact probation services	1.97* (1.52, 2.54)	2.08* (1.53, 2.82)	4.20* (2.71, 6.49)	3.36* (2.57, 4.39)	3.75* (2.99, 4.70)
Family contact children's department	2.53* (2.02, 3.18)	2.21* (1.67, 2.92)	4.69* (3.01, 7.30)	2.46* (1.89, 3.21)	3.29* (2.67, 4.06)
In care by age 16y	3.14* (2.29, 4.31)	3.43* (2.37, 4.95)	6.01* (3.56, 10.16)	2.58* (1.70, 3.91)	3.64* (2.68, 4.93)

Household dysfunction	Child maltreatment; OR (95% CI)				
	Psychological abuse	Physical abuse	Sexual abuse	Witnessed abuse	≥3 indicators of neglect
A lot of conflict	18.41* (15.76, 21.49)	13.16* (10.94, 15.82)	8.13* (5.82, 11.37)	18.16* (14.98, 22.02)	2.46* (2.15, 2.81)
Mother drink/drugs	3.40* (2.70, 4.29)	-	1.67 (0.91, 3.06)	3.85* (2.94, 5.03)	1.61* (1.29, 2.01)
Male	-	4.53* (3.01, 6.80)	-	-	-
Female	-	2.34* (1.57, 3.48)	-	-	-
Father drink/drugs	4.09* (3.47, 4.82)	3.81* (3.12, 4.64)	3.34* (2.33, 4.80)	5.87* (4.86, 7.09)	2.12* (1.82, 2.47)
Male	-	-	0.49 (0.07, 3.60)	-	-
Female	-	-	4.04* (2.76, 5.91)	-	-
Mother nervous trouble/depression	4.73* (4.10, 5.45)	3.53* (2.96, 4.22)	3.39* (2.44, 4.71)	3.92* (3.29, 4.68)	1.47* (1.31, 1.65)
Father nervous trouble/depression	4.08* (3.46, 4.82)	2.67* (2.15, 3.31)	2.51* (1.68, 3.75)	3.71* (3.02, 4.55)	1.13 (0.95, 1.34)
Strict/authoritarian upbringing	4.58* (3.98, 5.27)	6.22* (5.19, 7.46)	3.65* (2.62, 5.09)	3.00* (2.52, 3.57)	1.29* (1.16, 1.44)
Physical punishment	27.55* (23.04, 32.94)	66.14* (53.2, 82.24)	8.99* (6.40, 12.64)	13.11* (10.8, 15.91)	2.24* (1.88, 2.68)
Parental separation/divorce	3.54* (2.98, 4.22)	3.92* (3.18, 4.83)	5.92* (4.18, 8.39)	4.44* (3.63, 5.44)	2.62* (2.26, 3.04)
Male	4.36* (3.35, 5.66)	-	-	-	-
Female	3.03* (2.41, 3.81)	-	-	-	-

All models were adjusted for social class at birth. For most household dysfunction measures, OR (95%) was estimated for both genders combined, adjusting for gender. For some measures, there was a significant gender interaction, thus OR was given for each gender. * p<0.05

Appendix 3.3: Tetrachoric correlation matrix for indicators of neglect reported in childhood (ages 7, 11 and 16y) and adulthood

	I was neglected (45y)	Neglected appearance	Mother un-affectionate (45y)	Father un-affectionate (45y)	Mother hardly reads	Father hardly reads	Mother hardly outings	Father hardly outings	Mother little interest	Father little interest
Neglected appearance	0.24***	1								
Mother not affectionate at all	0.59***	0.07	1							
Father not affectionate at all	0.45***	0.12**	0.51***	1						
Mother hardly ever reads to child	0.08	0.24***	0.07	0.05	1					
Father hardly ever reads to child	0.09	0.27***	0.06	0.14***	0.67***	1				
Hardly ever takes outings with mother	0.17**	0.30***	0.04	0.05	0.38***	0.28***	1			
Hardly ever takes outings with father	0.16**	0.30***	-0.02	0.16***	0.31***	0.45***	0.83***	1		
Mother has little interest in education	0.18**	0.50***	0.15**	0.17***	0.26***	0.24***	0.37***	0.33***	1	
Father has little interest in education	0.18***	0.50***	0.14**	0.21***	0.25***	0.27***	0.36***	0.36***	0.93***	1
Low parental aspirations	0.05	0.27***	-0.02	0.09**	0.17***	0.21***	0.22***	0.23***	0.45***	0.43***

P<0.05-0.01**0.01-0.001***<0.001

Appendix 3.4: Tetrachoric correlation matrix of different forms of child maltreatment

	Psychological abuse	Physical abuse	Sexual abuse	Witnessed abuse
Physical abuse	0.83*	1		
Sexual abuse	0.58*	0.59*	1	
Witnessed intimate-partner violence	0.70*	0.76*	0.64*	1
High neglect score (≥ 3) [†]	0.26*	0.30*	0.29*	0.34*

[†]Three or more indicators of neglect (eight prospective and three retrospective measures); *p<0.001

Appendix 3.5: Child maltreatment[#] fit indices for latent class models by gender

Number of classes	Males				Females			
	LL†	BIC(LL)†	Class Error†	Entropy R ^{2‡}	LL†	BIC(LL)†	Class Error†	Entropy R ^{2‡}
1	-14361.81	28843.82	NA	NA	-16301.43	32724.28	NA	NA
2	-13068.81	26386.01	0.04	0.84	-15000.23	30251.38	0.05	0.78
3	-12646.23	25669.06	0.05	0.85	-14344.52	29069.46	0.05	0.84
4	-12393.47	25291.74	0.08	0.80	-14135.32	28780.57	0.10	0.76
5	-12240.39	25113.78	0.08	0.83	-13999.82	28639.07	0.11	0.76
6	-12157.48	25076.16	0.09	0.83	-13904.95	28578.85	0.12	0.76
7	-12099.99	25089.38	0.10	0.81	-13835.51	28569.46	0.10	0.81
8	-12074.92	25167.46	0.14	0.77	-13801.53	28631.01	0.10	0.81
9	-12029.07	25203.95	0.08	0.84	-13765.91	28689.28	0.11	0.81

[#]Four abuse measures at age 45y and 11 indicators of neglect (ate age 7, 11, 16 and 45y). †Lower LL, BIC, and class error values indicate better fit. ‡Entropy should be >0.7, with values closer to 1 indicating a better fit.

Appendix 3.6: Item probabilities for a three-class latent class model

Child maltreatment measures	Item probabilities								
	Class 1	Class 2	Class 3	Males			Females		
				Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
Psychological abuse	0.03	0.03	0.79	0.03	0.03	0.81	0.03	0.03	0.78
Physical abuse	0.01	0.02	0.58	0.02	0.02	0.65	0.00	0.01	0.54
Sexual abuse	0.00	0.01	0.11	0.00	0.00	0.04	0.00	0.02	0.15
Witnessed abuse	0.01	0.04	0.45	0.01	0.02	0.47	0.01	0.05	0.44
I was neglected	0.00	0.01	0.22	0.00	0.01	0.18	0.01	0.01	0.25
Neglected appearance	0.02	0.15	0.08	0.02	0.17	0.10	0.01	0.13	0.08
Mother unaffectionate	0.01	0.02	0.21	0.01	0.01	0.12	0.02	0.03	0.27
Father unaffectionate	0.05	0.09	0.41	0.06	0.10	0.53	0.04	0.07	0.35
Mother hardly read	0.11	0.25	0.19	0.11	0.26	0.21	0.11	0.24	0.18
Father hardly read	0.21	0.41	0.34	0.20	0.42	0.32	0.22	0.39	0.36
Hardly any outings mother	0.02	0.12	0.08	0.03	0.15	0.09	0.02	0.10	0.07
Hardly any outings father	0.06	0.22	0.17	0.06	0.21	0.15	0.07	0.23	0.17
Mother little interest education	0.01	0.83	0.32	0.02	0.84	0.37	0.01	0.82	0.30
Father little interest education	0.04	0.90	0.42	0.04	0.90	0.47	0.04	0.91	0.39
Low aspirations	0.19	0.53	0.29	0.19	0.52	0.32	0.19	0.54	0.28
Class Size (proportion)	0.67	0.25	0.08	0.68	0.26	0.06	0.66	0.24	0.10

Appendix 3.7: Odds ratios (OR: 95% CI) of neglect measures and relative risk ratio (RRR; 95% CI) of LCA model, by social class at birth

Neglect measures	n	Social class at birth; OR/RRR (95% CI)		
		III _{nm}	III _{Im}	IV/V
Neglected	9,032	1.94* (1.12, 3.35)	1.72* (1.12, 2.65)	2.33* (1.48, 3.68)
Physical neglect				
Neglected appearance	13,391	1.65* (1.14, 2.39)	2.82* (2.15, 3.70)	5.62* (4.28, 7.40)
Emotional neglect				
Mother not affectionate at all	9,032	1.11 (0.81, 1.51)	1.48* (1.20, 1.83)	1.55* (1.22, 1.96)
Father not affectionate at all	9,032	1.01 (0.57, 1.77)	1.78* (1.24, 2.57)	2.47* (1.68, 3.63)
Mother hardly ever reads to child	14,085	1.45* (1.19, 1.76)	1.51* (1.31, 1.74)	2.04* (1.75, 2.37)
Father hardly ever reads to child	13,630	1.15 (0.98, 1.34)	1.38* (1.23, 1.54)	1.86* (1.65, 2.10)
Hardly ever takes outings with mother	15,280	1.22 (0.87, 1.71)	1.92* (1.52, 2.43)	3.03* (2.38, 3.86)
Hardly ever takes outings with father	14,914	1.27 (0.99, 1.61)	1.79* (1.51, 2.12)	3.07* (2.57, 3.66)
Mother little interest in education	14,319	2.05* (1.70, 2.47)	4.14* (3.60, 4.76)	6.87* (5.94, 7.96)
Father little interest in education	13,950	1.94* (1.63, 2.31)	3.95* (3.47, 4.50)	6.79* (5.91, 7.79)
Low parental aspirations	13,993	2.14* (1.79, 2.55)	3.89* (3.41, 4.44)	5.88* (5.12, 6.76)
Maltreatment groups [^]				
Class 2 (neglect 'only')		2.18* (1.62, 2.93)	4.54* (3.66, 5.65)	7.68* (6.09, 6.69)
Class 3 (abuse and neglect)	6,290	1.78* (1.19, 2.66)	2.38* (1.77, 3.20)	3.63* (2.63, 5.01)

Values are odds ratios (OR); 95% CI in parenthesis, social class I/II used as reference category. [^]Values relative risk ratio (RRR), class 1 (low risk of maltreatment) used as reference category.*p<0.05

Appendix 4: Additional information for Chapter 5

Appendix 4.1: Unadjusted estimated mean differences in height SDS (cm) by age(s) indicators of neglect reported; males

Indicators of neglect: age(s) reported	7y		11y		16y		Adult		Leg length		
	n	SDS (cm)	n	SDS (cm)	n	SDS (cm)	n	SDS (cm)	n	SDS (cm)	
Mother hardly read; 7y	6,745	-0.16 (-0.93)	5,609	-0.18 (-1.21)	4,769	-0.14 (-1.13)	6,095	-0.14 (-0.98)	3,941	-0.16 (-0.78)	
Father hardly read; 7y	6,529	-0.10 (-0.59)	5,438	-0.12 (-0.81)	4,629	-0.12 (-0.96)	5,912	-0.07 (-0.47)	3,843	-0.11 (-0.54)	
Mother hardly any outings	0	5,220		5,115		3,926		4,895		3,242	
	7y	62	-0.30 (-1.75)	57	-0.24 (-1.67)	41	-0.65 (-5.13)	48	-0.48 (-3.29)	31	-0.32 (-1.58)
	11y	358	-0.30 (-1.74)	342	-0.32 (-2.19)	263	-0.29 (-2.26)	319	-0.33 (-2.22)	190	-0.18 (-0.92)
	7 & 11y	33	-0.88 (-5.09)	28	-0.86 (-5.89)	24	-0.66 (-5.25)	34	-0.59 (-3.88)	16	-0.27 (-1.35)
Father hardly any outings	0	4,791		4,707		3,622		4,509		3,018	
	7y	168	-0.28 (-1.64)	159	-0.33 (-2.25)	118	-0.25 (-1.99)	150	-0.48 (-1.93)	93	-0.35 (-1.76)
	11y	371	-0.26 (-1.52)	351	-0.31 (-2.12)	272	-0.29 (-2.33)	345	-0.33 (-1.87)	208	-0.17 (-0.83)
	7 & 11y	105	-0.28 (-1.60)	96	-0.37 (-2.54)	79	-0.45 (-3.55)	86	-0.20 (-1.35)	46	-0.05 (-0.24)
Mother little interest education	0	2,786		2,677		2,473		2,779		1,920	
	7y	266	-0.42 (-2.42)	251	-0.37 (-2.57)	223	-0.34 (-2.66)	265	-0.26 (-1.75)	156	-0.23 (-1.16)
	11y	231	-0.30 (-1.74)	208	-0.36 (-2.49)	188	-0.26 (-2.05)	231	-0.26 (-1.80)	140	-0.38 (-1.91)
	16y	335	-0.21 (-1.22)	322	-0.23 (-1.57)	268	-0.19 (-1.53)	329	-0.20 (-1.38)	210	-0.26 (-1.29)
	7 & 11y	91	-0.46 (-2.68)	87	-0.42 (-2.86)	85	-0.40 (-3.18)	99	-0.41 (-2.76)	55	-0.42 (-2.08)
	7 & 16y	117	-0.65 (-3.78)	105	-0.68 (-4.71)	84	-0.49 (-3.84)	112	-0.49 (-3.31)	57	-0.49 (-2.42)
	11 & 16y	115	-0.32 (-1.85)	99	-0.34 (-2.33)	86	-0.34 (-2.65)	98	-0.34 (-2.29)	59	-0.23 (-1.15)
	7, 11 & 16y	104	-0.53 (-3.09)	94	-0.60 (-4.13)	78	-0.57 (-4.47)	102	-0.38 (-2.60)	57	-0.47 (-2.32)

Indicators of neglect: age(s) reported	7y		11y		16y		Adult		Leg length		
	n	SDS (cm)	n	SDS (cm)	n	SDS (cm)	n	SDS (cm)	n	SDS (cm)	
Father little interest education	0	2,452		2,359		2,194		2,463		1,723	
	7y	224	-0.38 (-2.23)	219	-0.28 (-1.91)	186	-0.28 (-2.20)	225	-0.22 (-1.48)	139	-0.19 (-0.96)
	11y	273	-0.26 (-1.49)	255	-0.23 (-1.59)	236	-0.14 (-1.07)	279	-0.16 (-1.09)	166	-0.20 (-0.98)
	16y	313	-0.21 (-1.22)	301	-0.21 (-1.41)	257	-0.15 (-1.18)	299	-0.19 (-1.27)	190	-0.31 (-1.52)
	7 & 11y	112	-0.45 (-2.58)	104	-0.44 (-3.02)	93	-0.32 (-2.55)	117	-0.30 (-2.07)	67	-0.36 (-1.81)
	7 & 16y	114	-0.33 (-1.90)	101	-0.43 (-2.98)	83	-0.33 (-2.64)	105	-0.30 (-2.04)	61	-0.13 (-0.62)
	11 & 16y	129	-0.42 (-2.43)	115	-0.36 (-2.46)	95	-0.38 (-2.98)	121	-0.36 (-2.47)	74	-0.42 (-2.11)
Low parental aspirations	7, 11 & 16y	128	-0.49 (-2.83)	117	-0.51 (-3.51)	94	-0.42 (-3.30)	129	-0.29 (-1.98)	73	-0.40 (-1.98)
	0	2,607		2,582		2,383		2,540		1,793	
	7y	34	-0.36 (-2.09)	33	-0.33 (-2.24)	34	-0.46 (-3.62)	33	-0.35 (-2.39)	20	0.11 (0.54)
	11y	33	-0.20 (-1.26)	33	-0.38 (-2.65)	30	-0.45 (-3.55)	32	-0.24 (-1.60)	21	-0.28 (-1.40)
	16y	1,394	-0.23 (-1.53)	1,364	-0.23 (-1.59)	1,211	-0.26 (-2.05)	1,307	-0.23 (-1.56)	829	-0.22 (-1.11)
	7 & 11y	6	-0.34 (-1.99)	6	-0.18 (-1.27)	5	-0.50 (-3.95)	4	-0.54 (-3.68)	3	-0.25 (-1.27)
	7 & 16y	69	-0.34 (-1.98)	68	-0.35 (-2.40)	57	-0.39 (-3.07)	62	-0.08 (-0.52)	32	-0.04 (-0.19)
Neglected appearance	11 & 16y	122	-0.53 (-3.07)	114	-0.46 (-3.18)	101	-0.42 (-3.32)	100	-0.36 (-2.44)	57	-0.24 (-1.19)
	7, 11 & 16y	42	-0.45 (-2.60)	40	-0.30 (-2.07)	38	-0.28 (-2.22)	45	-0.14 (-0.98)	17	0.07 (0.35)
	0	2,418		2,281		1,894		2,324		1,536	
	7y	98	-0.48 (-2.78)	92	-0.39 (-2.68)	69	-0.32 (-2.54)	100	-0.23 (-1.56)	56	-0.20 (-1.02)
11y	100	-0.53 (-3.08)	82	-0.67 (-4.63)	69	-0.78 (-6.14)	97	-0.41 (-2.75)	53	-0.42 (-2.08)	
	7 & 11y	69	-0.92 (-5.33)	62	-0.89 (-6.16)	41	-0.90 (-7.14)	67	-0.59 (-3.98)	35	-0.55 (-2.74)

All values difference in SDS; difference in cm in parenthesis; dark grey areas indicate outcome preceded the full exposure.

Appendix 4.2: Unadjusted estimated mean differences in height SDS by age(s) indicators of neglect reported; females

Indicators of neglect: age(s) reported	7y		11y		16y		Adult		Leg length		
	n	SDS (cm)	n	SDS (cm)	n	SDS (cm)	n	SDS (cm)	n	SDS (cm)	
Mother hardly read; 7y	6,407	-0.14 (-0.83)	5,445	-0.12 (-0.89)	4,597	-0.14 (-0.90)	6,369	-0.12 (-0.77)	4,035	-0.06 (-0.28)	
Father hardly read; 7y	6,210	-0.14 (-0.84)	5,281	-0.12 (-0.93)	4,449	-0.11 (-0.70)	6,169	-0.10 (-0.61)	3,900	-0.02 (-0.09)	
Mother hardly any outings	0	5,178		5,103		3,941		5,262		3,242	
	7y	47	-0.07 (-0.41)	32	-0.19 (-1.45)	32	-0.40 (-2.48)	50	-0.20 (-1.25)	31	-0.12 (-0.61)
	11y	222	-0.28 (-1.69)	162	-0.28 (-2.09)	162	-0.26 (-1.63)	219	-0.20 (-1.27)	190	-0.20 (-0.98)
	7 & 11y	16	-0.44 (-2.64)	11	-0.43 (-3.21)	11	-0.35 (-2.20)	18	-0.19 (-1.22)	16	-0.15 (-0.75)
Father hardly any outings	0	4,556		4,521		3,472		4,620		3,018	
	7y	169	-0.25 (-1.53)	172	-0.25 (-1.84)	124	-0.26 (-1.62)	180	-0.15 (-0.99)	93	-0.03 (-0.14)
	11y	363	-0.26 (-1.60)	340	-0.26 (-1.92)	268	-0.18 (-1.12)	361	-0.18 (-1.15)	208	-0.15 (-0.73)
	7 & 11y	101	-0.42 (-2.54)	98	-0.32 (-2.37)	72	-0.39 (-2.41)	103	-0.26 (-1.67)	46	-0.25 (-1.21)
Mother little interest education	0	2,840		2,749		2,537		3,041		1,920	
	7y	224	-0.27 (-1.62)	213	-0.26 (-1.93)	186	-0.23 (-1.42)	254	-0.23 (-1.46)	156	-0.15 (-0.75)
	11y	190	-0.29 (-1.76)	178	-0.30 (-2.26)	175	-0.31 (-1.92)	218	-0.24 (-1.54)	140	-0.27 (-1.32)
	16y	318	-0.28 (-1.72)	301	-0.32 (-2.42)	260	-0.32 (-1.97)	338	-0.29 (-1.85)	210	-0.26 (-1.28)
	7 & 11y	92	-0.59 (-3.56)	83	-0.52 (-3.89)	74	-0.55 (-3.41)	101	-0.38 (-2.39)	55	-0.20 (-0.98)
	7 & 16y	115	-0.35 (-2.13)	104	-0.57 (-4.26)	88	-0.30 (-1.86)	123	-0.29 (-1.82)	57	-0.15 (-0.72)
	11 & 16y	97	-0.43 (-2.57)	91	-0.51 (-3.79)	76	-0.40 (-2.52)	106	-0.22 (-1.39)	59	-0.19 (-0.95)
	7, 11 & 16y	69	-0.81 (-4.89)	66	-0.68 (-5.10)	49	-0.47 (-2.91)	83	-0.49 (-3.14)	57	-0.39 (-1.93)

Indicators of neglect: age(s) reported	7y		11y		16y		Adult		Leg length		
	n	SDS (cm)	n	SDS (cm)	n	SDS (cm)	n	SDS (cm)	n	SDS (cm)	
Father little interest education	0	2,406		2,321		2,143		2,574		1,723	
	7y	202	-0.20 (-1.24)	196	-0.22 (-1.65)	177	-0.33 (-2.04)	230	-0.25 (-1.58)	139	-0.16 (-0.78)
	11y	232	-0.22 (-1.31)	221	-0.24 (-1.77)	202	-0.17 (-1.04)	249	-0.17 (-1.09)	166	-0.09 (-0.42)
	16y	332	-0.29 (-1.73)	312	-0.28 (-2.13)	277	-0.31 (-1.96)	353	-0.30 (-1.89)	190	-0.25 (-1.22)
	7 & 11y	93	-0.46 (-2.77)	85	-0.45 (-3.39)	78	-0.48 (-2.96)	106	-0.34 (-2.18)	67	-0.22 (-1.07)
	7 & 16y	84	-0.50 (-3.00)	86	-0.68 (-5.09)	66	-0.51 (-3.19)	93	-0.44 (-2.77)	61	-0.24 (-1.19)
	11 & 16y	111	-0.65 (-3.93)	96	-0.74 (-5.58)	79	-0.60 (-3.77)	119	-0.43 (-2.74)	74	-0.36 (-1.78)
	7, 11 & 16y	69	-0.65 (-3.90)	70	-0.61 (-4.57)	51	-0.61 (-3.81)	80	-0.41 (-2.63)	73	-0.34 (-1.68)
Low parental aspirations	0	2,689		2,683		2,491		2,820		1,793	
	7y	40	-0.25 (-1.52)	41	-0.10 (-0.77)	39	-0.36 (-2.23)	42	-0.42 (-2.64)	20	-0.34 (-1.68)
	11y	51	-0.07 (-0.43)	49	-0.17 (-1.28)	48	-0.11 (-0.70)	56	-0.11 (-0.70)	21	-0.08 (-0.40)
	16y	1,158	-0.27 (-1.63)	1,124	-0.28 (-2.10)	983	-0.20 (-1.27)	1,177	-0.18 (-1.16)	829	-0.12 (-0.59)
	7 & 11y	5	-0.35 (-2.10)	4	-0.34 (-2.52)	4	-0.44 (-2.76)	4	-0.24 (-1.53)	3	-0.19 (-0.91)
	7 & 16y	70	-0.47 (-2.83)	73	-0.28 (-2.07)	61	-0.42 (-2.59)	74	-0.31 (-1.94)	32	0.01 (0.07)
	11 & 16y	103	-0.38 (-2.28)	109	-0.35 (-2.60)	96	-0.29 (-1.79)	115	-0.31 (-1.97)	57	-0.35 (-1.72)
	7, 11 & 16y	38	-0.39 (-2.38)	38	-0.50 (-3.75)	35	-0.49 (-3.05)	43	-0.36 (-2.26)	17	-0.35 (-1.74)
Neglected appearance	0	3,000		2,870		2,348		3,161		1,536	
	7y	79	-0.43 (-2.61)	79	-0.29 (-2.18)	64	-0.38 (-2.37)	90	-0.31 (-1.99)	56	0.03 (0.15)
	11y	74	-0.60 (-3.65)	68	-0.81 (-6.10)	62	-0.31 (-1.92)	84	-0.26 (-1.69)	53	-0.25 (-1.21)
	7 & 11y	41	-1.21 (-7.34)	40	-1.02 (-7.61)	28	-0.92 (-5.71)	48	-0.82 (-5.24)	35	-0.74 (-3.62)

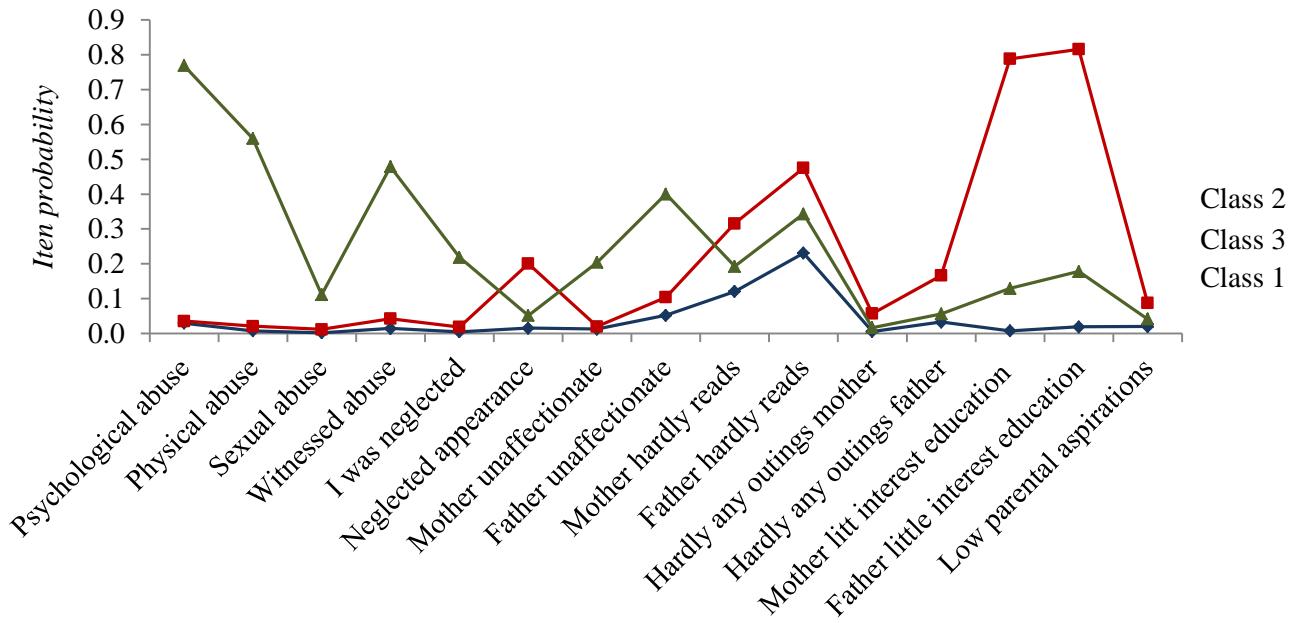
All values difference in SDS; difference in cm in parenthesis; dark grey areas indicate outcome preceded the full exposure.

Appendix 4.3: Fit indices for latent class models using five abuse and neglect measures at age 45y, and eight indicators of neglect at age 7y

Number of classes	LL [†]	BIC(LL) [†]	AIC(LL) [†]	Class Error [†]	Entropy R ^{2‡}	Boot -2LL Diff*	
						-2LL Diff	p- value
1	-19850.14	39829.16	39730.29	NA	NA	NA	NA
2	-18306.36	36879.06	36674.72	0.06	0.69	3087.57	0.00
3	-17494.87	35393.54	35083.74	0.04	0.82	1622.98	0.00
4	-17041.81	34624.89	34209.62	0.10	0.76	906.12	0.00
5	-16909.51	34497.75	33977.02	0.11	0.75	264.60	0.00
6	-16857.42	34531.03	33904.83	0.11	0.75	104.19	0.00
7	-16782.75	34519.17	33787.51	0.13	0.73	149.32	0.00
8	-16760.70	34612.53	33775.40	0.12	0.73	44.11	0.01
9	-16710.60	34649.79	33707.19	0.09	0.79	100.20	0.00

[†]Lower LL, BIC, AIC and class error values indicate better fit. [‡]Entropy should be greater than 0.7, with values closer to 1 indicating a better fit. *Bootstrap likelihood ratio test indicates an improvement in fit of a model compared to a model with k-1 latent classes/profiles. Significantly lower values indicate better fit.

Appendix 4.4: Profiles of the retrospective and prospective variables for three latent classes



Class 1: Low risk of maltreatment (79.5%)

Class 2: Low risk of abuse and neglect reported retrospectively, but high risk of neglect measured prospectively (11.4%)

Class 3: High risk of abuse and neglect reported retrospectively, intermediate risk of neglect measured prospectively (9.1%)

Appendix 4.5: Estimated effects (SE) of cumulative exposure to childhood indicators of neglect(age 7y) on height SDS at ages 7, 11 and 16y and in adulthood using multivariate response models, and adult leg length using linear regression models¹

		Unadjusted					Adjusted				
		7y	11y	16y	Adult	Leg	7y	11y	16y	Adult	Leg
Neglect score including neglected appearance (range 0-8) †	Males	-0.13* (0.01)	-0.12* (0.01)	-0.10* (0.01)	-0.09* (0.01)	-0.09* (0.02)	-0.06* (0.01)	-0.05* (0.01)	-0.04* (0.01)	-0.02* (0.01)	-0.03 (0.02)
	Females	-0.10* (0.01)	-0.11* (0.02)	-0.09* (0.01)	-0.08* (0.01)	-0.05* (0.02)	-0.04* (0.01)	-0.04* (0.01)	-0.04* (0.01)	-0.02 (0.01)	0.00 (0.02)
Adversity score including neglected appearance (range 0-15) ‡	Males	-0.12* (0.01)	-0.11* (0.01)	-0.09* (0.01)	-0.08* (0.01)	-0.08* (0.02)	-0.06* (0.01)	-0.05* (0.01)	-0.03* (0.01)	-0.02* (0.01)	-0.02 (0.02)
	Females	-0.09* (0.01)	-0.09* (0.01)	-0.07* (0.01)	-0.06* (0.01)	-0.04* (0.02)	-0.04* (0.01)	-0.04* (0.01)	-0.02* (0.01)	-0.01 (0.01)	0.00 (0.02)

¹All values are differences in SDS; SE in parenthesis. Adjusted models include parental height, birth weight, prematurity, maternal smoking during pregnancy, social class at birth, breastfed and household crowding, major disability, tenure of accommodation and amenity score at age 7y. † sum of 1 eight indicators of neglect, no. of observations 3,634 for height, 2,058 for leg length for males; 3,709 for height, 2,211 for leg length for females. ‡ sum of all eight indicators of neglect and seven household dysfunction measures at age 7y, no. of observations 3,227 for height, 1,833 for leg length for males; 3,310 for height, 1,972 for leg length for females. * p<0.05

Appendix 4.6: Unadjusted estimated effects (SE) of adverse childhood experiences on height SDS at age 7, 11 and 16y and in adulthood using multivariate response models, and adult leg length using linear regression models using all available data; males¹

Adverse childhood experiences	Height (SE)				Leg (SE)	
	n	7y	11y	16y	Adult	n
<i>Child abuse</i>						
Psychological abuse	4,622	-0.06 (0.05)	-0.04 (0.05)	0.00 (0.06)	0.03 (0.05)	4,522 0.03 (0.05)
Physical abuse	4,622	-0.22 ^c (0.06)	-0.22 ^c (0.06)	-0.15 ^a (0.07)	-0.12 ^a (0.06)	4,522 -0.09 (0.06)
Sexual abuse	4,622	-0.21 (0.21)	-0.26 (0.22)	-0.38 (0.22)	-0.24 (0.21)	4,522 -0.27 (0.22)
Witnessed abuse	4,622	-0.15 ^a (0.07)	-0.15 ^a (0.07)	-0.08 (0.07)	-0.06 (0.07)	4,522 -0.08 (0.07)
<i>Child neglect; 45y</i>						
I was neglected	4,622	-0.07 (0.11)	-0.14 (0.11)	-0.02 (0.12)	-0.04 (0.11)	4,522 -0.08 (0.11)
Unaffectionate mother	4,622	0.00 (0.11)	-0.08 (0.11)	-0.05 (0.11)	-0.01 (0.11)	4,522 0.02 (0.11)
Unaffectionate father	4,622	-0.13 ^a (0.05)	-0.10 ^a (0.05)	-0.05 (0.05)	-0.04 (0.05)	4,522 -0.03 (0.05)
<i>Indicators of neglect; 7y</i>						
Mother hardly reads	7,162	-0.17 ^c (0.03)	-0.17 ^c (0.03)	-0.14 ^c (0.03)	-0.16 ^c (0.03)	3,931 -0.15 ^c (0.04)
Father hardly reads	6,926	-0.10 ^c (0.03)	-0.11 ^c (0.03)	-0.11 ^c (0.03)	-0.07 ^b (0.03)	3,833 -0.10 ^b (0.04)
Mother hardly any outings	7,190	-0.48 ^c (0.09)	-0.42 ^c (0.09)	-0.55 ^c (0.09)	-0.44 ^c (0.09)	3,951 -0.31 ^b (0.13)
Father hardly any outings	6,970	-0.29 ^c (0.05)	-0.33 ^c (0.05)	-0.30 ^c (0.06)	-0.20 ^c (0.05)	3,854 -0.23 ^c (0.08)
Mother little in interest education	7,353	-0.43 ^c (0.03)	-0.37 ^c (0.03)	-0.31 ^c (0.04)	-0.26 ^b (0.03)	4,039 -0.25 ^c (0.05)
Father little interest in education	7,334	-0.38 ^c (0.03)	-0.34 ^c (0.03)	-0.31 ^c (0.03)	-0.24 ^b (0.03)	4,027 -0.20 ^c (0.05)
Low parental aspirations	7,244	-0.30 ^c (0.06)	-0.26 ^c (0.06)	-0.33 ^c (0.06)	-0.13 ^b (0.06)	3,971 -0.13 (0.09)
Neglected appearance	5,028	-0.62 ^c (0.06)	-0.53 ^c (0.06)	-0.51 ^c (0.06)	-0.34 ^c (0.06)	2,751 -0.35 ^c (0.09)
Neglect score (range 0-8)†	4,549	-0.14 ^c (0.01)	-0.12 ^c (0.01)	-0.12 ^c (0.01)	-0.09 ^c (0.01)	2,529 -0.09 ^c (0.02)
Neglect score (range 0-7)‡	6,661	-0.13 ^c (0.01)	-0.12 ^c (0.01)	-0.11 ^c (0.01)	-0.09 ^c (0.01)	3,698 -0.09 ^c (0.01)

Adverse childhood experiences	Height (SE)					Leg (SE)	
	n	7y	11y	16y	Adult	n	
<i>Maltreatment classes[#]</i>							
Neglected 'only'		-0.36 ^c (0.04)	-0.34 ^c (0.04)	-0.34 ^c (0.04)	-0.33 ^c (0.04)		-0.29 ^c (0.04)
Abused & neglected	3,019	-0.26 ^c (0.07)	-0.27 ^c (0.08)	-0.29 ^c (0.08)	-0.23 ^c (0.08)	2,956	-0.18 ^b (0.08)
<i>Household dysfunction; 7y</i>							
Domestic tension	7,229	-0.28 ^c (0.05)	-0.27 ^c (0.05)	-0.24 ^c (0.06)	-0.17 ^c (0.06)	3,962	-0.16 (0.08)
Alcoholism	7,227	-0.26 ^a (0.13)	-0.32 ^b (0.13)	-0.35 ^b (0.14)	-0.04 (0.14)	3,961	-0.05 (0.20)
Family member mental health problems	7,227	-0.39 ^c (0.06)	-0.32 ^c (0.06)	-0.27 ^c (0.06)	-0.28 ^c (0.06)	3,961	-0.16 (0.09)
Contact with probation officer	6,437	-0.51 ^c (0.09)	-0.37 ^c (0.10)	-0.34 ^c (0.10)	-0.39 ^c (0.10)	3,552	-0.15 (0.15)
Contact with children's department/charity	6,711	-0.36 ^c (0.06)	-0.29 ^c (0.06)	-0.25 ^c (0.06)	-0.17 ^b (0.06)	3,675	0.00 (0.09)
In care	7,572	-0.31 ^c (0.08)	-0.22 ^b (0.08)	-0.19 ^a (0.09)	-0.09 (0.09)	4,147	0.11 (0.12)
Parents divorced	6,896	-0.22 ^c (0.06)	-0.21 ^c (0.06)	-0.19 ^c (0.07)	-0.08 (0.06)	3,783	-0.12 (0.09)
Household dysfunction score (range 0-7)±	6,306	-0.15 ^c (0.02)	-0.13 ^c (0.02)	-0.10 ^c (0.02)	-0.08 ^c (0.02)	3,486	-0.03 (0.03)
Adversity score (range 0-15)≠	4,009	-0.13 ^c (0.01)	-0.11 ^c (0.01)	-0.10 ^c (0.01)	0.08 ^c (0.01)	2,246	-0.08 ^c (0.02)
Adversity score (range 0-14)¥	5,851	-0.12 ^c (0.01)	-0.11 (0.01)	-0.09 (0.01)	-0.08 ^c (0.01)	3,277	-0.08 ^c (0.01)

¹All values are differences in SDS; SE in parenthesis. [†]sum of all eight 7y indicators of neglect (including neglected appearance), [‡] sum of seven 7y indicators of neglect (excluding neglected appearance), [#]latent class model includes all fifteen child maltreatment measures collected at ages 7y and 45y ('non-maltreated' used as reference category), [±]sum of all seven household dysfunction measures at age 7y, [≠]sum of all eight indicators of neglect and seven household dysfunction measures at age 7y and [¥]sum of seven indicators of neglect (excluding neglected appearance) and seven household dysfunction measures at age 7y. ^ap<0.05; ^bp<0.01; ^cp<0.001.

Appendix 4.7: Unadjusted estimated effects (SE) of adverse childhood experiences on height SDS at age 7, 11 and 16y and in adulthood using multivariate response models, and adult leg length using linear regression models using all available data; females¹

Adverse childhood experiences	Height (SE)				Leg (SE)	
	n	7y	11y	16y	Adult	n
<i>Child abuse</i>						
Psychological abuse	4,687	-0.06 (0.05)	-0.06 (0.05)	-0.02 (0.05)	-0.02 (0.04)	4,556 -0.01 (0.05)
Physical abuse	4,687	-0.13 ^a (0.06)	-0.11 (0.06)	-0.13 ^a (0.06)	-0.11 (0.06)	4,556 -0.10 (0.06)
Sexual abuse	4,687	-0.27 ^c (0.09)	-0.15 (0.10)	-0.16 (0.09)	-0.14 (0.09)	4,556 -0.18 ^a (0.09)
Witnessed abuse	4,687	-0.17 ^c (0.06)	-0.09 (0.06)	-0.06 (0.06)	-0.05 (0.05)	4,556 -0.02 (0.06)
<i>Child neglect; 45y</i>						
I was neglected	4,687	0.05 (0.08)	-0.01 (0.08)	-0.04 (0.08)	-0.01 (0.08)	4,556 -0.04 (0.08)
Unaffectionate mother	4,687	-0.03 (0.07)	-0.11 (0.07)	-0.10 (0.07)	-0.12 ^a (0.06)	4,556 -0.05 (0.07)
Unaffectionate father	4,687	-0.06 (0.05)	-0.08 (0.5)	-0.03 (0.05)	-0.01 (0.05)	4,556 0.01 (0.05)
<i>Indicators of neglect; 7y</i>						
Mother hardly reads	6,863	-0.15 ^c (0.03)	-0.14 ^c (0.04)	-0.13 ^c (0.04)	-0.12 ^c (0.03)	3,997 -0.07 (0.05)
Father hardly reads	6,646	-0.14 ^c (0.03)	-0.14 ^c (0.03)	-0.10 ^c (0.03)	-0.09 ^b (0.03)	3,865 -0.03 (0.04)
Mother hardly any outings	6,894	-0.12 (0.11)	-0.17 (0.11)	-0.21 (0.11)	-0.12 (0.11)	4,014 -0.18 (0.16)
Father hardly any outings	6,692	-0.26 ^c (0.05)	-0.27 ^c (0.05)	-0.27 ^c (0.05)	-0.23 ^c (0.05)	3,893 -0.15 ^a (0.07)
Mother little in interest education	7,067	-0.33 ^c (0.03)	-0.33 ^c (0.04)	-0.26 ^c (0.04)	-0.24 ^c (0.04)	4,113 -0.17 ^c (0.05)
Father little interest in education	7,049	-0.28 ^c (0.03)	-0.28 ^c (0.04)	-0.25 ^c (0.04)	-0.20 ^c (0.03)	4,102 -0.15 ^c (0.05)
Low parental aspirations	6,940	-0.28 ^c (0.06)	-0.25 ^c (0.06)	-0.27 ^c (0.06)	-0.25 ^c (0.06)	4,032 -0.18 ^a (0.09)
Neglected appearance	5,194	-0.62 ^c (0.07)	-0.63 ^c (0.07)	-0.54 ^c (0.07)	-0.46 ^c (0.07)	3,032 -0.37 ^c (0.10)
Neglect score (range 0-8)†	4,668	-0.12 ^c (0.01)	-0.12 ^c (0.01)	-0.11 ^c (0.01)	-0.09 ^c (0.01)	2,741 -0.06 ^b (0.02)
Neglect score (range 0-7)‡	6,396	-0.12 ^c (0.01)	-0.11 ^c (0.01)	-0.10 ^c (0.01)	-0.09 ^c (0.01)	3,745 -0.06 ^c (0.01)

Adverse childhood experiences	Height (SE)					Leg (SE)	
	n	7y	11y	16y	Adult	n	
<i>Maltreatment classes[#]</i>							
Neglected 'only'		-0.34 ^c (0.04)	-0.36 ^c (0.04)	-0.35 ^c (0.04)	-0.31 ^c (0.04)		-0.25 ^c (0.04)
Abused & neglected	3,275	-0.17 ^c (0.06)	-0.11 (0.06)	-0.13 ^a (0.06)	-0.12 ^a (0.06)	3,182	-0.06 (0.06)
<i>Household dysfunction; 7y</i>							
Domestic tension	6,928	-0.26 ^c (0.05)	-0.28 ^c (0.06)	-0.23 ^c (0.06)	-0.20 ^c (0.06)	4,027	-0.04 (0.08)
Alcoholism	6,925	-0.48 ^c (0.12)	-0.44 ^c (0.13)	-0.35 ^b (0.13)	-0.19 (0.13)	4,025	-0.01 (0.18)
Family member mental health problems	6,933	-0.24 ^c (0.06)	-0.24 ^c (0.06)	-0.22 ^c (0.06)	-0.19 ^c (0.06)	4,028	-0.17 ^a (0.08)
Contact with probation officer	6,224	-0.54 ^c (0.09)	-0.59 ^c (0.09)	-0.49 ^c (0.10)	-0.41 ^c (0.09)	3,619	-0.25 (0.13)
Contact with children's department/charity	6,481	-0.42 ^c (0.06)	-0.42 ^c (0.07)	-0.35 ^c (0.07)	-0.29 ^c (0.06)	3,757	-0.13 (0.09)
In care	7,276	-0.29 ^c (0.09)	-0.29 ^c (0.09)	-0.21 ^a (0.09)	-0.23 ^b (0.09)	4,214	-0.19 (0.12)
Parents divorced	6,636	-0.18 ^c (0.06)	-0.20 ^c (0.07)	-0.22 ^c (0.07)	-0.21 ^c (0.07)	3,858	-0.08 (0.09)
Household dysfunction score (range 0-7)±	6,092	-0.15 ^c (0.02)	-0.15 ^c (0.02)	-0.12 ^c (0.02)	-0.10 ^c (0.02)	3,554	-0.05 (0.03)
Adversity score (range 0-15)≠	4,140	-0.11 ^c (0.01)	-0.10 ^c (0.01)	-0.08 ^c (0.01)	-0.07 ^c (0.01)	2,438	-0.04 ^b (0.01)
Adversity score (range 0-14)¥	5,651	-0.11 ^c (0.01)	-0.10 ^c (0.01)	-0.08 ^c (0.01)	-0.07 ^c (0.01)	3,320	-0.05 ^c (0.01)

¹All values are differences in SDS; SE in parenthesis. [†]sum of all eight 7y indicators of neglect (including neglected appearance), [‡]sum of seven 7y indicators of neglect (excluding neglected appearance), [#]latent class model includes all fifteen child maltreatment measures collected at ages 7y and 45y ('non-maltreated' used as reference category), [±]sum of all seven household dysfunction measures at age 7y, [≠]sum of all eight indicators of neglect and seven household dysfunction measures at age 7y and [¥]sum of seven indicators of neglect (excluding neglected appearance) and seven household dysfunction measures at age 7y. ^ap<0.05; ^bp<0.01; ^cp<0.001.

Appendix 4.8: Estimated effects (SE) of adverse childhood experiences on height SDS at age 7 and in adulthood using imputed data and linear regression models; males¹

Adverse childhood experiences	Height 7y (n=6,828)		Adult height (n=7,137)	
	Unadjusted	Adjusted	Unadjusted	Adjusted
<i>Child abuse; 45y</i>				
Psychological abuse	-0.11 ^a (0.05)	-0.10 ^a (0.05)	0.01 (0.05)	0.00 (0.04)
Physical abuse	-0.29 ^c (0.06)	-0.13 ^b (0.05)	-0.15 ^b (0.06)	-0.02 (0.05)
Sexual abuse	-0.31 (0.21)	-0.18 (0.19)	-0.22 (0.21)	-0.18 (0.22)
Witnessed abuse	-0.21 ^b (0.07)	-0.05 (0.06)	-0.09 (0.07)	0.02 (0.06)
<i>Indicators of neglect; 45y</i>				
I was neglected	-0.13 (0.10)	-0.04 (0.09)	-0.06 (0.10)	-0.03 (0.08)
Unaffectionate mother	-0.09 (0.10)	0.07 (0.10)	-0.05 (0.11)	0.10 (0.10)
Unaffectionate father	-0.14 ^b (0.05)	-0.08 (0.04)	-0.04 (0.05)	0.01 (0.04)
<i>7y measures</i>				
Neglect score† (range 0-8)	-0.13 ^c (0.01)	-0.06 ^c (0.01)	-0.08 ^c (0.01)	-0.02 ^b (0.01)
Neglect score‡ (range 0-7)	-0.13 ^c (0.01)	-0.06 ^c (0.01)	-0.09 ^c (0.01)	-0.02 ^b (0.01)
Household dysfunction score≠	-0.14 ^c (0.02)	-0.06 ^c (0.02)	-0.09 ^c (0.02)	-0.01 (0.02)
Adversity score‡ (range 0-15)	-0.11 ^c (0.01)	-0.05 ^c (0.01)	-0.07 ^c (0.01)	-0.02 ^b (0.01)
Adversity score± (range 0-14)	-0.11 ^c (0.01)	-0.05 ^c (0.01)	-0.07 ^c (0.01)	-0.02 ^c (0.01)
<i>Maltreatment groups§ (reference low risk of maltreatment)</i>				
Neglected 'only'	-0.32 ^c (0.04)	-0.14 ^c (0.03)	-0.27 ^c (0.04)	-0.11 ^c (0.03)
Abuse and neglect	-0.42 ^c (0.06)	-0.22 ^c (0.05)	-0.28 ^c (0.06)	-0.10 ^c (0.03)

¹All values are differences in SDS. Unadjusted models include age height at age 7y was recorded, adjusted models further include parental height, birth weight, prematurity, maternal smoking during pregnancy, social class at birth, breastfed, household crowding, disability, tenure of accommodation, amenity score; †sum of all eight indicators of neglect; ‡sum of seven indicators excluding neglected appearance; ≠sum of all seven household dysfunction; §sum of all eight indicators of neglect and seven household dysfunction measures at age 7y; ± sum of seven indicators of neglect (excluding neglected appearance) and seven household dysfunction measures at age 7y and §latent class model includes all fifteen child maltreatment measures collected at ages 7y and 45y. ^ap<0.05; ^bp<0.01; ^cp<0.001.

Appendix 4.9: Estimated effects (SE) of adverse childhood experiences on height SDS at age 7 and in adulthood using imputed data and linear regression models; females¹

Adverse childhood experiences	Height 7y (n=6,487)		Adult height (n=7,449)	
	Unadjusted	Adjusted	Unadjusted	Adjusted
<i>Child abuse; 45y</i>				
Psychological abuse	-0.10 (0.05)	-0.02 (0.04)	-0.03 (0.05)	0.04 (0.04)
Physical abuse	-0.14 ^a (0.07)	-0.02 (0.06)	-0.15 ^a (0.06)	-0.02 (0.06)
Sexual abuse	-0.36 ^c (0.12)	-0.17 (0.10)	-0.19 ^a (0.09)	0.01 (0.08)
Witnessed abuse	-0.20 ^c (0.06)	-0.10 (0.05)	-0.07 (0.05)	0.03 (0.05)
<i>Indicators of neglect; 45y</i>				
I was neglected	0.01 (0.10)	0.08 (0.08)	-0.05 (0.08)	0.04 (0.06)
Unaffectionate mother	-0.05 (0.09)	0.04 (0.08)	-0.17 ^b (0.07)	-0.07 (0.06)
Unaffectionate father	-0.10 (0.06)	0.00 (0.05)	-0.03 (0.06)	0.06 (0.05)
<i>7y measures</i>				
Neglect score† (range 0-8)	-0.12 ^c (0.01)	-0.06 ^c (0.01)	-0.10 ^c (0.01)	-0.04 ^c (0.01)
Neglect score‡ (range 0-7)	-0.12 ^c (0.01)	-0.06 ^c (0.01)	-0.09 ^c (0.01)	-0.04 ^c (0.01)
Household dysfunction score≠	-0.13 ^c (0.02)	-0.06 ^c (0.02)	-0.11 ^c (0.02)	-0.03 ^a (0.01)
Adversity score‡ (range 0-15)	-0.10 ^c (0.01)	-0.05 ^c (0.01)	-0.08 ^c (0.01)	-0.03 ^c (0.01)
Adversity score± (range 0-14)	-0.10 ^c (0.01)	-0.05 ^c (0.01)	-0.08 ^c (0.01)	-0.03 ^c (0.01)
<i>Maltreatment groups§ (reference low risk of maltreatment)</i>				
Neglected 'only'	-0.38 ^c (0.04)	-0.18 ^c (0.04)	-0.32 ^c (0.04)	-0.12 ^b (0.04)
Abuse and neglect	-0.22 ^c (0.05)	-0.10 ^a (0.04)	-0.18 ^c (0.05)	-0.06 (0.04)

¹All values are differences in SDS. Unadjusted models include age height at age 7y was recorded, adjusted models further include parental height, birth weight, prematurity, maternal smoking during pregnancy, social class at birth, breastfed, household crowding, disability, tenure of accommodation, amenity score; †sum of all eight indicators of neglect; ‡sum of seven indicators excluding neglected appearance; ≠sum of all seven household dysfunction; §sum of all eight indicators of neglect and seven household dysfunction measures at age 7y; ± sum of seven indicators of neglect (excluding neglected appearance) and seven household dysfunction measures at age 7y and §latent class model includes all fifteen child maltreatment measures collected at ages 7y and 45y. ^ap<0.05; ^bp<0.01; ^cp<0.001.

Appendix 4.10: Summary of proportion of participants with information on potential confounding factors by adverse childhood experiences

Adverse childhood experiences	Information on potential confounding factors (%)†					
	Males			Females		
	n	Missing	Complete	n	Missing	Complete
<i>Child abuse</i>						
Psychological abuse	383	9.7	7.7*	546	15.1	10.2*
Physical abuse	275	7.0	5.5*	288	8.8	5.0*
Sexual abuse	22	0.7	0.4	127	4.5	2.0*
Witnessed abuse	205	5.5	4.0*	355	10.4	6.4*
<i>Child neglect; 45y</i>						
I was neglected	83	2.7	1.4*	165	4.6	3.1*
Unaffectionate mother	86	2.5	1.6*	241	6.0	4.8
Unaffectionate father	469	11.4	9.6	382	9.7	7.5*
<i>Indicators of neglect; 7y</i>						
Mother hardly reads	1,195	18.6	16.2*	1,051	16.8	14.9
Father hardly reads	2,012	32.9	28.1*	1,838	28.8	27.4
Mother hardly any outings	136	2.9	1.6*	88	2.1	1.1*
Father hardly any outings	399	7.5	5.3*	415	9.5	5.3*
Mother little in interest education	1,138	20.7	13.8*	975	19.1	12.1*
Father little interest in education	1,184	20.7	14.7*	1,028	19.3	13.0*
Low parental aspirations	316	6.3	3.8*	291	5.4	3.9*
Neglected appearance	346	9.8	6.0*	239	7.4	3.7*
<i>Maltreatment classes‡</i>						
None maltreatment	2,111	75.2	83.9	2,223	69.8	81.0
Neglected 'only'	277	17.1	9.3	302	15.9	9.5
Abused & neglected	178	7.7	6.8*	295	14.3	9.6*
<i>Household dysfunction; 7y</i>						
Domestic tension	393	8.2	4.7*	342	6.9	4.4*
Alcoholism	62	1.3	0.7*	63	1.7	0.7*
Family member mental health problems	330	7.2	3.9*	325	6.8	4.1*
Contact with probation officer	119	3.0	1.6*	124	3.6	1.6*
Contact with children's department/charity	320	10.9	3.1*	277	9.6	2.8*
In care	155	4.7	1.2*	138	4.1	1.2*
Parents divorced	295	6.9	3.6*	262	6.4	3.3*

†Potential confounding factors include parental height, birth weight, prematurity, maternal smoking during pregnancy, social class at birth, breastfed and household crowding, major disability, tenure of accommodation and amenity score at age 7y; Δsum of all eight indicators of neglect at age 7y; ±latent class model includes all fifteen child maltreatment measures collected at ages 7y and 45y; ‡sum of all seven household dysfunction measures at age 7y. *p<0.05

Appendix 5: Additional information for Chapter 6

Appendix 5.1: Adjusted estimated effects (SE) of child maltreatment (reported at age 45y) on continuous markers of pubertal development; males

Adverse childhood experiences	Testicular ¹ ; 11y	Pubic hair ¹ ; 11y	Facial hair; 16y ²	Voice change [#]
<i>Child maltreatment; 45y (n=3,073-3,489)</i>				
Psychological abuse	0.04 (0.05)	0.00 (0.04)	0.05 (0.04)	-0.10 (0.07)
Physical abuse	0.02 (0.06)	-0.01 (0.04)	0.01 (0.05)	0.08 (0.09)
Sexual abuse	-0.05 (0.20)	0.18 (0.16)	-0.05 (0.15)	-0.26 (0.27)
Witnessed abuse	0.01 (0.06)	0.01 (0.05)	0.06 (0.06)	0.07 (0.10)
I was neglected	-0.20 ^a (0.10)	-0.18 ^a (0.08)	-0.02 (0.10)	0.04 (0.16)
Mother unaffectionate	-0.06 (0.10)	0.07 (0.08)	0.16 (0.09)	-0.07 (0.15)
Father unaffectionate	-0.02 (0.04)	0.02 (0.03)	-0.02 (0.04)	-0.06 (0.07)
<i>Indicators of neglect; 7y</i>				
Mother hardly reads (n=4,771-5,634)	-0.02 (0.03)	0.00 (0.02)	0.00 (0.02)	0.10 ^a (0.04)
Father hardly reads (n=4,629-5,463)	0.00 (0.02)	-0.01 (0.02)	-0.02 (0.02)	0.12 ^c (0.03)
Mother hardly any outings (n=4,792-5,658)	-0.04 (0.08)	-0.15 ^a (0.06)	-0.03 (0.07)	0.02 (0.12)
Father hardly any outings (n=4,659-5,495)	0.05 (0.05)	0.04 (0.04)	-0.02 (0.04)	0.17 ^b (0.07)
Mother little interest in education (n=4,863-5,726)	-0.02 (0.03)	-0.05 ^a (0.02)	-0.09 ^c (0.03)	0.07 (0.04)
Father little interest in education (n=4,849-5,710)	-0.03 (0.03)	-0.02 (0.02)	-0.08 ^c (0.03)	-0.01 (0.04)
Low parental aspirations (n=4,823-5,697)	0.03 (0.05)	0.00 (0.04)	-0.03 (0.05)	0.06 (0.08)
Neglected appearance (n=3,362-3,928)	-0.03 (0.05)	-0.07 (0.04)	-0.12 ^b (0.05)	0.04 (0.08)

Adverse childhood experiences	Testicular ¹ ; 11y	Pubic hair ¹ ; 11y	Facial hair; 16y ²	Voice change [‡]
Neglect score (range 0-8)† (n=3,087-3,613)	-0.00 (0.01)	-0.01 (0.01)	-0.02 ^a (0.01)	0.04 (0.02)
Neglect score (range 0-7)‡ (n=5,271-4,465)	-0.00 (0.01)	-0.01 (0.01)	-0.02 ^a (0.01)	0.04 ^b (0.01)
<i>Maltreatment classes[‡] (n=2,310-2,681)</i>				
Neglect 'only'	-0.01 (0.04)	0.00 (0.03)	-0.07 (0.03)	0.05 (0.05)
Abuse & neglect	0.06 (0.06)	0.05 (0.05)	-0.01 (0.06)	0.07 (0.10)
<i>Household dysfunction; 7y</i>				
Domestic tension (n=4,808-5,679)	-0.01 (0.05)	-0.06 (0.04)	-0.05 (0.04)	0.16 ^a (0.07)
Alcoholism (n=4,808-5,679)	-0.01 (0.11)	-0.07 (0.09)	-0.35 ^c (0.10)	0.18 (0.17)
Mental health problems (n=4,808-5,680)	0.02 (0.05)	0.01 (0.04)	-0.03 (0.04)	0.01 (0.07)
Contact probation officer (n=4,305-5,122)	0.05 (0.08)	-0.11 (0.07)	0.02 (0.08)	-0.11 (0.12)
Contact children's department (n=4,471-5,304)	0.00 (0.05)	-0.02 (0.04)	-0.11 ^b (0.05)	-0.04 (0.08)
In care (n=4,993-5,870)	-0.03 (0.07)	0.05 (0.06)	-0.19 ^c (0.06)	0.02 (0.11)
Parental divorce (n=4,589-5,454)	-0.02 (0.05)	-0.03 (0.04)	-0.08 (0.05)	0.01 (0.08)
Continuous household dysfunction score ^Δ (n=4,218-5,037)	0.01 (0.02)	-0.01 (0.01)	-0.04 ^a (0.02)	0.02 (0.03)
Adversity score (range 0-15) ∞ (n=2,741-3,223)	0.00 (0.01)	-0.00 (0.01)	-0.02 ^a (0.01)	0.04 ^b (0.01)
Adversity score (range 0-14) α (n=3,940-4,691)	0.01 (0.01)	-0.00 (0.01)	-0.02 (0.01)	0.03 (0.02)

Values are mean differences in ¹Tanner score (1to5), ²rating (absent to adult) or [‡]age (in year); SE in parenthesis. Adjusted models include age pubertal measure was recorded, ethnicity, social class at birth and household crowding. †sum of all eight indicators (range 0-8); ‡ sum of seven indicators of neglect excluding neglected appearance (range 0-7); [‡]latent class model includes all fifteen child maltreatment measures collected at ages 7y and 45y, 'non-maltreated' used as reference category; ^Δsum of all seven household dysfunction measures at age 7y (range 0-7); ∞ sum of all eight indicators of neglect and seven household dysfunction measures at age 7y and; α sum of seven indicators of neglect (excluding neglected appearance) and seven household dysfunction measures. ^ap<0.05; ^bp<0.01; ^cp<0.001.

Appendix 5.2: Adjusted estimated effects (SE) of adverse childhood experiences on continuous markers of pubertal development; females

Adverse childhood experiences	Breast ¹ ; 11y	Pubic hair ¹ ; 11y	Age of menarche ²
<i>Child maltreatment; 45y (n=2,405-3,378)</i>			
Psychological abuse	0.00 (0.05)	0.00 (0.05)	0.14 (0.09)
Physical abuse	0.07 (0.07)	0.04 (0.07)	0.05 (0.11)
Sexual abuse	0.06 (0.11)	-0.03 (0.11)	-0.16 (0.19)
Witnessed abuse	0.07 (0.06)	0.01 (0.06)	0.12 (0.11)
I was neglected	0.11 (0.09)	0.03 (0.09)	0.12 (0.15)
Mother unaffectionate	0.11 (0.07)	0.06 (0.07)	-0.15 (0.13)
Father unaffectionate	-0.02 (0.06)	-0.02 (0.06)	0.20 ^a (0.10)
<i>Indicators of neglect; 7y</i>			
Mother hardly reads (n=3,434-5,133)	-0.05 (0.04)	0.00 (0.04)	0.09 (0.06)
Father hardly reads (n=3,316-4,968)	-0.04 (0.03)	-0.05 (0.03)	0.02 (0.05)
Mother hardly any outings (n=3,451-5,156)	-0.10 (0.12)	-0.14 (0.11)	0.15 (0.23)
Father hardly any outings (n=3,349-5,010)	0.05 (0.06)	0.02 (0.06)	0.08 (0.10)
Mother little interest in education (n=3,492-5,198)	-0.14 ^c (0.04)	-0.11 ^c (0.04)	0.29 ^c (0.07)
Father little interest in education (n=3,485-5,186)	-0.09 ^c (0.04)	-0.05 (0.04)	0.20 ^c (0.07)
Low parental aspirations (n=3,458-5,166)	0.00 (0.07)	-0.05 (0.07)	-0.04 (0.13)
Neglected appearance (n=2,576-3,807)	-0.36 ^c (0.08)	-0.28 ^c (0.08)	0.37 ^b (0.14)
Neglect score (range 0-8) [†] (n=2,376-3,508)	-0.04 ^a (0.02)	-0.03 ^a (0.01)	0.04 (0.03)
Neglect score (range 0-7) [‡] (n=4,182-3,227)	-0.03 ^a (0.01)	-0.03 ^a (0.01)	0.06 ^b (0.02)
<i>Maltreatment classes[#] (n=2,001-2,765)</i>			
Neglect 'only'	-0.05 (0.04)	0.00 (0.05)	0.13 (0.07)
Abuse & neglect	0.11 (0.06)	0.04 (0.06)	0.07 (0.10)

Adverse childhood experiences	Breast ¹ ; 11y	Pubic hair ¹ ; 11y	Age of menarche ²
<i>Household dysfunction; 7y</i>			
Domestic tension (n=3,456-5,159)	-0.03 (0.06)	-0.10 (0.06)	-0.07 (0.11)
Alcoholism (n=3,455-5,158)	-0.15 (0.14)	-0.25 (0.14)	0.16 (0.23)
Mental health problems (n=3,456-5,161)	-0.05 (0.06)	-0.10 (0.06)	-0.02 (0.11)
Contact probation officer (n=3,125-4,650)	-0.12 (0.10)	-0.18 (0.10)	-0.16 (0.20)
Contact children's department (n=3,245-4,821)	-0.21 ^b (0.08)	-0.18 ^a (0.08)	0.23 (0.15)
In care (n=3,564-5,329)	-0.30 ^b (0.11)	-0.31 ^b (0.11)	-0.04 (0.22)
Parental divorce (n=3,326-4,951)	0.04 (0.07)	-0.03 (0.07)	-0.03 (0.14)
Continuous household dysfunction score ^Δ (n=3,063-4,556)	-0.04 (0.02)	-0.06 ^b (0.02)	0.00 (0.04)
Adversity score ∞ (range 0-15) (n=2,124-3,317)	-0.03 ^a (0.01)	-0.03 ^a (0.01)	0.03 (0.02)
Adversity score α (range 0-14) (n=2,867-4,257)	-0.03 ^a (0.01)	-0.03 ^a (0.01)	0.05 ^a (0.02)

Values are mean differences in ¹Tanner score (1to5), or ²age (in year); SE in parenthesis. Adjusted models include age pubertal measure was recorded, ethnicity, social class at birth, household crowding and maternal age of menarche. \dagger sum of all eight indicators (range 0-8); \ddagger sum of seven indicators of neglect excluding neglected appearance (range 0-7); latent class model includes all fifteen child maltreatment measures collected at ages 7y and 45y, 'non-maltreated' used as reference category; \wedge sum of all seven household dysfunction measures at age 7y (range 0-7); ∞ sum of all eight indicators of neglect and seven household dysfunction measures at age 7y and; α sum of seven indicators of neglect (excluding neglected appearance) and seven household dysfunction measures. ^ap<0.05; ^bp<0.01; ^cp<0.001

Appendix 5.3: Estimated effects (RRR) of adverse childhood experiences on testicular development at age 11y and pubic hair growth using all available data (reference category ‘intermediate’ development); males¹

Adverse childhood experiences	Testicular [†] ; 11y			Pubic hair [‡] ; 11 & 16y		
	n	Late (1)	Early (3-5)	n	Late	Early
<i>Child maltreatment; 45y</i>						
Psychological abuse		0.90 (0.69, 1.17)	1.14 (0.82, 1.57)		1.24 (0.96, 1.62)	1.26 (0.90, 1.78)
Physical abuse		0.89 (0.65, 1.22)	1.17 (0.81, 1.71)		1.25 (0.92, 1.71)	1.26 (0.84, 1.88)
Sexual abuse		3.02 (0.80, 11.39)	3.63 (0.81, 16.26)		1.67 (0.49, 5.73)	2.58 (0.64, 10.37)
Witnessed abuse		1.22 (0.85, 1.74)	1.60 ^a (1.05, 2.44)		1.07 (0.76, 1.50)	0.93 (0.57, 1.49)
I was neglected		1.29 (0.77, 2.19)	0.79 (0.36, 1.74)		1.51 (0.90, 2.53)	0.42 (0.14, 1.21)
Unaffectionate mother		0.87 (0.51, 1.49)	0.74 (0.35, 1.57)		1.32 (0.76, 2.27)	1.10 (0.52, 2.32)
Unaffectionate father	3,718	1.13 (0.89, 1.44)	1.27 (0.94, 1.71)	3,687	1.05 (0.82, 1.33)	1.05 (0.76, 1.43)
<i>Indicators of neglect; 7y</i>						
Mother hardly reads	5,637	1.13 (0.97, 1.32)	1.03 (0.84, 1.27)	5,606	1.02 (0.87, 1.19)	0.95 (0.76, 1.17)
Father hardly reads	5,465	1.08 (0.95, 1.23)	1.03 (0.87, 1.23)	5,434	1.08 (0.95, 1.23)	0.94 (0.78, 1.12)
Mother hardly any outings	5,661	1.71 ^a (1.07, 2.74)	1.44 (0.78, 2.65)	5,630	1.73 ^a (1.09, 2.75)	0.89 (0.43, 1.85)
Father hardly any outings	5,497	1.17 (0.90, 1.53)	1.37 (0.99, 1.90)	5,465	1.15 (0.88, 1.50)	1.22 (0.86, 1.72)
Mother little interest in education	5,748	1.11 (0.94, 1.30)	0.97 (0.78, 1.21)	5,713	1.31 ^c (1.12, 1.54)	0.88 (0.70, 1.12)
Father little interest in education	5,732	1.20 ^a (1.03, 1.41)	1.07 (0.87, 1.32)	5,697	1.29 ^c (1.11, 1.51)	0.90 (0.72, 1.13)
Low parental aspirations	5,701	0.92 (0.68, 1.24)	0.99 (0.68, 1.46)	5,670	1.13 (0.84, 1.51)	0.78 (0.50, 1.22)
Neglected appearance	3,942	1.17 (0.88, 1.54)	1.03 (0.72, 1.50)	3,914	1.45 ^b (1.10, 1.92)	0.82 (0.54, 1.26)
Neglect score [#] (range 0-8)	Continuous		1.06 ^a (1.00, 1.12)	1.01 (0.94, 1.09)	1.08 ^b (1.02, 1.14)	0.95 (0.88, 1.03)
	Categorical	1	1.07 (0.89, 1.30)	0.95 (0.73, 1.22)	1.00 (0.83, 1.21)	1.11 (0.86, 1.42)
		2	1.14 (0.92, 1.40)	1.20 (0.91, 1.57)	1.05 (0.85, 1.30)	0.99 (0.75, 1.32)
		3	1.02 (0.74, 1.41)	1.12 (0.75, 1.66)	1.03 (0.76, 1.41)	0.79 (0.51, 1.23)
		4+	3,614	1.39 ^a (1.00, 1.92)	0.92 (0.58, 1.47)	3,590

Adverse childhood experiences	Testicular [†] ; 11y			Pubic hair [‡] ; 11 & 16y		
	n	Late (1)	Early (3-5)	n	Late	Early
Continuous Neglect score [¥] (range 0-7)	Continuous		1.07 ^a (1.01, 1.12)	1.03 (0.96, 1.10)	1.08 ^a (1.02, 1.13)	0.96 (0.90, 1.04)
	1		1.06 (0.91, 1.24)	1.04 (0.85, 1.28)	1.00 (0.86, 1.17)	0.98 (0.80, 1.21)
	2		1.14 (0.96, 1.35)	0.99 (0.79, 1.25)	1.05 (0.89, 1.25)	0.88 (0.70, 1.12)
	3		1.11 (0.85, 1.47)	1.46 ^b (1.05, 2.02)	1.18 (0.90, 1.54)	1.00 (0.70, 1.45)
	4+	5,273	1.34 (0.99, 1.81)	0.89 (0.57, 1.37)	5,242	1.66 ^c (1.22, 2.25)
						0.80 (0.49, 1.30)
<i>Household dysfunction; 7y</i>						
Domestic tension	5,684	1.13 (0.87, 1.47)	1.14 (0.81, 1.60)	5,653	1.18 (0.91, 1.52)	
	Alcoholism	5,684	0.90 (0.48, 1.67)	0.84 (0.36, 1.96)	5,653	1.75 (0.93, 3.28)
	Mental health problems	5,685	1.10 (0.82, 1.47)	1.17 (0.80, 1.69)	5,654	0.95 (0.71, 1.26)
	Contact probation officer	5,125	1.41 (0.87, 2.28)	1.57 (0.87, 2.82)	5,098	1.24 (0.79, 1.94)
	Contact children's department	5,308	1.21 (0.90, 1.61)	1.15 (0.79, 1.68)	5,278	1.19 (0.90, 1.58)
	In care	5,894	1.08 (0.72, 1.62)	0.95 (0.55, 1.65)	5,859	0.80 (0.54, 1.19)
	Parental divorce	5,459	1.10 (0.82, 1.49)	1.09 (0.74, 1.61)	5,430	1.54 ^b (1.14, 2.08)
	Household dysfunction score [¥] (range 0-7) [¥]	Continuous		1.02 (0.93, 1.12)	1.05 (0.97, 1.18)	0.91 (0.79, 1.05)
	1		1.14 (0.88, 1.48)	1.23 (0.89, 1.69)	1.21 (0.94, 1.57)	1.11 (0.79, 1.58)
	2		1.17 (0.83, 1.63)	0.76 (0.47, 1.24)	1.12 (0.80, 1.57)	0.79 (0.48, 1.30)
	3+	5,040	0.86 (0.54, 1.36)	1.30 (0.77, 2.20)	5,013	1.09 (0.71, 1.67)
Adversity score [∞] (range 0-15)		3,223	1.03 (0.98, 1.09)	0.98 (0.92, 1.05)	3,202	1.07 ^a (1.02, 1.13)
Adversity score ^α (range 0-14)		4,693	1.04 (1.00, 1.09)	1.01 (0.95, 1.07)	4,666	1.07 ^a (1.02, 1.12)
						0.98 (0.92, 1.04)

[†]All values are relative risk ratio (RRR); 95% CI in parenthesis, [†]'stage 2' and [‡]'normal' used as reference categories. Unadjusted models include age pubertal measure was recorded; [¥]sum of all eight indicators (range 0-8); [¥] sum of seven indicators of neglect, excluding neglected appearance (range 0-7); [¥]sum of all seven household dysfunction measures at age 7y; [∞]sum of all eight indicators of neglect and seven household dysfunction measures (range 0-15) and ^αsum of seven indicators of neglect, excluding neglected appearance, and seven household dysfunction variables (range 0-14); ^ap<0.05; ^bp<0.01; ^cp<0.001.

Appendix 5.4: Estimated effects (RRR) of adverse childhood experiences on facial hair growth at age 16y and age of voice change using all available data (reference category ‘intermediate’ development, or onset of voice change age 12-14y); males¹

Adverse childhood experiences	Facial hair [†] ; 16y			Voice change [‡]		
	n	Late (absent)	Early (adult)	n	Late (≥ 15)	Early (≤ 12)
<i>Child maltreatment; 45y</i>						
Psychological abuse		1.00 (0.76, 1.31)	1.39 (0.90, 2.14)		1.13 (0.87, 1.47)	1.37 (0.92, 2.05)
Physical abuse		0.95 (0.69, 1.29)	0.96 (0.55, 1.68)		1.22 (0.90, 1.64)	0.91 (0.53, 1.56)
Sexual abuse		1.47 (0.55, 3.93)	1.70 (0.36, 8.08)		0.77 (0.29, 2.08)	1.00 (0.22, 4.66)
Witnessed abuse		0.88 (0.61, 1.27)	1.56 (0.91, 2.69)		1.17 (0.83, 1.66)	0.94 (0.51, 1.72)
I was neglected		1.04 (0.58, 1.86)	1.22 (0.47, 3.20)		1.03 (0.61, 1.76)	1.00 (0.41, 2.45)
Unaffectionate mother		0.63 (0.34, 1.16)	1.70 (0.78, 3.71)		0.94 (0.55, 1.61)	0.98 (0.40, 2.38)
Unaffectionate father	3,382	1.13 (0.89, 1.45)	1.24 (0.81, 1.89)	3,635	0.90 (0.71, 1.14)	0.92 (0.62, 1.37)
<i>Indicators of neglect; 7y</i>						
Mother hardly reads	4,773	0.98 (0.83, 1.15)	0.89 (0.66, 1.19)	5,243	1.27 ^c (1.09, 1.49)	0.94 (0.72, 1.23)
Father hardly reads	4,631	1.10 (0.96, 1.27)	1.01 (0.80, 1.29)	5,081	1.37 ^c (1.20, 1.55)	1.09 (0.88, 1.36)
Mother hardly any outings	4,794	1.03 (0.65, 1.62)	0.65 (0.26, 1.64)	5,266	1.15 (0.74, 1.78)	1.17 (0.58, 2.35)
Father hardly any outings	4,661	1.29 (0.99, 1.69)	1.40 (0.91, 2.16)	5,115	1.55 ^b (1.20, 2.00)	1.24 (0.81, 1.89)
Mother little interest in education	4,885	1.22 (1.03, 1.44)	0.65 (0.46, 0.92)	5,374	1.22 ^a (1.04, 1.43)	1.21 (0.94, 1.56)
Father little interest in education	4,871	1.19 ^a (1.01, 1.40)	0.59 (0.41, 0.83)	5,360	1.12 (0.95, 1.31)	1.29 ^a (1.01, 1.65)
Low parental aspirations	4,826	1.30 (0.96, 1.76)	1.26 (0.75, 2.11)	5,300	1.29 (0.97, 1.72)	1.28 (0.81, 2.02)
Neglected appearance	3,374	1.42 ^a (1.06, 1.90)	0.72 (0.39, 1.34)	3,694	1.19 (0.90, 1.57)	1.12 (0.72, 1.74)
Neglect score \neq (range 0-8)	Continuous		1.08 ^b (1.02, 1.15)	0.93 (0.83, 1.04)	1.11 ^c (1.05, 1.18)	1.03 (0.94, 1.13)
	1		0.84 (0.68, 1.03)	1.07 (0.77, 1.49)	1.36 ^b (1.13, 1.65)	0.91 (0.66, 1.27)
	2		1.00 (0.81, 1.25)	1.08 (0.75, 1.56)	1.21 (0.98, 1.48)	1.01 (0.73, 1.41)
	3		1.05 (0.76, 1.46)	0.59 (0.29, 1.20)	1.33 (0.96, 1.84)	1.82 ^b (1.17, 2.83)
	4+	3,088	1.75 ^b (1.25, 2.46)	0.63 (0.29, 1.41)	3,379	1.68 ^c (1.22, 2.31)

Adverse childhood experiences	Facial hair [†] ; 16y			Voice change [‡]		
	n	Late (absent)	Early (adult)	n	Late (≥ 15)	Early (≤ 12)
Neglect score \mathbb{Y} (range 0-7)	Continuous		1.07 ^a (1.02, 1.13)	0.91 (0.83, 1.01)	1.12 ^b (1.07, 1.18)	1.06 (0.98, 1.15)
	1		0.86 (0.73, 1.02)	1.02 (0.78, 1.34)	1.20* (1.03, 1.40)	0.82 (0.63, 1.09)
	Categorical	2	1.13 (0.95, 1.35)	0.88 (0.64, 1.22)	1.16 (0.98, 1.37)	1.10 (0.84, 1.44)
	3		1.05 (0.79, 1.40)	0.74 (0.43, 1.27)	1.41 ^b (1.07, 1.86)	1.87 ^b (1.27, 2.75)
	4+	4,467	1.59 ^b (1.17, 2.15)	0.55 (0.26, 1.15)	4,911	1.78 ^c (1.33, 2.40)
<i>Household dysfunction; 7y</i>						
Domestic tension		4,811	1.12 (0.85, 1.49)	0.78 (0.45, 1.35)	5,285	1.49 ^c (1.14, 1.93)
Alcoholism		4,811	3.34 ^c (1.64, 6.81)	0.55 (0.07, 4.31)	5,284	1.46 (0.75, 2.82)
Mental health problems		4,811	0.86 (0.64, 1.15)	0.43 (0.22, 0.85)	5,286	1.27 (0.96, 1.67)
Contact probation officer		4,307	1.06 (0.63, 1.76)	1.27 (0.56, 2.88)	4,711	0.97 (0.61, 1.55)
Contact children's department		4,473	1.54 ^c (1.14, 2.06)	0.96 (0.54, 1.71)	4,905	1.15 (0.86, 1.53)
In care		5,017	1.58 ^a (1.05, 2.39)	0.42 (0.13, 1.35)	5,511	1.13 (0.76, 1.69)
Parental divorce		4,592	1.27 (0.92, 1.75)	0.83 (0.44, 1.57)	5,041	1.08 (0.80, 1.46)
Household dysfunction score (range 0-7) $^{\mathbb{Y}}$	Continuous		1.13 ^a (1.00, 1.24)	0.85 (0.68, 1.07)	1.10 (1.00, 1.22)	1.11 (0.96, 1.29)
	1		1.37 ^a (1.05, 1.78)	0.79 (0.47, 1.35)	1.12 (0.87, 1.45)	1.51 ^a (1.04, 2.20)
	Categorical	2	1.24 (0.86, 1.78)	0.96 (0.49, 1.88)	1.21 (0.86, 1.71)	0.92 (0.50, 1.69)
	3+	4,220	1.38 (0.88, 2.18)	0.46 (0.14, 1.49)	4,614	1.31 (0.84, 2.06)
Adversity score ∞ (range 0-15)		2,742	1.07 ^a (1.01, 1.13)	0.93 (0.84, 1.04)	2,984	1.09 ^a (1.03, 1.15)
Adversity score a (range 0-14)		3,942	1.06 ^a (1.01, 1.11)	0.91 (0.83, 1.00)	4,314	1.10 ^a (1.05, 1.16)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis; [†]'sparse' and [‡]age 12-14y used as reference categories. Unadjusted models include age pubertal measure was recorded; \mathbb{Y} sum of all eight indicators (range 0-8); \mathbb{Y} sum of seven indicators of neglect, excluding neglected appearance (range 0-7); $^{\mathbb{Y}}$ sum of all seven household dysfunction measures at age 7y; ∞ sum of all eight indicators of neglect and seven household dysfunction measures (range 0-15) and a sum of seven indicators of neglect, excluding neglected appearance, and seven household dysfunction variables (range 0-14); ^ap<0.05; ^bp<0.01; ^cp<0.001.

Appendix 5.5: Estimated effects (SE) of adverse childhood experiences on continuous markers of pubertal development using all available data; males

Adverse childhood experiences	Testicular ¹ ; 11y	Pubic hair ¹ ; 11y	Facial hair; 16y ²	Voice change [‡]
<i>Child maltreatment; 45y (n=3,382-3,718)</i>				
Psychological abuse	0.05 (0.05)	0.01 (0.04)	0.04 (0.04)	-0.09 (0.07)
Physical abuse	0.06 (0.05)	0.00 (0.04)	0.01 (0.05)	0.09 (0.08)
Sexual abuse	-0.05 (0.19)	0.20 (0.15)	-0.04 (0.14)	-0.21 (0.26)
Witnessed abuse	0.03 (0.06)	0.02 (0.05)	0.09 (0.05)	0.03 (0.09)
I was neglected	-0.14 (0.09)	-0.13 (0.07)	0.01 (0.08)	-0.01 (0.14)
Mother unaffectionate	0.00 (0.09)	0.16 ^a (0.07)	0.18 ^b (0.08)	-0.04 (0.14)
Father unaffectionate	0.01 (0.04)	0.04 (0.03)	-0.01 (0.04)	-0.07 (0.06)
<i>Indicators of neglect; 7y</i>				
Mother hardly reads (n=4,773-5,637)	-0.03 (0.03)	-0.01 (0.02)	-0.01 (0.02)	0.10 ^a (0.04)
Father hardly reads (n=4,631-5,465)	-0.01 (0.02)	-0.01 (0.02)	-0.03 (0.02)	0.12 ^c (0.03)
Mother hardly any outings (n=4,794-5,661)	-0.06 (0.08)	-0.16 ^b (0.06)	-0.05 (0.07)	0.02 (0.12)
Father hardly any outings (n=4,661-5,497)	0.03 (0.05)	0.02 (0.04)	-0.03 (0.04)	0.16 ^a (0.07)
Mother little interest in education (n=4,885-5,748)	-0.04 (0.03)	-0.06 ^b (0.02)	-0.10 ^c (0.03)	0.05 (0.04)
Father little interest in education (n=4,871-5,732)	-0.05 (0.03)	-0.04 (0.02)	-0.10 ^c (0.02)	-0.02 (0.04)
Low parental aspirations (n=4,826-5,701)	0.02 (0.05)	-0.01 (0.04)	-0.05 (0.05)	0.05 (0.08)
Neglected appearance (n=3,374-3,942)	-0.05 (0.05)	-0.08 ^a (0.04)	-0.13 ^c (0.04)	0.03 (0.07)
Neglect score ≠ (range 0-8) (n=3,088-3,641)	-0.01 (0.01)	-0.01 (0.01)	-0.03 ^a (0.01)	0.04 ^a (0.02)
Neglect score¥ (range 0-7) (n=5,273-4,467)	-0.01 (0.01)	-0.01 (0.01)	-0.03 ^a (0.01)	0.04 ^a (0.01)
<i>Maltreatment classes[‡] (n=2,311-2,681)</i>				
Neglect 'only'	-0.03 (0.03)	-0.01 (0.03)	-0.08 ^a (0.03)	0.03 (0.05)
Abuse & neglect	0.04 (0.06)	0.05 (0.05)	-0.01 (0.06)	0.05 (0.10)

Adverse childhood experiences	Testicular ¹ ; 11y	Pubic hair ¹ ; 11y	Facial hair; 16y ²	Voice change [#]
<i>Household dysfunction; 7y</i>				
Domestic tension (n=4,811-5,684)	-0.02 (0.05)	-0.07 (0.04)	-0.06 (0.04)	0.15 ^a (0.07)
Alcoholism (n=4,811-5,684)	-0.02 (0.11)	-0.07 (0.09)	-0.37 ^c (0.10)	0.17 (0.17)
Mental health problems (n=4,811-5,684)	0.00 (0.05)	0.00 (0.04)	-0.03 (0.04)	0.00 (0.07)
Contact probation officer (n=4,307-5,125)	0.01 (0.08)	-0.13 ^a (0.06)	0.01 (0.07)	-0.11 (0.12)
Contact children's department (n=4,473-5,308)	-0.03 (0.05)	-0.03 (0.04)	-0.12 ^b (0.04)	-0.05 (0.08)
In care (n=5,017-5,894)	-0.05 (0.07)	0.04 (0.06)	-0.19 ^a (0.06)	0.01 (0.11)
Parental divorce (n=4,592-5,459)	-0.02 (0.05)	-0.03 (0.04)	-0.08 (0.05)	-0.01 (0.08)
Household dysfunction score (range 0-7) [¥] (n=4,220-5,040)	0.00 (0.02)	-0.01 (0.01)	-0.05 ^b (0.01)	0.01 (0.03)
Adversity score (range 0-15) ∞ (n=2,742-3,223)	-0.01 (0.01)	-0.01 (0.01)	-0.02 ^a (0.01)	0.03 ^a (0.01)
Adversity score (range 0-14) α (n=3,942-4,693)	-0.01 (0.01)	-0.01 (0.01)	-0.02 ^a (0.01)	0.03 ^a (0.01)

Values are mean differences in ¹Tanner score (1to5), ²rating (absent to adult) or [#]age (in year); SE in parenthesis. Unadjusted models include age pubertal measure was recorded; $\#$ sum of all eight indicators (range 0-8); ∞ sum of seven indicators of neglect, excluding neglected appearance (range 0-7); α sum of all seven household dysfunction measures at age 7y; ∞ sum of all eight indicators of neglect and seven household dysfunction measures (range 0-15) and α sum of seven indicators of neglect, excluding neglected appearance, and seven household dysfunction variables (range 0-14); ^ap<0.05; ^bp<0.01; ^cp<0.001.

Appendix 5.6: Estimated effects (RRR) of adverse childhood experiences on markers of pubertal development using all available data (reference category ‘intermediate’ development, or age of menarche 12-13y); females¹

Adverse childhood experiences	Breast [†] ; 11y			Pubic hair [†] ; 11y			Age of menarche [‡]		
	n	Late (1)	Early (3-5)	n	Late (1)	Early (3-5)	n	Late (≥ 14)	
<i>Child maltreatment; 45y</i>									
Psychological abuse		1.15 (0.91, 1.46)	1.05 (0.82, 1.36)		1.10 (0.88, 1.39)	1.07 (0.81, 1.40)		1.45 ^c (1.13, 1.87)	
Physical abuse		1.06 (0.76, 1.46)	1.12 (0.80, 1.58)		1.16 (0.84, 1.60)	1.31 (0.91, 1.89)		1.24 (0.88, 1.74)	
Sexual abuse		1.15 (0.71, 1.88)	0.94 (0.54, 1.62)		1.38 (0.85, 2.24)	1.13 (0.63, 2.05)		1.79 ^a (1.04, 3.09)	
Witnessed abuse		0.99 (0.74, 1.33)	1.01 (0.74, 1.38)		1.17 (0.87, 1.55)	1.18 (0.85, 1.66)		1.52 ^b (1.11, 2.08)	
I was neglected		0.95 (0.62, 1.44)	1.11 (0.72, 1.72)		0.91 (0.61, 1.36)	0.99 (0.62, 1.58)		1.37 (0.89, 2.10)	
Unaffectionate mother		0.92 (0.66, 1.30)	1.03 (0.72, 1.46)		1.03 (0.74, 1.42)	1.10 (0.75, 1.62)		1.00 (0.68, 1.48)	
Unaffectionate father	3,802	0.99 (0.75, 1.30)	0.87 (0.65, 1.18)	3,776	1.17 (0.90, 1.52)	1.00 (0.73, 1.38)	3,010	1.47 ^b (1.09, 1.99)	
<i>Indicators of neglect; 7y</i>									
Mother hardly reads	5,487	1.31 ^c (1.11, 1.56)	1.07 (0.88, 1.30)	5,455	1.17 (0.99, 1.39)	1.08 (0.88, 1.32)	4,023	1.23 ^a (1.01, 1.50)	
Father hardly reads	5,320	1.04 (0.90, 1.20)	0.96 (0.82, 1.12)	5,290	1.13 (0.98, 1.30)	1.03 (0.87, 1.21)	3,899	1.23 ^b (1.05, 1.45)	
Mother hardly any outings	5,510	1.04 (0.62, 1.73)	0.6 (0.32, 1.15)	5,478	1.57 (0.93, 2.66)	0.88 (0.43, 1.79)	4,043	1.33 (0.68, 2.60)	
Father hardly any outings	5,361	1.17 (0.89, 1.52)	1.04 (0.78, 1.39)	5,330	1.06 (0.82, 1.37)	0.94 (0.69, 1.29)	3,930	1.26 (0.92, 1.72)	
Mother little interest in education	5,588	1.14 (0.95, 1.36)	0.73* (0.59, 0.90)	5,553	1.11 (0.93, 1.32)	0.78* (0.62, 0.97)	4,215	1.57* (1.28, 1.93)	
Father little interest in education	5,576	1.14 (0.95, 1.35)	0.78* (0.64, 0.96)	5,542	1.18 (0.99, 1.40)	0.91* (0.74, 1.13)	4,113	1.49* (1.22, 1.82)	
Low parental aspirations	5,542	1.23 (0.89, 1.69)	1.12 (0.79, 1.59)	5,510	1.03 (0.76, 1.39)	0.87 (0.59, 1.26)	4,065	1.46* (1.01, 2.11)	
Neglected appearance	4,100	1.73* (1.24, 2.42)	0.58 (0.36, 0.92)	4,081	1.61* (1.16, 2.25)	0.52 (0.30, 0.87)	3,038	1.58* (1.08, 2.33)	
Neglect score [≠] (range 0-8)	Continuous		1.10* (1.03, 1.17)	0.94 (0.87, 1.01)		1.08* (1.01, 1.15)	0.95 (0.88, 1.03)	1.16* (1.08, 1.25)	
	1		1.18 (0.97, 1.44)	0.93 (0.75, 1.16)		1.00 (0.82, 1.20)	0.84 (0.67, 1.06)	1.22 (0.97, 1.53)	
	2		1.03 (0.83, 1.29)	0.97 (0.77, 1.22)		1.09 (0.88, 1.35)	1.01 (0.78, 1.30)	1.42* (1.10, 1.83)	
	3		1.55* (1.08, 2.23)	0.94 (0.62, 1.43)		1.32 (0.93, 1.88)	0.90 (0.58, 1.40)	1.58* (1.03, 2.41)	
	4+	3,744	1.53* (1.05, 2.23)	0.61 (0.37, 1.00)	3,727	1.39 (0.96, 2.03)	0.68 (0.40, 1.15)	2,762	1.76* (1.12, 2.77)
								1.16 (0.64, 2.11)	

Adverse childhood experiences	n	Breast [†] ; 11y		Pubic hair [†] ; 11y		Age of menarche [‡]			
		Late (1)	Early (3-5)	n	Late (1)	Early (3-5)	n	Late (≥ 14)	Early (≤ 11)
Neglect score (range 0-7) [¥]	Continuous	1.07* (1.01, 1.13)	0.95 (0.89, 1.01)	5,136	1.06* (1.01, 1.12)	0.97 (0.90, 1.04)	3,770	1.04 (0.96, 1.13)	1.15* (1.08, 1.23)
	1	1.13 (0.96, 1.34)	0.96 (0.80, 1.15)		1.01 (0.86, 1.18)	0.86 (0.71, 1.05)		0.99 (0.78, 1.26)	1.17 (0.96, 1.42)
	2	1.13 (0.94, 1.36)	1.02 (0.83, 1.24)		1.10 (0.92, 1.31)	0.97 (0.79, 1.21)		1.08 (0.83, 1.41)	1.37* (1.11, 1.70)
	3	1.28 (0.93, 1.75)	0.97 (0.69, 1.38)		1.26 (0.92, 1.71)	1.00 (0.69, 1.45)		1.52* (1.00, 2.31)	1.55* (1.09, 2.23)
Household dysfunction; 7y	4+	1.22 (0.87, 1.71)	0.53* (0.34, 0.84)	5,107	1.33 (0.95, 1.88)	0.77 (0.48, 1.22)	3,770	0.86 (0.48, 1.56)	1.66* (1.10, 2.49)
	Domestic tension	5,530	1.00 (0.75, 1.34)	5,499	1.24 (0.93, 1.64)	1.07 (0.76, 1.51)	4,059	0.95 (0.68, 1.32)	0.98 (0.66, 1.47)
	Alcoholism	5,528	1.19 (0.66, 2.17)	5,496	1.88* (1.02, 3.49)	0.76 (0.31, 1.88)	4,057	0.92 (0.45, 1.86)	0.69 (0.26, 1.80)
	Mental health problems	5,532	1.16 (0.86, 1.55)	5,500	1.27 (0.96, 1.69)	0.88 (0.61, 1.27)	4,061	1.26 (0.90, 1.76)	1.22 (0.82, 1.83)
	Contact probation officer	4,978	1.73* (1.09, 2.75)	4,949	1.40 (0.91, 2.15)	0.66 (0.35, 1.23)	3,670	1.09 (0.60, 2.00)	1.02 (0.48, 2.14)
	Contact children's department	5,172	1.47* (1.07, 2.01)	5,142	1.22 (0.90, 1.65)	0.72 (0.48, 1.09)	3,811	1.29 (0.87, 1.90)	0.87 (0.51, 1.48)
	In care	5,744	1.43 (0.92, 2.21)	5,709	1.14 (0.75, 1.72)	0.43* (0.22, 0.85)	4,229	1.12 (0.64, 1.95)	0.98 (0.48, 1.98)
	Parental divorce	5,303	1.10 (0.79, 1.54)	5,274	1.23 (0.89, 1.70)	1.13 (0.77, 1.67)	3,899	1.16 (0.79, 1.72)	0.95 (0.58, 1.58)
Household dysfunction score (range 0-7) [¥]	Continuous	1.09 (0.99, 1.21)	0.96 (0.85, 1.07)	4,872	1.11* (1.00, 1.22)	0.89 (0.77, 1.01)	3,590	1.04* (1.00, 1.18)	0.99 (0.85, 1.15)
	1	1.15 (0.88, 1.50)	0.87 (0.64, 1.18)		1.17 (0.90, 1.52)	0.88 (0.63, 1.22)		1.09 (0.80, 1.49)	1.00 (0.68, 1.47)
	2	1.53* (1.04, 2.25)	1.03 (0.66, 1.62)		1.10 (0.77, 1.58)	0.67 (0.41, 1.09)		1.72* (1.10, 2.70)	1.36 (0.77, 2.39)
	3+	1.14 (0.71, 1.84)	0.87 (0.51, 1.50)	4,844	1.43 (0.91, 2.26)	0.73 (0.38, 1.38)	3,590	0.79 (0.43, 1.47)	0.74 (0.34, 1.59)
Adversity score [∞] (range 0-15)	3,318	1.08* (1.02, 1.14)	0.95 (0.89, 1.01)	3,303	1.08* (1.02, 1.14)	0.95 (0.88, 1.02)	2,463	1.12* (1.05, 1.20)	1.05 (0.97, 1.14)
Adversity score ^α (range 0-14)	4,531	1.06* (1.01, 1.11)	0.94* (0.88, 0.99)	4,505	1.07* (1.02, 1.12)	0.95 (0.89, 1.01)	3,347	1.02 (0.94, 1.10)	1.12* (1.05, 1.18)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis, [†]'stage 2' and [‡]age 12-13y used as reference categories. Unadjusted models include age pubertal measure was recorded; [¥]sum of all eight indicators (range 0-8); [¥] sum of seven indicators of neglect, excluding neglected appearance (range 0-7); [¥] sum of all seven household dysfunction measures at age 7y; [∞]sum of all eight indicators of neglect and seven household dysfunction measures (range 0-15) and ^αsum of seven indicators of neglect, excluding neglected appearance, and seven household dysfunction variables (range 0-14). * p<0.05

Appendix 5.7: Estimated effects (SE) of adverse childhood experiences on continuous markers of pubertal development using all available data; females

Adverse childhood experiences	Breast ¹ ; 11y	Pubic hair ¹ ; 11y	Age of menarche ²
<i>Child maltreatment; 45y (n=3,010-3,802)</i>			
Psychological abuse	-0.02 (0.05)	-0.01 (0.05)	0.15 (0.08)
Physical abuse	0.04 (0.07)	0.04 (0.07)	0.08 (0.10)
Sexual abuse	-0.07 (0.10)	-0.09 (0.10)	0.05 (0.16)
Witnessed abuse	0.02 (0.06)	0.00 (0.06)	0.20 (0.10)
I was neglected	0.07 (0.08)	0.01 (0.08)	0.20 (0.13)
Mother unaffectionate	0.06 (0.07)	0.02 (0.07)	-0.02 (0.11)
Father unaffectionate	-0.04 (0.06)	-0.03 (0.06)	0.27 ^a (0.09)
<i>Indicators of neglect; 7y</i>			
Mother hardly reads (n=4,023-5,487)	-0.08 ^a (0.04)	-0.02 (0.04)	0.14 ^a (0.06)
Father hardly reads (n=3,899-5,320)	-0.04 (0.03)	-0.05 (0.03)	0.08 (0.05)
Mother hardly any outings (n=4,043-5,510)	-0.13 (0.11)	-0.17 (0.11)	0.38 (0.21)
Father hardly any outings (n=3,930-5,361)	-0.01 (0.05)	-0.04 (0.05)	0.15 (0.10)
Mother little interest in education (n=4,125-5,588)	-0.16 ^c (0.04)	-0.13 ^c (0.04)	0.29 ^c (0.07)
Father little interest in education (n=4,113-5,576)	-0.12 ^c (0.04)	-0.08 ^a (0.04)	0.21 ^c (0.06)
Low parental aspirations (n=4,065-5,542)	-0.03 (0.07)	-0.07 (0.06)	0.07 (0.11)
Neglected appearance (n=3,038-4,100)	-0.38 ^c (0.07)	-0.34 ^c (0.07)	0.47 ^c (0.12)
Neglect score ≠ (range 0-8)† (n=2,762-3,744)	-0.05 ^c (0.01)	-0.04 ^b (0.01)	0.07 ^c (0.02)
Neglect score¥ (range 0-7) (n=3,770-5,136)	-0.04 ^b (0.01)	-0.04 ^b (0.01)	0.08 ^c (0.02)
<i>Maltreatment classes[#] (n=2,918-2,243)</i>			
Neglect 'only'	-0.07 (0.04)	-0.03 (0.04)	0.15 ^a (0.07)
Abuse & neglect	0.07 (0.06)	0.00 (0.06)	0.10 (0.09)

Adverse childhood experiences	Breast ¹ ; 11y	Pubic hair ¹ ; 11y	Age of menarche ²
<i>Household dysfunction; 7y</i>			
Domestic tension (n=4,059-5,530)	-0.02 (0.06)	-0.09 (0.06)	-0.01 (0.10)
Alcoholism (n=4,057-5,528)	-0.26 ^a (0.13)	-0.33 ^b (0.13)	0.22 (0.21)
Mental health problems (n=4,061-5,532)	-0.07 (0.06)	-0.12 ^a (0.06)	0.04 (0.10)
Contact probation officer (n=3,670-4,978)	-0.20 ^a (0.09)	-0.24 ^b (0.09)	0.04 (0.18)
Contact children's department (n=3,811-5,172)	-0.20 ^c (0.07)	-0.20 ^c (0.07)	0.25 (0.12)
In care (n=3,899-5,303)	-0.25 ^b (0.09)	-0.25 ^b (0.09)	0.04 (0.17)
Parental divorce (n=3,899-5,303)	0.04 (0.07)	-0.06 (0.07)	0.04 (0.12)
Household dysfunction score (range 0-7) [¥] (n=3,590-4,872)	-0.05 ^a (0.02)	-0.08 ^b (0.02)	0.04 (0.04)
Adversity score ∞ (range 0-15) (n=2,463-3,318)	-0.05 ^b (0.01)	-0.04 ^a (0.01)	0.06 ^b (0.02)
Adversity score α (range 0-14) (n=3,347-4,505)	-0.04 ^a (0.01)	-0.04 ^a (0.01)	0.06 ^b (0.02)

Values are mean differences in ¹Tanner score or ²age (in year); SE in parenthesis. Unadjusted models include age pubertal measure was recorded; #sum of all eight indicators (range 0-8); ¥ sum of seven indicators of neglect, excluding neglected appearance (range 0-7); [¥]sum of all seven household dysfunction measures at age 7y; ∞ sum of all eight indicators of neglect and seven household dysfunction measures (range 0-15) and α sum of seven indicators of neglect, excluding neglected appearance, and seven household dysfunction variables (range 0-14) ; ^ap<0.05; ^bp<0.01; ^cp<0.001.

Appendix 5.8: Adjusted estimated effects (RRR) of neglect score (range 0-8) and adversity score (range 0-15) including neglected appearance on markers of pubertal development (reference category ‘intermediate’ development, or onset of voice change age 12-14y); males¹

Indicators of neglect; 7y	Testicular [†] ; 11y		Pubic hair [‡] ; 11 & 16y		Facial hair [‡] ; 16y		Voice change [‡]	
	Late (1)	Early (3-5)	Late	Early	Late (absent)	Early (adult)	Late (≥ 15)	Early(≤ 12)
Neglect score [†] (range 0-8)	1.03 (0.97, 1.09)	1.02 (0.94, 1.10)	1.07 ^a (1.01, 1.13)	0.98 (0.91, 1.07)	1.07 ^a (1.01, 1.14)	0.92 (0.82, 1.03)	1.11 ^b (1.05, 1.18)	1.01 (0.92, 1.11)
Adversity score [‡] (range 0-15)	1.01 (0.95, 1.06)	0.99 (0.92, 1.07)	1.06 ^a (1.00, 1.12)	1.00 (0.93, 1.09)	1.06 ^a (1.00, 1.12)	0.92 (0.82, 1.03)	1.09 ^a (1.03, 1.15)	1.01 (0.92, 1.10)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis, [†]‘stage 2’, [‡]‘normal’, ^a‘sparse’ and ^bage 12-14y used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity social class at birth and household crowding; [†] sum of all eight indicators (range 0-8), no. of observations 3087-3613; [‡] sum of all eight indicators of neglect and seven household dysfunction measures at age 7y, no. of observations 2,983-3,222, * p<0.05; italic indicates significant linear trend (Appendix 5.9)

Appendix 5.9: Adjusted estimated effects (RRR) of neglect score (range 0-8) and adversity score (range 0-15) including neglected appearance on markers of pubertal development (reference category ‘intermediate’ development, or age of menarche 12-13y); females¹

Indicators of neglect; 7y	Breast [†] ; 11y		Pubic hair [†] ; 11y		Age of menarche [‡]	
	Late (1)	Early (3-5)	Late (1)	Early (3-5)	Late (≥ 14)	Early (≤ 11)
Neglect score [†] (range 0-8)	1.11 ^a (1.03, 1.19)	0.96 (0.89, 1.05)	1.05 (0.98, 1.13)	0.96 (0.88, 1.05)	1.11 ^a (1.02, 1.21)	1.02 (0.91, 1.14)
Adversity score [‡] (range 0-15)	1.07 ^a (1.01, 1.14)	0.96 (0.90, 1.03)	1.05 (0.99, 1.11)	0.96 (0.89, 1.03)	1.06 (0.98, 1.15)	1.02 (0.93, 1.13)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis, [†]‘stage 2’, [‡]‘normal’, ^a‘sparse’ and ^bage 12-14y used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity social class at birth and household crowding; [†] sum of all eight indicators (range 0-8), no. of observations 2,376-3,508; [‡] sum of all eight indicators of neglect and seven household dysfunction measures at age 7y, no. of observations 2,124-3,117 * p<0.05; italic indicates significant linear trend (Appendix 5.10)

Appendix 5.10: Adjusted estimated effects (RRR) of categorical neglect score (age 7y) on markers of pubertal development (reference category 'intermediate' development, or onset of voice change age 12-14y); males¹

Neglect score	Testicular [†] ; 11y		Pubic hair [‡] ; 11 & 16y		Facial hair [‡] ; 16y		Voice change [‡]	
	Late (1)	Early (3-5)	Late	Early	Late (absent)	Early (adult)	Late (≥ 15)	Early (≤ 12)
Neglect score (range 0-8) [†]	1	1.05 (0.86, 1.27)	0.94 (0.73, 1.22)	1.00 (0.82, 1.21)	1.14 (0.88, 1.46)	0.84 (0.68, 1.03)	1.07 (0.77, 1.50)	1.36* (1.12, 1.65)
	2	1.09 (0.88, 1.35)	1.20 (0.91, 1.57)	1.04 (0.84, 1.28)	1.05 (0.79, 1.40)	0.99 (0.79, 1.23)	1.05 (0.72, 1.52)	1.20 (0.98, 1.48)
	3	0.94 (0.68, 1.30)	1.10 (0.74, 1.66)	1.00 (0.73, 1.37)	0.87 (0.55, 1.36)	1.03 (0.74, 1.43)	0.57 (0.28, 1.15)	1.34 (0.96, 1.86)
	4+	1.20 (0.85, 1.70)	0.95 (0.58, 1.55)	1.68* (1.19, 2.38)	0.90 (0.51, 1.57)	1.66* (1.16, 2.39)	0.59 (0.26, 1.34)	1.63* (1.17, 2.29)
Neglect score (range 0-7) [‡]	1	1.04 (0.89, 1.21)	1.05 (0.86, 1.29)	0.99 (0.85, 1.16)	1.01 (0.82, 1.25)	0.85 (0.72, 1.01)	1.03 (0.78, 1.35)	1.20* (1.02, 1.40)
	2	1.10 (0.92, 1.31)	1.01 (0.80, 1.27)	1.04 (0.87, 1.23)	0.94 (0.74, 1.19)	1.09 (0.91, 1.31)	0.90 (0.65, 1.24)	1.17 (0.99, 1.39)
	3	1.04 (0.79, 1.38)	1.48* (1.06, 2.06)	1.12 (0.85, 1.48)	1.11 (0.77, 1.19)	1.00 (0.75, 1.33)	0.73 (0.42, 1.26)	1.42* (1.08, 1.88)
	4+	1.20 (0.88, 1.64)	0.93 (0.59, 1.45)	1.60* (1.16, 2.19)	0.94 (0.57, 1.54)	1.50* (1.09, 2.07)	0.55 (0.26, 1.18)	1.71* (1.26, 2.33)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis; [†]'stage 2', [‡]'normal', [‡]'sparse' and [‡]age 12-14y used as reference categories. Adjusted models include age pubertal measure was recorded, ethnicity social class at birth and household crowding; [†]sum of all eight indicators (range 0-8) and [‡]sum of seven indicators excluding neglected appearance. * p<0.05

Appendix 5.11: Adjusted estimated effects (RRR) of categorical neglect score (age 7y) on markers of pubertal development (reference category 'intermediate' development, or age of menarche 12-13y); females¹

Neglect score [‡]	Breast [†] ; 11y		Pubic hair [†] ; 11y		Age of menarche [‡]	
	Late (1)	Early (3-5)	Late (1)	Early (3-5)	Late (≥ 14)	Early (≤ 11)
1	1.23* (1.00, 1.51)	0.97 (0.77, 1.21)	0.97 (0.79, 1.18)	0.88 (0.69, 1.12)	1.18 (0.92, 1.51)	0.95 (0.70, 1.30)
Neglect score (range 0-8) [†]	2	1.04 (0.82, 1.31)	1.03 (0.80, 1.31)	1.05 (0.84, 1.31)	1.06 (0.81, 1.38)	1.24 (0.93, 1.66)
3	1.63* (1.11, 2.40)	0.93 (0.59, 1.46)	1.31 (0.89, 1.91)	0.95 (0.59, 1.54)	1.38 (0.85, 2.22)	1.20 (0.67, 2.15)
4+	1.58* (1.04, 2.38)	0.72 (0.42, 1.24)	1.16 (0.77, 1.74)	0.66 (0.37, 1.17)	1.44 (0.83, 2.48)	1.09 (0.54, 2.22)
Neglect score (range 0-7) [‡]	1	1.13 (0.95, 1.33)	0.99 (0.82, 1.19)	0.99 (0.84, 1.16)	0.88 (0.72, 1.07)	1.16 (0.94, 1.44)
2	1.11 (0.92, 1.34)	1.06 (0.86, 1.29)	1.06 (0.88, 1.27)	0.99 (0.80, 1.23)	1.21 (0.95, 1.54)	0.93 (0.69, 1.25)
3	1.24 (0.90, 1.70)	1.05 (0.74, 1.49)	1.18 (0.86, 1.61)	1.04 (0.72, 1.52)	1.47 (0.99, 2.21)	1.34 (0.83, 2.18)
4+	1.17 (0.83, 1.66)	0.59* (0.37, 0.93)	1.22 (0.86, 1.73)	0.81 (0.50, 1.29)	1.31 (0.81, 2.09)	0.81 (0.41, 1.59)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis, [†]stage 2' and [‡]age 12-13y used as reference categories. Adjusted models include age pubertal measure was recorded, ethnicity, social class at birth, household crowding and maternal age of menarche; [†]sum of all eight indicators (range 0-8) and [‡]sum of seven indicators excluding neglected appearance. *p<0.05

Appendix 5.12: Estimated effects (RRR) of child maltreatment (reported at age 45y) on testicular development at age 11y (reference category Tanner stage 2) using imputed data (n=6,330); males¹

Adverse childhood experiences	Unadjusted		Adjusted	
	Late (stage 1)	Early (stage 3-5)	Late (stage 1)	Early (stage 3-5)
<i>Child maltreatment; 45y</i>				
Psychological abuse	1.05 (0.82, 1.34)	1.18 (0.88, 1.59)	1.01 (0.78, 1.29)	1.11 (0.82, 1.49)
Physical abuse	1.10 (0.84, 1.42)	1.25 (0.88, 1.76)	1.03 (0.78, 1.35)	1.16 (0.82, 1.66)
Sexual abuse	2.09 (0.96, 4.55)	2.16 (0.65, 7.24)	1.96 (0.89, 4.32)	1.98 (0.58, 6.79)
Witnessed abuse	1.32 (0.97, 1.81)	1.59 ^a (1.06, 2.38)	1.23 (0.89, 1.71)	1.52 (0.99, 2.32)
I was neglected	1.33 (0.89, 1.98)	1.15 (0.65, 2.01)	1.24 (0.82, 1.87)	1.01 (0.56, 1.82)
Unaffectionate mother	0.96 (0.63, 1.46)	0.88 (0.46, 1.66)	0.90 (0.59, 1.38)	0.78 (0.40, 1.55)
Unaffectionate father	1.16 (0.93, 1.44)	1.32 ^a (1.00, 1.74)	1.12 (0.90, 1.41)	1.26 (0.95, 1.68)
<i>7y measures</i>				
Neglect score† (range 0-8)	1.05 ^a (1.01, 1.10)	1.03 (0.97, 1.10)	1.03 (0.99, 1.08)	1.04 (0.97, 1.10)
Neglect score‡ (range 0-7)	1.06 ^a (1.01, 1.11)	1.04 (0.98, 1.11)	1.04 (0.99, 1.09)	1.04 (0.97, 1.11)
Household dysfunction score≠	1.06 (0.98, 1.16)	1.07 (0.96, 1.19)	1.04 (0.95, 1.14)	1.06 (0.95, 1.18)
Adversity score‡ (range 0-15)	1.05 ^a (1.01, 1.08)	1.03 (0.99, 1.09)	1.03 (0.99, 1.07)	1.03 (0.98, 1.09)
Adversity score± (range 0-14)	1.05 ^a (1.01, 1.09)	1.04 (0.99, 1.09)	1.03 (0.99, 1.07)	1.04 (0.98, 1.10)
<i>Maltreatment groups§ (reference low risk of maltreatment)</i>				
Neglected 'only'	1.12 (0.95, 1.33)	1.10 (0.89, 1.36)	1.07 (0.89, 1.28)	1.12 (0.89, 1.28)
Abuse and neglect	1.19 (0.89, 1.36)	1.27 (0.88, 1.83)	1.10 (0.85, 1.43)	1.21 (0.81, 1.81)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis, stage 2 used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity, social class at birth and household crowding; †sum of all eight indicators of neglect; ‡sum of seven indicators excluding neglected appearance; ≠sum of all seven household dysfunction; ‡sum of all eight indicators of neglect and seven household dysfunction measures at age 7y; ± sum of seven indicators of neglect (excluding neglected appearance) and seven household dysfunction measures at age 7y and §latent class model includes all fifteen child maltreatment measures collected at ages 7y and 45y; ^ap<0.05; ^bp<0.01; ^cp<0.001.

Appendix 5.13: Estimated effects (RRR) of child maltreatment (reported at age 45y) on age of menarche (reference category age 12-13y) using imputed data (n=4,646); females¹

Adverse childhood experiences	Unadjusted		Adjusted	
	Late (≥ 14y)	Early (≤ 11y)	Late (≥ 14y)	Early (≤ 11y)
<i>Child abuse; 45y</i>				
Psychological abuse	1.40 ^a (1.06, 1.85)	1.10 (0.82, 1.48)	1.40 ^a (1.06, 1.84)	1.06 (0.78, 1.43)
Physical abuse	1.17 (0.83, 1.65)	1.12 (0.75, 1.66)	1.10 (0.78, 1.56)	1.07 (0.72, 1.60)
Sexual abuse	1.80 ^a (1.12, 2.90)	1.91 ^a (1.10, 3.31)	1.67 ^a (1.03, 2.72)	1.84 ^a (1.05, 3.22)
Witnessed abuse	1.39 ^a (1.05, 1.84)	1.12 (0.78, 1.62)	1.32 (0.99, 1.76)	1.10 (0.76, 1.61)
I was neglected	1.26 (0.79, 2.00)	0.94 (0.55, 1.62)	1.22 (0.76, 1.94)	0.91 (0.53, 1.57)
Unaffectionate mother	0.95 (0.67, 1.34)	0.92 (0.60, 1.40)	0.86 (0.60, 1.23)	0.94 (0.61, 1.44)
Unaffectionate father	1.34 ^a (1.01, 1.78)	0.85 (0.57, 1.26)	1.32 (0.98, 1.77)	0.84 (0.56, 1.25)
<i>7y measures</i>				
Neglect score† (range 0-8)	1.16 ^c (1.10, 1.23)	1.03 (0.95, 1.11)	1.14 ^c (1.08, 1.22)	1.02 (0.94, 1.11)
Neglect score‡ (range 0-7)	1.16 ^c (1.10, 1.24)	1.04 (0.96, 1.12)	1.15 ^c (1.07, 1.22)	1.03 (0.94, 1.12)
Household dysfunction score≠	1.06 (0.96, 1.17)	1.01 (0.89, 1.15)	1.04 (0.95, 1.15)	0.99 (0.86, 1.13)
Adversity score‡ (range 0-15)	1.10 ^c (1.06, 1.15)	1.02 (0.96, 1.08)	1.09 ^c (1.04, 1.14)	1.01 (0.94, 1.08)
Adversity score± (range 0-14)	1.10 ^c (1.05, 1.16)	1.02 (0.96, 1.09)	1.09 ^c (1.04, 1.15)	1.01 (0.95, 1.08)
<i>Maltreatment groups§ (reference low risk of maltreatment)</i>				
Neglected 'only'	1.52 ^c (1.25, 1.86)	1.02 (0.80, 1.29)	1.47 ^c (1.17, 1.83)	0.98 (0.76, 1.27)
Abuse and neglect	1.37 ^a (1.03, 1.82)	1.08 (0.79, 1.49)	1.33 ^a (1.00, 1.78)	1.03 (0.74, 1.43)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis, age 12-13y used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity, social class at birth, household crowding and maternal age of menarche; †sum of all eight indicators of neglect; ‡sum of seven indicators excluding neglected appearance; ≠sum of all seven household dysfunction; §sum of all eight indicators of neglect and seven household dysfunction measures at age 7y; ± sum of seven indicators of neglect (excluding neglected appearance) and seven household dysfunction measures at age 7y and §latent class model includes all fifteen child maltreatment measures collected at ages 7y and 45y; ^ap<0.05; ^bp<0.01; ^cp<0.001.

Appendix 5.14: Estimated effects (RRR) of child maltreatment (reported at 45y) on facial hair growth and age of voice change (reference category ‘intermediate’ development, or onset of voice change age 12-14y); males

Child maltreatment	Facial hair [‡] ; 16y		Voice change [‡]	
	Late (absent)	Early (adult)	Late (≥ 15)	Early (≤ 12)
<i>Child abuse</i>				
Psychological abuse	Unadjusted	0.95 (0.71, 1.26)	1.36 (0.86, 2.15)	1.12 (0.85, 1.48)
	Adjusted	0.93 (0.70, 1.23)	1.29 (0.81, 2.04)	1.11 (0.85, 1.47)
Physical abuse	Unadjusted	0.96 (0.69, 1.33)	0.89 (0.48, 1.66)	1.18 (0.86, 1.62)
	Adjusted	0.92 (0.66, 1.28)	0.84 (0.45, 1.57)	1.17 (0.85, 1.61)
Sexual abuse	Unadjusted	1.65 (0.60, 4.57)	1.95 (0.40, 9.46)	0.67 (0.24, 1.89)
	Adjusted	1.56 (0.56, 4.32)	2.00 (0.41, 9.69)	0.68 (0.24, 1.91)
Witnessed abuse	Unadjusted	0.90 (0.61, 1.31)	1.18 (0.63, 2.22)	1.19 (0.83, 1.71)
	Adjusted	0.84 (0.57, 1.23)	1.13 (0.60, 2.13)	1.16 (0.81, 1.67)
<i>Indicators of neglect</i>				
I was neglected	Unadjusted	0.98 (0.52, 1.87)	0.61 (0.14, 2.63)	0.89 (0.49, 1.61)
	Adjusted	0.92 (0.48, 1.76)	0.56 (0.13, 2.40)	0.86 (0.48, 1.56)
Unaffectionate mother	Unadjusted	0.70 (0.38, 1.31)	1.70 (0.74, 3.92)	0.94 (0.53, 1.67)
	Adjusted	0.68 (0.36, 1.28)	1.59 (0.69, 3.67)	0.91 (0.51, 1.61)
Unaffectionate father	Unadjusted	1.12 (0.86, 1.44)	1.07 (0.67, 1.71)	0.93 (0.73, 1.19)
	Adjusted	1.09 (0.84, 1.41)	1.00 (0.62, 1.60)	0.92 (0.71, 1.18)

[†]All values are relative risk ratio (RRR); 95% CI in parenthesis, [‡]‘sparse’ and [‡]age 12-14y used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity, social class at birth and household crowding; no. of observations 3,073-3,613; ^ap<0.05; ^bp<0.01; ^cp<0.001; *italic* indicates p<0.05 for linear trend (Appendix 5.1).

Appendix 5.15: Estimated effects (RRR) of child maltreatment (reported at age 45y) on breast and pubic hair development (reference category ‘intermediate’ development); females¹

Child maltreatment	Breast [†] ; 11y		Pubic hair [†] ; 11y	
	Late (1)	Early (3-5)	Late (1)	Early (3-5)
<i>Child abuse</i>				
Psychological abuse	Unadjusted	1.10 (0.85, 1.42)	1.06 (0.80, 1.40)	1.11 (0.87, 1.43)
	Adjusted	1.10 (0.85, 1.42)	1.08 (0.81, 1.43)	1.10 (0.85, 1.41)
Physical abuse	Unadjusted	0.93 (0.66, 1.32)	1.05 (0.73, 1.50)	1.14 (0.82, 1.60)
	Adjusted	0.91 (0.64, 1.29)	1.08 (0.75, 1.55)	1.11 (0.79, 1.56)
Sexual abuse	Unadjusted	1.01 (0.58, 1.74)	1.10 (0.62, 1.95)	1.51 (0.87, 2.60)
	Adjusted	0.98 (0.56, 1.70)	1.13 (0.63, 2.02)	1.44 (0.83, 2.50)
Witnessed abuse	Unadjusted	0.88 (0.64, 1.21)	0.99 (0.71, 1.38)	1.14 (0.84, 1.55)
	Adjusted	0.85 (0.62, 1.18)	1.05 (0.75, 1.47)	1.09 (0.80, 1.49)
<i>Indicators of neglect</i>				
I was neglected	Unadjusted	0.83 (0.52, 1.32)	1.01 (0.63, 1.62)	0.88 (0.57, 1.36)
	Adjusted	0.80 (0.50, 1.27)	1.06 (0.66, 1.70)	0.84 (0.54, 1.30)
Unaffectionate mother	Unadjusted	0.92 (0.63, 1.33)	1.04 (0.70, 1.53)	0.95 (0.66, 1.36)
	Adjusted	0.87 (0.60, 1.27)	1.15 (0.77, 1.70)	0.91 (0.63, 1.30)
Unaffectionate father	Unadjusted	0.96 (0.72, 1.29)	0.89 (0.65, 1.23)	1.11 (0.83, 1.47)
	Adjusted	0.97 (0.72, 1.30)	0.91 (0.66, 1.25)	1.09 (0.82, 1.45)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis, [†]‘stage 2’ used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity, social class at birth, household crowding and maternal age of menarche; no. of observations 2,405-3,378; ^ap<0.05; ^bp<0.01; ^cp<0.001; *italic* indicates p<0.05 for linear trend (Appendix 5.2)

Appendix 5.16: Estimated effects (RRR) of neglect (reported at age 7y) on testicular development at age 11y (reference category ‘intermediate’ development); males¹

Indicators of neglect; 7y	Testicular [†] ; 11y			
	Late (1)		Early (3-5)	
	Unadjusted	Adjusted	Unadjusted	Adjusted
Mother hardly reads	1.13 (0.97, 1.32)	1.10 (0.94, 1.29)	1.03 (0.84, 1.27)	1.04 (0.85, 1.28)
Father hardly reads	1.08 (0.95, 1.23)	1.05 (0.92, 1.19)	1.03 (0.87, 1.23)	1.04 (0.87, 1.23)
Mother hardly any outings	1.71 ^a (1.07, 2.74)	1.60 ^a (1.00, 2.56)	1.44 (0.78, 2.65)	1.45 (0.78, 2.69)
Father hardly any outings	1.17 (0.90, 1.53)	1.11 (0.85, 1.45)	1.37 (0.99, 1.90)	1.40 ^a (1.01, 1.95)
Mother little interest education	1.10 (0.94, 1.30)	1.04 (0.88, 1.23)	0.97 (0.78, 1.20)	0.97 (0.78, 1.22)
Father little interest education	1.20 ^a (1.02, 1.40)	1.13 (0.96, 1.33)	1.07 (0.87, 1.31)	1.08 (0.87, 1.34)
Low parental aspirations	0.92 (0.68, 1.24)	0.86 (0.64, 1.17)	0.99 (0.67, 1.46)	0.99 (0.67, 1.46)
Neglected appearance	1.16 (0.88, 1.53)	1.04 (0.78, 1.38)	0.99 (0.68, 1.44)	0.98 (0.67, 1.45)
Continuous neglect score [‡]	1.07 ^a (1.01, 1.12)	1.04 (0.99, 1.10)	1.03 (0.96, 1.10)	1.03 (0.96, 1.11)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis, [†]‘stage 2’ used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity, social class at birth and household crowding; no. of observations 3,362-5,710;
[‡]sum of seven indicators excluding neglected appearance (range 0-7), no. of observations 4,465-5,271; ^ap<0.05; ^bp<0.01; ^cp<0.001; *italic* indicates p<0.05 for linear trend (Appendix 5.1)

Appendix 5.17: Estimated effects (RRR) of household dysfunction (reported at age 7y) on markers of pubertal development (reference category ‘intermediate’ development, or age of menarche 12-13y)¹

Household dysfunction; 7y		Males			Females		
		Testicular [†] ; 11y		Pubic hair [‡] ; 11 & 16y		Age of menarche [‡]	
		Late (1)	Early (3-5)	Late	Early	Late (≥ 14)	Early (≤ 11)
Domestic tension	Unadjusted	1.14 (0.87, 1.48)	1.15 (0.82, 1.62)	1.17 (0.90, 1.51)	0.81 (0.55, 1.19)	0.79 (0.54, 1.17)	0.91 (0.58, 1.42)
	Adjusted	1.10 (0.85, 1.44)	1.15 (0.82, 1.62)	1.13 (0.87, 1.47)	0.85 (0.58, 1.26)	0.77 (0.52, 1.14)	0.87 (0.55, 1.37)
Alcoholism	Unadjusted	0.90 (0.48, 1.67)	0.84 (0.36, 1.96)	1.75 (0.93, 3.28)	0.71 (0.23, 2.14)	1.04 (0.49, 2.22)	0.51 (0.15, 1.71)
	Adjusted	0.85 (0.46, 1.59)	0.80 (0.34, 1.87)	1.60 (0.85, 3.02)	0.78 (0.26, 2.36)	0.86 (0.40, 1.87)	0.53 (0.15, 1.80)
Mental health problems	Unadjusted	1.07 (0.80, 1.44)	1.16 (0.80, 1.69)	0.93 (0.70, 1.23)	0.78 (0.52, 1.18)	1.06 (0.72, 1.55)	1.13 (0.72, 1.78)
	Adjusted	1.03 (0.77, 1.39)	1.17 (0.80, 1.69)	0.89 (0.67, 1.19)	0.83 (0.55, 1.26)	1.04 (0.70, 1.53)	1.08 (0.68, 1.71)
Contact probation officer	Unadjusted	1.37 (0.84, 2.23)	1.57 (0.87, 2.82)	1.21 (0.77, 1.91)	0.44 (0.18, 1.05)	1.14 (0.58, 2.25)	1.29 (0.60, 2.78)
	Adjusted	1.28 (0.78, 2.09)	1.63 (0.90, 2.95)	1.14 (0.72, 1.80)	0.50 (0.21, 1.20)	0.99 (0.50, 1.98)	1.28 (0.59, 2.80)
Contact children’s department	Unadjusted	1.19 (0.89, 1.60)	1.15 (0.79, 1.68)	1.18 (0.89, 1.57)	0.78 (0.51, 1.21)	1.38 (0.86, 2.21)	0.99 (0.53, 1.85)
	Adjusted	1.11 (0.83, 1.50)	1.17 (0.80, 1.72)	1.12 (0.83, 1.49)	0.88 (0.57, 1.37)	1.20 (0.74, 1.95)	1.00 (0.53, 1.89)
In care	Unadjusted	1.06 (0.70, 1.60)	0.96 (0.56, 1.65)	0.78 (0.52, 1.17)	0.76 (0.43, 1.33)	1.26 (0.62, 2.56)	1.21 (0.51, 2.87)
	Adjusted	0.99 (0.65, 1.49)	0.95 (0.55, 1.64)	0.72 (0.48, 1.08)	0.84 (0.48, 1.49)	1.12 (0.54, 2.31)	1.17 (0.49, 2.82)
Parental divorce	Unadjusted	1.12 (0.83, 1.51)	1.10 (0.75, 1.63)	1.53 ^b (1.13, 2.07)	0.97 (0.62, 1.52)	1.01 (0.63, 161)	0.94 (0.53, 1.67)
	Adjusted	1.06 (0.81, 1.47)	1.08 (0.73, 1.60)	1.48 ^b (1.09, 2.02)	1.02 (0.65, 1.60)	0.98 (0.61, 1.58)	0.86 (0.48, 1.55)
Continuous household dysfunction score ^A	Unadjusted	1.01 (0.92, 1.12)	1.05 (0.93, 1.18)	1.05 (0.96, 1.16)	0.91 (0.79, 1.05)	1.02 (0.88, 1.18)	0.99 (0.83, 1.18)
	Adjusted	1.01 (0.92, 1.12)	1.05 (0.93, 1.18)	1.04 (0.94, 1.14)	0.95 (0.82, 1.09)	0.97 (0.83, 1.13)	0.98 (0.82, 1.18)

¹All values are relative risk ratio (RRR); 95% CI in parenthesis, [†]‘stage 2’, [‡]‘normal’ and [‡]age 12-13y used as reference categories. Unadjusted models include age pubertal measure was recorded, adjusted models further include ethnicity, social class at birth, household crowding and maternal age of menarche for females; no. of observations 4,305-5,870 males and 3,063-4,556 females; ^Asum of all seven household dysfunction measures at age 7y (range 0-7), no. of observations 4,218-5,037 males and 3,063-4,556 females; ^ap<0.05; ^bp<0.01; ^cp<0.001; *italic* indicates p<0.05 for linear trend (Appendix 5.1 and 5.2)

Appendix 5.18: Correlation coefficients between markers of pubertal development; males[†]

	Testicular; 11y	Pubic hair; 11y	Facial hair; 16y
Pubic hair	0.48	1.00	
Facial hair	0.15	0.16	1.00
Voice change	-0.10	-0.06	-0.19

[†]Spearman's rank correlation coefficients; all correlation coefficients were statistically significant ($P < 0.001$)

Appendix 5.19: Correlation coefficients between markers of pubertal development; females[†]

	Breast; 11y	Pubic hair; 11y
Pubic hair	0.71	
Age of menarche	-0.49	-0.42

[†]Spearman's rank correlation coefficients; all correlation coefficients were statistically significant ($P < 0.001$)

