Investigating the longitudinal association of body composition and body image in young people, and its implications for mental health and obesity policy in the UK

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Declaration

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

Acknowledgements

Dedicated to Cleo,
who was always interested in my research,
and who always had thoughts and anecdotes to share.

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Abstract

Body image concerns are a potentially modifiable mechanism that may explain why young people with higher weights experience greater depressive symptoms. However, there is a lack of evidence from longitudinal, nationally representative studies that investigates body image concerns and its risk factors in childhood. Further knowledge will help in development of interventions aimed at improving mental health.

Using data from the Millennium Cohort Study, a nationally representative study of around 19,000 children born around the millennium, this thesis aimed to first investigate whether there are distinct childhood trajectories of adiposity (FMI and FM/FFM) and a proxy for muscularity (FFMI) using latent class growth analysis. Regression modelling was then used to investigate whether adiposity and muscularity trajectories are differentially associated with body image concerns in adolescence. Causal mediation analyses investigated the extent to which body satisfaction in early adolescence mediates the association between childhood weight trajectory and depressive symptoms in later adolescence. Finally, multilevel models were used to investigate whether parental concern about their child's weight, and control of their child's diet, at age 5 were associated with BMI and body satisfaction across adolescence.

Distinct trajectories of adiposity and a proxy for muscularity were observed up to age 14. There was some evidence that adiposity and muscularity trajectories were differentially associated with adolescent body image concerns. Almost half of the association between weight trajectory and depressive symptom was mediated by body satisfaction in early adolescence. Parental control of their child's diet, which is a common response to a public health strategy aimed at reducing childhood overweight, was not associated with substantial changes in BMI across adolescence but was associated with lower body satisfaction scores.

These findings suggest that current obesity policies in the UK may be contributing to increasing levels of mental ill-health in young people.

Impact Statement

Overweight and depression in young people are major public health priorities in the UK, affecting a growing proportion of the population. Recent Government strategies on major conditions, including both overweight and mental ill-health, have emphasised the importance of prevention and early intervention.

The findings of this thesis will help elucidate the potential benefit to young people's mental health of interventions to improve body satisfaction in people with higher weights. This has important relevance for mental health professionals and schools to help identify individuals who could benefit from early mental health intervention. This also has benefits to eating disorder clinicians and researchers, as body image concerns are a key part of diagnostic criteria for body dysmorphic disorder and most eating disorders. Findings are also relevant to policymakers, highlighting the importance of incorporating body image promotion into mental health prevention strategies. This thesis also provides evidence to suggest that current policies targeting childhood overweight may have unintended consequences for young people's mental health and calls for further evaluation of strategies such as the National Child Measurement Programme. Findings may also help parents consider how they discuss weight with their children and invite wider discussion around societal weight stigma more broadly.

Work in this thesis around the potential limitations of BMI also contributes to furthering academic knowledge of the use of BMI as a proxy for adiposity and calls for further research into body composition. Findings are also relevant to clinicians and policymakers and raise awareness of the limitations of using BMI to categorise an individual's weight. Findings from this thesis have been presented to academic and clinician researchers at national and international conferences and invited talks. Work from empirical chapters is being prepared for publication in peer-reviewed journals and a wider audience will be reached by contacting UCL Media Relations and utilising social media. Given the relevance to mental health and obesity policy, findings will be disseminated to policymakers through knowledge exchange programmes and connecting with civil servants. Findings have also been discussed in lectures given to Masters students and in public engagement with schools.

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1 Introduction

This thesis investigates two major public health priorities in young people – depression and overweight. Focussing on expanding knowledge of their risk factors in childhood and early adolescence, this thesis aims to generate evidence to support their prevention, with strong relevance to health policy in the United Kingdom (UK).

This chapter introduces the epidemiology and public health importance of depression and overweight in youth. The policy context in the UK is also described. The chapter ends with an outline of the thesis.

1.1 Depression

1.1.1 Epidemiology

Depression is a major public health priority globally, as a leading and increasing cause of disease burden (1). Among adolescents and young adults, depression is one of the top three leading causes of morbidity and mortality globally (2). It is common in young people, with global prevalence estimated to be 5.7% in adolescents (13 to 18 years old) and 2.8% in children (under 13 years old) (3). Symptoms of depression commonly include low mood, loss of interest in activities, or feelings of hopelessness (4). Other non-affective symptoms also occur, including poor concentration and disturbed sleep, all of which can contribute to difficulties in day-to-day life, such as struggles with work and social activities (4). Diagnostic criteria require five or more symptoms, which must cause significant distress; however, depressive symptoms on a sub-threshold level are also common, affecting an estimated 2.2 to 9.3% of adolescents, are associated with lower quality of life, and represent a major risk factor for later clinical depression (5).

The UK has seen a substantial increase in depressive symptoms in young people across recent decades (6–9), with one study suggesting that incidence rates have more than doubled between 2000 and 2020 (8). There is some evidence that depressive symptoms have increased more in young girls compared to boys (7,9), with depression being approximately two to three times more prevalent in women and girls than boys (10). This gender difference emerges in adolescence (10) and by late adolescence, an estimated one in twelve boys (7.9%) and one in four girls (22.4%) have an emotional disorder such as depression or anxiety, according to surveys in England (11). In addition, prevalence is higher among young people from White and Mixed ethnic backgrounds compared to their Black and Asian peers, and in young people from more socioeconomically disadvantaged families compared to those from the most advantaged families (11).

1.1.2 Long-term impacts

Depression in young people increases their risk of other mental health problems, including eating disorders (12). Adolescents with depression are more likely to self-harm, and are also at an increased risk of suicidality (13,14); this is important as suicide is the leading cause of death in young adults in the UK (15). Psychosocial impacts are wide ranging; depression is associated with increased loneliness (16), lower educational attainment (17), and unemployment (18) in early adulthood.

Furthermore, depression in adolescence is strongly associated with depression in adulthood (14). Adult physical health consequences of adolescent depression include increased risks of cardiovascular disease, obesity, and premature mortality (19). Mental health problems broadly are estimated to cost the UK economy approximately £118 billion per year, in both direct costs from healthcare and indirect costs such as lost employment (20).

1.1.3 Treatment and prevention

Treatment for depression in both young people and adults includes psychological therapy, with or without antidepressant medication. However, evidence of the efficacy of treatment options in young people is weak (3,21), and increasing demand and waiting times for young people’s mental health services indicate increasing unmet need (22,23). Approximately half of mental health conditions emerge by age 14 years and three-quarters before the mid-20s (24). Earlier onset of depression in young people is associated with recurrent or persistent depression in adulthood (18). Therefore, given the importance of adolescent mental health for lifelong wellbeing, prevention of depression and promotion of mental wellbeing is critical (25).

1.1.4 Policy context

Given the high and increasing prevalence of depression and other mental health problems in young people, reducing mental ill-health is a major health policy priority in the UK. Mental health was first formally recognised as of equal importance as physical health in 2010 (26), after which the then-government published the *No Health Without Mental Health* strategy, affirming mental health as central to quality of life, economic success, and reducing problems such as homelessness (27). Since then, both government and the National Health Service (NHS) have committed to increased funding for mental health services, though demand continues to outpace provision (28). Furthermore, as funding for mental health services is not ring-fenced and local commissioners assume the responsibility for allocation of funding from an overall budget, this can result in inequitable access to diagnoses and treatment across the UK (29,30).

In 2022, the Department of Health published a call for evidence for a mental health and wellbeing plan, which explicitly focussed on promotion of positive mental health, prevention of mental ill-health and suicide, and early intervention (31). This has since been stepped back, with mental health being incorporated into a single strategy alongside physical health. This *Major Conditions Strategy* retains a focus on prevention and early intervention, acknowledging that the basis for a healthy life is formed in childhood (32). However, this is an area where UK health policy and planning has signalled that further research is needed (33); in particular, further evidence of the risk factors for depression in young people will help identify how to intervene and prioritise who to target for prevention.

1.2 Overweight

1.2.1 Epidemiology

Overweight, defined as an excess of adipose tissue, is another major global public health issue (34). Across the globe, 39% of adults are overweight (35). In young people, the prevalence of overweight has more than quadrupled since 1975, rising from 4% to over 18% as of 2016 (36). Using international thresholds to compare the prevalence of overweight in young people under 18 years old across countries, the UK has higher percentages of overweight boys (26.1%) and girls (29.2%) than the average in developed countries (23.8% of boys and 22.6% of girls) (37).

Childhood overweight is strongly socially patterned. Health surveillance in England demonstrates that childhood overweight is two to three times more prevalent in children from disadvantaged backgrounds than their advantaged peers (38). Parental employment is associated with reduced odds of childhood overweight (39), though not in two-parent households were both parents work full-time; children from these families are also more likely to be overweight (39). Such families are likely to be more economically advantaged, but time poor, suggesting that the societal or environmental context in which children live and grow may influence their weight development.

At a simple level, overweight is a result of an imbalance between energy intake (e.g. food consumption) and expenditure. In industrialised societies in particular, production of energy-dense, high fat, salt and sugar foods has risen exponentially. In tandem, societal changes in the nature of work, transportation, and urban planning has helped to promote a more sedentary life. These changes have coincided with increases in overweight, suggesting that wider environmental and societal changes could be driving increases in prevalence around the world (40–42).

1.2.2 Long-term impacts

Higher weight is a risk factor for several health conditions including cardiovascular disease, diabetes, and some cancers and this risk increases with increasing weight (43,44). These conditions are associated with significant morbidity and are estimated to cost the NHS more than £22 billion per year by 2050 (45). As children who are overweight are more likely to be overweight in adulthood (46), there has been significant policy focus on preventing or reducing childhood overweight.

1.2.3 Policy context

Successive UK governments have introduced policies aimed at reducing and preventing childhood overweight (47–49). These have included a range of interventions, some targeting individual behaviour and others aimed at structural factors. Strategies targeting individuals include education of healthy lifestyles in schools, and promoting healthy food choices through calorie labelling on menus and traffic light labels of nutrient content (49). A health surveillance programme in school children (the National Child Measurement Programme) also generates annual statistics of the prevalence of overweight, with families of overweight children receiving advice on healthy lifestyles and referrals to weight management services, where available. For these individual-level strategies to be successful, young people, or their parents, are required to enact changes to their diets, lifestyles, or purchasing habits.

Structural strategies have targeted the commercial determinants of health, such as banning the promotion of foods high in fat, salt, or sugar in shops and in media, although these have been delayed (49,50). Most notably, the soft drinks industry levy, which was introduced in 2018, has led to widespread reformulation removing an estimated 46,000 tonnes of sugar from soft drinks (51). New research suggests that the levy may have reduced the prevalence of overweight in early adolescent girls (52).

Some have criticised successive childhood obesity policies as too focused on individual responsibility, which may be ineffective and inequitable, and not doing enough to target the social determinants of childhood overweight (53–56).

1.3 Thesis outline

This introductory chapter has highlighted the increasing prevalence of depression and overweight in young people, and the importance of prevention and early intervention to promote lifelong health and wellbeing.

Chapter 2 provides a literature review of the evidence linking overweight and depression in young people and a modifiable factor (body image concerns) that may underlie their association, which could be targeted by interventions. The chapter also considers issues in the measurement of weight and the evidence for early life risk factors for body image concerns. Evidence is critically appraised and gaps in current knowledge are highlighted. In Chapter 3, the aims, objectives, and hypotheses of the thesis are outlined, and Chapter 4 sets out the data and key measures that are used.

Chapters 5 to 8 present the empirical research conducted for this thesis, which broadly aims to understand the role that body image concerns play in the association between childhood weight and adolescent depressive symptoms and investigate whether potentially modifiable early life family factors are associated with changes in weight and body image concerns across adolescence. Each chapter takes the form of a research paper, with a detailed review of the literature, summarising the research gaps and aims, and sets out the methods and results and critically discusses the main findings.

The final chapter (Chapter 9) is the general discussion, which summarises and critiques the main findings of this thesis. Finally, limitations and implications for policy and future research are discussed.

2 Literature Review

This chapter critically appraises the existing evidence for an association between overweight and depressive symptoms in young people. A potentially modifiable mechanism is introduced, for which the evidence is discussed. Gaps in current knowledge, which will be addressed in the thesis, are highlighted. First, key theoretical and measurement considerations are outlined.

2.1 Theoretical and measurement considerations

2.1.1 Lifecourse theory

A key theoretical basis underpinning the research in this thesis, and the evidence discussed in this chapter, is a lifecourse perspective. This approach considers the trajectories of individuals' lives across a sequence of life stages through which development and decline is occurring from conception through to death (57). Life trajectories are also studied in relation to the historical, social, and cultural contexts in which individuals are embedded and which shape development (58). In this sense, a lifecourse approach is interdisciplinary, acknowledging the possible biological, psychosocial, environmental, and behavioural factors that may impact health and disease (59). Crucially, these factors are considered to potentially interact with one another or accumulate over the lifecourse to influence health and wellbeing. A lifecourse perspective emphasises that promoting health and wellbeing in early life can have lifelong effects (60). This approach also helps to understand when prevention or health promotion interventions could be most effective, acknowledging that the development of ill-health begins far earlier than disease detection.

Several lifecourse models have been proposed to understand how exposures in early life may affect lifelong health. These include the accumulation of risk model, which suggests that different exposures may accumulate over time to have a cumulative effect on health (58). Exposures may be independent or may cluster within socioeconomic circumstances, for example. An alternative is the chain of risk model, which considers that one negative exposure may lead to a sequence of other negative exposures over time (58). This may involve mediating or modifying factors, the former of which describes a factor which follows chronologically from the exposure on the causal pathway, while the latter describes a factor by which the causal effect varies. Finally, the concept of trajectories considers a long-term measure of health or a risk factor for ill-health over the lifecourse using repeated measurements (58). This can include investigating patterns of change, or the concept of a normative trajectory from which individuals or groups can deviate.

In the context of health promotion or ill-health prevention, life course theory also offers conceptual frameworks, for instance in critical or sensitive periods of development, during which a positive or negative exposure can affect subsequent health (59). Infancy and adolescence are both considered to be critical or sensitive periods, as they are times of rapid physiological and psychosocial development (61). Focusing research on these critical or sensitive periods may help to identify times when interventions may be most effective for long-term health.

2.1.2 Measurement of weight in young people

A number of measures exist in the identification of overweight, including waist circumference and waist-to-hip ratio, but the most commonly used is the Body Mass Index (BMI). BMI was created in the early 19th century to define the normal weight for an average man (62). As weight naturally increases with height, BMI is calculated as weight in kilograms divided by the square of height in metres, to account for the correlation between weight and height. In adults, cut offs defined by the World Health Organization are used to contextualise BMI values as underweight (≤18.5), overweight (BMI ≥25), and obese (BMI ≥30) (63). In children, BMI values are standardised according to centiles for a child's age and sex (64). National or international thresholds can then be applied to contextualise child BMI in relation to the categories of underweight, healthy weight, overweight, and very overweight (or obese).

BMI is widely used due to its ease of measurement. However, there are several issues with BMI. First, it was developed based on data from European men in the 19th century (62). There is evidence that it is biased for women and different ethnic groups, who may have different distributions of adipose tissue to White men (65,66). Secondly, the index of height squared may not fully account for the correlation between weight and height (67). As a result, BMI tends to overestimate overweight in taller people and underestimate it in shorter people.

Crucially, the major challenge with BMI is that it measures total body weight. This comprises fat, bone, muscle, organs, and other tissue. While BMI is ubiquitously used as a proxy for adiposity, it cannot distinguish between individuals with different proportions of fat and lean mass (67). This is particularly important in young people as proportions of fat and lean mass fluctuate across childhood and adolescence, clearly diverging in males and females around the pubertal transition (68). Although BMI is generally highly correlated with adiposity, this is predominantly due to correlations at both low and high BMI values (69). In middle ranges, which are common in young people, BMI has a low sensitivity as a measure of adiposity (69). In adults, evidence from meta-analytic studies suggests that half of adults classified as having excess adiposity according to body fat percentage were not identified as obese by BMI (70). In children, studies have demonstrated that individuals with the same BMI can have vastly different body fat percentages, with BMI being less reliable in Black adolescent males in particular (69).

An alternative lies in measures of body composition, which break the body down into distinct components. This may have substantial value for health research, as measures of fat mass specifically may provide a better understanding of the association between weight and health outcomes. Measures of adiposity include body fat percentage, which is the proportion of total body weight that is estimated to be fat mass. However, this is not an optimal measure of adiposity as it does not account for the correlation between weight and height (71). Instead, raw measures of fat mass can be indexed to account for height following the same formula as BMI, thus calculating Fat Mass Index (FMI). Similarly, measures of muscularity can be obtained by estimating either lean mass itself or fat-free mass (i.e., any mass that is not estimated to be fat). Indices can then be calculated to account for correlations with height, thereby measuring lean mass index as a direct measure of muscularity, or fat-free mass index (FFMI) as a proxy measure when specific measures of lean mass are unavailable (72). However, these measures of body composition are rare, particularly in research of children where BMI is conventionally used to indicate weight status.

2.2 Association between overweight and depressive symptoms

With both overweight and depressive symptoms rising in parallel in young people, many have hypothesised that the two may be linked. Indeed, comparisons of two recent UK birth cohorts (the Avon Longitudinal Study of Parents and Children (ALSPAC; children born around 1990) and the Millennium Cohort Study (children born around 2000)) suggest that the cross-sectional association between weight, as measured by BMI, and depressive symptoms has increased in magnitude over time (73). Research has suggested that the association between weight and depressive symptoms may be bidirectional (74). From a prevention perspective, it is important to understand if one is more likely to occur before the other in the young lifecourse. Therefore, this chapter begins by reviewing the evidence for both directions of association.

2.2.1 Childhood overweight and subsequent depressive symptoms

A number of longitudinal studies have investigated the association of childhood overweight and later depressive symptoms. In a study of more than 2,000 Australians who were aged 7 to 15 years old in 1985 (75), childhood overweight was associated with increased risk of mood disorder 20 years later compared to participants who were not overweight in childhood. This was seen in both girls and boys but was particularly evident in girls who were overweight in childhood and adulthood. Similarly, in a large retrospective study (N=11,825) of Spanish university graduates (76), childhood overweight was associated with increased risk of depression diagnosis or antidepressant use in adulthood. However, this was based on retrospective reporting of childhood weight in adulthood (age range when reporting childhood weight was 24 to 54 years). Nevertheless, this is supported by a small prospective Icelandic study of men and women born between 1907 and 1935 (N=889) and with BMI measured at age 8 (77), which found that overweight at age 8 was associated with increased lifetime depression over more than 60 years of follow-up. This highlights the potential lifecourse nature of this association. Conversely, a longitudinal study of nearly 17,000 children born in 1970 in the UK (BCS70) did not find evidence of an association between BMI measured at age 10 and later psychological distress at age 30, using the Malaise inventory (78).

These studies did not account for existing mental health difficulties in childhood. It could be that overweight and poor mental health co-occur in early life and these studies observe longitudinal associations between early and later life mental health. This was examined in a cohort of more than 18,000 British individuals born in 1958 (the 1958 National Child Development Study, NCDS) (79), which investigated the prospective longitudinal associations between BMI and depression from ages 7 to 50 years using a time-lagged approach. After adjusting for baseline mental health, overweight was associated with subsequent depression in girls only, while in both sexes, underweight was associated with subsequent depression.

The above studies have investigated associations between childhood BMI and depression measured in adulthood. As half of mental illness occurs by age 14 (80), it is important to investigate associations between weight and depressive symptoms earlier in the lifecourse. Longitudinal research in this area is limited, but analysis of a large, nationally representative cohort of children in the UK born around the millennium (the Millennium Cohort Study, N=16,936) found that children with increasing BMI trajectories from ages 3 to 11 had higher emotional symptoms at age 11 compared to children with stable, low trajectories (81). This is supported by a longitudinal study of Australian children born around the same time (Longitudinal Study of Australian Children (LSAC), N=3363), for whom higher BMI values around the age of 5 were associated with higher emotional problems at age 9 (82), even after adjusting for baseline emotional symptoms. While neither study is measuring depression, elevated emotional symptoms in childhood are risk factors for depression in adolescence (25).

2.2.2 Depressive symptoms and subsequent weight

It is also highly plausible that depressive symptoms in young people may lead to weight changes, although the evidence is less conclusive. Understanding this association is complicated by substantial weight changes being part of the criteria for assessing clinical depression (83). Two longitudinal studies in the United States (US), both of adolescent samples born in the 1980s, found evidence that adolescent depression by the age of 14 is associated with higher risks of subsequent adolescent or young adulthood overweight (84,85), though one found evidence only in girls (84). These were a study of 1,512 Minnesotan twins followed from ages 11 to 24 (84) and a study of 4,175 adolescents in Houston, Texas aged 11 to 17 at baseline and followed up one year later (85). In the latter only, adjustment was made for baseline weight.

The association between adolescent depressive symptoms and weight later in the lifecourse has also been investigated. For example, in a UK cohort of participants (N=4,559) born in 1946 (the 1946 National Survey of Health and Development, NHSD)

(86), women with symptoms of depression by age 15 gained more weight between the ages of 15 and 53 years compared to those with no depressive symptoms in adolescence, while men with depressive symptoms by age 15 had lower weights at all ages to 53. In another cohort of 13,753 British participants born twelve years later (1958 NCDS) (79), depression was associated with subsequent underweight in men only, using a time-lagged method to analyse data from ages 7 to 45 years. There was no evidence that depression was associated with later overweight in men or women. Similarly, in a cohort of 5,723 individuals born in 1970 in the UK (BCS70), there was no evidence of an association between psychological distress at age 16 and change in weight between ages 16 and 30 (87). However, in other analyses of the same cohort (N=7,588), teacher-reported emotional symptoms at age 10 (a risk factor for adolescent depression) was associated with greater weight gain from age 10 to 30 in women, but not men (88).

It is rare to find studies examining indicators of mental health concerns or risk factors for depression earlier in the lifecourse, such as in the study above. One other study used data from the Millennium Cohort Study (N=17,215) to investigate the potential reciprocal associations between weight and internalising symptoms from age 3 to 14 years (89). They found no longitudinal associations between ages 3 and 7 years old, but higher BMI at age 7 was associated with higher internalising symptoms at 11 and higher internalising symptoms at 11 were associated with higher BMI at age 14.

2.2.3 Causality in observational studies

There appears to be conflicting evidence for the associations between weight, indicated by BMI, and depression. These inconsistencies may be, in part, due to differences between samples and settings. Despite their longitudinal approaches and adjustment for putative confounders and, in some cases, baseline measurements of the outcome of interest, there may be unmeasured confounding of the associations. This is unavoidable in observational studies and may explain the discordant findings.

In recent years, studies have used genetic instruments associated with weight and with depression to investigate their associations with each other. These have provided important insights in relation to the causal nature of their associations; however, the body of evidence is suggestive of wider social or environmental pathways. For example, studies of unrelated adults have supported a causal association between weight and depression. In one analysis of UK Biobank data of over 48,000 adults with depression and over 291,000 controls (90), genetic variants associated with higher BMI in adulthood were associated with increased odds of adult depression. As some of this association could be due to physiological pathways, analyses were repeated using genetic variants associated with higher BMI but lower risk of metabolic disease, and the same association was observed. Another study investigated the potential bidirectional association between weight and depression combining genetics data from studies of European adults (91). This study found no association between genetic variants associated with adult depression and adult BMI, but strong evidence that genetic variants associated with adult BMI were associated with increased depression.

Yet, subsequent evidence from related individuals suggest that the above studies may have overestimated the association between weight and depression. In a study of over 40,000 Norwegian 8-year-olds (Norwegian Mother, Father and Child Cohort Study, MoBa) (92), after parental genetics were accounted for, there was little evidence that genetic variants associated with child body size were associated with depressive symptoms, while there was some evidence of an association when using adult BMI genetic variants. Although this measured depression at age 8 when depression is likely to be rare, results may suggest that, rather than the child's weight directly affecting their mental health, environmental or societal factors may in fact play a critical role.

2.2.4 Interim summary

The possible bidirectional associations between weight and depressive symptoms across the lifecourse have been much investigated, given their potential implications for public health. Longitudinal studies across multiple generations in the UK have found mixed evidence of an association between childhood weight and adult depressive symptoms, and between childhood mental health and adult weight, in cohorts of children born earlier in the 20th century (e.g., cohorts born in 1946, 1958 and 1970). However, evidence from children born toward the end of the 20th and beginning of the 21st centuries (ALSPAC and Millennium Cohort Studies) suggests a pathway from childhood weight to higher depressive symptoms in adolescence, even after adjusting for baseline mental health. This could suggest that the association between weight and depressive symptoms is changing over time and affecting younger generations to a greater extent. However, the research to date has used BMI to indicate weight status, which cannot distinguish between fat and lean mass. It is important that the associations between these component parts of total body weight with depressive symptoms are investigated, alongside exploration of potential mechanisms, which may elucidate opportunities for intervention.

2.3 Mechanisms linking overweight and depressive symptoms in youth

The evidence discussed so far favours an early life pathway from weight to later depressive symptoms. It is likely that there are multiple complex mechanisms by which this may occur. Much attention has been given to potential physiological mechanisms in studies of adults, including inflammation and metabolic dysregulation (93). However, metabolic disorders are uncommon in children (94). Furthermore, evidence that the magnitude of association between weight and depressive symptoms has increased in children born 10 years apart opposes a genetic basis (73). This suggests that societal or environmental mechanisms are highly plausible.

Societal weight stigma is a cultural phenomenon of negative perceptions towards people with higher weights. These include sometimes subconscious negative stereotyping of people with higher weights as lazy, lacking willpower, or as less intelligent (95). This stigma can affect individuals across the lifecourse. For example, teachers may assign lower grades to students with higher weights compared to healthy weight students (96). There is evidence that women with higher weights may have poorer employment outcomes (78). Healthcare workers have been shown to hold negative perceptions of people with higher weights, which can lead to reduced trust and avoidance of care (97). In media, television shows popular with adolescents commonly portray weight stigmatising content, including stigma targeted toward women with average weights (98). More recently, social media has provided a new medium for the perpetuation of weight stigma to young people (99).

Interpersonal relationships can also be a source of weight stigma messaging. This can include overt bullying by peers, which is significantly more likely in young people with higher weights (100). Families can also perpetuate this messaging, through the modelling of dieting behaviours and negative weight-based commentary (101–103).

Indeed, studies have shown that children as young as three years old show weight bias (104–106).

Exposure to weight stigmatising messaging may also contribute to an association between weight and depressive symptoms via effects on physical activity. This may be due to experiences of, or fears of, victimisation from peers and feelings of insecurity as some studies have shown (107). Physical activity, in turn, may have a protective effect on depressive symptoms, evidenced by intervention studies (108). Therefore, weight stigma, perpetuated through a range of sources may act as a barrier to physical activity in children and adolescents with higher weights, which may increase their risk of depression or elevated depressive symptoms.

Through exposure to societal weight stigma from an early age and potentially from multiple sources, these beliefs can become internalised, leading to body image concerns.

2.4 Body image concerns

Body image encompasses how individuals feel about and see their own bodies. It has been theorised as a multidimensional construct, comprising perceptions, attitudes, cognitions, and behaviours in relation to appearance, shape, and size (109). Thus, body image concerns can include inaccurate perceptions of weight, dissatisfaction with the body, and the use of unhealthy behaviours to try to change weight. Body image is dynamic across the lifecourse, though there is evidence that adolescence is a sensitive period for body image concerns due to the physiological, social, and psychological changes that occur (110).

2.4.1 Epidemiology

Evidence from annual national surveys in the UK and conducted since 2009-10 (Understanding Society) show that young people's satisfaction with their appearance has been decreasing. In these surveys, young people aged 10 to 15 report their happiness with various aspects of their life, including family, school, friends, and life as a whole. While satisfaction with some aspects such as their family was high and has not changed over the decade to 2020-21 (mean happiness with family in 2020-21: 8.9, scale 0 to 10), satisfaction with their appearance was lowest out of all aspects of life (mean 6.8 in 2020-21) and was significantly lower than when the survey began (mean 7.2 in 2009-10) (111). More young people were unhappy with their appearance than any other aspect of life (defined as scoring less than 5 on the happiness scale 0 to 10). In 2021, approximately one in seven children were unhappy with their appearance (15.2%), an increase from one in ten (11.1%) in 2009 and substantially higher than other aspects of life (e.g., 5.1% unhappy with friends, 1.6% unhappy with family) (111).

Evidence suggests that body image concerns have been rising in young people over a longer period of time, however. Analyses of two cohorts of 14-16 year olds from across the UK in 1986 and 2015 (BCS70 and the Millennium Cohort Study) showed that a greater proportion of adolescents saw themselves as overweight in 2015 (33.4%) than did adolescents in 1986 (22.2%) (112). This increase was not explained by changes in the distribution of BMI over this time, as even after adjusting for their measured BMI, adolescents in 2015 were more likely to see themselves as overweight compared with those in 1986. Similarly, more adolescents in 2015 reported dieting to try to lose weight compared to those in 1986 (44.4% compared to 37.7%). Greater increases were seen in the proportion who had exercised to try to lose weight (60.5% in 2015 compared to 6.8% in 1986).

Body image concerns are more prevalent in girls but recent increases in boys have reduced this gender gap (111,112). Prevalence also increases with age across adolescence (111) and can persist into mid- and later life (113) suggesting that body image concerns arising in or prior to adolescence can become chronic over the lifecourse.

2.4.2 Links with eating disorders and disordered eating

Body image concerns are a key diagnostic criterion of many eating disorders, including Anorexia Nervosa and Bulimia Nervosa (83). In addition, body image concerns are strongly linked to disordered eating behaviours, such as binge eating (i.e., eating more than a normal amount of food in a short time while experiencing a sense of loss of control), purging (e.g., inducing vomiting after eating), or extreme dietary restriction (e.g., fasting for long periods of time or skipping meals). Eating disorders tend to have their onset during adolescence or young adulthood (114), but subclinical symptoms, including body image concerns are likely to predate this. An estimated 90% of eating disorders occur in women, and data on lifetime prevalence of eating disorders in women by mid-life suggests that approximately one in seven meet criteria for an eating disorder diagnosis at some point in their lives (115). Eating disorders are associated with psychological and physiological morbidity and mortality; for example, mortality rates can be over 5 times higher in people with an eating disorder than in the general population (116).

Related to eating disorders is body dysmorphic disorder, which is considered an obsessive-compulsive disorder (83). Body dysmorphic disorder is characterised by an extreme preoccupation with a perceived defect in physical appearance that causes significant impairment to daily functioning. In men, this can present as muscle dysmorphia specifically, although in both sexes, the dysmorphia may be unrelated to body size or shape but could focus on a particular aspect of appearance (e.g., nose). As with eating disorders, body dysmorphic disorder disproportionately affects young women, affecting approximately 6% of late adolescent girls (11). Body dysmorphic disorder is associated with almost four times higher odds of suicidality (117).

These close links with eating disorders and other serious mental illnesses highlight the need for further research attention into the development of body image concerns.

2.4.3 Measurement of body image concerns

As a multi-dimensional construct, there are multiple aspects to body image concerns that may be measured in scientific studies (118). This may include affective aspects, such as satisfaction with overall appearance or with specific body parts. Cognitive aspects, such as how important appearance or thinness is to an individual, or behavioural aspects, including whether an individual is trying to alter their weight, are also commonly measured. Weight perceptions may also be measured. Often researchers have been interested in distorted perceptions of weight, perhaps due to the relevance this may have for eating disorder diagnostic criteria (i.e., inaccurate perceptions). However, a recent systematic review of 78 studies, half of which were in young people, suggested that individuals who see themselves as overweight may gain more weight over time, regardless of actual weight status (119), potentially via disordered eating behaviours. This highlights that accurate weight perceptions may be equally harmful to wellbeing.

Figure rating scales

Body image assessment in children or adolescents often uses Figure Rating scales, such as those developed by Stunkard (120). Often these are sex-specific and the number of figures for each sex ranges from seven to nine. On one extreme is a very thin child with protruding ribs, while on the other is a very overweight child with excess weight around the stomach. Young people are asked to select the body type that they think best represents their current body size and which represents their ideal size. A difference between current and ideal body size is interpreted as body dissatisfaction. However, some have criticised figure rating scales due to modest correlations between young people's self-rated current body size and their actual BMI, while others suggest that this does not limit their use as a measure of body dissatisfaction (121).

Questionnaires

Questionnaires are commonly used to capture relevant constructs in young people's body image. In children, the Body Esteem Scale is frequently used (122), which uses 20 items relating to overall appearance, body shape and weight, and the weight-related opinions of parents and peers. This has been demonstrated as having good reliability and validity (122). A large number of questionnaires have been developed to measure body image concerns in adolescents, which capture satisfaction with overall appearance, weight or shape, or with specific body parts or characteristics (123). Commonly these use Likert-style response scales to measure on a satisfaction-dissatisfaction continuum.

Most epidemiologic research has focused on attitudinal components of body image, predominantly using scales of body satisfaction. In large cohort studies, which aim to generate rich data about many aspects of people's lives, full body image scales may be too long for inclusion. Therefore, many large, longitudinal studies of adolescent health and wellbeing feature a similar set of a few items that capture different dimensions of body image. For example, the National Longitudinal Study of Adolescent Health (Add Health) in the US and ALSPAC in the UK have established the use of single questionnaire items capturing different aspects of body image (124). This includes, for example, measuring weight perceptions by asking participants to describe their weight from the options underweight, about right, slightly overweight or very overweight. These surveys also ask participants about weight control behaviours such as purging, dieting, or the use of diet pills.

Body image concerns in boys

Historically, body image concerns were considered to be a phenomenon only occurring in women and girls (125). Boys were largely excluded from research until the end of the 20th century (126,127). As a result, many established and well-validated measures are designed to capture the female experience of body image concerns, which reflects the societal desire for thinness. This may not translate fully to the male experience, which is more focused on gaining a muscular physique and being tall. Specific scales have been developed for use in men, such as the Drive for Leanness Scale (128). However, large, population-representative surveys of young people frequently use one set of body image questions for both sexes, which primarily focus on thinness. This may still be appropriate, given that the social stigmatisation of weight affects all genders.

2.4.4 Associations between body image concerns and weight

Numerous studies have demonstrated the presence of an association between weight, measured by BMI, and body dissatisfaction. Evidence from Project-EAT, a study of more than 4,700 adolescents in Minnesota, US starting in 1998 (mean age 14.9), showed that 66% of girls with BMIs in the very overweight range reported low body satisfaction (129). In boys, the figure was 48%. However, even amongst those with BMIs in the healthy range, low body satisfaction was present in 38% of girls and 19% of boys. This cross-sectional evidence demonstrates the high prevalence of body image concerns in young people with higher weights and that body image concerns occur across the weight spectrum, particularly in girls.

The association between weight and body image concerns has been further elucidated in cross-sectional and the few existing longitudinal studies in early adolescence. Cross-sectional evidence from a large sample (N=4,254) of 10-11 year olds in Nova Scotia, Canada in 2003 suggests that in girls, the association appears to be linear, with increasing BMI associated with increased body dissatisfaction (130). This is consistent with societal body ideals in women, which favour thinness and stigmatise fat (128). In boys, however, there is evidence that the association is U-shaped, with both underweight and overweight BMIs associated with increased body dissatisfaction (130). This finding was also replicated in a nationally representative longitudinal study of 9 to 18 year olds in the United States (N=16,882) between 1996 and 2001, albeit using self-reported measures of weight and height (131). This non-linear association in boys may reflect societal body ideals in men, which promote lean muscularity, thereby stigmatising both overweight and low muscle mass (128), although this explanation is speculative.

Longitudinal evidence from the UK also supports an association between weight and body image concerns. Analysis of 16,936 children in the Millennium Cohort Study suggested that children with higher BMI trajectories from age 3 to 11 years had lower body satisfaction scores at age 11, compared to those with BMIs in the healthy range across childhood (81).

2.4.5 Associations between body image concerns and depressive symptoms

Evidence supports a longitudinal association between body dissatisfaction and depressive symptoms in young people. For example, in a sample of early (mean age 12.9) and mid adolescent (mean age 15.9 years) cohorts in Minnesota, US (N=1,902) starting in 1998, body dissatisfaction at baseline was associated with higher depressive symptoms five- and 10 years later (132). Similar associations have been observed in the UK. For example, in ALSPAC participants, body dissatisfaction at age 14 was associated with increased depressive symptoms at age 18 in both girls and boys (133). This has been replicated in Millennium Cohort Study participants (N=12,450), who were born approximately 10 years later (134).

These are pertinent findings in relation to UK mental health policy, as body image is potentially modifiable. Indeed, evidence from intervention studies targeting body image concerns have also shown improvements to depressive symptoms (135). Therefore, understanding the earlier life determinants of body image concerns may help elucidate new ways to reduce body image concerns or prevent them from occurring in the first place.

2.4.6 Childhood risk factors for body image concerns

Longitudinal studies have predominantly focussed on body weight as a risk factor for body image concerns. It has previously been suggested that body dissatisfaction or accurate weight perceptions in people with higher weights may be beneficial, as a potential motivator for weight loss (136). However, this is contrary to the evidence. A ten-year study in Project EAT in the United States found that high body satisfaction is associated with less weight gain over time in girls with overweight BMIs (137). A recent review of 78 studies also found that people who perceived themselves as overweight gained more weight over time, regardless of their actual weight status (119). Both weight and body image concerns may be barriers to physical activity, which may affect long term health (110,119). In addition, links with depression, self-harm and eating disorders highlight the potential health benefits that may arise from interventions to reduce or prevent body image concerns. This is notable, as body image concerns are modifiable. However, they have the potential to become chronic across the lifecourse (138).

This suggests that early interventions to promote positive body image, particularly in people with higher weights, may have long-term benefits to health and wellbeing. However, there has been little attention given to potentially modifiable environmental factors in childhood which could be targeted for intervention to improve body image. Some longitudinal evidence suggests that family members and peers may influence body image concerns in adolescence. For example, evidence from a cohort of adolescents aged 11 to 18 years in Minnesota, US, starting in 1998 (Project EAT, N=1,655) found that body dissatisfaction was higher ten years later in adolescents whose parents or peers dieted or teased them about their weight, compared to those whose parents or peers did not (139). There has also been interest in the role of media, particularly social media, in the development of body image concerns. Cross-sectional evidence from the Millennium Cohort Study (N=10,904) suggests that greater social media use is associated with greater body dissatisfaction in 14-year-olds (140).

Longitudinal studies, including those mentioned above, which investigate socio-environmental risk factors for body image concerns predominantly examine risk factors in adolescence. It is rare for prospective studies to examine risk factors in childhood. However, this is important in terms of prevention, as studies suggest that children, including pre-school aged children, demonstrate weight stigmatising beliefs (105). At this stage of socio-emotional development, peers and social media may be relatively less important to investigate, whereas familial factors may be much more pertinent. There is a dearth of evidence into potential familial risk factors in childhood. In ALSPAC (N=5,703), childhood family risk factors for eating disorder symptoms were investigated, but this was limited to early childhood financial problems and maternal history of eating disorders (141). Therefore, there is a need to investigate modifiable childhood risk factors for body image concerns that could be targeted for intervention, particularly within the family as childhood obesity policy in the UK places a high level of responsibility on families making lifestyle changes to reduce the prevalence of childhood overweight (see **1.2.3**).

2.4.7 Parental feeding practices

Given the policy focus on reducing the prevalence of childhood overweight and attention on the role of families, there has been growing research into how parents can shape their child's diet and eating habits, and whether this influences their child's weight development. Evidence suggests that appetite has a strong genetic basis, but is also influenced by the food environment, including parental feeding practices (142). This term captures the strategies a parent may use to control or change how much and of what their child eats. This could be done through, for example, avoiding having certain foods in the home, overtly restricting certain foods, or pressuring their child to eat more of some foods. These practices are likely to occur in response to both the child's appetite and their prior or current weight development (143,144). For example, parents who are concerned about their child being underweight or having a low appetite may encourage or pressure their child to eat more; parents of children who are overweight or have an avid appetite may use more restrictive feeding practices (145).

Although these strategies may be used to encourage healthy weight development in children, evidence of a longitudinal association with weight is mixed. Although some longitudinal studies have found that parental control of their child's diet is associated with changes in child BMI (146), recent studies seem to suggest that parental dietary control does not influence their child's subsequent weight (144,145). However, it is plausible that certain parental feeding practices, including dietary control or restriction, or using food as a reward or punishment, could have a negative impact on the child's subsequent body image.

This has received limited research attention to date. A retrospective study of adult women found that those who recalled receiving more restrictive eating messages from caregivers as children reported greater body shame and disordered eating behaviours in adulthood (147), although there was a high risk of recall bias in this study. Yet, similar findings were observed in analyses of two prospective cohorts (Generation R in the Netherlands and the Gemini twin study in the UK), in which parental restriction and use of food as a reward or punishment at age 4-5 was associated with small increases in some disordered eating behaviours at ages 12-14 (148). It is important, therefore, to examine this in a more representative cohort of young people in the UK and investigate the association with body image concerns more broadly, which may be more prevalent at this age and could be leveraged to improve mental health.

2.5 Gaps in current knowledge

This section summarises the major gaps in current knowledge that will be addressed in this thesis. More detailed discussion of the existing evidence and gaps in knowledge relevant to each study within this thesis are presented in the analytical chapters that follow.

2.5.1 Methodological issues in body image research

There are a number of methodological issues affecting the body image research field, which have been highlighted in reviews and rapid assessments of the evidence. First, certain populations are over-represented in the literature (149), including women, participants from White ethnic groups, and late adolescent or young adult samples, particularly university attendees. This represents a relatively advantaged subgroup of the general population. Investigation of body image concerns in other groups, for example in men and boys, often specifically samples boys only and is therefore unable to investigate potential differences between boys and girls (150).

Second, the field is dominated by correlational studies, particularly with cross-sectional designs (149). Given the evidence of bidirectional associations between weight, body image and depressive symptoms, there is a need for methodologically rigorous studies from large, longitudinal datasets that can generate evidence in support of causal associations. This can be achieved with observational data through causal diagrams, extensive adjustment for putative confounders, and controlling for baseline measurements of the outcome variable to assess unidirectional associations. Studies using these approaches are relatively uncommon in relation to body image concerns. For example, there are few longitudinal studies testing the mechanistic role of body image concerns in the association between weight and depressive symptoms

(134,151). Most are cross-sectional studies with limited or no adjustment for confounders and, although they hypothesise that body image concerns are mediators, they use statistical adjustment as a proxy for mediation analysis (152–154). This results in weaker evidence that is less likely to provide a strong case in support of changes in practice or policy.

Third, even where longitudinal designs are used, studies of body image concerns commonly focus on adolescence. However, from a lifecourse perspective, it is likely that risk factors for body image concerns and depressive symptoms occur in early life. Yet, there are few studies investigating risk factors in early childhood. Furthermore, although there has been a relatively large number of studies investigating the association between weight and body image concerns or depressive symptoms, these generally measure weight at a single time point, mostly in adolescence or late childhood. Few consider the lifecourse nature of weight development (81), which may highlight opportunities for intervention.

2.5.2 Limitations of Body Mass Index

Weight has been demonstrated as a major risk factor for body image concerns and is also longitudinally associated with depressive symptoms. This is based on extensive research using BMI, which measures total body weight. However, theory relating to gendered body ideals and societal weight stigma suggests that distinct components of total body weight, namely levels of adiposity and muscularity, may be important risk factors for body image, but these are not distinguished in BMI. In boys, who have historically been excluded from body image research, levels of muscularity may be as important or more important than adiposity levels. Potential sex differences in associations between body composition measures and body image concerns may become increasingly apparent across the pubertal transition, as lean mass increases in boys, while adiposity increases in girls (68,69). These physiological changes in puberty may result in boys developing to be closer to the societal body ideal, while physiological changes in girls may result in body changes that are further from the societal ideal for feminine bodies.

This is speculative as there has been no investigation of the roles of adiposity and muscularity in the development of body image concerns or depressive symptoms in longitudinal studies of large, UK-representative samples of youth. However, these measures of body composition, which include fat mass and fat-free mass, are available in UK cohort studies. Utilising these measures, the limitations associated with BMI may be mitigated, while also addressing the methodological issues in the body image field that were highlighted above, such as by using repeated measures across childhood.

2.5.3 Parental dietary control as a modifiable childhood risk factor for body image concerns

There is great value in researching body image concerns as a mechanism linking overweight and depressive symptoms. This is due to body image concerns being potentially modifiable. However, it is important to also elucidate potential avenues for intervention to improve or prevent body image concerns. Evidence suggests that exercise-based interventions, media literacy, and psychotherapeutic programmes may be effective at improving body image concerns (149). Yet, with increasing demand for mental health support, there is a growing focus on prevention. For effective prevention to occur in relation to body image concerns, it is necessary to understand the role of early childhood factors, given that pre-school aged children display weight stigmatised beliefs (105). Both body image theory and childhood obesity policy place a high value on the role of families early in life, and there is evidence that body weight and body image are bidirectionally associated (81,137). There is a need, therefore, for investigation of how families can shape both healthy weight and healthy body image across the early lifecourse in the context of societal weight stigma. In particular, parental messaging around what and how much to eat, including dietary control and the use of food as a reward or punishment, could increase the risk of a child developing body image concerns in adolescence. Given that parental dietary control is modifiable, this warrants further investigation.

2.6 Summary

Increasing rates of mental health concerns and overweight in young people are major public health priorities in the UK, particularly as both may have long-term health and social consequences and could be reduced through early intervention. Evidence from longitudinal studies supports a bidirectional association between weight and depressive symptoms, with stronger evidence to support a pathway from weight to depressive symptoms in young people. Although there are likely to be many potential pathways through which overweight may lead to increased depressive symptoms, evidence suggests that environmental explanations are credible. A highly plausible environmental mechanism that may link weight and depressive symptoms is societal weight stigma, which encompasses the cultural disapproval of higher weight.

Exposure to societal weight stigma can lead to its internalisation and therefore body image concerns, such as body dissatisfaction. Evidence demonstrates an association between body image concerns and both weight and depressive symptoms, though this is predominantly cross-sectional and often lacks generalisability to the general population of young people. Body image concerns are considered an important potential pathway underlying the association between weight and depressive symptoms in young people which warrants further attention for several reasons. First, body image concerns have been rising in tandem with BMIs and depressive symptoms in young people. Second, it is potentially modifiable, and interventions improving body image have been shown to also reduce depressive symptoms. Improving body image is also a key element of the treatment of eating disorders and body dysmorphic disorder.

However, there are a number of key limitations in this area of research that will be addressed in this thesis. First, most evidence into the associations between weight, body image, and depressive symptoms is cross-sectional and does not appropriately account for potential confounders of these associations. Of particular importance is adjustment for baseline measurements of the outcomes of interest.

Second, these associations should be examined in large, diverse samples of young people in the UK. Relatively advantaged subgroups have been overrepresented in this field, such as White and more economically advantaged groups. Furthermore, most research focuses on body image and its risk factors in later adolescence, but it is likely that development of body image concerns begins earlier in the lifecourse. Therefore, it is crucial to examine the influence of risk factors for body image concerns, such as body weight, across the early lifecourse.

Third, existing evidence into the associations between body weight, body image and depressive symptoms in young people uses BMI to indicate weight. This is generally as a proxy for measures of adiposity, given that excess adiposity is stigmatised in society. However, the validity of BMI as a proxy for adiposity is disputed. Additionally, there are differences in the societal body ideals that boys and girls may favour. Desires for thinness in girls and lean muscularity in boys are ignored using BMI, as it cannot distinguish between fat and lean mass. This should be addressed to further understand how body weight influences body image in girls and boys. A lifecourse approach, which considers long-term weight development is necessary.

Finally, there is a need for more research into the early life factors that are associated with the development of both overweight and body image concerns, which may help elucidate opportunities for prevention. Family factors in early childhood warrant special attention as weight bias has been displayed in pre-school aged children, and childhood obesity policies in the UK place a large responsibility on families making lifestyle changes to reduce weight, which could contribute to internalised weight stigma and body image concerns in young people.

Addressing these limitations and research gaps could generate strong and robust evidence to better understand the links between two major public health challenges in young people – overweight and depression – and potentially expose new opportunities to promote health.

3 Aims and Objectives

The overall aim of this thesis is to understand the role that body image concerns play in the association between childhood body composition and adolescent depressive symptoms. To achieve this, the associations between each of these are investigated, before the mediating mechanism of body image concerns is formally tested. Finally, the thesis explores potentially modifiable early life familial factors that may be associated with weight development and body image concerns that could be targeted to reduce or prevent body image concerns.

The work presented in this thesis is iterative, such that findings from each objective outlined below influence the research that follows. This is described in detail in relevant results chapters.

3.1 Objective 1: Model childhood trajectories of body composition and investigate their early life correlates

In the first objective of this thesis, trajectories of BMI, adiposity, and muscularity are modelled across childhood through to age 14. Their early life correlates are investigated, in a hypothesis-generating descriptive study. This study aims to identify antecedents of body composition trajectories that can be considered as potential confounders of the associations investigated in Objectives Two and Three.

The following hypothesis is tested:

> ***Hypothesis 1:*** *There are distinct trajectories of adiposity and muscularity across childhood, as have previously been seen for BMI.*

3.2 Objective 2: Investigate associations between childhood body composition trajectories and adolescent body image concerns

Building on the work in the first objective, the associations between childhood trajectories of BMI, adiposity, and muscularity and adolescent body image concerns are investigated. This study aims to test whether adiposity and muscularity trajectories to age 14 are differentially associated with body image concerns at ages 14 and 17 in boys and girls.

The following hypotheses are tested:

> ***Hypothesis 2:*** *Higher trajectories of adiposity are associated with greater body image concerns compared to low trajectories, and the magnitude of association will be greater in girls compared to boys.*
>
> ***Hypothesis 3:*** *The magnitude of association is greater using adiposity trajectories compared to BMI trajectories.*
>
> ***Hypothesis 4:*** *Higher trajectories of muscularity are associated with fewer body image concerns compared to low trajectories, and the magnitude of association will be greater in boys compared to girls.*

3.3 Objective 3: Investigate the extent to which body satisfaction mediates the association between childhood body composition trajectory and adolescent depressive symptoms

The third objective focusses on one aspect of body image concerns – body satisfaction. The associations between body composition trajectory and depressive symptoms, and body satisfaction and depressive symptoms are investigated. Then, the extent to which body satisfaction at age 14 mediates the association between childhood body composition trajectory and adolescent depressive symptoms at age 17 is formally assessed. Potential bidirectionality of associations is addressed through baseline and intermediate confounder adjustment.

The following hypotheses are tested:

> ***Hypothesis 5:*** *Higher trajectories of BMI and adiposity are associated with higher depressive symptoms in adolescence, with a greater magnitude of association with adiposity-specific trajectories.*
>
> ***Hypothesis 6:*** *Higher body satisfaction is associated with lower depressive symptoms at a later age.*

Hypothesis 7: *Body satisfaction partially mediates the association between childhood body composition trajectory and adolescent depressive symptoms.*
Hypothesis 8: *The proportion of the association mediated by body satisfaction is greater for adiposity trajectory than for BMI trajectory.*

3.4 Objective 4: Investigate the association between a parent's concern about their child's future weight and control of their diet with trajectories of BMI and body satisfaction

The final objective investigates potentially modifiable familial factors in early childhood that may be associated with both weight development and body image concerns in adolescence, again focussing on body satisfaction. Potential modifiable familial factors considered are parental concern about their child's future weight and control of their child's diet for weight-related reasons, both measured when the child is age 5. These are selected as they are common targets for behaviour change in childhood obesity strategies.

The following hypotheses are tested:

Hypothesis 9: *Higher parental concern about their child's future weight and control of their child's diet for weight-related reasons are not associated with differences in adolescent BMI trajectories to age 17 after adjusting for prior BMI.*
Hypothesis 10: *Higher parental concern about their child's future weight and control of their child's diet for weight-related reasons are associated with lower body satisfaction from age 11 to 14 after adjusting for prior BMI.*

4 Data

The UK is home to a wealth of large-scale, longitudinal datasets dating back to the end of the Second World War, including four birth cohorts started in 1946, 1958, 1970 and 2000. These studies provide lifecourse data across times of huge societal shifts, including the introduction of the National Health Service and transitions in working practices, nutrition, and activity levels. More recently, rapid technological advancements, such as the internet and social media, have further altered the social landscapes in which people grow and develop. To generate findings most relevant to the experiences of young people today, this thesis uses data from the most recent cohort study, the Millennium Cohort Study.

4.1 Introduction to the Millennium Cohort Study

The UK Millennium Cohort Study is a prospective, longitudinal cohort study of around 19,000 children living in the UK at 9 months of age and born around the year 2000. The Millennium Cohort Study is a nationally representative study which over-sampled children from ethnic minorities, disadvantaged backgrounds, and devolved nations (155). To date, there have been seven waves of data collection, from 9 months to 17 years old, with additional surveys conducted during the COVID-19 pandemic. With repeated questionnaires from multiple sources, the sweeps provide longitudinal, life course data on children's physical, psychosocial, cognitive, and behavioural development, in addition to their family and economic circumstances (155). The data collection sweeps and sources of data in each are depicted in **Figure 4-1**.

4.2 Eligibility and sampling methods

The target population was identified through government records of universal child benefits (156). This sampling method captured almost all children in the UK, as only very few children, such as asylum seekers, were ineligible. In England and Wales, children born between 1st September 2000 and 31st August 2001 were eligible to participate in the Millennium Cohort Study, while in Scotland and Northern Ireland, the birth date range for inclusion was 24th November 2000 and 11th January 2002.

From its inception, the Millennium Cohort Study was designed to be representative of the UK population. To achieve this, a stratified sampling frame was used, with additional oversampling of children traditionally under-represented in research. Stratification was done at an area level, based on electoral wards (157). Oversampling of children from ethnic minority backgrounds was done in England only, using data from the 1991 Census to identify wards with at least 30% of the population from minority ethnic backgrounds. For all UK nations, children from disadvantaged backgrounds were those living in the poorest 25% of wards according to the Child Poverty Index. Areas which were not identified as 'ethnic minority' or 'disadvantaged' strata were considered 'advantaged' areas. Within these three strata (two in devolved nations), clustered sampling was used to select electoral wards, within which a random sample of eligible families was selected. Families were identified from Department for Work and Pensions (formerly the Department of Social Security) lists of children turning nine months old from child benefit records, which was a universal programme at the time. Sensitive cases, such as families where children had been taken into care by the local authority, were removed by the Department for Work and Pensions.

4.3 Sample

At baseline (MCS 1, age 9 months), 18,552 families were recruited, which included 246 sets of twins and 10 sets of triplets, resulting in 18,818 cohort members (156). Notably, at the second sweep (when the cohort member was around 3 years old), a further 1,389 families were identified as potentially living in sampled wards at baseline but whose details were not provided in time to be included in the first sweep. This resulted in a further 692 families joining the survey (156). At each data collection sweep, all families not identified as ineligible were invited to take part (referred to as the issued sample). Families could become ineligible due to death or emigration, permanent refusal to take part, or sensitive situations. **Figure 4-2** details the sample achieved at each sweep to date (to MCS 7, age 17) (156,158,159).

Non-response in one data collection sweep does not prevent Millennium Cohort Study families from being reissued (reinvited) to participate in later sweeps, as shown in **Figure 4-2**. The Millennium Cohort Study team uses a number of tracking procedures to minimise attrition due to loss of contact; for example, families are requested to update their contact details annually, and electoral or phone records and provided "stable contacts" are used to locate families who move address without providing new details (155). These methods aid in maintaining response rates in each data collection

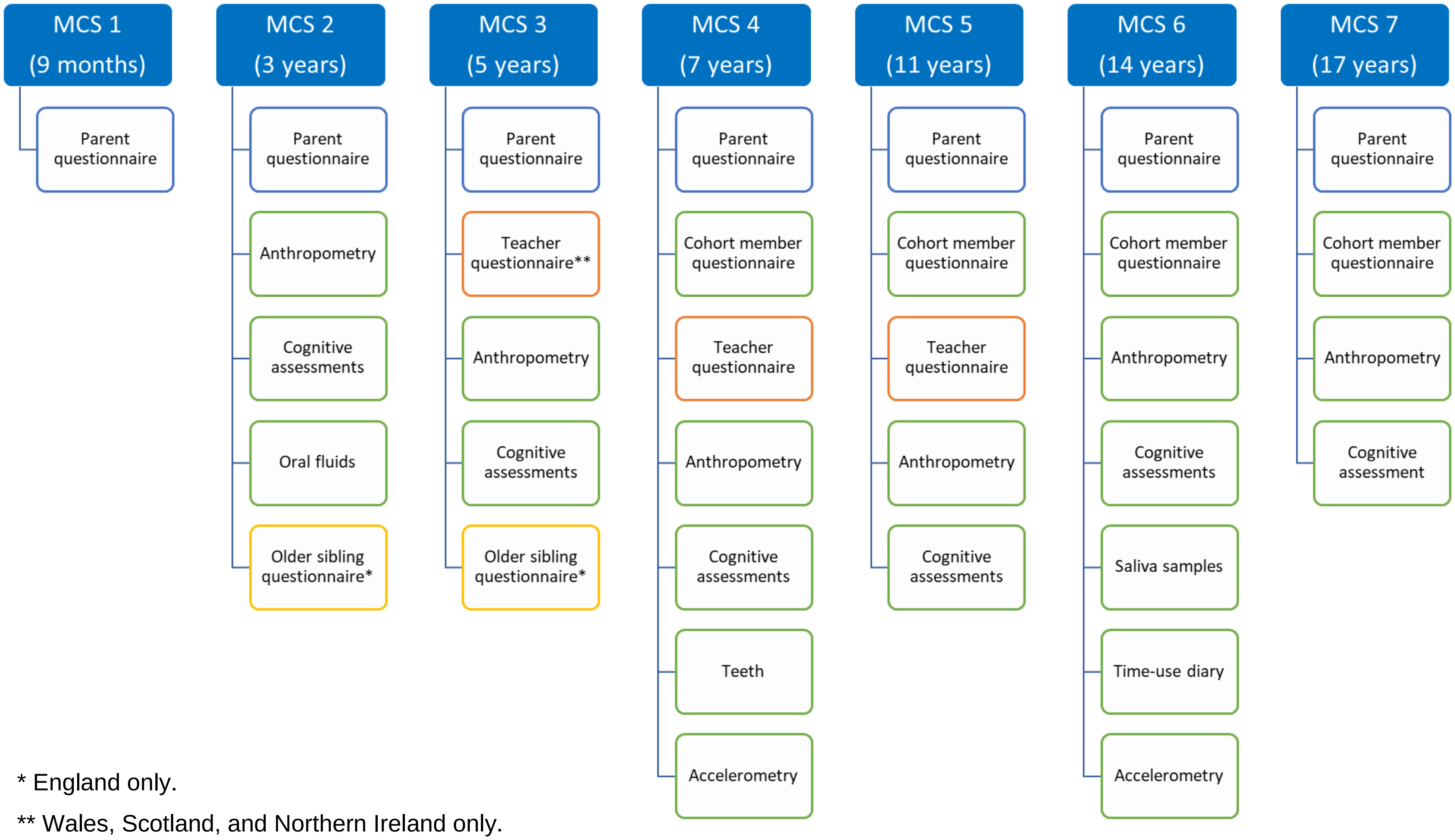

Figure 4-1. Millennium cohort study data collection sweeps and sources of data.

Collated from Millennium Cohort Study User Guides.

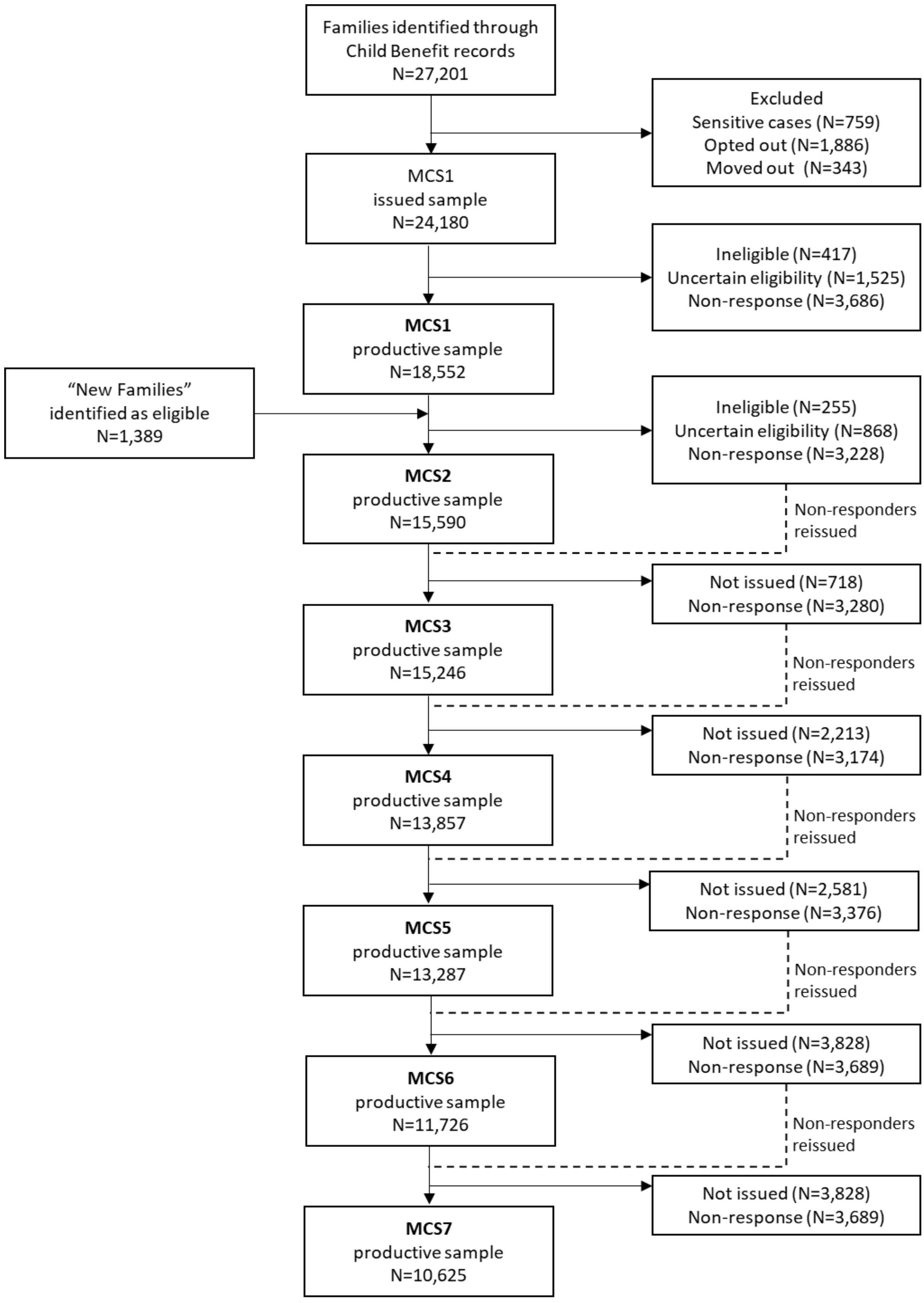

Figure 4-2. Flowchart of productive and non-productive families across Millennium Cohort Study sweeps.

sweep above 70% of the issued sample (

Table 4-1). By MCS 7 (age 17), 40.7% (N=7,842) of respondents had participated in all seven data collection sweeps and 25.1% (N=4,822) have interrupted response patterns (159). Analysis by the Millennium Cohort Study team shows that 56.9% of respondents participated in at least six out of the seven data collection sweeps, demonstrating a high proportion of complete or near-complete records (159). Non-response across sweeps remains higher in ethnic and disadvantaged strata compared to advantaged strata (**Table 4-2**) (156). To account for the stratified sampling methods and non-random attrition, sampling weights must be applied to all analyses. These are provided by the Millennium Cohort Study team and include a number of predictors of non-response, including the cohort member's gender, ethnic group and their family's housing tenure (157).

All analyses described in this thesis were conducted on participants with valid data on the exposure of interest, with any missing data on confounders and outcomes imputed using multiple imputation by chained equations (described in more detail in each empirical chapter) assuming that data are missing at random. To reduce the risk of bias due to shared genetic and environmental factors, in cases of multiple births, data on one child at random was selected for inclusion. Additionally, data from the new families joining from MCS 2 (age 3) was excluded due to potential biases arising from sociodemographic data being collected at a later age compared to the core sample at MCS 1 (age 9 months). The sample analysed for each study is further described in each empirical chapter as this varies based on the exposure of interest.

4.4 Ethical considerations

Ethical approval was granted by the National Health Service Ethical Authority (MCS 1), the London Multi-Centre Research Ethics Committee (MCS 2, MCS 3), the Northern and Yorkshire Multi-Centre Research Ethics Committee (MCS 4, MCS 5), the National Research Ethics Service Research Ethics Committee London – Central (MCS 6) and the UCL IOE Research Ethics Committee (MCS 7). Further details of these procedures can be found in User Guides to the Millennium Cohort Study (156,158,159).

Table 4-1. Response rates to Millennium Cohort Study sweeps.

Sweep	Year	Age	Issued Sample	Achieved Family Sample	% of Issued Sample Achieved
MCS1	2001/2	9 months	21,180	18,552	87.6
MCS2	2003/4	3 years	19,244	15,590	81.0
MCS3	2006/7	5 years	18,528	15,246	82.3
MCS4	2008/9	7 years	17,031	13,857	81.4
MCS5	2012/13	11 years	16,393	13,287	81.1
MCS6	2015/16	14 years	15,415	11,726	76.1
MCS7	2018/19	17 years	14,496	10,625	73.3

Table 4-2. Stratum-specific response rates to Millennium Cohort Study baseline sweep.

Strata	Child Benefit Sample	Productive Sample	% of Child Benefit Sample Productive
England			
Advantaged	6364	4617	73
Disadvantaged	6678	4522	68
Ethnic Minority	3906	2394	61
Total	16948	11533	68
Wales			
Advantaged	1074	832	77
Disadvantaged	2784	1928	69
Total	3858	2760	72
Scotland			
Advantaged	1579	1145	73
Disadvantaged	1748	1191	68
Total	3327	2336	70
N. Ireland			
Advantaged	1109	723	65
Disadvantaged	1959	1200	61
Total	3068	1923	63
UK All	27201	18552	68

Consent was obtained from the cohort members' parents (or carers/guardians) up to and including MCS 6 (age 14). From MCS 5 onwards (when cohort members were approximately 11 years old), cohort members also gave their consent to measurements, questionnaires, and data linkage. In order to give informed consent, cohort members had to understand each element of data collection, storage and usage (156). Procedures were also put in place to maintain confidentiality, wellbeing, and safety of participants (159). Respondents' data were handled in accordance with the Data Protection Act and General Data Protection Regulation by interviewers and the Millennium Cohort Study team. Data security was also preserved during analyses for this thesis. Parents and cohort members were signposted to appropriate support services during data collection sweeps.

4.5 Key measures common to all studies

The following variables are common to all empirical chapters presented in this thesis and their measurement is described in detail.

4.5.1 Body Mass Index and body composition

When cohort members were around the age of 3 years, their height and weight was measured by trained interviewers using a standardised procedure to ensure reliability (156). Height was measured using a Leicester height stadiometer and Frankfort Plane card to ensure correct position of the cohort member's head. Cohort members were required to remove shoes and socks to increase the accuracy of the measurement. Height was measured to the nearest millimetre and range checks were included in the data collection script to further improve accuracy. This procedure was used to measure cohort member height again at ages 5, 7, 11, 14, and 17 years.

Weight was measured to the nearest 0.1 kilogram using Tanita scales (BF-522W), which were calibrated prior to use (156). Interviewers were requested to place the scales on an uncarpeted surface, or record whether only a carpeted surface was available. Again, cohort members were asked to remove their shoes, socks, and any bulky items such as belts, and wear light indoor clothing. For cohort members with valid data for both height (in metres) and weight (in kilograms), their BMI was calculated using the standard formula, described in **Table 4-3**. BMI is used as an exposure variable in **Chapters 5, 6 and 7** and as an outcome variable in **Chapter 8**.

Table 4-3. Calculation of body composition measures in Millennium Cohort Study.

Body Composition Measure	**Calculation**
Body Mass Index, kg/m^2 (BMI)	Body Weight / Height^2
Fat Mass Index, kg/m^2 (FMI)	Fat Mass / Height^2 where Fat Mass = (Body Fat (%) / 100) x Body Weight
Fat-Free Mass Index, kg/m^2 (FFMI)	Fat-Free Mass / Height^2 where Fat-Free Mass = Body Weight – Fat Mass
Fat Mass to Fat-Free Mass Ratio (FM/FFM)	Fat Mass / Fat-Free Mass

From age 7 years, Tanita scales, in addition to measuring weight, measured body fat percentage to the nearest 0.1% using bioelectrical impedance analysis (156). For cohort members who consented to have body fat percentage measured, their age, gender and height in centimetres was first entered into the scales by the interviewer (156). Then, a weak electrical current is sent from one foot to the other and the amount of electrical resistance encountered is measured. Adipose (fat) tissue has a lower water content than muscle, meaning adipose tissue has a greater electrical resistance. As a result, a body with a higher proportion of fat is likely to record more electrical impedance, compared to one with a lower fat proportion. Using the information on the cohort member's age, gender and height, body fat percentage can therefore be estimated. This procedure was used to estimate body fat percentage again at ages 11, 14, and 17 years.

Body fat percentage does not account for height, however, and cannot evaluate fat-free mass (71). Therefore, using the equations shown in **Table 4-3**, body fat percentage and weight were used to calculate fat mass and fat-free mass. Both were indexed to account for their correlations with height. Fat Mass Index (FMI) therefore represents a measure of adiposity, while Fat-Free Mass Index (FFMI) could be considered a proxy for lean mass when more specific measurements (such as those from dual x-ray absorptiometry) are not available. Additionally, the ratio of fat to fat-free mass (FM/FFM) was calculated, which measures the relative proportions of fat mass in the body, without requiring adjustment for height and irrespective of total body weight. This can be interpreted as the proportion of fat mass, accounting for the amount of fat-free mass, and may therefore be used as another measure of adiposity. These three measures of different aspects of body composition are used as exposure variables in **Chapters 5 and 6**, and FM/FFM was used as an exposure variable in **Chapter 7**.

4.5.2 Body image concerns

At ages 11, 14 and 17, cohort members completed questionnaires, which included questions relating to their evaluation of their appearance and weight. The questions vary across age as outlined below and summarised in

Table 4-4.

Cohort members' satisfaction with their appearance was measured at ages 11 and 14 using a single item Likert scale question, as part of a wider set of questions measuring their satisfaction with various aspects of their life. They were asked "On a scale of 1 to 7 where 1 means completely happy and 7 means not at all happy, how happy do you feel about the way you look?". In this thesis, responses are reverse coded so that higher scores indicate greater satisfaction. Body satisfaction at age 14 is used as an outcome variable in **Chapter 6** and a mediator in **Chapter 7**. Data at both 11 and 14 are used as outcome variables in **Chapter 8**.

At ages 14 and 17, cohort members were asked "Which of these do you think you are?" with options: Underweight; About the right weight; Slightly overweight; Very overweight. This is referred to henceforth as their weight perception. They were also asked "Which of the following are you trying to do about your weight?" with options: Lose weight; Gain weight; Stay the same weight; I am not trying to do anything about my weight. This is referred to henceforth as their weight intention. Both weight perceptions and intentions are considered as outcome variables in **Chapter 6**.

The behaviours cohort members may have used to control their weight were also measured. At age 14, cohort members were asked "Have you ever exercised to lose

Table 4-4. Measures of body image concerns in Millennium Cohort Study.

Outcome Measures	**Questionnaire Item**	**MCS Sweep (Age)**
Body Satisfaction	On a scale of 1 to 7, where 1 means completely happy and 7 means not at all happy, how do you feel about the way you look?	MCS5 (11) MCS6 (14) -
Weight Perception	Which of these do you think you are? - Underweight - About the right weight - Slightly overweight - Very overweight	- MCS6 (14) MCS7 (17)
Weight Intention	Which of the following are you trying to do about your weight? - Lose weight - Gain weight - Stay the same weight - I am not trying to do anything about my weight	- MCS6 (14) MCS7 (17)
Weight Control Behaviours	In the past 12 months, have you exercised to lose weight or avoid gaining weight?* (Y/N) In the past 12 months, have you eaten less food, fewer calories, or foods low in fat to lose weight or avoid gaining weight?* (Y/N)	- MCS6 (14) MCS7 (17)

*At age 14, participants were asked if they have ever done so.

weight or to avoid gaining weight?" and "Have you ever eaten less food, fewer calories, or foods low in fat to lose weight or to avoid gaining weight?". These are referred to henceforth as exercise for weight loss and dieting for weight loss, respectively. For both, response options were Yes or No. The same questions were asked at age 17, but these measured behaviour in the past 12 months, rather than lifetime behaviour. Weight control behaviours at 14 and 17 are used as outcome variables in **Chapter 6**.

The above body image variables measured at age 17 were not part of the main Young Person questionnaire or self-completion questionnaire at MCS7, but as part of the first online questionnaire utilised in the Millennium Cohort Study (159). Cohort members were asked to complete the online questionnaire after the interviewer had left. Response rates to the online questionnaire were lower than those of the main questionnaire. More detail on response rates to this questionnaire is provided in **Chapter 6**.

5 Childhood Body Composition Trajectories and their Early Life Correlates

5.1 Introduction

Longitudinal studies have generally found that there are distinct trajectories of BMI across childhood (81,160–165). These commonly find three similar patterns of BMI development, representing a group with stable, non-overweight BMIs across childhood and two groups with increasing BMIs which cross into overweight and obese categories at various points during childhood (81,160,163–166). Some also find a fourth group with decreasing trajectories (81,167). Broadly, these studies find that there are early life correlates of these trajectories, including higher maternal BMI, smoking in pregnancy, lower socioeconomic position, and not having been breastfed (81,165,168). Kelly and colleagues also investigated the association of childhood BMI trajectories with early adolescent psychosocial outcomes in the Millennium Cohort Study and found that children with increasing trajectories had lower body satisfaction and higher emotional symptom scores at age 11 compared to children with stable, non-overweight BMIs (81).

Few studies appear to have examined whether there are also distinct trajectories of the body composition components of total body weight. In a cohort of children in New York, Lovinsky-Desir and colleagues found that there were three distinct trajectories of body fat percentage, measured with bioelectrical impedance analysis (169). This study, with a relatively small sample of 418 children, was focused on the association between trajectories of BMI or body fat percentage and asthma and did not investigate whether BMI and body fat percentage trajectories share the same early life correlates. Furthermore, there are potential limitations with body fat percentage as a measure of adiposity – namely, that it does not account for height, which is highly correlated with weight and fat mass (71). Therefore, it is not clear to what extent the trajectories of body fat percentage found in the study of New York children are capturing height trajectories. Two cohort studies of UK children have found evidence of social inequalities in body composition trajectories; one using ALSPAC data and investigating differences by maternal education (170), and the other using Millennium Cohort Study data and measures of family- and area-level deprivation (171). However, these do not investigate other early life factors that have been shown to correlate with trajectories of BMI.

Therefore, this study aimed to model trajectories of BMI, adiposity, and a proxy measure of muscularity across childhood and investigate whether they share early life correlates. These trajectories are used in **Chapters 6 and 7**. Assessment of early life correlates is intended to investigate putative confounders to be considered in later studies.

The following hypothesis was tested, based on the evidence discussed above:

> ***Hypothesis 1:*** *There are distinct trajectories of adiposity and muscularity across childhood, as have previously been seen for BMI.*

5.2 Methods

5.2.1 Sample

Millennium Cohort Study participants with at least one valid measure of BMI, adiposity, and a proxy for muscularity were included in trajectory modelling. This was 14,675 for BMI (79.2% of the baseline sample) and 13,025 for adiposity and muscularity measures (70.3%). When investigating the early life correlates of body composition trajectories, analysis was restricted to those with data available on all body composition trajectories (N=13,025) to aid comparison across measures.

5.2.2 Body composition trajectories

Body composition measures, captured through bioelectrical impedance analysis are described in detail in **4.5.1 Body Mass Index and body composition**. BMI was measured at ages 3, 5, 7, 11, and 14. Adiposity, indicated by FMI and the ratio of FM/FFM, was measured at ages 7, 11, and 14. FFMI, as a proxy for muscularity, was also measured at ages 7, 11, and 14.

Latent class growth analysis (LCGA) was used to model trajectories of body composition across childhood and early adolescence. LCGA is a type of growth mixture modelling, which allows identification of different trajectory groups within a population (172). This is advantageous over traditional growth modelling approaches (e.g. multilevel random effects models), which assume that a single trajectory adequately describes the population. Growth mixture modelling techniques allow different groups of individual trajectories to vary around different means and, in LCGA specifically, the variance and covariance estimates within each class are assumed to be fixed to zero. The assumption, therefore, is that individual growth trajectories within a class are homogeneous. A major benefit of this is that models are less computationally intensive and converge faster than traditional growth mixture modelling (172). The Guidelines for Reporting on Latent Trajectory Studies checklist was used to guide reporting of methods and results (173).

5.2.3 Model specification

LCGA was performed in Stata MP version 17, using the *traj* package (174). For each measure of body composition, censored normal distribution models were estimated where each measure of body composition data up to age 14 years was the dependent variable and age in years was the independent variable. Beginning with a two-class model and increasing the number of classes, all combinations of polynomial shapes were modelled. Polynomial shapes for BMI models could be intercept only, linear, quadratic, or cubic. In LCGA of FMI, FFMI, and FM/FFM, the most complex polynomial shape that could be modelled was quadratic, as data for these measures were only available at three time points. Separate models were considered for boys and girls, based on sex assigned at birth which was reported by their parents when the cohort member was around 9 months old, and were performed if distinct differences between sexes were observed.

The *traj* package uses maximum likelihood estimation to account for missing body composition data, assuming that data are missing at random (174), therefore models were specified to be performed on a sample with at least one valid measurement of the body composition measure in each case.

5.2.4 Model evaluation and visualisation of trajectories

The optimal number of classes and their polynomial shapes was chosen based on multiple metrics including goodness of fit (sample size adjusted Bayesian Information Criterion (aBIC), Akaike Information Criterion (AIC)) and neatness of classification (Entropy Index). For aBIC and AIC, lower numbers represent improved fit for the data, while entropy indices closer to 1.0 represent more accurate class assignment. A user-defined program was employed to calculate the average posterior probabilities, which evaluate the average probability of the model accurately predicting class membership, and odds of correct classification, a similar statistic (175). These were considered in tandem with each model's ability to identify distinct and meaningful patterns in the data, while maintaining group sample sizes sufficient for subsequent analyses.

Estimated values and their 95% confidence intervals were exported to Excel, along with observed values for each class. To assess whether models were identifying distinct patterns in the data, estimated BMI values were plotted as line graphs alongside International Obesity Task Force cut off values (64). This provided context to the trajectory values; however, this was more complicated for FMI, FFMI and FM/FFM, as there are no accepted cut off values. Therefore, the 5^{th}, 85^{th} and 95^{th} centile values for each body composition measure were taken from the sample and plotted alongside the model estimates to provide some further meaning. These centiles were selected as they correspond to World Health Organisation and United States BMI centiles for overweight (85^{th} centile) (176,177); they are not intended to categorise body composition trajectories but provide some context.

After selecting the optimal trajectory model, participants were assigned to their most likely class, thus creating a categorical variable to represent their trajectory group for each body composition measure. This is the most commonly used three-step method of latent class analysis, also known as Modal Standard (178).

5.2.5 Early life correlates of body composition trajectories

Following trajectory modelling, early life correlates of body composition trajectories were investigated. This was based on existing evidence of their association with childhood weight development as outlined below. Cohort members with valid trajectories for all body composition measures (BMI, FMI, FFMI and FM/FFM) were included in this analysis (N=13,025). Those with valid BMI data but no data on other body composition measures were excluded to improve comparability across measures (N=1,650). Available data on early life correlates was used (i.e., non-missing data). Imputation of missing data on these measures is performed for inferential analyses in **Chapter 6**.

Child characteristics and family socioeconomic position

These were all reported by the cohort member's main respondent parent when the cohort member was around 9 months old. Child characteristics were sex assigned at birth (Male or Female) and ethnicity (White; Mixed; Indian; Pakistani or Bangladeshi; Black or Black British; Other, including Chinese and Arab). These child characteristics were selected based on existing evidence of their associations with child BMI trajectory (81).

Measures of family socioeconomic position were: household income as OECD-equivalised quintiles, which account for the size of the household; the highest educational qualification reported by parents, reported as NVQ level equivalents (None; Level 1 or GCSEs graded D-G; Level 2 or GCSEs graded A*-C; Level 3 or A levels; Level 4 or one year of Undergraduate study; Level 5 or two years of Undergraduate study); and the most advantaged occupational class of parents, reported according to the five-class NS-SEC classification. Composite variables were derived for educational qualification and occupational class which in two-parent households took the highest reported by either parent. This was done to attempt to consider the contribution of partners to household resources without excluding children from single-parent households. Previous studies have shown that socioeconomic position is associated with BMI trajectory across childhood (81,160,163).

Perinatal factors

Also reported by the cohort member's parent when they were around 9 months old, these were: Birthweight in kilograms, categorised as low birthweight (<2.5kg) or not low birthweight; gestational age at birth, categorised as pre-term or term); maternal pre-pregnancy BMI, derived from self-reported height and weight and categorised using World Health Organisation cut offs for overweight and obese; maternal cigarette use during pregnancy (None or Any); maternal alcohol use during pregnancy (None or Any); and maternal age when the cohort member was born (Under 20; 20-29; 30-39; 40+). In a subsample of cohort members living in two-parent households, paternal age when the cohort member was born was also examined, using the same categories. These were selected based on existing evidence (81,166).

Parental mental health

When the cohort member was around 3 years old, their parents completed the Kessler K6 scale, which is a well-validated measure of psychological distress (179). Maternal and, in children from two-parent households, paternal psychological distress were both investigated as potential correlates as existing evidence has suggested that maternal and paternal psychological distress may be differentially associated with child adiposity and this may be modified by child sex at birth (180). These were categorised as low (<5), moderate (5-11), or severe (12+), with the latter indicating clinically relevant symptoms (181).

5.2.6 Descriptive analyses

Sample characteristics were described using frequencies with proportions and means with standard deviations. The extent of missing data on all variables was also described using frequencies and proportions. The association between early life correlates and body composition trajectories was investigated descriptively using proportions. Analyses were conducted in Stata MP 17 (StataCorp LLC, College Station, TX), with sampling weights applied to account for stratified sampling and attrition.

5.2.7 Sensitivity analysis

To evaluate the impact of restricting descriptive analyses to those with both BMI and body composition trajectories (thereby excluding 1,650 participants who were assigned a BMI trajectory only), descriptive analyses of the association between early life correlates and BMI were repeated including all participants with valid data (N=14,675) to check whether results were comparable to those in the main analysis.

5.3 Results

5.3.1 Sample characteristics

Among cohort members with valid data on both BMI and body composition measures (N=13,025), approximately half were male (50.8%), and the majority were White (84.4%), as described in

Table 5-1. Few cohort members had parents with no educational qualifications (10.8%), while the majority had attained qualifications equivalent to A level or higher (58.7%). The largest proportion had parents who worked

Table 5-1. Characteristics of sample with both BMI and body composition data. Sample with valid data (N=13,025). Unweighted proportions.

Characteristic	Sample with BMI and body composition data (N=13,025)	
	N	**%**
Cohort member mean age in years (SD)		
3	3.14	0.2
5	5.22	0.2
7	7.24	0.3
11	11.17	0.3
14	14.26	0.3
Cohort member sex at birth		
Male	6612	50.8
Female	6413	49.2
Cohort member ethnicity		
White	10968	84.4
Mixed	346	2.7
Indian	312	2.4
Pakistani and Bangladeshi	828	6.4
Black and Black British	383	3.0
Other ethnic group	160	1.2
Fifth of household income at 9 months		
Most disadvantaged	2804	21.6
Second	2786	21.4
Third	2526	19.4
Fourth	2521	19.4
Least disadvantaged	2355	18.1
Highest parental education qualification at 9 months		
None	1403	10.8
NVQ Level 1 (GCSE grade D-G)	775	5.9
NVQ Level 2 (GCSE grade A*-C)	3199	24.6
NVQ Level 3 (A Level)	2151	16.5
NVQ Level 4 (One year Undergraduate)	4593	35.3
NVQ Level 5 (Two years Undergraduate or more)	896	6.9
Highest parental occupational class at 9 months		
Not in work	2924	22.5
Semi-routine or routine	1900	14.6
Lower supervisory or technical	1043	8.0
Small employers or self-employed	863	6.7
Intermediate occupations	1199	9.2
Managerial or professional	5050	38.9

Characteristic	Sample with BMI and body composition data (N=13,025)	
	N	%
Cohort member birthweight		
Low birthweight (≤2.5kg)	890	6.8
Birthweight >2.5kg	12106	93.2
Cohort member gestation		
Pre-term (<37 weeks)	915	7.0
Term	12110	93.0
Maternal pre-pregnancy BMI		
BMI <25	8416	70.3
BMI 25-29.9	2465	20.6
BMI 30+	1083	9.1
Cohort member was breastfed		
No	3870	29.8
Yes	9135	70.2
Mother smoked in pregnancy		
No	11057	84.9
Yes	1962	15.1
Mother drank alcohol in pregnancy		
No	9020	69.4
Yes	3982	30.6
Maternal age at child's birth		
Under 20	938	7.2
20 to 29	5843	44.9
30 to 39	5941	45.6
40 or older	302	2.3
Maternal psychological distress at 3 years		
Low	8591	75.0
Moderate	2472	21.6
Severe	388	3.4
Paternal age at child's birth [a]		
Under 20	146	1.3
20 to 29	3505	31.9
30 to 39	6180	56.3
40 or older	1150	10.5
Paternal psychological distress at 3 years [a]		
Low	6716	78.2
Moderate	1739	20.2
Severe	136	1.6

[a] In subsample of two-parent families (N=11,135)

in a managerial or professional occupation when the cohort member was 9 months old (38.9%). Few cohort members were classified as having a low birthweight (6.8%) or were born before term (7.0%). The majority were breastfed (70.2%) and were born to mothers who did not smoke (84.9%) or drink alcohol during pregnancy (69.4%) and who had a pre-pregnancy BMI under 25 (70.3%). Few cohort members were born to mothers aged under 20 years (7.2%) or over 40 (2.3%) and most mothers had low levels of psychological distress when the cohort member was 3 years old (75.0%), as described in **Table 5-1**. In a sub-sample of cohort members from two-parent households (N=11,135), few cohort members had fathers under 20 years old (1.3%) or over 40 (10.5%) at the time of their birth. The majority of fathers had low levels of psychological distress when the cohort member was 3 years old (78.2%).

Among the larger sample of all cohort members with valid BMI data (i.e., additionally including participants who had been excluded due to missing body composition data, previously described in **5.2.7**, N=14,675), sample characteristics were similar to those of the sample described above (see **Appendix for Chapter 5, Table 1.** Characteristics of sample with BMI data. 206

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Appendix for Chapter 5, Table 7. Proportions of missing data in analytical sample. 219

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Appendix for Chapter 5, Table 1). In the sample with valid BMI data, the proportion of girls, White cohort members, and those from more socioeconomically advantaged backgrounds was slightly higher, suggesting that attrition was more likely to occur in boys and those from disadvantaged groups.

Mean BMI increased with advancing age and was higher in boys prior to age 7, after which it was higher in girls (**Table 5-2**). Broadly, the proportions of boys and girls with BMIs above the healthy weight range increased with age. Mean adiposity measures (FMI and FM/FFM) increased with age in girls but remained relatively stable in boys. Increasing values for FM/FFM in girls indicate increasing relative proportions of fat mass. In boys, FM/FFM was lowest at age 14, suggesting a higher relative proportion of fat-free mass. Mean muscularity (FFMI) increased with age in both sexes and was higher in boys at all ages. The proportion of missing BMI and body composition data also increased with age.

Correlations between raw measures and indices of weight, fat and fat-free were also examined (**Table 5-3**). Strong correlations were observed between FMI and FM/FFM measures, as well as between BMI and FMI. Despite these measures being indexed to height, weak correlations remained with height at each age.

Table 5-2. Means of BMI and body composition measures used in Latent Class Growth Analysis. Proportions of BMI classification according to International Obesity Taskforce (IOTF) cut offs.

Mean (SD)		**Age 3**	**Age 5**	**Age 7**	**Age 11**	**Age 14**
Boys						
BMI	N	6924	6590	6032	5691	4917
	Missing %	7.4	11.8	19.3	23.8	34.2
	Mean (SD)	17.02 (2.2)	16.39 (1.9)	16.60 (2.3)	19.01 (3.5)	20.93 (4.0)
	Underweight	4.7	5.3	6.1	5.7	7.6
	Healthy	72.0	75.4	75.8	68.7	67.1
	Overweight	17.6	14.0	12.6	19.6	18.1
	Very overweight	5.7	5.3	5.4	6.0	7.2
	N	-	-	5943	5621	4844
	Missing %			20.5	24.8	35.2
FMI	Mean (SD)			3.44 (1.5)	4.07 (2.5)	3.80 (2.7)
FFMI	Mean (SD)			13.16 (1.1)	14.94 (1.5)	17.12 (1.9)
FM/FFM	Mean (SD)			0.26 (0.1)	0.27 (0.1)	0.22 (0.1)
Girls						
BMI	N	6778	6376	5950	5590	4789
	Missing (%)	5.8	11.4	17.3	22.3	33.5
	Mean (SD)	16.70 (1.9)	16.30 (1.9)	16.69 (2.4)	19.45 (3.7)	21.94 (4.1)
	Underweight	5.2	4.4	6.2	7.3	6.2
	Healthy	70.5	71.9	70.6	63.2	66.3
	Overweight	18.5	17.7	16.5	22.5	20.2
	Very overweight	5.8	6.0	6.7	7.0	7.2
	N	-	-	5867	5536	4736
	Missing (%)			18.5	23.1	34.2
FMI	Mean (SD)			3.82 (1.6)	5.04 (2.5)	6.20 (2.9)
FFMI	Mean (SD)			12.87 (1.0)	14.39 (1.4)	15.73 (1.4)
FM/FFM	Mean (SD)			0.29 (0.1)	0.34 (0.1)	0.38 (0.1)

Table 5-3. Correlations between anthropometric measures and indices. Pearson's corelation coefficients reported. Colour used to highlight the strength of the correlation.

Age 7	*BMI*	*FMI*	*FFMI*	*FM/FFM*	*Height*	*Weight*	*Fat Mass*
FMI	0.93						
FFMI	0.86	0.61					
FM/FFM	0.86	0.98	0.47				
Height	0.29	0.27	0.26	0.24			
Weight	0.89	0.83	0.46	0.76	0.69		
Fat Mass	0.92	0.98	0.62	0.95	0.44	0.91	
Fat-free Mass	0.71	0.55	0.77	0.45	0.82	0.92	0.67
Age 11	*BMI*	*FMI*	*FFMI*	*FM/FFM*	*Height*	*Weight*	*Fat Mass*
FMI	0.94						
FFMI	0.82	0.58					
FM/FFM	0.87	0.98	0.44				
Height	0.30	0.26	0.28	0.23			
Weight	0.92	0.86	0.76	0.78	0.64		
Fat Mass	0.93	0.98	0.59	0.96	0.41	0.92	
Fat-free Mass	0.71	0.53	0.80	0.42	0.78	0.89	0.63
Age 14	*BMI*	*FMI*	*FFMI*	*FM/FFM*	*Height*	*Weight*	*Fat Mass*
FMI	0.92						
FFMI	0.74	0.41					
FM/FFM	0.82	0.97	0.23				
Height	0.07	-0.09	0.32	-0.15			
Weight	0.89	0.74	0.78	0.63	0.51		
Fat Mass	0.92	0.98	0.45	0.94	0.06	0.83	
Fat-free Mass	0.51	0.20	0.83	0.05	0.79	0.80	0.32

5.3.2 Body composition trajectories

Evaluation of LCGA model fit parameters showed that increasing the number of classes reduced adjusted BIC and AIC values, indicating greater information loss. A summary of the model fit statistics by the number of classes is shown in Error! Reference source not found., while a more detailed evaluation of polynomial shapes within these classes can be found in the **Appendix for Chapter 5, Table 2.** Results of BMI trajectory modelling using different polynomial shapes. Only for FM/FFM was there evidence that sex-specific trajectories best fit the data, mirroring the linear increase in mean FM/FFM with age in girls and non-linear change in boys.

For all measures, the three-class model was considered optimal; models with fewer classes provided limited explanatory power, while those with more classes resulted in very small sample sizes in some groups and reduced model fit. Three-class models also had relatively high Entropy indices, indicating a lower chance of error in class assignment. Other trajectory class numbers are depicted in **Appendix for Chapter 5, Figure 1**. BMI trajectories are depicted in **Figure 5-1**. These were classified as a stable, low group, where BMI remained in the non-overweight category across childhood; a moderate increasing group, where BMI crossed into the overweight category during early childhood; and a high increasing group, where BMI was in the overweight category at age 3 and crossed over into the obese category in early childhood. The majority of cohort members were assigned to the stable, low trajectory (62.6%), with 30.5% belonging to the moderate increasing and 6.9% to the high increasing trajectories.

Trajectories of other measures of body composition were similarly classified into low, moderate, and high groups. These are depicted in **Figure 5-2** and clearly show the different trajectory shapes of FM/FFM in girls and boys. The majority of cohort members were assigned to the low FMI trajectory (67.6%), while 26.3% had moderate and 6.1% had high trajectories. Differences were observed in assignment to FFMI trajectories, with 44.2% having low trajectories, 45.4% moderate, and 10.4% high. The vast majority of boys were assigned to the low FM/FFM trajectory (82.0%), while 15.6% had moderate and 2.4% had high trajectories. A greater proportion of girls were assigned to the moderate and high trajectories of FM/FFM, with 59.8% having low trajectories, 32.2% moderate and 8.0% high trajectories.

Table 5-4. Summary of latent class growth analysis modelling results.

Model and Number of Classes	AIC	Entropy
BMI modelling		
2	-137700.98	0.831
3	-133965.65	0.786
4	-132343.57	0.728
5	-130978.68	0.763
FMI modelling		
2	-67272.92	0.872
3	-63993.01	0.841
4	-62371.31	0.745
5	-61456.30	0.696
FFMI modelling		
2	-53907.96	0.722
3	-52132.05	0.701
4	-51311.81	0.702
5	-51120.97	0.697
FM/FFM modelling		
Boys		
2	13202.91	0.913
3	14580.72	0.905
4	15042.52	0.800
5	15586.24	0.699
Girls		
2	13516.86	0.838
3	14797.75	0.805
4	15409.36	0.775
5	15662.00	0.694

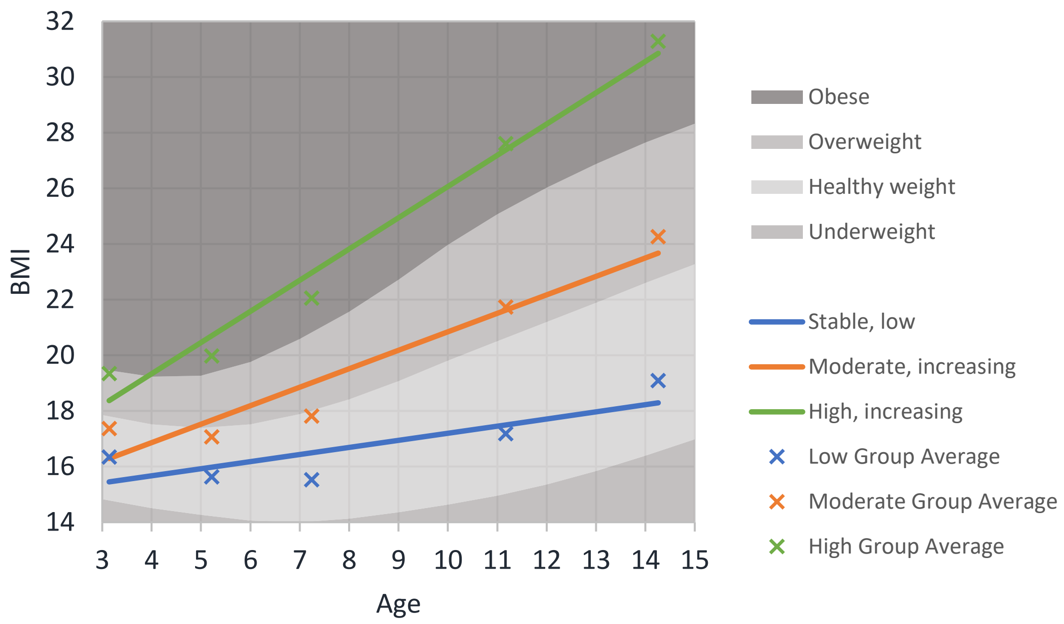

Figure 5-1. BMI trajectories, age 3 to 14 years, from latent class growth analysis. Lines represent trajectories estimated in modelling. Crosses depict the average data points for each group. Shaded areas show International Obesity Task Force BMI cut off values.

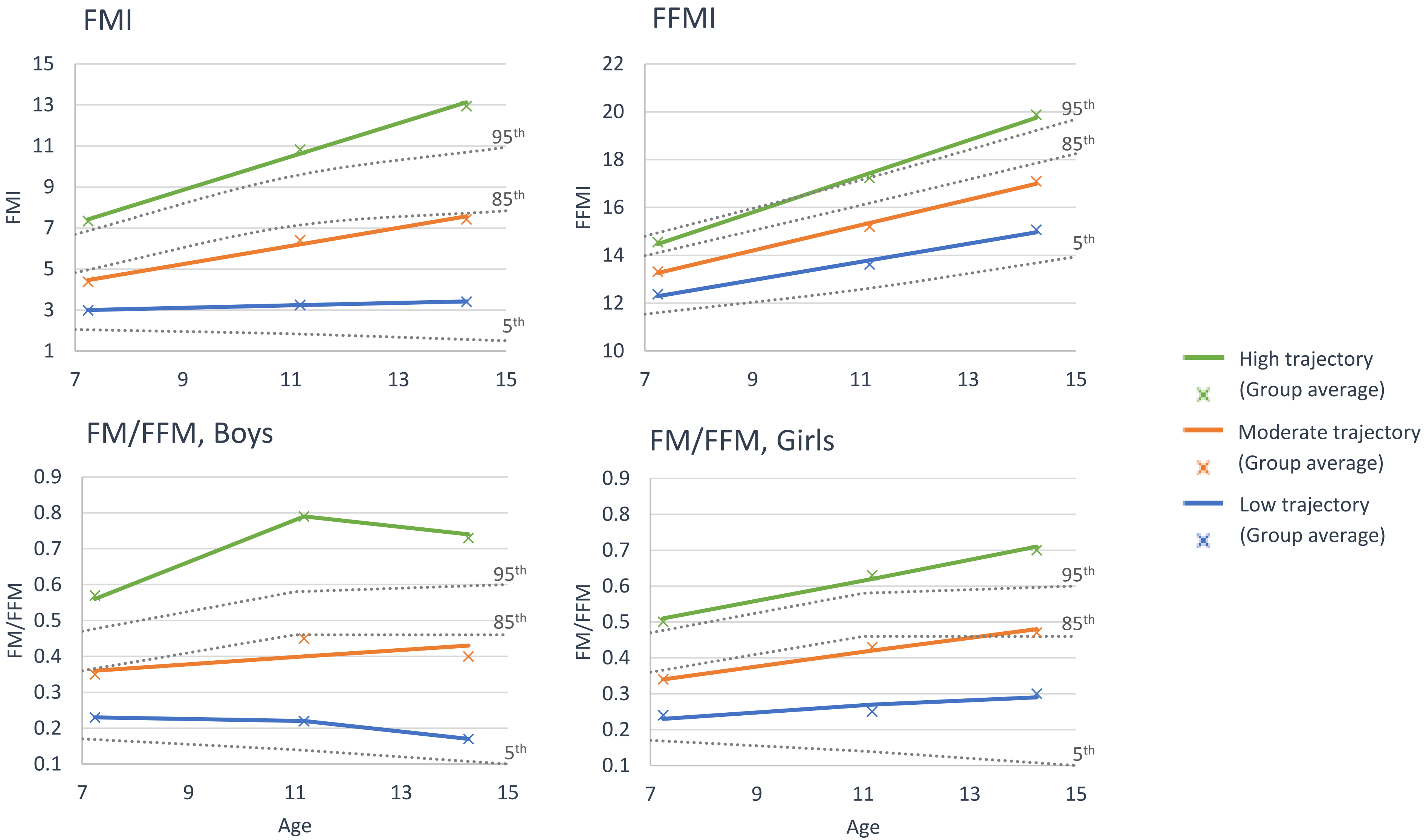

Figure 5-2. Trajectories of body composition, age 7 to 14, from latent class growth analysis.
Lines represent trajectories estimated in modelling. Crosses depict the average data points for each group.
Dotted grey lines represent 5th, 85th and 95th centiles for context.

Cohort members were assigned to their most likely class for BMI and the correlations between body composition measures was explored descriptively by examining the distributions of trajectory membership across different body composition measures.

Almost all participants assigned to a low trajectory of BMI also had a low FMI trajectory (95.2%, see **Table 5-5**), while a large majority assigned to a high trajectory of BMI also had a high FMI trajectory (78.3%). There was less congruence between BMI trajectory and FFMI trajectory membership, with 66.7% of those with a low BMI trajectory also being assigned to a low FFMI trajectory, and 63.7% with a high BMI trajectory being assigned to a high FFMI trajectory. Among those assigned to a low trajectory of FFMI, 90.5% had a low FMI trajectory, showing high concordance at lower values. However, among those assigned to a high FFMI trajectory, 26.9% had low FMI, 38.7% moderate FMI and 34.4% had high FMI trajectories. These distributions were different to that of BMI trajectory membership among those with high FFMI trajectories, suggesting that BMI and FMI are capturing different aspects of body composition.

5.3.3 Missing data

Among those with valid BMI and body composition trajectory data (N=13,025), missing data on early life correlates was minimal with the exception of maternal pre-pregnancy BMI and maternal psychological distress level, where 8.2% and 12.1% of participants were missing these data, respectively. Additionally, in a subsample of participants from two-parent households (N=11,135), 26.2% were missing data for paternal psychological distress level. On all other early life correlates, missing data was less than 1.5%, as shown in **Appendix for Chapter 5, Table 7.** Proportions of missing data in analytical sample.

5.3.4 Early life correlates

The distribution of BMI and body composition trajectories by early life correlates is shown in **Table 5-6** and described below.

Child demographics and family socioeconomic position

Trajectory membership varied by sex registered at birth. A greater proportion of boys had low trajectories of BMI than did girls (66.0% vs 58.6%), while more girls had moderate and high trajectories. Similar patterns were observed in adiposity trajectories (low FMI trajectories 79.7% vs 54.5%; low FM/FFM trajectories 82.0% vs 59.8%).

Table 5-5. Distribution of trajectory membership across different measures of body composition.

	BMI Trajectory			FMI Trajectory			FFMI Trajectory			FM/FFM Trajectory		
BMI Trajectory (%)	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
Low				95.2	4.8	0.0	66.7	33.1	0.2	95.6	4.3	0.1
Moderate				25.1	71.6	3.3	6.8	76.7	16.6	33.8	63.2	3.0
High				0.8	20.9	78.3	1.3	35.1	63.7	2.1	31.8	66.1
FMI Trajectory (%)												
Low	89.3	10.6	0.1				59.3	37.1	3.6	98.4	1.6	0.0
Moderate	12.2	82.3	5.5				16.4	69.5	14.1	15.9	82.9	1.2
High	0.1	15.7	84.2				2.2	46.7	51.1	0.0	18.7	81.3
FFMI Trajectory (%)												
Low	95.4	4.4	0.2	90.5	9.2	0.3				91.3	8.2	0.5
Moderate	46.4	48.5	5.1	55.4	38.3	6.3				58.8	35.4	5.8
High	1.6	52.3	46.1	26.9	38.7	34.4				37.4	35.9	26.7
FM/FFM Trajectory (%)												
Low	86.1	13.7	0.2	94.4	5.6	0.0	57.4	37.8	4.8			
Moderate	11.8	79.0	9.2	4.9	90.1	5.0	15.9	69.9	14.2			
High	1.0	16.6	82.4	0.0	5.6	94.4	4.5	49.6	45.9			

Table 5-6. Distribution of BMI and body composition trajectories by early life correlates. Descriptive analyses in a sample with trajectories of BMI and body composition measures (N=13,025) and available data on early life correlates.

Characteristic	BMI Trajectory (%)			FMI Trajectory (%)			FFMI Trajectory (%)			FM/FFM Trajectory (%)		
	Low	Mod ǂ	High	Low	Mod ǂ	High	Low	Mod ǂ	High	Low	Mod ǂ	High
N	8375	3783	867	8930	328	807	5851	5977	1197	9306	3024	695
%	62.4	30.8	6.9	67.6	26.3	6.1	44.2	45.4	10.4	71.3	23.6	5.1
Cohort member sex at birth												
Male	66.0	27.8	6.2	79.7	19.4	3.9	32.5	51.2	16.3	82.0	15.6	2.4
Female	58.6	33.8	7.6	54.5	37.0	8.5	56.8	39.1	4.1	59.8	32.2	8.0
Cohort member ethnicity												
White	62.9	30.8	6.3	68.8	25.8	5.4	43.3	46.1	10.6	72.8	22.8	4.4
Mixed	64.6	25.5	9.9	66.8	24.7	8.5	41.4	48.1	10.5	70.5	21.8	7.7
Indian	67.9	25.7	6.4	64.1	27.7	8.2	63.9	32.8	3.3	64.8	29.4	5.8
Pakistani and Bangladeshi	59.0	30.0	11.0	56.5	32.5	11.0	54.7	39.0	6.3	57.3	31.2	11.5
Black and Black British	51.9	36.6	11.5	57.3	31.8	10.9	40.9	44.2	14.9	61.1	29.2	9.7
Other ethnic group	64.0	27.0	9.0	63.2	28.5	8.2	51.2	40.4	8.4	62.2	29.6	8.2
Fifth of household income at 9 months												
Most disadvantaged	57.0	33.2	9.8	61.9	29.4	8.7	43.0	45.1	11.9	65.4	27.4	7.2
Second	59.2	32.9	7.9	63.2	30.2	6.6	43.7	44.8	11.5	66.9	27.3	5.8
Third	62.4	31.2	6.4	68.7	25.1	6.2	43.2	45.2	11.6	72.4	22.7	4.9
Fourth	63.7	30.8	5.5	69.4	26.1	4.5	42.6	48.1	9.3	73.5	22.8	3.7
Least disadvantaged	73.7	23.1	3.2	78.5	18.6	2.9	49.6	43.8	6.6	82.1	15.3	2.7
Highest parental education level at 9 months												
None	54.7	35.1	10.2	60.1	31.1	8.8	45.2	40.9	13.9	63.8	28.4	7.8
NVQ Level 1 (GCSE grade D-G)	62.3	29.1	8.6	68.4	25.1	6.5	45.3	44.5	10.2	72.4	22.1	5.5
NVQ Level 2 (GCSE grade A*-C)	58.7	33.6	7.7	63.3	29.4	7.3	41.6	46.8	11.6	67.1	27.0	5.9
NVQ Level 3 (A Level)	63.4	28.9	7.7	69.1	24.6	6.3	44.1	44.8	11.1	72.2	22.4	5.4
NVQ Level 4 (One year Undergraduate)	66.8	28.5	4.7	71.6	24.2	4.2	44.6	47.2	8.2	75.4	21.2	3.4
NVQ Level 5 (Two years Undergraduate +)	73.0	24.5	2.5	79.2	18.2	2.6	51.5	42.0	6.5	83.1	14.4	2.5

Characteristic	BMI Trajectory (%)			FMI Trajectory (%)			FFMI Trajectory (%)			FM/FFM Trajectory (%)		
	Low	Mod ⁱ	High	Low	Mod ⁱ	High	Low	Mod ⁱ	High	Low	Mod ⁱ	High
Highest parental occupational class at 9 months												
Not in work	57.2	33.9	8.9	62.0	29.7	8.3	43.1	44.7	12.3	65.6	27.7	6.7
Semi-routine or routine	59.4	31.5	9.2	63.3	29.3	7.4	43.6	44.0	12.4	67.9	25.4	6.7
Lower supervisory or technical	57.7	34.3	7.9	66.0	26.8	7.2	40.1	49.6	10.3	68.9	24.9	6.2
Small employers or self-employed	61.4	32.2	6.4	66.1	28.1	5.8	44.4	45.0	10.6	70.5	24.1	5.4
Intermediate occupations	69.0	24.9	6.0	71.3	23.4	5.3	47.0	44.9	8.1	73.9	22.0	4.1
Managerial or professional	67.5	28.2	4.3	73.4	22.8	3.8	45.7	45.7	8.6	77.1	19.8	3.0
Cohort member birthweight												
Low birthweight (≤2.5kg)	66.6	27.0	6.4	66.2	27.1	6.6	53.1	39.5	7.5	70.1	24.9	5.0
Birthweight >2.5kg	62.1	31.0	6.9	67.7	26.2	6.1	43.5	45.8	10.7	71.4	23.5	5.1
Cohort member gestation												
Pre-term (<37 weeks)	63.2	28.9	7.9	66.0	26.3	7.7	47.1	42.1	10.8	69.8	24.1	6.1
Term	62.4	30.8	6.8	67.7	26.3	6.0	44.0	45.6	10.4	71.4	23.6	5.0
Maternal pre-pregnancy BMI												
BMI <25	70.0	25.8	4.2	74.1	22.3	3.6	50.4	42.3	7.3	77.5	19.4	3.2
BMI 25-29.9	50.1	39.8	10.1	58.0	33.3	8.7	32.6	52.1	15.4	63.5	29.4	7.1
BMI 30+	35.0	46.7	18.3	42.3	39.4	17.3	21.4	54.9	23.7	48.0	38.2	13.8
Cohort member was breastfed												
No	58.4	33.4	8.2	63.6	29.2	7.2	42.3	46.0	11.7	67.7	26.3	6.0
Yes	64.6	29.2	6.2	69.8	24.7	5.5	45.2	45.0	9.8	73.2	22.1	4.6
Mother smoked in pregnancy												
No	63.7	30.0	6.2	68.5	28.9	5.6	45.9	44.8	9.3	72.0	23.4	4.6
Yes	56.3	33.7	10.0	63.1	28.7	8.2	36.3	48.0	15.7	67.9	24.9	7.2
Mother drank alcohol in pregnancy												
No	60.9	31.7	7.4	66.2	26.9	6.9	44.4	44.8	10.8	69.3	24.8	5.9
Yes	66.1	28.2	5.7	70.8	24.9	4.3	43.7	46.7	9.6	75.7	20.9	3.4

Characteristic	BMI Trajectory (%)			FMI Trajectory (%)			FFMI Trajectory (%)			FM/FFM Trajectory (%)		
	Low	Mod ǂ	High	Low	Mod ǂ	High	Low	Mod ǂ	High	Low	Mod ǂ	High
Maternal age at child's birth												
Under 20	59.7	33.4	6.9	66.0	28.8	5.2	42.0	46.4	11.6	69.1	26.9	4.0
20 to 29	61.8	31.0	7.2	66.3	27.1	6.6	44.0	45.5	10.5	70.0	24.6	5.4
30 to 39	64.0	29.5	6.5	69.5	24.8	5.7	45.2	44.9	9.9	73.4	21.7	4.9
40 or older	58.9	32.5	8.6	66.9	26.3	6.8	40.5	47.0	12.5	70.0	23.4	6.6
Maternal psychological distress at 3 years												
Low	63.3	30.4	6.3	69.1	25.5	5.4	43.7	46.1	10.2	73.0	22.5	4.5
Moderate	59.6	32.3	8.1	64.6	28.0	7.4	41.2	46.3	12.5	69.1	24.6	6.3
Severe	59.1	32.1	8.8	63.7	28.0	8.3	40.3	50.5	9.2	67.5	24.5	8.0
Paternal age at child's birth [a]												
Under 20	56.5	42.0	1.5	64.5	34.0	1.5	42.6	50.5	6.9	66.0	32.5	1.5
20 to 29	62.6	30.6	6.8	67.9	25.8	6.3	44.0	46.1	9.9	71.3	23.8	4.9
30 to 39	65.0	29.1	5.9	70.2	24.6	5.2	45.7	44.5	9.8	73.7	21.8	4.5
40 or older	59.5	33.2	7.4	63.9	29.1	7.0	40.8	49.1	10.1	69.1	24.8	6.1
Paternal psychological distress at 3 years [a]												
Low	64.7	29.6	5.7	69.7	25.0	5.3	45.0	45.5	9.5	73.6	22.2	4.2
Moderate	63.3	29.0	7.7	69.6	23.4	7.0	43.3	46.6	10.1	72.3	21.8	5.9
Severe	68.3	27.6	4.0	77.4	16.7	5.8	45.5	45.5	9.0	79.3	15.5	5.2

[a] In a sub-sample of two-parent households (N=11,135).

ǂ Mod = Moderate.

In contrast, a larger proportion of girls were assigned to low trajectories of FFMI compared to boys (56.8% vs 32.5% vs 56.8%).

Fewer Pakistani and Bangladeshi and Black cohort members had low trajectories of BMI compared to White cohort members, and a greater proportion of children from these ethnicities had high trajectories of BMI compared to other ethnic groups. These differences were also seen in trajectories of FMI and FM/FFM, with Pakistani and Bangladeshi children having the highest proportion of high trajectory membership compared to other ethnic groups. Differences were seen in FFMI trajectories, where fewer Indian, Pakistani and Bangladeshi cohort members had high trajectories. A greater proportion of Black cohort members had high trajectories of FFMI compared to other ethnic groups (**Table 5-6**).

There were clear social gradients in trajectories of BMI and adiposity across three measures of socioeconomic position. Higher proportions of moderate and high trajectory membership were observed in children with more disadvantaged socioeconomic positions at age 9 months old. Socioeconomic patterns were also present, but less pronounced in FFMI trajectories, though a greater proportion of children from the most disadvantaged backgrounds had high trajectories of FFMI.

Perinatal factors

There were few observable differences in the distribution of BMI and adiposity trajectories by birthweight. However, a greater proportion of children with a normal birthweight had moderate and high trajectories of FFMI compared to those classed as low birthweight. There were also few differences according to gestational age at birth, with a slightly greater proportion of children born preterm having low trajectories of FFMI compared to those born at term. In contrast, maternal pre-pregnancy BMI was strongly associated with child trajectory membership across BMI and all measures of body composition. Fewer children born to mothers with overweight or obese BMIs had low trajectories of BMI, adiposity and muscularity, compared to those born to mothers with underweight or healthy weight BMIs.

Moderate and high trajectory membership was also more common in children who were not breastfed and whose mother smoked during pregnancy. This was seen in BMI and all body composition trajectories, such that there were no differences in the associations when comparing measures of adiposity and muscularity. In contrast, a greater proportion of children whose mothers consumed alcohol during pregnancy had low trajectories of BMI and adiposity measures compared to those who did not, but there were no differences in FFMI trajectory membership (**Table 5-6**).

There were no clear differences in BMI or adiposity trajectory membership according to maternal age when the cohort member was born, though a greater proportion of children born to mothers in their 30s had low trajectories of these measures. These differences were relatively small. This was similarly observed with fathers in their 30s in a sub-sample of children from two-parent households.

Parental mental health

A greater proportion of children whose mothers had low levels of psychological distress also had low trajectories of BMI and adiposity measures. Moderate or severe levels of psychological distress were associated with higher trajectories of BMI and adiposity. More children whose mothers had higher levels of psychological distress had moderate trajectories of FFMI. In contrast, in a sub-sample of children from two-parent households, more children with fathers who had severe levels of psychological distress had low trajectories of adiposity. Paternal psychological distress did not appear to be associated with trajectories of FFMI.

5.3.5 Sensitivity analysis

Descriptive statistics were repeated investigating the distribution of BMI trajectories in a sample with available BMI trajectory data (i.e., not restricted to those who also have body composition trajectory data, N=14,675). These results were highly similar to those discussed above and are shown in **Appendix for Chapter 5, Table 8**.

5.4 Discussion

5.4.1 Summary of main findings

This study aimed to model trajectories of BMI and measures of adiposity and muscularity up to age 14 in a diverse sample of young people. A further aim was to investigate whether BMI, adiposity and muscularity trajectories share early life correlates that may be confounders in subsequent analyses in this thesis. It was hypothesised that there would be distinct trajectories of adiposity and muscularity as has been observed with BMI in previous research. This hypothesis was supported, as three trajectories were found in measures of adiposity (FMI and FM/FFM). Similarly, three trajectories of a measure of muscularity (FFMI) were also found. All were interpreted as comprising a low, a moderate and a high trajectory of development from age 7 to 14.

Descriptive analyses were performed to investigate whether BMI, adiposity, and muscularity trajectories share early life correlates. There were clear differences in trajectory membership by child sex and ethnicity and according to family socioeconomic position, with girls, Pakistani, Bangladeshi and Black cohort members, and those from more disadvantaged backgrounds having higher trajectories of adiposity, for example. Maternal pre-pregnancy BMI was strongly positively correlated with BMI and all body composition trajectories. Differences by other perinatal factors were less clear, though being breastfed appeared to be associated with lower BMI and adiposity trajectories. Exposure to maternal smoking in pregnancy was associated with higher trajectories of BMI and adiposity up to age 14, while exposure to maternal alcohol consumption appeared to be associated with lower trajectories. These results are based on descriptive analyses and associations may not be independent once other factors are accounted for.

5.4.2 Comparison with previous literature

Results showing three distinct BMI trajectories across childhood are consistent with most (160,163–166,169), but not all (81,161,167,168), of the existing literature. In some samples, a fourth trajectory group has been found, commonly representing a group with high BMIs in early childhood and decreasing trajectories into the healthy weight category (81,167). This decreasing trajectory has previously been found in analysis of Millennium Cohort Study data up to age 11 (81). A similar trajectory group was observed in this current study when using a five-class model in LCGA, however, this had suboptimal model fit statistics and very small group sample sizes that would have precluded further analysis. Furthermore, where this decreasing trajectory has previously been observed (81), it typically depicts a rapid decrease in BMI in early childhood, such that from approximately age 7 onwards the BMIs in this group track closely with the stable, healthy weight BMI trajectory. Therefore, in this study, where BMIs were modelled into mid-adolescence, this trajectory may not appear distinct from the low BMI trajectory, and this may explain why it was not observed in the four-class model.

Findings of distinct trajectories of FMI, FFMI and FM/FFM are novel. In a previous study of children in New York, researchers had found three distinct trajectories of body fat percentage from age 1 to 10 years (169), which are broadly similar to the adiposity trajectories modelled in this study. Additionally, findings relating to early life correlates of these adiposity and muscularity trajectories are also novel. Early life correlates of adiposity-specific measures of body composition were highly similar to those of BMI trajectories, which in turn were consistent with previous studies. Prior research suggests broad agreement that modifiable factors such as breastfeeding and maternal smoking in pregnancy are correlated with childhood BMI trajectories (81,168).

In contrast to results seen for maternal smoking, descriptive statistics suggested that maternal alcohol consumption in pregnancy was associated with lower body composition trajectories. Maternal alcohol consumption is not often investigated as a potential early life correlate of childhood weight, though there is a plausible clinical link – for example, infant growth restriction is a symptom of antenatal exposure to heavy drinking (182). A previous study in ALSPAC participants has shown that heavy alcohol consumption in pregnancy is associated with lower weight in infancy, although there was no evidence that this persisted across childhood (183). In the current study, the frequency or amount of alcohol used was not investigated – though previous evidence suggests the proportion of heavy alcohol consumption in Millennium Cohort Study mothers is low (184) – instead, the current study used a measure of exposure to any alcohol consumption compared to none. These data were self-reported, which may lead to social desirability bias, however results may also be reflective of a social patterning of alcohol consumption in pregnancy.

The current study found clear social gradients in body composition trajectories across childhood using three indicators of family socioeconomic position. This is consistent with previous evidence from the ALSPAC cohort (170,185). Furthermore, other analyses of Millennium Cohort Study participants using different trajectory modelling techniques supports the presence socioeconomic inequalities in muscularity trajectories (171), and also showed that higher disadvantage was associated with higher FFMI, but that this observation was reversed after adjusting for the level of FMI.

These findings are important as Millennium Cohort Study families, and particularly more disadvantaged families, may have had access to community-based early years support services, such as Sure Start, for which funding and access has been eroded due to subsequent spending cuts. Evidence suggests that programmes such as Sure Start, which provided support for breastfeeding, health, and nutrition, among other services, had positive impacts on both child and family health and wellbeing (186). Furthermore, cuts to Sure Start since 2010 have been linked to increases in the prevalence of childhood overweight (187). These cuts may have exposed more children to social deprivation and may lead to a widening of social inequalities in adiposity and muscularity trajectories across childhood, with potential lifelong health consequences (188).

5.4.3 Limitations

Several limitations should be acknowledged. Firstly, body composition data were measured using bioelectrical impedance analysis, meaning that calculations of fat and fat-free mass are derived from estimated body fat percentage. The gold standard for body composition measurement is dual x-ray absorptiometry scanning, as it can accurately measure fat, lean, and bone mass as distinct components of total body weight. However, previous research suggests that, at a population level, bioelectrical impedance analysis provides body composition measures similar to those from dual x-ray absorptiometry, particularly if measuring change over time (189–191). Yet, bioelectrical impedance analysis does not distinguish lean and bone mass, instead providing an estimate of fat-free mass. Therefore, in this study FFMI is used as a proxy measure for muscularity, though higher FFMI values could represent higher proportions of bone mass to some extent. Furthermore, individuals with higher adiposity levels are likely to also have higher muscle mass as an adaptation (192,193) and therefore in these descriptive analyses it is not possible to examine associations between early life correlates and muscularity trajectories independent of fat mass. However, this may explain why similar associations are seen in both adiposity and muscularity trajectories, for example, that smoking in pregnancy is associated with both increased adiposity and increased muscularity trajectories.

The use of LCGA to model trajectories of body composition relies on certain assumptions, including that individual growth trajectories within a class are homogeneous, and is often intended to be used as a precursor to tradition growth mixture modelling. However, its standalone application to modelling trajectories of BMI has been established in a body of published literature (81,161,165). Furthermore, in the current study, participants were assigned to their most likely class without incorporating weights to account for the potential for error in class assignment. Sampling and attrition weights were instead accounted for. These were considered to be more important, particularly as high Entropy indices suggested that uncertainty in class membership did not need to be incorporated (194).

Investigation of early life correlates used available data, and as most were measured at the first data collection sweep when the cohort member was around 9 months old, the proportion of missing data was generally low. Nevertheless, despite LCGA using maximum likelihood estimation to account for missing data, body composition measures from bioelectrical impedance analysis were not introduced in the Millennium Cohort Study until age 7. Comparison of samples with available BMI data and those with later body composition measures suggested that there was some attrition bias whereby those from more socially and economically disadvantaged backgrounds were less represented in the analytical sample in the main analysis presented. However, the sensitivity analysis suggested that this did not alter the descriptive investigation of early life correlates. Despite this, imputation of missing data will be conducted in subsequent inferential statistics in this thesis.

Finally, investigation of early life correlates was based on descriptive analyses. Observed associations may not be independent once other factors are taken into account. The aim of these descriptive analyses was to investigate early life correlates of body composition trajectories that may be included as confounders in further analyses in this thesis and, as such, ascertaining the independence of observed associations was not an objective of this study. However, it is plausible that some associations, such as that seen between maternal alcohol consumption in pregnancy and lower BMI trajectories for example, may be explained by socioeconomic confounding. Additionally, early life correlates were coded into categories. In the majority of instances, this was based on existing, well-validated or clinically relevant thresholds. However, particularly where early life correlates were dichotomised, this may mask more complex associations, including potential dose-response relationships in the frequency or quantity of cigarette and alcohol consumption during pregnancy or breastfeeding duration.

5.4.4 Interim conclusions

The results of this study suggest that there are distinct trajectories of adiposity, and of a proxy measure of muscularity, from age 7 to 14. For both adiposity and muscularity measures, these can be broadly identified as a low, a moderate, and a high trajectory, which appear stable from age 7 to 14. Consistent with previous research into childhood trajectories of BMI, early life socioeconomic disadvantage is associated with increased trajectories of adiposity and muscularity. Similarly, potentially modifiable early life factors including raised maternal pre-pregnancy BMI, smoking during pregnancy and not being breastfed were associated with increased trajectories of adiposity and a proxy measure of muscularity across childhood and early adolescence.

6 Association of Childhood Body Composition Trajectories and Body Image Concerns in Adolescence

6.1 Introduction

Previous research has established a cross-sectional association between body weight and body image concerns (81,129,130,195). Cross-sectional evidence suggests that this association may vary by sex; increasing weight appears to be linearly associated with lower body satisfaction in girls, while in boys, both those with lower BMIs and higher BMIs have lower body satisfaction (130,195). This is consistent with gendered societal body ideals, which endorse thinness in women and lean muscularity in men.

However, this is based on studies that use BMI to measure weight, which captures total body weight and cannot distinguish between the composite parts, adiposity and muscularity, that may be driving body satisfaction in girls and boys, respectively. In addition to the limitations of BMI in this field, there is limited longitudinal evidence that considers the role of weight across childhood. This is important from a lifecourse perspective, as there is evidence that weight and body image concerns are bidirectionally associated (137). Longitudinal studies which capture the development of weight and body composition across childhood, and collect data on potential early life confounding factors, may provide a deeper understanding of how this association develops over young people's lives.

Previous longitudinal analysis in Millennium Cohort Study participants has shown that children with higher BMI growth trajectories from age 3 to 11 years report lower levels of body satisfaction at age 11 years (81). However, potential differences in adiposity and muscularity trajectories have not been examined. Furthermore, though body satisfaction provides a global indicator of body image concerns, investigating the association with weight control behaviours, such as dieting and exercise for weight loss, is pertinent as these are risk factors for eating disorders and future weight gain and are also associated with depressive symptoms (137,132,141). Therefore, this may also provide further evidence around the childhood risk factors for mental health problems.

In the previous chapter (**Chapter 5**), childhood trajectories of BMI, measures of adiposity (Fat Mass Index (FMI) and the ratio of fat mass to fat-free mass (FM/FFM)) and a proxy for muscularity (Fat-Free Mass Index (FFMI)) to age 14 were modelled. The current study aims to investigate their association with measures of body image concerns in adolescence and whether there are differences in this association by sex. The following hypotheses were tested:

> ***Hypothesis 2:*** *Higher trajectories of adiposity are associated with greater body image concerns compared to low trajectories, and the magnitude of association will be greater in girls compared to boys.*
>
> ***Hypothesis 3:*** *The magnitude of association is greater using adiposity trajectories compared to BMI trajectories.*
>
> ***Hypothesis 4:*** *Higher trajectories of muscularity are associated with fewer body image concerns compared to low trajectories, and the magnitude of association will be greater in boys compared to girls.*

6.2 Methods

6.2.1 Sample

Millennium Cohort Study participants with valid BMI and body composition trajectories were included in this analysis, with data collected as described in **4.5.1 Body Mass Index and body composition.** Those who had been assigned to a BMI trajectory group but no other body composition trajectory (due to attrition prior to the sweep at 7 years) were excluded to allow comparison of associations in the same samples. This excluded 1,650 cohort members from the analysis, leaving 13,025 with valid exposure data. Missing data on outcomes and confounders was imputed using multiple imputation by chained equations (described further in **6.2.5 Analysis**).

6.2.2 Body composition trajectories

Trajectories of BMI from age 3 to 14 and FMI, FFMI and FM/FFM from age 7 to 14 were modelled using latent class growth analysis (described in detail in **5.2.2**). For each measure of BMI and body composition, there were three trajectory groups, classified broadly as low, moderate and high. Cohort members were assigned to their most likely trajectory group, such that trajectories were handled as a categorical variable in analyses.

6.2.3 Body image concerns

Measures of body image concerns in the Millennium Cohort Study are described in detail in **4.5.2 Body image concerns**. In this study, measures at ages 14 and 17 were used. At age 14, these were body satisfaction score, on a scale 1 to 7, where higher scores indicated greater satisfaction; weight perception (underweight, about the right weight, slightly overweight, very overweight); weight intention (lose weight, gain weight, stay the same weight, doing nothing), and lifetime use of exercise or dieting for weight loss (No; Yes). At age 17, measures available were weight perception, weight intention, and past year use of exercise or dieting for weight loss.

6.2.4 Confounding variables

Potential confounding variables were reported by parents during the first wave of data collection when cohort members were 9 months old, unless stated otherwise.

Child characteristics and family socioeconomic position

These were sex assigned at birth, ethnicity, family income, and parental education and occupation. Additionally, age at outcome measurement was included to increase precision of estimates, as age at the age 14 sweep, for example, could vary from 13 to 15 years. Household income was categorised into OECD-equivalised quintiles, which account for household size. Parents' highest educational qualification was measured according to NVQ Level equivalents (None to Level 5, as previously described in **5.2.5**). Parent occupational class was assessed according to the NS-SEC and categorised as the five-class version. For two-parent households, the highest parent education and occupation of available data was used in analyses. These were included as confounders due to existing evidence of their associations with weight development (163) and body image concerns (130).

Perinatal factors

These were cohort member birthweight in kilograms, maternal pre-pregnancy BMI, whether the cohort member was breastfed (any versus none), and whether their mother had smoked or consumed alcohol during pregnancy (any versus none). These were hypothesised as confounding variables based on evidence of their associations with weight development (81) and the development of eating disorders (196). Gestational age and parental age when the cohort member was born were also considered but were excluded as they did not meet the conditions of confounding and in the case of parental age were theorised to be capturing socioeconomic effects.

For descriptive purposes only, a binary variable was generated from recorded birthweight to capture whether this was considered low birthweight using the World Health Organisation definition (<2.5kg) (197). Similarly, a categorical variable for maternal pre-pregnancy BMI was created according to World Health Organisation thresholds for overweight and obesity (198). In the main analyses, continuous variables were used.

Parental mental health

This was measured using the Kessler K6 scale when the child was 3 years old. Evidence suggests that both maternal and paternal psychological distress is associated with child body composition (180). However, there are many single-parent households in the dataset so, to avoid excluding these households but include paternal mental health data where available, a new variable was derived to indicate whether any parent in the household had a Kessler score indicating moderate or severe distress (scores greater than or equal to 5) (181).

6.2.5 Analysis

Missing data

Frequencies and proportions of missing outcome and confounder data among those with available exposure data were explored descriptively. Additionally, among those with available exposure data, proportions with complete and missing outcome data were explored to investigate whether those with missing outcome data were similar to those with valid data. Missing data on outcomes and confounders was then imputed using multiple imputation (MICE), assuming that data are missing at random. Fifty datasets were imputed using all analysis variables and additional auxiliary variables to improve precision, including measures of child emotional and behavioural symptoms (Strengths and Difficulties Questionnaire scores) and raw BMI scores at ages 3, 5, 7, 11, 14 and 17 years and body satisfaction at age 11. Characteristics of imputed and non-imputed samples with valid exposure data were compared using proportions.

Statistical analysis

Body satisfaction scores by body composition trajectory groups were described using means and standard deviations. Weight perceptions, weight intentions, and use of dieting and exercise by body composition trajectory groups were described using proportions. These were conducted on a sample with valid exposure data and available outcome data and were stratified by sex. Although stratified analyses are generally only recommended when there is evidence of interactions (which is the approach used in regression modelling below), this is performed for descriptive purposes only, given existing evidence that weight concerns may differ among boys and girls and as associations with different measures of body composition have not been previously shown (112).

Among those with valid exposure data and imputed outcomes and confounders, the associations between body composition trajectories and body image outcomes were investigated using regression analysis with sampling weights applied. Linear regressions were performed for body satisfaction, logistic regressions for dieting and exercise, and multinomial logistic regressions for weight perceptions and intentions. Univariable models were run before multivariable models with blocks of adjustment for confounding variables, as follows:

- Model 0: Unadjusted
- Model 1: Model 0 + sociodemographic factors (sex, age at outcome measurement, ethnicity, family income, parent education and occupation)
- Model 2: Model 0 + perinatal factors (maternal pre-pregnancy BMI, child birthweight, maternal cigarette and alcohol consumption in pregnancy, breastfeeding)
- Model 3: Model 0 + parental mental health
- Model 4: Model 0 + all confounding variables above

Following this, an exposure*sex interaction term was included in Model 4 to investigate whether the association between exposure and outcome varied by sex assigned at birth. Where evidence of interaction was found (interaction p values <0.05), Model 4 was then stratified by sex. Given the large number of interactions tested, with eight per body image outcome, there was an increased risk of Type I errors leading to spurious results. With four outcomes and two time points, a total of 72 interaction tests were expected to be run. Based on an alpha of 0.05, it was anticipated that between three and four interaction tests could be expected to be found as significant based on chance alone (199,200). Therefore, interaction term results are interpreted with this expectation in mind.

Sensitivity analysis

The impact of imputing missing outcome and confounder data was explored by repeating regression models on a sample with complete data on all analysis variables (applying sampling and attrition weights) and results were compared with those of the imputed sample. As the analysis excluded 1,650 cohort members with a valid BMI trajectory but no other body composition trajectory, unadjusted models were repeated in the larger sample with valid BMI trajectories and compared to the results in the restricted sample to test the impact of this decision.

An additional sensitivity analysis was conducted with further adjustment for pubertal status at ages 11 and 14 years, to explore the extent to which the association between body composition trajectory and body image is explained by pubertal status, potentially via a mediating pathway (110,201). Due to the longitudinal nature of the trajectories, disentangling the temporal relationship of these associations is challenging, as higher childhood weight is associated with earlier puberty in girls (202), and puberty results in physiological changes in body composition (69). As a result, this adjustment was not part of the main analysis. Pubertal status was indicated by menarche in girls and by self-reported voice changes in boys (203), which were reported by parents at age 11 and by cohort members at 14. Univariable and multivariable regression models were conducted as follows on participants with valid body composition trajectories and imputed outcomes and confounders:

Model S0: Unadjusted
Model S1: Model S0 + pubertal status
Model S2: Model S0 + all confounding variables in main analysis + pubertal status

All analyses were conducted in StataMP 17 (StataCorp. 2021. College Station, TX: StataCorp LLC).

6.3 Results

6.3.1 Sample description

Of the total 18,540 cohort members (taking one cohort member at random in cases of multiple births as outlined in **4.3 Sample**, 14,675 had valid data on BMI trajectory (79.2% of total) and, of these, 13,025 (70.3% of total) had data on all three body composition trajectories and were included in analyses. Characteristics of the sample are detailed in **Table 6-1**, presented by BMI trajectory for simplicity as there are multiple exposures. Approximately half were male (50.8%). The majority were of White ethnicity (84.4%) and most commonly were born to parents with an educational qualification equivalent to degree level or higher (35.3%) and who worked in a managerial or professional occupation (38.9%). Most were not classified as low birthweight (93.1%) and were born to a mother with a pre-pregnancy BMI below 25 (70.3%). Approximately one-third of cohort members had at least one parent with elevated levels of psychological distress (34.5%). Most cohort members had not started puberty by age 11 (93.6%), whereas the majority had done by age 14 (77.0%).

As described in the previous chapter (**5.3.1**), a greater proportion of girls and cohort members of mixed, Pakistani, Bangladeshi, or Black ethnicity and from more socioeconomically disadvantaged family backgrounds were in the ‘high’ trajectory of BMI across childhood compared to boys, White cohort members and those from more advantaged backgrounds, respectively (**Table 6-1**). More cohort members whose mothers smoked in pregnancy were in the ‘high’ trajectory of BMI, compared to those whose mothers did not. ‘High’ BMI trajectory membership was also more prevalent among cohort members whose mothers did not drink alcohol in pregnancy and did not breastfeed compared to those whose mothers did drink alcohol and did breastfeed, respectively. More cohort members with at least one parent with elevated levels of psychological distress were in the ‘high’ BMI trajectory compared to those with no parent(s) with elevated psychological distress, but these differences were small. Maternal pre-pregnancy BMI was highly correlated with cohort member BMI trajectory

Table 6-1. Characteristics of sample by BMI trajectory. Sample with valid exposure data and available data on characteristics (unweighted proportions).

Characteristic	N (%)	BMI Trajectory (%)		
		Low	Moderate	High
Cohort member sex at birth				
Male	6612 (50.8)	67.6	26.5	5.9
Female	6413 (49.2)	60.9	31.6	7.4
Cohort member age at 14 year interview				
Mean (SD)	14.3 (0.3)	14.3 (0.3)	14.3 (0.3)	14.2 (0.3)
Cohort member ethnicity				
White	10968 (84.4)	64.6	29.2	6.2
Mixed	346 (2.7)	65.6	25.4	9.0
Indian	312 (2.4)	68.6	26.0	5.4
Pakistani or Bangladeshi	828 (6.4)	62.2	27.9	9.9
Black or Black British	383 (2.9)	52.0	36.0	12.0
Other, including Chinese and Arab	160 (1.2)	70.0	23.1	6.9
Family income fifth at 9 months				
Most disadvantaged	2804 (21.6)	60.4	30.3	9.3
Second	2786 (21.4)	62.4	30.0	7.6
Third	2526 (19.4)	62.4	31.1	6.5
Fourth	2521 (19.4)	64.7	29.7	5.6
Least disadvantaged	2355 (18.1)	72.8	23.5	3.7
Highest parental education qualification at 9 months				
None	1403 (10.8)	60.1	29.9	10.0
NVQ Level 1 (GCSE grade D-G)	775 (5.9)	62.6	29.9	7.5
NVQ Level 2 (GCSE grade A*-C)	3199 (24.6)	60.6	31.4	8.0
NVQ Level 3 (A Level)	2151 (16.5)	63.6	29.2	7.2
NVQ Level 4 (One year Undergraduate)	4593 (35.3)	67.2	27.9	4.9
NVQ Level 5 (Two years Undergraduate+)	896 (6.9)	72.5	23.9	3.6
Highest parental occupational class at 9 months				
Not in work	2924 (22.5)	60.5	30.6	8.9
Routine or semi-routine	1900 (14.6)	60.7	30.5	8.8
Lower supervisory or technical	1043 (8.0)	59.2	33.2	7.6
Small employers or self-employed	863 (6.7)	63.6	29.8	6.6
Intermediate occupations	1199 (9.2)	66.3	27.5	6.2
Managerial or professional	5050 (38.9)	68.5	271	4.4
Cohort member birthweight				
Low birthweight (≤2.5kg)	890 (6.9)	68.7	24.9	6.4
Birthweight >2.5kg	12106 (93.1)	64.0	29.3	6.7
Maternal pre-pregnancy BMI				
BMI <25	8416 (70.3)	71.4	24.6	4.0
BMI 25 – 29.9	2465 (20.6)	53.6	36.7	9.7
BMI ≥30	1083 (9.1)	38.2	43.1	18.7
Cohort member was breastfed				
No	3870 (29.8)	60.8	31.0	8.2
Yes	9135 (70.2)	65.8	28.2	6.0
Mother smoked in pregnancy				
No	11057 (84.9)	65.3	28.6	6.1
Yes	1962 (15.1)	58.7	31.5	9.8

Characteristic	N (%)	BMI Trajectory (%)		
		Low	Moderate	High
Mother drank alcohol in pregnancy				
No	9020 (69.4)	63.0	29.7	7.3
Yes	3982 (30.6)	67.4	27.3	5.3
Any parent psychological distress at 3 years				
No	7965 (65.5)	64.8	29.1	6.2
Yes	4192 (34.5)	62.9	29.8	7.3
Cohort member pubertal status at 11 years				
Not yet started	10339 (93.6)	64.9	29.0	6.1
Started puberty[b]	709 (6.4)	41.9	43.3	14.8
Cohort member pubertal status at 14 years				
Not yet started	2249 (23.0)	72.2	22.4	5.4
Started puberty[b]	7519 (77.0)	60.1	33.0	6.9

[a] Ns may not total 13025 due to missing data; see Appendix Table 1 for more on missing data.

[b] Puberty indicated by menstruation in girls and voice changes in boys.

and a greater proportion of cohort members who had started puberty by age 11 were in the ‘high’ BMI trajectory compared to those who had not started puberty.

6.3.2 Missing data

Among cohort members with complete trajectory data, missing data on confounders was minimal (

Appendix for Chapter 6, Table 1), with the exception of maternal pre-pregnancy BMI and parent psychological distress where 1,061 (8.2%) and 868 (6.7%) cohort members were missing these data, respectively. Also, among participants with complete trajectory data, 3,237 (24.8%) were missing at least one body image outcome at age 14 and 7,012 (53.8%) were missing at least one at age 17 (**Appendix for Chapter 6, Table 2**). Compared to those with complete outcome data, a greater proportion of those missing at least one outcome were male, of mixed or Black ethnicity, and from more socioeconomically disadvantaged families. Additionally, more participants with a low birthweight, who were not breastfed, and had a mother who smoked during pregnancy were missing outcome data, compared to those with complete outcome data. There was no clear patterning of missing outcome data by BMI trajectory membership.

6.3.3 Reported body image concerns by body composition trajectory

Body satisfaction

Mean body satisfaction was lower in girls than in boys (mean 4.31 (SD 1.6) versus 5.22 (SD 1.4), **Table 6-2**). For both sexes, satisfaction was lowest in those with high trajectories of BMI, adiposity and muscularity. However, in boys, the difference in body satisfaction between those with high and low trajectories of muscularity was much smaller than the differential seen in BMI or adiposity trajectories. There was no difference observed between muscularity and adiposity measures in girls.

Weight perception and intention

At age 14, 64.4% of boys and 56.6% of girls saw themselves as ‘about the right weight’ (**Table 6-2**). A greater proportion of boys saw themselves as underweight than did girls (9.5% versus 4.6%), while more girls saw themselves as overweight to some extent than did boys (38.8% versus 26.1%). In both sexes, the proportion seeing themselves as under or about the right weight was higher in those with low trajectories of body composition, while a greater proportion with moderate or high trajectories saw themselves as overweight to some extent. Around 95% of boys and girls with high trajectories of adiposity saw themselves as overweight to some extent (boys: 94.2% and 97.8% for FMI and FM/FFM, respectively; girls: 94.5% and 94.7%). The proportion of girls with high muscularity trajectories who saw themselves as overweight to some extent was similar to that seen in high adiposity trajectories at 95.8%, but this was lower in boys with high muscularity trajectories (68.2%). Additionally, it was common for boys and girls with low adiposity trajectories to report seeing themselves as overweight (15.9% and 18.9% respectively for FM/FFM).

At age 17 (**Table 6-3**), fewer girls (52.3%) and boys (59.4%) saw themselves as about the right weight compared to age 14 (56.6% in girls; 64.4% in boys). The proportion of boys who saw themselves as underweight increased relative to age 14 (14.5%), as did the proportion of girls who saw themselves as overweight to some extent (42.4%). As at age 14, weight perception was highly correlated with body composition trajectory, but, again, a large proportion of those with low trajectories of BMI or adiposity reported seeing themselves as overweight, particularly in girls (21.3% for FM/FFM).

Table 6-2. Body image concerns at age 14 by body composition trajectory. Participants with valid data (sampling weights applied).

Trajectory	N	%	Body Satisfaction	Weight Perception (%)				Weight Intention (%)				Exercised (%)	Dieted (%)
			Mean (SD)	Under	About Right	Slightly Over ǂ	Very Over ǂ	Lose	Gain	Stay the Same	Do Nothing	Yes	Yes
Boys			**N=4876**		**N=4883**				**N=4890**			**N=4889**	**N=4883**
N				469	3111	1153	150	1529	621	1395	1345	2674	1666
%			5.22 (1.4)	9.5	64.4	23.2	2.9	30.4	12.2	29.1	28.4	53.4	33.2
BMI Trajectory													
Low	4467	70.9	5.33 (1.3)	13.6	76.7	9.3	0.4	16.2	16.7	33.4	33.7	42.6	21.9
Moderate	1754	23.9	5.04 (1.4)	0.8	41.1	53.5	4.6	60.7	1.6	19.9	17.8	76.3	55.0
High	391	5.2	4.66 (1.6)	0.0	10.3	60.9	28.7	81.4	0.0	10.0	8.6	83.1	73.1
FMI Trajectory													
Low	5265	81.5	5.30 (1.3)	11.7	74.2	13.5	0.6	21.7	14.4	32.2	31.7	47.5	26.0
Moderate	1068	14.9	4.90 (1.5)	0.3	21.3	70.0	8.4	71.2	0.4	15.3	13.1	80.8	65.0
High	279	3.6	4.65 (1.6)	0.0	5.8	57.0	37.2	83.6	0.2	5.3	10.9	84.0	74.1
FFMI Trajectory													
Low	2257	33.3	5.33 (1.3)	22.5	69.7	7.5	0.3	10.2	23.6	30.8	35.4	34.6	17.9
Moderate	3422	52.7	5.23 (1.4)	4.3	70.3	23.7	1.7	33.8	7.7	31.0	27.5	57.7	34.9
High	933	14.0	4.95 (1.5)	0.4	31.4	55.2	13.0	65.6	1.4	17.1	15.9	78.9	59.6
FM/FFM Trajectory													
Low	5422	84.0	5.29 (1.3)	11.4	73.7	15.2	0.7	22.9	14.1	31.8	31.2	48.3	27.0
Moderate	1014	13.8	4.90 (1.6)	0.2	22.1	66.9	10.8	72.0	0.4	14.8	12.7	81.4	64.7
High	176	2.2	4.51 (1.7)	0.0	2.2	53.2	44.6	84.5	0.3	1.9	13.3	80.7	75.9
Girls			**N=4998**		**N=4989**				**N=4997**			**N=4997**	**N=4989**
N				227	2791	1670	301	2595	196	1153	1053	3280	2723
%			4.31 (1.6)	4.6	56.6	32.9	5.9	51.1	3.8	23.7	21.4	66.1	54.7
BMI Trajectory													
Low	3908	65.1	4.50 (1.5)	7.6	74.0	16.7	1.7	34.7	6.5	31.3	27.5	55.8	42.9
Moderate	2029	28.4	4.08 (1.6)	0.3	34.2	57.5	8.0	74.2	0.0	13.2	12.6	81.5	70.7
High	476	6.4	3.61 (1.8)	0.0	5.5	63.8	30.7	88.7	0.0	2.4	8.9	87.3	85.1
FMI Trajectory													
Low	3665	58.9	4.51 (1.5)	8.2	75.4	14.7	1.7	33.2	7.0	31.9	27.9	54.5	41.3
Moderate	2220	33.6	4.12 (1.6)	0.3	37.3	55.6	6.8	71.2	0.0	14.7	14.0	80.4	69.7
High	528	7.5	3.62 (1.8)	0.0	5.5	63.0	31.5	89.2	0.0	2.0	8.8	88.3	85.2
FFMI Trajectory													
Low	3594	56.7	4.51 (1.5)	7.9	73.5	16.9	1.7	34.8	6.6	32.0	26.6	56.0	42.8
Moderate	2555	39.6	4.05 (1.6)	0.4	35.1	56.0	8.5	72.7	0.4	12.2	14.7	80.3	70.3
High	264	3.7	3.54 (1.9)	0.0	4.2	52.4	43.4	86.7	0.0	4.4	8.9	85.3	85.7
FM/FFM Trajectory													
Low	3884	62.6	4.48 (1.5)	7.5	73.9	16.9	1.7	35.8	6.3	30.8	27.1	56.6	43.2
Moderate	2010	30.1	4.12 (1.6)	0.3	32.1	60.0	7.6	73.4	0.1	13.4	13.0	81.0	71.2
High	519	7.3	3.57 (1.8)	0.0	5.3	61.6	33.1	91.1	0.0	1.8	7.1	89.2	86.9

ǂ Overweight

Table 6-3. Body image concerns at age 17 by body composition trajectory. Participants with valid data (sampling weights applied).

Trajectory	N	%	Weight Perception (%)				Weight Intention (%)				Exercised (%)	Dieted (%)
			Under	About Right	Slightly Over ǂ	Very Over ǂ	Lose	Gain	Stay the Same	Do Nothing	Yes	Yes
Boys			**N=2670**				**N=2665**				**N=2669**	**N=2669**
N			389	1550	619	112	845	598	517	705	1442	999
%			14.5	59.4	22.1	4.0	29.7	22.4	20.5	27.4	53.4	36.7
BMI Trajectory												
Low	4467	69.1	20.5	68.0	10.6	0.9	16.7	29.0	22.2	32.1	43.0	25.3
Moderate	1754	25.7	1.0	41.8	49.5	7.6	57.0	5.7	16.7	20.6	76.7	61.0
High	391	5.2	1.4	16.2	47.6	34.8	81.8	3.5	4.8	9.9	82.8	77.0
FMI Trajectory												
Low	5265	81.5	18.1	65.8	14.8	1.3	21.3	26.5	22.0	30.2	47.4	29.9
Moderate	1068	14.9	1.0	25.9	61.3	11.8	67.9	3.4	16.2	15.5	81.3	67.9
High	279	3.6	0.0	14.3	39.8	45.8	87.8	2.3	4.8	5.1	84.2	77.3
FFMI Trajectory												
Low	2257	33.3	35.0	57.9	6.0	1.1	10.7	40.2	16.5	32.6	32.2	18.3
Moderate	3422	52.7	5.9	67.3	24.2	2.6	32.6	15.7	24.7	27.1	59.5	41.1
High	933	14.0	0.9	27.6	53.8	17.7	67.2	4.4	12.7	15.7	80.5	63.6
FM/FFM Trajectory												
Low	5422	84.0	17.5	64.7	16.2	1.5	22.2	25.8	22.0	30.0	48.3	30.5
Moderate	1014	13.8	1.5	26.5	58.5	13.5	71.8	3.4	11.0	13.8	82.2	69.5
High	176	2.2	0.0	7.9	37.0	55.1	87.6	3.4	2.9	6.1	81.3	85.6
Girls			**N=3355**				**N=3355**				**N=3358**	**N=3358**
N			176	1713	1154	312	2024	174	557	600	2338	2121
%			5.4	52.3	33.6	8.8	60.5	4.9	16.8	17.8	70.6	64.1
BMI Trajectory												
Low	3908	62.5	8.8	66.3	21.4	3.5	49.5	8.5	20.4	21.6	64.1	55.1
Moderate	2029	30.8	0.5	30.6	54.3	14.6	77.8	0.5	10.7	11.0	80.1	77.4
High	476	6.7	0.4	2.3	51.4	45.9	88.9	0.2	1.8	9.1	84.5	83.3
FMI Trajectory												
Low	3665	58.9	8.9	70.0	19.5	1.6	47.0	8.4	22.1	22.5	63.6	54.1
Moderate	2220	33.6	0.8	32.5	53.4	13.2	77.9	0.6	10.4	11.1	79.1	76.5
High	528	7.5	0.0	2.4	52.7	44.9	87.4	0.2	2.8	9.6	84.9	83.9
FFMI Trajectory												
Low	3594	56.7	8.8	68.4	20.8	2.0	47.8	8.2	21.4	22.6	63.2	54.9
Moderate	2555	39.6	0.8	31.4	53.0	14.8	78.1	0.8	10.3	10.8	80.5	76.6
High	264	3.7	0.0	5.7	41.0	53.3	87.8	0.3	4.5	7.4	86.1	83.1
FM/FFM Trajectory												
Low	3884	62.6	8.1	68.7	21.3	1.9	48.3	7.6	21.5	22.6	64.3	55.2
Moderate	2010	30.1	0.8	27.7	56.3	15.2	81.2	0.7	9.3	8.8	81.0	79.0
High	519	7.3	0.4	2.7	52.7	44.2	87.8	0.2	2.4	9.6	84.0	82.6

ǂ Overweight

At age 14, 51.1% of girls and 30.4% boys reported wanting to lose weight (**Table 6-2**). Few girls reported wanting to gain weight (3.8%), whereas a relatively large proportion of boys did (12.2%). Weight intentions were highly correlated with body composition trajectories, with more than 80% of boys and almost 90% of girls with high BMI or adiposity trajectories wanting to lose weight (boys: 83.6% and 84.5% for BMI and adiposity, respectively; girls: 89.2% and 91.1%). Almost no boys or girls in these high trajectory groups reported wanting to gain weight (boys: 0.2% and 0.3% in FMI and FM/FFM, respectively; girls: 0.0% in both). Even among those with low adiposity trajectories, indicated by FM/FFM, 22.9% of boys and 35.8% of girls reported wanting to lose weight.

At age 17 (**Table 6-3**), the proportion of boys wanting to lose weight (29.7%) was similar to that observed at age 14 (30.4%), while in girls it rose to 60.5% at age 17 from 51.1%. The overall proportion of boys wanting to gain weight almost doubled to 22.4% and was highest in boys with low muscularity trajectories (40.2%). As with the age 14 results, intentions were highly correlated with body composition trajectory. A large majority of adolescents with high trajectories of adiposity wanted to lose weight (87.6% of boys and 87.8% of girls with high FM/FFM trajectories), while this was slightly lower among boys with high trajectories of muscularity (67.2%). Among girls with low adiposity trajectories, almost half wanted to lose weight (48.3% of girls with low FM/FFM trajectories).

Exercise and dieting for weight loss

At age 14, 53.4% of boys and 66.1% of girls reported lifetime exercise for weight loss (**Table 6-2**). Similar proportions were reported at age 17, when exercise for weight loss in the past year was reported (53.4% and 70.6% respectively, **Table 6-3**). The prevalence of exercising for weight loss was lowest in those with low trajectories and highest in those with high trajectories of BMI, adiposity, and muscularity (e.g., at age 17, 81.3% in boys and 84.0% in girls with high FM/FFM trajectories). However, even among those with low trajectories, exercising for weight loss was highly prevalent (48.3% of boys and 63.2% of girls at age 17 (FM/FFM)).

The prevalence of lifetime dieting for weight loss was 33.2% in boys and 54.7% in girls at age 14 (**Table 6-2**). The prevalence of past year dieting for weight loss at age 17 was 36.7% in boys and 64.1% in girls (**Table 6-3**). As with exercise for weight loss, the prevalence of dieting was highest in those with high trajectories of BMI, adiposity and muscularity (e.g., at age 17, 85.6% of boys and 82.6% of girls with high FM/FFM trajectories). The proportion of boys who reported dieting for weight loss was lower among those with high muscularity trajectories compared to those with high adiposity trajectories, but this represented the majority in both groups (63.6% in FFMI versus 85.6% for FM/FFM at age 17). As with other measures of body image concerns, dieting for weight loss was highly prevalent even among those with low trajectories of adiposity.

6.3.4 Association between body composition trajectories and body image measures

Weight perceptions and intentions

Due to their high correlations with body composition trajectories as discussed above, and the extreme values observed, it was deemed that further exploration of weight perceptions and intentions through regression analysis would not be beneficial. For illustrative purposes only, multinomial regression models of the association between body composition trajectory and weight perception at age 14 are detailed in **Appendix for Chapter 6, Table 3**. These demonstrate the extreme strength of these associations with risk ratios ranging from 0 to more than 450 estimated. Therefore, these outcomes were excluded from further analysis.

Body satisfaction

Table 6-4 shows the results of linear regression modelling of the association between body composition trajectory and body satisfaction at age 14. Overall, there was strong evidence for an association between childhood body composition trajectory and body satisfaction score. Adolescents with moderate or high increasing trajectories of adiposity reported lower body satisfaction compared to those with low trajectories, consistent with Hypothesis 2. Full adjustment for confounding variables resulted in some attenuation of these associations; this was most pronounced when controlling for sociodemographic factors. There was some weak evidence in support of Hypothesis 3, as the magnitude of association with body satisfaction score was greater using adiposity trajectories compared to BMI trajectories, though these differences were relatively small with largely overlapping confidence intervals: for example, the

Table 6-4. Results of univariable and multivariable linear regression analysis of the association between body composition trajectory and body satisfaction at age 14. Participants with valid exposure data and imputed outcomes and confounders (sampling weights applied).

		Body Satisfaction at Age 14 Years					
Whole sample N=13025	N	**Model 0 - unadjusted**	**Model 1 – 0 + sociodemographic factors[a]**	**Model 2 – 0 + perinatal factors[b]**	**Model 3 – 0 + parent mental health[c]**	**Model 4 – fully adjusted[d]**	**Exposure * Sex interaction**
		Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	P value
BMI Trajectory							
Low	8375	ref	ref	ref	ref	ref	ref
Moderate	3783	-0.41 (-0.49, -0.33)	-0.34 (-0.42, -0.27)	-0.39 (-0.48, -0.31)	-0.41 (-0.49, -0.33)	-0.32 (-0.39, -0.24)	0.151
High	867	-0.85 (-1.01, -0.69)	-0.77 (-0.92, -0.61)	-0.78 (-0.94, -0.62)	-0.85 (-1.01, -0.69)	-0.70 (-0.86, -0.55)	0.117
FMI Trajectory							
Low	8930	ref	ref	ref	ref	ref	ref
Moderate	3288	-0.59 (-0.67, -0.51)	-0.37 (-0.45, -0.28)	-0.57 (-0.66, -0.49)	-0.59 (-0.67, -0.51)	-0.34 (-0.42, -0.25)	0.863
High	807	-1.00 (-1.17, -0.83)	-0.79 (-0.96, -0.62)	-0.94 (-1.12, -0.77)	-1.00 (-1.17, -0.83)	-0.72 (-0.89, -0.55)	0.157
FFMI Trajectory							
Low	5851	ref	ref	ref	ref	ref	ref
Moderate	5977	-0.09 (-0.17, -0.01)	-0.27 (-0.35, -0.20)	-0.05 (-0.13, 0.03)	-0.09 (-0.16, -0.01)	-0.24 (-0.32, -0.16)	<0.001
High	1197	-0.16 (-0.29, -0.03)	-0.55 (-0.68, -0.42)	-0.05 (-0.19, 0.08)	-0.15 (-0.28, -0.03)	-0.47 (-0.61, -0.33)	0.002
FM/FFM Trajectory							
Low	9306	ref	ref	ref	ref	ref	ref
Moderate	3024	-0.57 (-0.66, -0.49)	-0.36 (-0.45, -0.28)	-0.55 (-0.64, -0.47)	-0.57 (-0.66, -0.49)	-0.34 (-0.42, -0.25)	0.791
High	695	-1.12 (-1.30, -0.94)	-0.84 (-1.02, -0.67)	-1.06 (-1.24, -0.87)	-1.11 (-1.29, -0.93)	-0.77 (-0.95, -0.59)	0.522

[a] Adjusting for sex, age at interview, ethnicity, family income, parental education, and parental occupational class at 9 months old.
[b] Adjusting for birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy.
[c] Adjusting for parent psychological distress at 3 years old.
[d] Adjusting for all confounding variables in models 1 to 3.

mean difference in body satisfaction score in those with high BMI trajectories compared to the low BMI trajectory group was -0.70 (95% CI -0.86, -0.55); using FM/FFM trajectories, the mean difference in the high compared to the low trajectory group was -0.77 (95% CI -0.95, -0.59). In contrast to Hypothesis 2, there was no evidence that associations with adiposity trajectory varied by sex. Only for muscularity trajectories was there strong evidence for sex differences (p for moderate FFMI*sex <0.001; p high FFMI*sex 0.002). In girls, associations with muscularity trajectories were similar to those seen with adiposity trajectories (moderate FFMI trajectory mean difference -0.40 (95% CI -0.51, -0.28); high FFMI trajectory mean difference -0.80 (95% CI -1.11, -0.48) compared to the low FFMI group, see

Appendix for Chapter 6, Table 5). There was no evidence that boys with moderate FFMI trajectories had different body satisfaction scores than those with low FFMI trajectories (mean difference -0.06, 95% CI -0.16, 0.04). Boys with high muscularity trajectories had body satisfaction scores 0.29 points lower than those with low muscularity trajectories (95% CI -0.44, -0.14). These results are in contrast to Hypothesis 4, which speculated that higher muscularity trajectories would be associated with more positive body image compared to low trajectories.

To best illustrate the differences between boys and girls, predicted mean body satisfaction scores by trajectory group are shown in **Figure 6-1**, depicting the results from fully adjusted models with the sex interaction term. This is done for all body composition measures, even where there was no evidence of exposure*sex interactions to make the different associations with adiposity and muscularity measures clearer. The figure highlights that the same associations are seen in girls, regardless of the body composition measure used, whereas in boys, there appears to be a different association with muscularity trajectories compared to BMI and adiposity measures.

Exercise for weight loss

The association between body composition trajectory and lifetime exercise for weight loss at age 14 is shown in **Table 6-5**. Unadjusted results for BMI trajectory suggested that compared to those with low BMI trajectories, cohort members with moderate BMI trajectories had 3.88 times higher odds of reporting exercising for weight loss at age

14 (95% CI 3.46, 4.36) and those with high trajectories had 5.94 times higher odds (95% CI 4.53, 7.78). After adjustment for all putative confounders, there was minimal

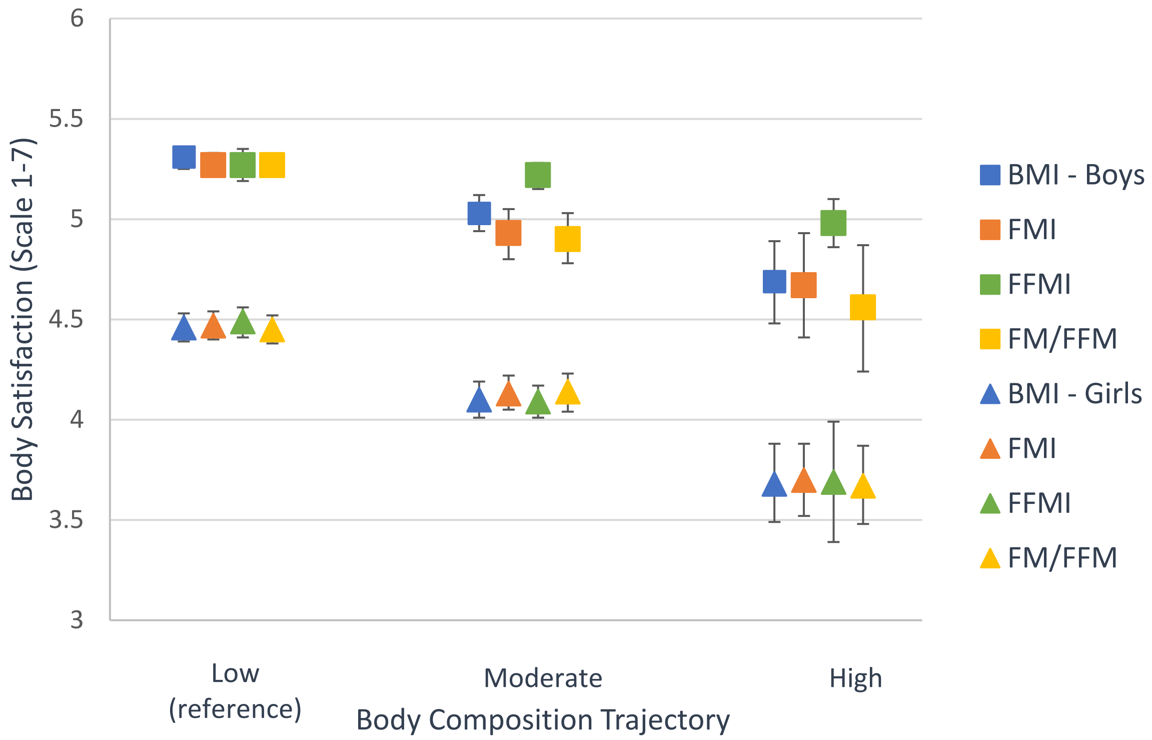

Figure 6-1. Body satisfaction score according to body composition trajectory among boys and girls, compared to their respective low trajectory. Predicted margins of fully adjusted estimates from linear regression modelling with 95% confidence intervals.

attenuation to these associations (moderate BMI odds ratio 3.74, 95% CI 3.31, 4.22; high BMI odds ratio 5.61, 95% CI 4.25, 7.41). There was no evidence for sex differences in this association (p value for moderate trajectory 0.161; p for high trajectory 0.635).

Results for adiposity-specific trajectories were similar to those of BMI. In the fully adjusted model, cohort members with moderate FMI trajectories had 3.54 times higher odds of reporting exercising for weight loss at age 14 (95% CI 3.11, 4.03) and those with high trajectories had 5.53 times higher odds (95% CI 4.21, 7.26) compared to those with low trajectories. Similarly, cohort members with moderate FM/FFM trajectories had 3.45 times higher odds (95% CI 3.01, 3.96) and those with high trajectories had 5.32 times higher odds (3.93, 7.20). of exercising for weight loss. Only for the moderate FM/FFM trajectory was there evidence that the association varied by sex (p value 0.019), in contrast with initial hypotheses (Hypothesis 2).

Table 6-5. Results of univariable and multivariable logistic regression analysis of the association between body composition trajectory and having ever exercised for weight loss at age 14. Participants with valid exposure data and imputed outcome and confounder data (sampling weights applied).

		Exercise for Weight Loss at Age 14 Years					
Whole sample N=13025	N	**Model 0 - unadjusted**	**Model 1 – 0 + sociodemographic factors[a]**	**Model 2 – 0 + perinatal factors[b]**	**Model 3 – 0 + parent mental health[c]**	**Model 4 – fully adjusted[d]**	**Exposure * Sex interaction**
		Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	P value
BMI Trajectory							
Low	8375	ref	ref	ref	ref	ref	ref
Moderate	3783	3.88 (3.46, 4.36)	3.81 (3.38, 4.29)	3.82 (3.40, 4.31)	3.82 (3.42, 4.27)	3.74 (3.31, 4.22)	0.161
High	867	5.94 (4.53, 7.78)	5.83 (4.43, 7.67)	5.73 (4.36, 7.54)	5.95 (4.53, 7.81)	5.61 (4.25, 7.41)	0.635
FMI Trajectory							
Low	8930	ref	ref	ref	ref	ref	ref
Moderate	3288	3.91 (3.46, 4.42)	3.59 (3.16, 4.07)	3.82 (3.38, 4.32)	3.85 (3.42, 4.35)	3.54 (3.11, 4.03)	0.081
High	807	6.21 (4.75, 8.13)	5.87 (4.44, 7.75)	5.88 (4.50, 7.68)	6.26 (4.74, 8.28)	5.53 (4.21, 7.26)	0.910
FFMI Trajectory							
Low	5851	ref	ref	ref	ref	ref	ref
Moderate	5977	2.22 (2.03, 2.44)	2.77 (2.51, 3.06)	2.16 (1.96, 2.38)	2.21 (2.01, 2.43)	2.70 (2.43, 2.99)	0.066
High	1197	4.37 (3.51, 5.42)	6.62 (5.124, 8.36)	4.07 (3.26, 5.07)	4.29 (3.48, 5.29)	6.26 (4.94, 7.94)	0.123
FM/FFM Trajectory							
Low	9306	ref	ref	ref	ref	ref	ref
Moderate	3024	3.78 (3.31, 4.30)	3.58 (3.13, 4.10)	3.70 (3.24, 4.23)	3.80 (3.34, 4.34)	3.45 (3.01, 3.96)	0.019
High	695	6.38 (4.70, 8.67)	5.76 (4.26, 7.79)	5.87 (4.36, 7.90)	6.27 (4.65, 8.47)	5.32 (3.93, 7.20)	0.532

[a] Adjusting for sex, age at interview, ethnicity, family income, parental education, and parental occupational class at 9 months old.

[b] Adjusting for birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy.

[c] Adjusting for parent psychological distress at 3 years old.

[d] Adjusting for all confounding variables in models 1 to 3.

In the unadjusted models for muscularity trajectories (**Table 6-5**), cohort members with moderate muscularity trajectories had 2.22 times higher odds of reporting exercising for weight loss at age 14 (95% CI 2.03, 2.44) compared to those with low muscularity trajectories. Cohort members with high trajectories had 4.37 times higher odds (95% CI 3.51, 5.42) compared to those with low trajectories. The magnitude of association increased after adjusting for all confounding variables, predominantly driven by the inclusion of sociodemographic factors; in the fully adjusted model, cohort members with moderate muscularity trajectories had 2.70 times higher odds (95% CI 2.43, 2.99) and those with high trajectories had 6.26 times higher odds of reporting exercising for weight loss (95% CI 4.94, 7.94) compared to the low trajectory group. There was no evidence that these associations differed according to cohort member sex at birth (p for moderate group 0.066; p for high group 0.123), in contrast with Hypothesis 4.

Results for past year exercise for weight loss at age 17 were similar to age 14 (lifetime exercise). In fully adjusted models (Table 6-6), cohort members with moderate BMI trajectories had 3.09 times higher odds (95% CI 2.67, 3.59) and those with high trajectories had 4.14 times higher odds of exercising for weight loss (95% CI 3.05, 5.63) compared to those with low BMI trajectories. Highly similar results were seen using adiposity trajectories; for example, those with moderate FM/FFM trajectories had 2.93 times higher odds (95% CI 2.49, 3.45) and those with high trajectories had 3.65 times higher odds of reporting exercising for weight loss (95% CI 2.64, 5.02) compared to those with low FM/FFM trajectories. For BMI, FMI and FM/FFM trajectories there was strong evidence that the association varied by sex at birth only in the moderate groups (p = 0.001; 0.001, 0.004, respectively) but not the high groups (p = 0.225, 0.314; 0.443). Sex-stratified results suggested that the magnitude of association was greater in boys than in girls; for example, boys with moderate BMI trajectories had 3.77 times higher odds of reporting exercising for weight loss (95% 3.04, 4.67), while in girls this was estimated to be 2.49 (95% CI 2.05, 3.02) compared to their respective low trajectory group. The same was seen in both adiposity measures, detailed in

Appendix for Chapter 6, Table 5.

These results provide evidence that higher trajectories of adiposity are associated with more negative body image compared to low trajectories, in support of Hypothesis 2, although in contrast to the initial hypothesis, the magnitude of association between adiposity trajectory and exercise for weight loss by age 17 was greater in boys than

Table 6-6. Results of univariable and multivariable logistic regression analysis of the association between body composition trajectory and having exercised for weight loss in the past year at age 17. Participants with valid exposure data and imputed outcome and confounder data (sampling weights applied).

		Exercise for Weight Loss at Age 17 Years					
Whole sample N=13025	N	**Model 0 - unadjusted**	**Model 1 – 0 + sociodemographic factors[a]**	**Model 2 – 0 + perinatal factors[b]**	**Model 3 – 0 + parent mental health[c]**	**Model 4 – fully adjusted[d]**	**Exposure * Sex interaction**
		Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	P value
BMI Trajectory							
Low	8375	ref	ref	ref	ref	ref	ref
Moderate	3783	3.06 (2.66, 3.52)	3.15 (2.73, 3.63)	3.05 (2.63, 3.53)	3.05 (2.66, 3.51)	3.09 (2.67, 3.59)	0.001
High	867	3.90 (2.90, 5.24)	4.31 (3.16, 5.88)	3.89 (2.91, 5.21)	3.89 (2.89, 5.23)	4.14 (3.05, 5.63)	0.225
FMI Trajectory							
Low	8930	ref	ref	ref	ref	ref	ref
Moderate	3288	3.22 (2.78, 3.74)	2.99 (2.58, 3.48)	3.19 (2.74, 3.71)	3.22 (2.78, 3.74)	2.89 (2.48, 3.38)	0.001
High	807	4.14 (3.11, 5.52)	4.28 (3.18, 5.77)	4.07 (3.06, 5.42)	4.13 (3.10, 5.50)	4.00 (2.97, 5.39)	0.314
FFMI Trajectory							
Low	5851	ref	ref	ref	ref	ref	ref
Moderate	5977	1.93 (1.73, 2.16)	2.60 (2.29, 2.95)	1.92 (1.70, 2.15)	1.93 (1.72, 2.16)	2.57 (2.25, 2.93)	0.507
High	1197	3.90 (3.00, 5.07)	7.03 (5.31, 9.30)	3.82 (2.93, 4.99)	3.89 (2.99, 5.06)	6.84 (5.17, 9.06)	0.103
FM/FFM Trajectory							
Low	9306	ref	ref	ref	ref	ref	ref
Moderate	3024	3.21 (2.73, 3.77)	3.05 (2.59, 3.58)	3.16 (2.68, 3.72)	3.21 (2.73, 3.77)	2.93 (2.49, 3.45)	0.004
High	695	4.01 (2.95, 5.45)	3.96 (2.87, 5.46)	3.92 (2.88, 5.33)	4.00 (2.94, 5.44)	3.65 (2.64, 5.02)	0.443

[a] Adjusting for sex, age at interview, ethnicity, family income, parental education, and parental occupational class at 9 months old.
[b] Adjusting for birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy.
[c] Adjusting for parent psychological distress at 3 years old.
[d] Adjusting for all confounding variables in models 1 to 3.

girls. They do not provide evidence in support of Hypothesis 3, as associations for exercise for weight loss using adiposity-specific measures were not greater in magnitude that those seen using BMI trajectories. There was also no evidence that higher muscularity trajectories are associated with more positive body image (i.e., lower odds of exercise for weight loss) in boys, in contrast to Hypothesis 4.

Dieting for weight loss

The associations between body composition trajectories and lifetime dieting for weight loss at age 14 are shown in **Table 6-7**. As with other body image measures, there was strong evidence that higher body composition trajectories across childhood were associated with greater odds of having dieted for weight loss at age 14. In the unadjusted model for BMI trajectory, odds of reporting dieting for weight loss were 3.73 times higher in those with moderate trajectories (95% CI 3.37, 4.13) and 8.24 times higher in those with higher BMI trajectories (95% CI 6.63, 10.23) compared to those with low BMI trajectories. Full adjustment for putative confounders resulted in minimal attenuation of the estimated association (odds ratio for moderate BMI trajectory 3.62, 95% CI 3.24, 4.04; odds ratio for high BMI trajectory 7.85, 95% CI 6.26, 9.84). There was some evidence that the association varied by sex in the moderate trajectory group only (p for sex interaction 0.017). When results were stratified by sex at birth, the magnitude of association appeared to be greater in boys compared to girls, although confidence intervals overlapped to some extent (boys moderate BMI odds ratio 4.09, 95% CI 3.48, 4.81; girls 3.20, 95% CI 2.74, 3.73, see **Appendix for Chapter 6, Table 6**).

Results were very similar when using trajectories of adiposity. In fully adjusted models using FMI, those with moderate trajectories had 3.63 times higher odds of dieting for weight loss at age 14 (95% CI 3.20, 4.11) and in those with high trajectories this was 7.48 times higher (95% CI 5.87, 9.53) compared to those with low FMI trajectories. Using FM/FFM, odds ratios for the moderate and high groups were 3.57 (95% CI 3.11, 4.09) and 7.69 (95% CI 5.86, 10.10). As with BMI, there was strong evidence that the association varied by sex only in the moderate adiposity group (moderate FMI*sex p= 0.001; moderate FM/FFM*sex p=0.002). Consistent with BMI results, the magnitude of association was greater in boys relative to girls, though again this was small and there was overlap in confidence intervals; for example, boys with moderate FM/FFM

Table 6-7. Results of univariable and multivariable logistic regression analysis of the association between body composition trajectory and having ever dieted for weight loss at age 14. Participants with valid exposure data and imputed outcome and confounder data (sampling weights applied).

		Dieting for Weight Loss at Age 14 Years					
Whole sample N=13025	N	**Model 0 - unadjusted**	**Model 1 – 0 + sociodemographic factors[a]**	**Model 2 – 0 + perinatal factors[b]**	**Model 3 – 0 + parent mental health[c]**	**Model 4 – fully adjusted[d]**	**Exposure * Sex interaction**
		Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	P value
BMI Trajectory							
Low	8375	ref	ref	ref	ref	ref	ref
Moderate	3783	3.73 (3.37, 4.13)	3.71 (3.33, 4.21)	3.68 (3.31, 4.10)	3.73 (3.36, 4.13)	3.62 (3.24, 4.04)	0.017
High	867	8.24 (6.63, 10.23)	8.25 (6.60, 10.3)	7.95 (6.39, 9.87)	8.21 (6.61, 10.19)	7.85 (6.26, 9.84)	0.492
FMI Trajectory							
Low	8930	ref	ref	ref	ref	ref	ref
Moderate	3288	4.35 (3.85, 4.91)	3.76 (3.33, 4.26)	4.25 (3.76, 4.81)	4.34 (3.85, 4.91)	3.63 (3.20, 4.11)	0.001
High	807	9.08 (7.19, 11.47)	8.04 (6.34, 10.21)	8.62 (6.81, 10.91)	9.05 (7.17, 11.43)	7.48 (5.87, 9.53)	0.977
FFMI Trajectory							
Low	5851	ref	ref	ref	ref	ref	ref
Moderate	5977	1.98 (1.81, 2.17)	2.80 (2.52, 3.11)	1.92 (1.75, 2.11)	1.98 (1.81, 2.17)	2.70 (2.43, 3.00)	0.042
High	1197	3.79 (3.18, 4.52)	7.42 (6.10, 9.03)	3.47 (2.89, 4.16)	3.78 (3.17, 4.51)	6.84 (5.59, 8.37)	0.609
FM/FFM Trajectory							
Low	9306	ref	ref	ref	ref	ref	ref
Moderate	3024	4.26 (3.74, 4.85)	3.72 (3.25, 4.25)	4.14 (3.62, 4.73)	4.25 (3.73, 4.84)	3.57 (3.11, 4.09)	0.002
High	695	10.10 (7.77, 13.12)	8.42 (6.45, 11.00)	9.47 (7.27, 12.33)	10.05 (7.73, 13.05)	7.69 (5.86, 10.10)	0.923

[a] Adjusting for sex, age at interview, ethnicity, family income, parental education, and parental occupational class at 9 months old.

[b] Adjusting for birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy.

[c] Adjusting for parent psychological distress at 3 years old.

[d] Adjusting for all confounding variables in models 1 to 3.

trajectories had 4.29 times higher odds of reporting dieting for weight loss (95% CI 3.51, 5.25) compared to the low FM/FFM trajectory, while in girls this was 3.20 (95% CI 2.71, 3.77). These are detailed in **Appendix for Chapter 6, Table 6**.

Results for the association between muscularity trajectories and dieting for weight loss at 14 were similar to those of BMI and adiposity trajectories. Compared to those with low muscularity trajectories, cohort members with moderate trajectories had 2.70 times higher odds (95% CI 2.43, 3.00) and those with high trajectories had 6.84 times higher odds of reporting dieting for weight loss (95% CI 5.59, 8.37) in the fully adjusted model (**Table 6-7**). There was weak evidence that the association for the moderate trajectory group varied by sex (p=0.042), and results were not stratified by sex due to the high number of interaction tests run. There was no evidence that the association differed by sex in the high trajectory group (p=0.609).

Results for the association between body composition trajectories and past year dieting for weight loss at age 17 were highly similar to those observed with lifetime dieting at age 14 (**Table 6-8**). There was evidence that the association with dieting for those with moderate trajectories of BMI or adiposity differed by sex (moderate BMI p for interaction=0.022; moderate FM/FFM p=0.014). Although there was some overlap in confidence intervals, odds ratios appeared to be higher in boys relative to girls; for example, the odds ratio in boys with moderate BMI trajectories was 3.99 (95% CI 3.22, 4.94) and in girls was 2.98 (95% CI 2.48, 3.57) compared to their respective low BMI trajectory group. Further sex-stratified results are shown in **Appendix for Chapter 6, Table 7**.

These results are consistent with the hypothesis that higher adiposity trajectories are associated with more body image concerns (Hypothesis 2). However, it was hypothesised that the magnitude of this association would be greater in girls relative to boys, but there was weak evidence to suggest a greater magnitude in boys. There was no evidence that the magnitude of association was greater using adiposity-specific measures compared to BMI trajectories, in contrast to Hypothesis 3. Additionally, higher muscularity trajectories were not associated with more positive body image (i.e., reduced odds of dieting for weight loss), which was not in line with Hypothesis 4.

Table 6-8. Results of univariable and multivariable logistic regression analysis of the association between body composition trajectory and having dieted for weight loss in the past year at age 17. Participants with valid exposure data and imputed outcome and confounder data (sampling weights applied).

		Dieting for Weight Loss at Age 17 Years					
Whole sample N=13025	N	**Model 0 - unadjusted**	**Model 1 – 0 + sociodemographic factors[a]**	**Model 2 – 0 + perinatal factors[b]**	**Model 3 – 0 + parent mental health[c]**	**Model 4 – fully adjusted[d]**	**Exposure * Sex interaction**
		Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	P value
BMI Trajectory							
Low	8375	ref	ref	ref	ref	ref	ref
Moderate	3783	3.39 (2.98, 3.86)	3.56 (3.09, 4.09)	3.37 (2.95, 3.85)	3.39 (2.98, 3.86)	3.46 (3.01, 3.99)	0.022
High	867	5.49 (4.16, 7.24)	6.21 (4.56, 8.46)	5.40 (4.05, 7.19)	5.49 (4.16, 7.24)	5.88 (4.28, 8.06)	0.154
FMI Trajectory							
Low	8930	ref	ref	ref	ref	ref	ref
Moderate	3288	4.07 (3.55, 4.66)	3.51 (3.03, 4.06)	4.02 (3.50, 4.62)	4.07 (3.55, 4.67)	3.38 (2.92, 3.91)	0.013
High	807	6.47 (4.92, 8.52)	6.20 (4.58, 8.40)	6.32 (4.76, 8.40)	6.48 (4.91, 8.53)	5.74 (4.22, 7.82)	0.251
FFMI Trajectory							
Low	5851	ref	ref	ref	ref	ref	ref
Moderate	5977	1.74 (1.56, 1.93)	2.66 (2.33, 3.03)	1.68 (1.51, 1.87)	1.74 (1.56, 1.93)	2.57 (2.25, 2.92)	0.771
High	1197	2.89 (2.33, 3.58)	6.64 (5.15, 8.56)	2.66 (2.14, 3.31)	2.88 (2.32, 3.58)	6.15 (4.76, 7.95)	0.339
FM/FFM Trajectory							
Low	9306	ref	ref	ref	ref	ref	ref
Moderate	3024	4.14 (3.55, 4.83)	3.68 (3.13, 4.33)	4.08 (3.49, 4.78)	4.14 (3.55, 4.83)	3.53 (2.99, 4.17)	0.014
High	695	7.02 (5.15, 9.58)	6.27 (4.45, 8.85)	6.81 (4.95, 9.38)	7.02 (5.14, 9.59)	5.73 (4.05, 8.11)	0.071

[a] Adjusting for sex, age at interview, ethnicity, family income, parental education, and parental occupational class at 9 months old.
[b] Adjusting for birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy.
[c] Adjusting for parent psychological distress at 3 years old.
[d] Adjusting for all confounding variables in models 1 to 3.

6.3.5 Sensitivity analyses

Complete case analysis

Regression models were repeated in a sample with complete data on exposures, outcomes and confounders and results were highly consistent with those found in the imputed sample. This was in terms of the magnitude of effect estimates, strength of the association, and evidence of interactions by sex (**Appendix for Chapter 6, Table 8-12**).

Results of full sample with available BMI trajectory data

The impact of restricting the sample to those with available data on both BMI and other body composition trajectories (N=13,025) was checked by testing the associations in cohort members with available BMI trajectory data (N=14,675). These results were consistent with those of the restricted sample (**Appendix for Chapter 6, Table 13**).

Additionally accounting for pubertal status

A further sensitivity analysis looked at the impact of adjusting for pubertal status in the association of body composition trajectory and body image outcomes. Additional adjustment for pubertal status at ages 11 and 14 resulted in minimal change in the associations observed with confidence intervals almost completely overlapping those of the main analysis (**Appendix for Chapter 6, Table 14-18**).

6.4 Discussion

6.4.1 Summary of main findings

This study aimed to investigate the associations between trajectories of different aspects of body composition across childhood and body image concerns at 14 and 17 years and explore sex differences in these associations. Results suggested that higher adiposity trajectories across childhood were associated with lower levels of body satisfaction and increased odds of using exercise and dieting for weight loss, in line with hypotheses. The magnitude of these associations were largely consistent with those observed using childhood trajectories of BMI, which was contrary to a priori hypotheses. Also, in contrast to initial hypotheses, there was inconsistent evidence for sex differences in associations between adiposity trajectories and body image concerns; where there was evidence of differences, these suggested a greater magnitude of association in boys relative to girls, which was opposite to the hypothesised gendered associations. Initial descriptive analyses suggested that body image concerns and weight-control behaviours were highly prevalent irrespective of weight trajectory, particularly in girls. Around two in five girls saw themselves as overweight to some extent, more than half were trying to lose weight, and the majority had tried to use exercise or dieting to lose weight by age 14. These negative self-evaluations and behaviours were commonly reported even in girls with low BMI or adiposity trajectories.

There was some evidence that adiposity and a proxy for muscularity are differentially associated with body image concerns. However, in contrast to hypothesis 4, adolescents with high trajectories of muscularity reported lower body satisfaction and greater odds of exercising and dieting for weight loss. Furthermore, although it was hypothesised that associations with muscularity trajectory would be of a greater magnitude in boys relative to girls, this was not supported by the results. There was no evidence for sex differences in the association between muscularity trajectory and weight control behaviours. In contrast to hypotheses, while the association between muscularity trajectory and body satisfaction differed by sex, the magnitude of association appeared to be stronger in girls relative to boys.

6.4.2 Comparison with previous literature

The high prevalence of body image concerns, particularly in girls and irrespective of weight is consistent with previous evidence (112,129,204), which has shown body image concerns in girls with low BMI values. These findings are concerning as previous studies have suggested that body dissatisfaction may be associated with later depression, self-harm, and behaviours such as drug use in adolescence (132,133,205). Additionally, although some have posited that body image concerns may be a useful motivator for weight loss (136), a number of studies suggest that this is not the case. In particular, multiple analyses of longitudinal data from the United States have previously found that adolescents with lower body satisfaction or who use weight-control behaviours gain more weight in the long-term (137,206,207). These highlight a need for a holistic approach to childhood obesity policies to ensure that strategies aimed at reducing weight do not contribute to weight stigma and negative body image.

The positive association between muscularity trajectories and body image concerns is discordant with known desires for leanness in boys. Few studies have looked at the association of other body composition measures with body image concerns. Gualdi-Russo and colleagues explored stature, waist circumference, body fat percentage and fat-free mass as predictors of body image concerns in Italian university students (208). Consistent with the current study, they found that both higher body fat percentage and higher fat-free mass were associated with lower body satisfaction. Similarly, in ALSPAC participants, genetic variants associated with fat-free mass index were associated with increased body image concerns in adolescence (209). This provides some support for these findings, although it appears to be at odds with theories of societal body ideals which favour lean muscularity in men.

This could be explained by the measure of muscularity used in both this study and those mentioned above. All measure fat-free mass, as a proxy for muscularity. This includes all mass not estimated to be fat and therefore captures not only lean mass but bone and skeletal mass. Previous evidence suggests, that with increased adiposity, there are adaptive increases in lean mass (192,193). Therefore, FFMI as a measure of muscularity may still be capturing higher levels of adiposity to some extent and thus may hinder accurate measurement of the association between muscularity and body image concerns. Alternatively, it may be that muscularity concerns may not have as great an impact on body image as was hypothesised. This explanation is supported by a longitudinal study by Carlson Jones and colleagues, who found that although both weight concerns and muscularity concerns are associated with body dissatisfaction in adolescent boys, concern with weight loss had a greater effect on body dissatisfaction than did muscularity concerns (210).

Beyond the evidence for sex differences in the association between muscularity trajectories and body satisfaction, there was little evidence of associations varying by sex. Previous cross-sectional studies have suggested that the association between BMI and body satisfaction is linear in girls and U-shaped in boys (130,195). However, in this thesis categories of BMI trajectories were used and did not find an underweight trajectory, which is consistent with much of the existing literature (160,163,165,168,211). Additionally, although Kelly and colleagues found four BMI trajectories in Millennium Cohort Study data up to age 11, which included a decreasing trajectory group, they did not find differences in body satisfaction score between the decreasing and low trajectory groups at age 11, although there may not have been sufficient statistical power to detect differences as the decreasing group was 0.6% of the sample (81). This could also be because decreasing and low trajectories were converging by age 11; This potentially highlights that using such data-driven approaches to handle longitudinal BMI data may preclude replication of previously suggested sex differences in body image concerns. These sex differences have been seen at lower BMI values; however, modelling of distinct trajectories of BMI development in childhood tends not to observe a distinct group of children with underweight BMI values from those with healthy BMI values. The summarising of longitudinal BMI data into these latent classes may therefore mask differences at lower BMI values.

It was also initially hypothesised that the greatest magnitude of association would be seen in girls relative to boys when using adiposity trajectories. This was not borne out in results, perhaps due to high levels of body image concerns regardless of weight status in girls. In addition to the lack of sex differences, it was surprising that across both body satisfaction and exercise and dieting for weight loss, results for BMI and adiposity trajectories were highly similar. As BMI is unable to distinguish between fat and lean mass (72), it was expected that more accurately measuring adiposity levels would result in a different magnitude of association with body image concerns compared to BMI. Additionally, as girls have higher proportions of adiposity compared to boys (69), it was considered that the differences would be starker in girls. There are several potential explanations for why this was not borne out in the results. Firstly, the social stigma of obesity is likely to affect both girls and boys. Studies have shown that pre-school aged children show anti-fat bias (106,212), regardless of their gender or body size, and that the social stigma of obesity appears to be increasing in tandem with rising obesity levels (213). For both girls and boys, societal body ideals are framed around low levels of adiposity.

Secondly, evidence suggests that the validity of BMI as a proxy for adiposity is related to the level of adiposity (214). That is, at higher levels of adiposity, BMI is more highly correlated with adiposity level, as a greater proportion of total body weight is fat mass (72). This makes plausible why similar associations were seen across any measure of body composition trajectory in girls, as these measures are all, to some extent, capturing adiposity – given the potentially limited specificity of FFMI discussed above and the known higher proportions of adiposity in girls. The similarities of BMI and adiposity are supported by a study of the association of adiposity and body satisfaction. Zaccagni and colleagues used body fat percentage to classify Italian university students into underfat, normal fat, overfat and very overfat statuses (215). They found that body satisfaction decreased in girls with higher fat statuses, whereas in boys, both those with underfat and very overfat statuses reported lower body satisfaction. These results mirror those seen when using BMI, such as reported by Austin and colleagues (130), suggesting that there may not be differences between BMI and adiposity in their associations with body image concerns, particularly at a population level.

6.4.3 Limitations

Some limitations should be noted. Firstly, using trajectories of body composition measures, thereby deriving categorical variables from repeated continuous measurements of body composition data, may have resulted in reduced statistical power in regression modelling. This may limit the ability to detect associations or to detect exposure*sex interactions. This is particularly relevant as body composition trajectories appear to be stable and track in parallel with one another. Future research should investigate the associations with adolescent body image of adiposity and muscularity measurements at one time. This would allow for investigation of non-linear associations, as well as adjustment for FMI in FFMI models. This would be pertinent given that there are adaptive increases in fat-free mass at higher levels of adiposity. As body composition trajectories were used in this study, it was not possible to appropriately account for this correlation in analyses, and therefore caution should be used when interpreting results for muscularity trajectories, as higher trajectories of FFMI could occur due to cohort members having elevated adiposity levels. In addition, body composition was measured using bioelectrical impedance analysis, which cannot distinguish the contributions of bone and lean mass to fat-free mass, which has previously been discussed in detail in **5.4.3 Limitations** in the previous chapter. Previous research has suggested that bioelectrical impedance analysis and dual x-ray absorptiometry scans provide similar estimates of body composition at the population level (190,191). Nonetheless, it should be acknowledged that FFMI is used as a proxy measure of muscularity in this study, as specific estimation of lean mass was not performed in the Millennium Cohort Study.

As exercise and dieting for weight loss at age 14 years are investigated as lifetime behaviours, disentangling the temporal nature of their association with BMI is challenging, as these behaviours might alter weight and, as such, could affect body composition (i.e. the exposure under investigation). Existing studies have shown that high proportions of children as young eight years of age have dieted for weight loss (216), and children as young as five are able to define dieting as restrictive behaviours and trying to lose weight (217). The trajectories modelled collect data from age 3 for BMI and from age 7 for adiposity and muscularity, which suggests that some of the anthropometric data collected could have been affected by contemporaneous attempts to alter weight. However, a previous study in ALSPAC using genetic variants associated with body composition supports an association with body image concerns including dieting and exercise for weight loss in adolescence (209). However, the study used genetic variants associated with adult body composition and may therefore be prone to reverse causation. Nevertheless, the findings for weight control behaviours in the current study should be interpreted with some caution, due to the potential for lifetime weight control behaviours to affect body composition trajectory.

Longitudinal studies are prone to attrition bias, as those with worse health are often more likely to discontinue their involvement with the study over time (218). In addition, there was a high proportion of missing data on body image outcomes at age 17. This was due to the fact that body image questions were asked in a separate web-based questionnaire that followed on from the main age 17 questionnaire. Analysis suggested that participants with missing outcome data at 17 were disproportionately those from socioeconomically disadvantaged backgrounds. This could have resulted in biased results; however, the issue has been mitigated through imputation of missing data. The decision to restrict the analytic sample to those with BMI and other body composition trajectories – the latter not being collected until the sweep at age 7 – could have also increased the risk of biased estimates. This was assessed in a sensitivity analysis, which suggested that the association between BMI trajectory and body image concerns in the full sample with available BMI trajectories did not differ to those in the restricted sample.

Additionally, due to the stratified sampling methods used in the Millennium Cohort Study, the analyses include sampling weights, meaning it was not possible to incorporate into the analysis potential errors in assignment to trajectory groups.

However, as discussed in the previous chapter (**5.4.3 Limitations**), high Entropy indices were reported for all body composition trajectories, suggesting that the risk of error in group assignment is low.

Another potential limitation of this study is that many interaction tests that were performed, which may increase the risk of Type I errors. In the main analyses, a total of 40 interaction tests were conducted. This was fewer than planned as multinomial logistic regression models for weight perceptions and intentions were not run. Based on an alpha of 0.05, it was anticipated that two significant interaction results would be found due to chance alone. A more formal approach would have been to apply adjustments for multiple testing, however as sex differences were expected as part of a priori hypotheses and not part of exploratory analyses, a less formal approach was used, which has been previously demonstrated in prior literature (199,200). Nevertheless, evidence relating to sex differences should be interpreted with caution, both due to the risk of Type I errors and due to the potential reduced statistical power using trajectories, as discussed above.

Finally, as the study used observational data, there may be unmeasured confounding of the results. A number of child and family factors were included as confounders, but it was not possible to account for genetic predisposition to mental health concerns, including body dissatisfaction and disordered eating behaviours. To mitigate this, parent psychological distress levels, measured when the cohort member was aged 3 years, were controlled for. These data were dichotomised to avoid either restricting the sample to children from two-parent households, which would severely limit the generalisability of findings, or disregard paternal mental health altogether. However, the decision to dichotomise these data may have reduced the ability in statistical modelling to account for potential confounding by parental mental health. As such, there may be residual confounding of the estimated associations and results should not be interpreted as causal.

6.4.4 Interim conclusions

These findings support an association between childhood weight trajectory and adolescent body image concerns. There was some evidence that a proxy measure of muscularity is differentially associated with body image concerns in boys, although this could still be representing higher adiposity to some extent due to limitations with the measurement of muscularity. Associations between adiposity measures and body image concerns were similar in girls and boys, potentially reflecting the impact of societal weight stigma on all young people. These findings are important in the context of rising BMIs in the UK, as weight and body image concerns have been shown to be associated with depressive symptoms and other poor mental health outcomes. The potential implications of the associations between weight and body image for adolescent depressive symptoms will be explored in the next chapter.

7 Investigating the Mediating Role of Body Satisfaction in the Association of Childhood Body Composition Trajectory and Adolescent Depressive Symptoms

7.1 Introduction

The previous chapter showed that childhood body composition trajectories are longitudinally associated with adolescent body image concerns. This has important potential policy implications, as higher weight and body image concerns have both been linked to poor mental health in young people (81,132). These are likely to be bidirectionally associated across the lifecourse, but research in young people has focused on the pathway from weight to depressive symptoms and the possible mediating role of body image concerns (134,219,220). This is underpinned by the theory of weight stigma in societies such as the UK (221), and such environmental mechanisms linking the two have been supported by a recent genetically informed study in young people (92). This study, which analysed data from children and their parents in Norway (MoBa data, N=40,949), suggested that previous genetic studies of unrelated individuals had overestimated the association between BMI and depression in young people. This suggests that shared environmental factors, rather than shared genetics, may explain the association between weight and depression.

One plausible environmental factor is weight stigma and body image concerns, of which body satisfaction can be considered a marker. Body satisfaction as a mediating pathway in the association between weight and depressive symptoms in young people has received significant research attention over recent decades. Much of the research into young people is cross-sectional in nature (152–154,222–225), and most (152–154,223–225), but not all (222), of these give support to the hypothesis of mediation. Many find evidence of differing associations in girls and boys, but these differences are not consistently observed (152,154,224,225). However, this evidence is weakened by limited adjustment for factors that may confound this association.

There are few longitudinal studies exploring the mediating role of body satisfaction in samples of young people (219,220). Two recent analyses of different British cohorts have found conflicting results in relation to depressive symptoms at age 14. The first analysed data from children born in 1991 in ALSPAC (N=8,915) and found no evidence for mediation (220). Another used data from Millennium Cohort Study children born a decade later (N=13,135) and found strong evidence for mediation, particularly in girls (151). Their different results may be attributable to different methodological approaches, as the former modelled both depressive symptoms and disordered eating as joint outcomes in a single structural equation model, which may mask associations with depressive symptoms due to its cross-sectional association with disordered eating. However, the discordant results may also be explained by cohort effects, with associations potentially increasing in strength over time due to wider social changes, such as the rise of social media, and increases in the prevalence of both overweight and mental health problems in youth.

Importantly, both studies focussed on pre-adolescent measures of BMI and body satisfaction, with depressive symptoms measured at age 14. As the prevalence of depression increases with age (24), it may be that the associations between weight, body satisfaction and depressive symptoms may change with age. This may be particularly true for boys, for whom depression is rare at age 14. Therefore, it is pertinent to examine these pathways later in adolescence when the majority of girls and boys have commenced the pubertal transition. Indeed, this is supported by a study examining clinically relevant depressive symptoms at age 17 (134). This analysis of Millennium Cohort Study children found evidence in support of these pathways in both girls and boys. However, it is necessary to investigate pathways to depressive symptoms on a subclinical level at age 17. Furthermore, the above studies all measure child weight using BMI at one time point, but it is important to consider the lifecourse development of child weight using trajectories. Additionally, in the previous chapter (**Chapter 6**), there was some evidence that the association between childhood adiposity trajectory and body satisfaction at age 14 may be greater in magnitude using adiposity compared to BMI (although these differences were small), and this may also be observed, perhaps to a greater extent, in associations with depressive symptoms in later adolescence.

Therefore, this study aimed to investigate the extent to which body satisfaction mediates the association of childhood BMI and adiposity trajectory with depressive symptoms later in adolescence. Trajectories of FFMI, a proxy measure of muscularity, were not included in this study, given the limitations of FFMI as a proxy for muscularity that were discussed in **6.4.3 Limitations**, and because this study was focused on the societal stigma attached to excess weight. The following hypotheses were tested:

> ***Hypothesis 5:*** *Higher trajectories of BMI and adiposity are associated with higher depressive symptoms in adolescence, with a greater magnitude of association with adiposity-specific trajectories.*
>
> ***Hypothesis 6:*** *Higher body satisfaction is associated with lower depressive symptoms at a later age.*
>
> ***Hypothesis 7:*** *Body satisfaction partially mediates the association between childhood body composition trajectory and adolescent depressive symptoms.*
>
> ***Hypothesis 8:*** *The proportion of the association mediated by body satisfaction is greater for adiposity trajectory than for BMI trajectory.*

7.2 Methods

7.2.1 Sample

Millennium Cohort Study participants with valid BMI and body composition trajectories were included in this analysis (as described in **4.5.1**). Those who had been assigned to a BMI trajectory group but not an adiposity trajectory (due to attrition prior to the sweep at 7 years) were excluded to allow comparison of associations in the same samples. This excluded 1,650 cohort members from the analysis, leaving 13,025 with valid exposure data. Missing data on outcome, mediator, and confounding variables was imputed using multiple imputation by chained equations (described further in **7.2.6 Analysis**).

7.2.2 Depressive symptoms

The outcome was depressive symptom score measured when cohort members were approximately 17 years old. Cohort members completed the Kessler K6 scale, a well-validated six item scale measuring non-specific psychological distress (179). The scale captures the frequency of symptoms such as feeling depressed or hopeless during the last 30 days, which are rated on a five-point Likert scale (0= “None of the time”, to 4= “All of the time”). Scores for all items are summed to create a total score with a range 0 to 24, where higher scores indicate greater psychological distress. The scale has previously been demonstrated as a valid and accurate screening tool for serious mental illness in population-based health surveys (226,227).

7.2.3 Body satisfaction

The proposed mediator was body satisfaction, measured at age 14. Cohort members answered the question “On a scale of 1 to 7, where 1 means completely happy and 7 means not at all happy, how do you feel about the way you look?” This scale was reverse scored so that higher scores indicated greater body satisfaction (as described in **4.5.2**). This measure of body image concerns was used over other available measures at age 14 as it is an assessment of overall self-evaluation. Additionally, as measures of dieting and exercise for weight loss covered lifetime behaviours at age 14, there were concerns that these could have affected the exposure, body composition trajectory, if used. Other available measures outlined in **4.5.2**, including weight perceptions, were not considered due to their high correlations with body composition trajectories.

7.2.4 Body composition trajectory

The exposures were childhood trajectories of BMI and adiposity up to age 14, modelled using latent class growth analysis. These have previously been described in **5.2.2**. Adiposity was measured as the ratio of fat mass to fat-free mass (FM/FFM), which captures the relative proportion of fat mass, or the amount of fat mass adjusting for the proportion of fat-free mass. This was considered advantageous over FMI as it compares levels of fat and fat-free mass and removes the need to account for correlations with height, as previous research has suggested that current indexing to account for height (i.e., height squared) may be insufficient (228). For both of the exposures, there were three trajectories - a stable, low trajectory, a moderate trajectory and a high trajectory of body composition development. Due to the limitations of the measurement of muscularity, discussed in **6.4.3 Limitations**, namely that it is not possible to determine whether high FFMI levels indicate increased lean muscularity or an adaptive response to raised adiposity levels, this study focuses only on BMI and a specific measure of adiposity.

7.2.5 Confounders

Common to all models

The following variables were identified as associated with the exposure, mediator, and outcome, based on existing evidence.

Sociodemographic factors

These were cohort member's sex assigned at birth and ethnic group, both reported by parents at 9 months of age. These were selected as confounders based on previous research (163,229). In addition, age at outcome assessment was included to increase precision of estimates, due to variability in age at each data collection sweep.

Pubertal status was not included as a confounder in these associations, as it was considered to potentially influence the exposure due to the use of trajectories up to age 14. Furthermore, in the previous chapter, additional adjustment for pubertal status did not alter estimates (**6.3.5 Sensitivity analyses**).

Measures of family socioeconomic position were household income, parents' highest educational qualification, and parent occupational class. Household income was OECD-equivalised to account for household size and then categorised into quintiles. Parents' highest educational qualification was measured according to NVQ Level equivalents (None to Level 5, as previous described in **5.2.5**). Parent occupational class was assessed according to the National Statistics Socio-economic Classification and categorised as the five-class version. For two-parent households, the highest parent education and occupation of available data was used in analyses. Existing evidence has shown socioeconomic differences in weight development and mental ill-health (163,229).

Perinatal factors

These were the cohort member's natural mother's pre-pregnancy BMI, cohort member's birthweight, maternal smoking and alcohol consumption during pregnancy, and whether the cohort member was breastfed. These were all self-reported by parents at 9 months of age. Smoking, alcohol, and breastfeeding were all dichotomised as any versus none. Maternal pre-pregnancy BMI and cohort member birthweight were handled as continuous variables in analyses, although for descriptive purposes categorical variables were derived using World Health Organisation thresholds for adult BMI and for low birthweight. These were considered as confounders in other mediation analyses of these associations (219).

Parental mental health

Maternal and paternal psychological distress levels were measured using the Kessler K6 scale when the child was 3 years old. Responses to the six items were summed to give a score ranging 0 to 24 and were dichotomised to identify families where any parent has Kessler scores indicating moderate or severe psychological distress (a score of 5 or above) (181). This decision was taken to avoid excluding single-parent households from analysis or imputing paternal psychological distress scores when the father may be absent from the cohort member's life. Previous evidence supports an association between parent mental health, child weight and mental wellbeing (180,230).

Model-specific confounders

In addition to the confounders discussed above, a number of model-specific confounders were considered as outlined below. A simplified conceptual diagram is depicted in **Figure 7-1**.

BMI/adiposity trajectory – depressive symptoms

In the association between BMI/adiposity trajectory and depressive symptoms at 17 years, models additionally adjusted for the cohort member's baseline mental health, to reduce the risk of reverse causation. This was reported by parents using the Strengths and Difficulties Questionnaire (SDQ) when the cohort member was 3 years old. The SDQ is a well-validated 20-question scale that captures internalising (emotional symptoms and peer problems) and externalising (conduct, hyperactivity, inattention) problems on a three-point Likert scale (0= Not true, to 2= Certainly true) (231). Scores for all items were summed to give a total score of difficulties ranging from 0 to 40, with higher scores indicating greater mental health difficulties. For descriptive purposes only, a binary variable was created to indicate whether the SDQ score was above existing thresholds for high internalising or externalising problems (a score ≥17) (231).

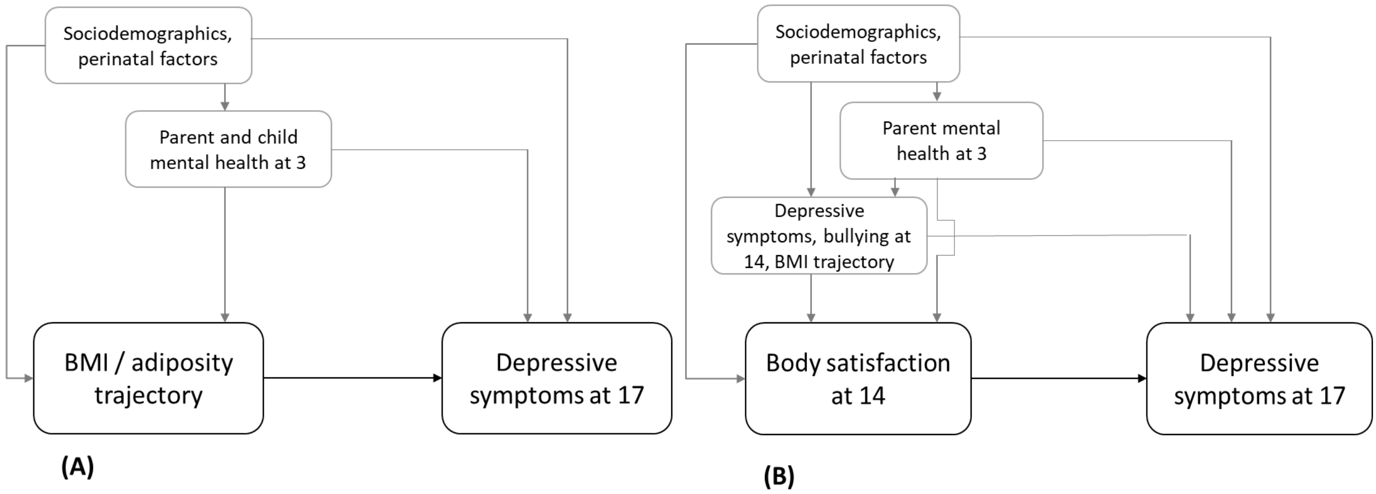

Figure 7-1. Simple conceptual diagram of confounding variables of the association between (A) exposure and outcome, and (B) mediator and outcome in regression modelling.

Body satisfaction – depressive symptoms

To account for baseline depressive symptoms when investigating the association between body satisfaction at 14 years and depressive symptoms at 17 years, models additionally adjusted for the cohort member's depressive symptoms at age 14. This was reported by cohort members themselves at age 14 years using the short Moods and Feelings Questionnaire (sMFQ) (232). This well-validated 13-item questionnaire measures depressive symptoms in the previous two weeks, including feeling miserable or unhappy and not enjoying anything. Items are rated on a three-point Likert scale (0= Not true, to 2= True), with responses summed to give a total score (range 0-26) where higher scores indicate greater depressive symptoms. For descriptive purposes only, scores were dichotomised according to validated cut offs indicating clinically relevant depressive symptoms (233).

In addition, it was hypothesised that the association between body satisfaction and depressive symptoms could be confounded by the cohort member's experiences of bullying victimisation (234,235). At age 14 years, cohort members were asked "How often do other children hurt you or pick on you on purpose?" and "How often have other children sent you unwanted or nasty emails, texts or messages, or posted something nasty about you on a website?", which are henceforth referred to as peer bullying and cyber bullying, respectively. For both, responses were dichotomised into

Any or None, under the hypothesis that any experience of bullying, regardless of frequency, may be detrimental to mental health.

These models also additionally adjusted for BMI trajectory group. This assumes that BMI precedes body satisfaction temporally, despite the final timepoint of the trajectory occurring at the same age that body satisfaction is measured. The trajectories are derived using at least two time points which precede the measurement of body satisfaction and reflect weight trajectories from age 3 (for BMI), providing support to this assumption. Studies using genetic variants associated with body composition provide further evidence of this (209).

7.2.6 Analysis

Missing data

Among participants with complete exposure data, frequencies and proportions of missing outcome, mediator, and confounder data among participants with available exposure data were explored descriptively. For those with complete exposure data, the proportions with complete and missing outcome data at age 17 were explored to investigate whether those with missing outcome data were similar to those with valid data. Missing data on outcome, mediator, and confounders was imputed using multiple imputation (MICE) assuming that data are missing at random. Fifty datasets were imputed using all analysis variables and additional auxiliary variables to improve precision. These were measures of child mental health (SDQ scores) and raw BMI scores from ages 3 to 17 years and body satisfaction at age 11. Characteristics of imputed and non-imputed samples of participants with valid exposure data were compared using proportions.

Regression analysis

The associations between exposure–outcome and mediator–outcome were explored using univariable and multivariable linear regressions (the association between exposure–mediator having been explored in the previous chapter). The impact of different blocks of confounding variables on the estimates was assessed before fully adjusted models were run, as detailed in **Table 7-1**. The fully adjusted model was then run again including an interaction term between the exposure and sex assigned at

Table 7-1. Specification of confounders in regression modelling.

<table>
<tr><th>Model</th><th colspan="2">Confounders</th></tr>
<tr><td>0</td><td colspan="2">Unadjusted</td></tr>
<tr><td>1</td><td colspan="2">Model 0 + sociodemographic factors
(cohort member sex, age at interview, and ethnicity; family socioeconomic position)</td></tr>
<tr><td>2</td><td colspan="2">Model 0 + perinatal factors
(Maternal pre-pregnancy BMI, cigarette and alcohol consumption, breastfeeding; cohort member birthweight)</td></tr>
<tr><td>3</td><td colspan="2">Model 0 + mental health
(Parent psychological distress; cohort member baseline mental health*)</td></tr>
<tr><td rowspan="2">4</td><td>BMI – depressive symptoms</td><td>Body satisfaction – depressive symptoms</td></tr>
<tr><td>Model 0 + all confounders in 1-3</td><td>Model 0 + bullying victimization and BMI trajectory</td></tr>
<tr><td>5</td><td>-</td><td>Model 0 + all confounders in 1-4</td></tr>
</table>

*In BMI–depressive symptoms, this is cohort member mental health at age 3; in body satisfaction–depressive symptoms, this is mental health at age 14.

birth, to assess whether the associations differ in boys and girls. A p value for the interaction term of around or less than 0.05 was considered evidence for interaction with sex. Sampling weights were applied to account for the stratified sampling methods employed in the Millennium Cohort Study.

Counterfactual mediation analysis

<u>Counterfactuals and potential outcomes</u>

In longitudinal observational data, the exposure status and subsequent outcome of an individual can be measured, and their association modelled at a population level. It would not be possible to observe in the same individual what their outcome would have been had their exposure status been different, for example. This would be counter to the fact.

Counterfactuals allow for the estimation of potential outcomes in observational data. The potential outcomes in this example are the potential depressive symptom scores (Y) if exposure (X) and the mediator (M) were set, possibly contrary to fact, to certain levels. These are best exemplified if X, M, and Y are all assumed to be dichotomous, which would give four potential outcomes of Y (236). These can be written as Y(X,M) – that is, Y at values of X and M. These four potential outcomes would therefore be Y(0,0), the potential depressive symptoms when X is set to 0 and M is set to the level it would take under X=0; Y(0,1), where X is set to 0 but M is set to the level it would take under X=1; Y(1,0) where X is set to 1 and M set to the level it would take under X=0; and Y(1,1) where X is set to 1 and M is set to the level it would take under X=1. Two of these outcomes, Y(0,1) and Y(1,0), could not ever be observed in real world data.

This example is complicated by the exposure in this study being a categorical variable (e.g., BMI trajectory: low, moderate, high) and the mediator being a continuous score (body satisfaction). Therefore, the equations described below are performed comparing each of the moderate and high trajectory group to the low trajectory group (the baseline level of X) and where the value for M to take is the natural level of body satisfaction that would be observed for a specified trajectory group (236). For brevity, the equations below are interpreted comparing the high BMI group to the low group, although they apply to the moderate vs low group and to adiposity trajectories in the same way.

Total causal effect

First, it is necessary to estimate the total causal effect (TCE) – that is the total effect of the exposure on the outcome, including that which may be transferred indirectly. This is calculated as:

$$TCE = \mathbb{E}[Y_{1,M1}] - \mathbb{E}[Y_{0,M0}]$$

This represents a comparison of the expectation at the population level ($\mathbb{E}$) of potential depressive symptoms (Y) in two hypothetical worlds. In the first, $Y_{1,M1}$ represents the potential depressive symptoms for those with a high BMI trajectory (X=1) and with the body satisfaction score of those with a high BMI trajectory (M when X=1). In the second, $Y_{0,M0}$ is the potential depressive symptoms for those with a low BMI trajectory (X=0) and with the body satisfaction score of those with a low BMI trajectory (M when X=0). Therefore, the TCE is simply the difference in expected mean depressive symptoms for those with a high BMI compared to those with a low BMI trajectory.

Decomposition of direct and indirect effects

The value of counterfactual mediation analysis lies in its ability to decompose the TCE into the effect the exposure has directly on the outcome (depicted as path a in **Figure 7-2**) and that which is passed indirectly via a mediating pathway (depicted as path b).

To estimate the direct effect, two hypothetical worlds are again compared. This time the worlds have different levels of the exposure but, in both, the value of the mediator is set to the natural value it would take under the baseline level of exposure (X=0). As it uses the natural level for the mediator, this is considered the natural direct effect (NDE), and is calculated as:

$$NDE = \mathbb{E}[Y_{1,M0}] - \mathbb{E}[Y_{0,M0}]$$

In this equation, $Y_{1,M0}$ represents the potential depressive symptoms for those with a high BMI trajectory, but with the body satisfaction score of those with a low BMI trajectory. $Y_{0,M0}$ is the potential depressive symptoms for those with a low BMI trajectory and with the body satisfaction score of those with a low BMI trajectory. Thus, overall, this is the difference in mean depressive symptoms between the high and low BMI trajectory groups, but where in both scenarios the value of the mediator is the same. As only the level of the exposure varies, this estimates the direct effect of X on Y.

Estimating the indirect effect, two hypothetical worlds are compared with different levels of body satisfaction but where body composition trajectory is set to the same non-baseline level (X=1). Again, as it uses the natural levels of body satisfaction scores for different exposure levels, this is the natural indirect effect (NIE), and is calculated as:

$$NIE = \mathbb{E}[Y_{1,M1}] - \mathbb{E}[Y_{1,M0}]$$

In the first, $Y_{1,M1}$ represents the potential depressive symptoms in those with high BMI trajectories and the natural level of body satisfaction score of those with high BMI trajectories. In the second, $Y_{1,M0}$, is the potential depressive symptoms in those with high BMI trajectories but the natural level of body satisfaction of those with a low BMI trajectory. Therefore, overall, this is the difference in mean depressive symptoms that follow from the body satisfaction scores seen in those with high versus low BMI

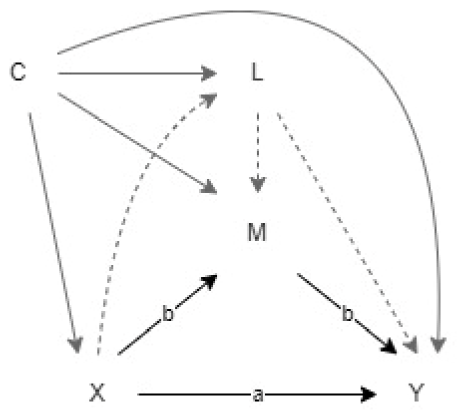

Figure 7-2. Simplified mediation diagram showing the direct effect of the exposure (X) on the outcome (Y), denoted as path a, and the indirect effect via a mediator (M), denoted as path b. Both effects account for baseline confounders (C), with potentially biasing biasing pathways shown by full grey arrows, and intermediate confounders (L), with potentially biasing pathways shown by dashed grey arrows.

trajectories, but when both worlds have high BMI trajectory groups. As the exposure is fixed but the mediator is allowed to vary, this estimates the indirect effect of X on Y.

<u>Proportion mediated</u>

Of additional value is the ability to quantify the proportion of the total effect of BMI on depressive symptoms that is transmitted via an effect on body satisfaction. This is termed the proportion mediated and is calculated as the NIE divided by the TCE. This is estimated separately for each non-baseline level of BMI trajectory and is interpreted as a percentage of the total effect.

<u>Model specification</u>

All continuous variables were mean-centred to prevent issues of multicollinearity (237). Mediation analyses were performed using the *gformula* command in Stata (236). Separate models were run looking at the effects of BMI and of adiposity trajectory on depressive symptoms. Models conditioned on baseline confounders, measured at or before age 3 (denoted as *C* in **Figure 7-2.** Simplified mediation diagram showing the direct effect of the exposure (X) on the outcome (Y), denoted as path a, and the indirect effect via a mediator (M), denoted as path b. Both effects account for baseline confounders (C), with potentially biasing biasing pathways shown by full grey arrows, and intermediate confounders (L), with potentially biasing pathways shown by dashed grey arrows.), and intermediate confounders, which are hypothesized to confound the mediator–outcome association and could be caused by the exposure (*L* in **Figure 7-2**). Baseline confounders were described in detail in **7.2.5 Confounders**; these were sociodemographic and perinatal factors and baseline parent and child mental health measured at age 3 years. Intermediate confounders were peer and cyber bullying and child depressive symptoms at 14 years. These could be alternative pathways by which higher BMI may cause higher depressive symptoms, such that omitting these could bias the estimation of the indirect effect via body satisfaction.

The *gformula* command is able to handle missing data on any variable using single stochastic imputation using chained equations (236). All models were performed in Stata using 100 imputation cycles, 1000 bootstrap samples and 20,000 Monte Carlo simulations. As with regression analyses, analyses were performed on a sample with valid exposure data. The code used to execute the mediation analysis is reported in

Appendix for Chapter 7, Table 1.

Assumptions

Natural direct and indirect effects can be estimated under several technical assumptions (236). First, it is assumed that no individual's exposure status affects another individual's outcome or mediator. It is also assumed that there is no interaction between the exposure and mediator. Finally, it is assumed that there is no unmeasured confounding of the associations between exposure–outcome, exposure–mediator, or mediator–outcome. The assumed causal associations are depicted in a simplified directed acyclic graph in **Figure 7-3**.

Sensitivity analysis

All regression and mediation models were repeated on a sample of participants with complete data on all variables of interest to test the impact of missing data. Although the sample was restricted to those with both BMI and body composition trajectories (thereby excluding 1,650 participants), which could have introduced bias, this was not investigated further as it was demonstrated in the previous chapter that this did not alter results (see **6.3.5 Sensitivity analyses**).

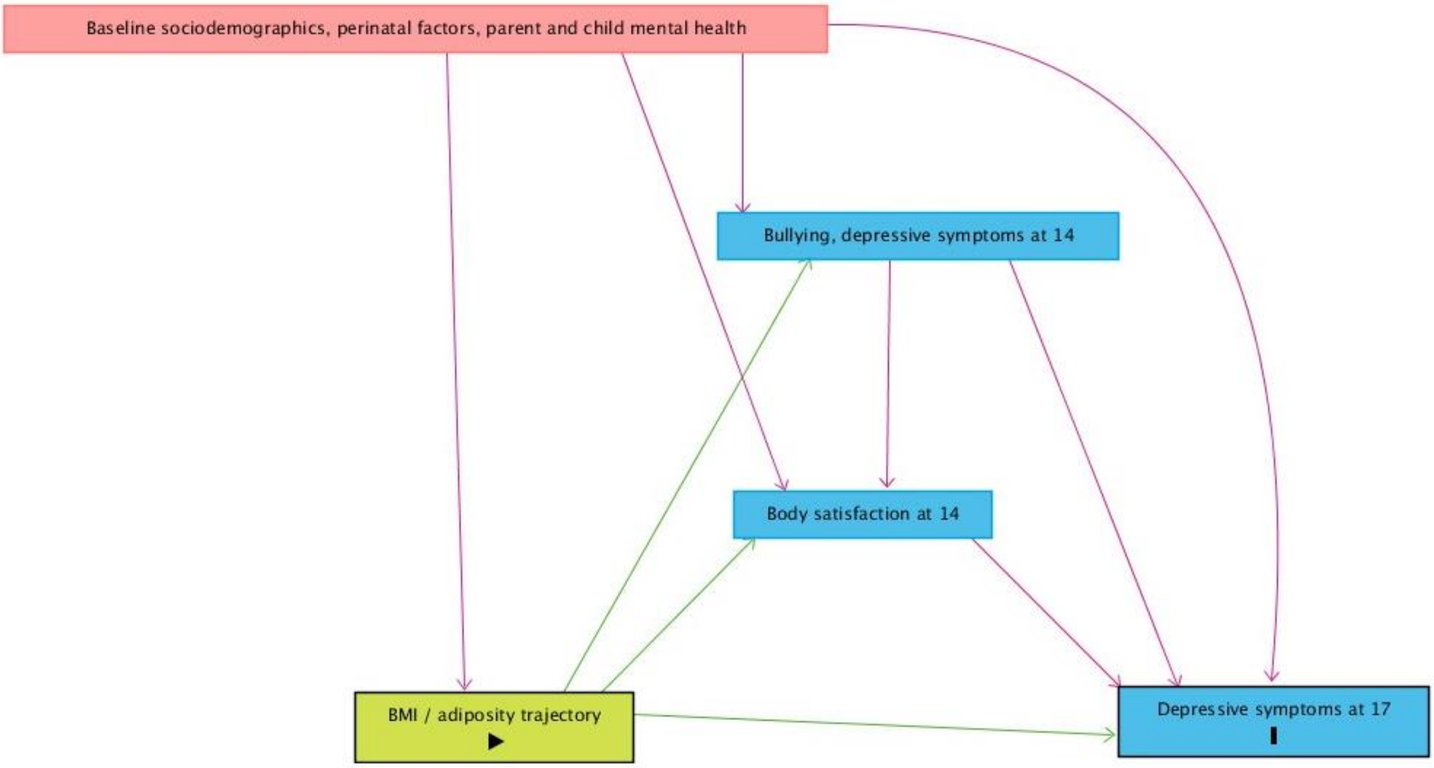

Figure 7-3. Simplified directed acyclic graph of associations modelled in mediation analysis.

It was considered that the use of trajectories, handled as a categorical variable, could have lower explanatory power than BMI or adiposity measured at a single time point and handled as a continuous variable. This was investigated by running the linear regression model for the association between BMI and depressive symptoms adjusting for all baseline confounding variables, described as Model 4 in **Table 7-1.** Specification of confounders in regression modelling.using BMI measured at age 11 as a continuous variable (prior to the measurement of body satisfaction). Estimated coefficients and R-squared values, which measure the amount of variation in the outcome that is explained by all explanatory variables, were compared to results using BMI trajectory in the main analysis.

7.3 Results

7.3.1 Sample

Of the total 18,540 cohort members (taking one cohort member at random in cases of multiple births as outlined in **4.3 Sample**), 14,675 had valid data on BMI trajectory (79.2% of total) and, of these, 13,025 (70.3% of total) cohort members also had valid data on adiposity trajectory. Characteristics of the sample are detailed in **Table 7-2**. Approximately half of cohort members were male (50.8%), the majority were White (84.4%) and a plurality had parents who were educated to degree level or higher (35.3%) and worked in a professional occupation (38.9%). The majority of cohort members did not have any parent(s) with elevated levels of psychological distress (65.5%) and did not themselves have elevated SDQ scores at age 3 (89.5%).

Approximately half reported being bullied by their peers (48.9%) and 29.0% had reported being bullied online. At age 14, 13.2% of cohort members had high depressive symptoms as indicated by sMFQ scores ≥12. A greater proportion of cohort members who were assigned female at birth or were from minority ethnic or socioeconomically disadvantaged groups had high BMI trajectories. More cohort members with at least one parent with elevated psychological distress levels and clinically relevant child SDQ scores had high BMI trajectories, although these differences were small. There appeared to be no differences in BMI trajectory membership according to peer or cyber bullying status. A greater proportion of cohort members with elevated sMFQ scores at age 14 had high trajectories of BMI across childhood.

7.3.2 Missing data

Among those with complete data on BMI and adiposity trajectories, missing data on confounders was minimal (see **Appendix for Chapter 7, Table 2**), with the exception of maternal pre-pregnancy BMI (8.2% missing), parent and child mental health at 3 (6.7 and 6.8% missing, respectively), peer and cyber bullying at 14 (24.0% missing), and depressive symptoms at 14 (24.9% missing). Furthermore, among those with complete data on BMI and adiposity trajectories, 24.2% were missing body satisfaction data and 32.7% were missing depressive symptoms at age 17.

Table 7-2. Sample characteristics by BMI trajectory membership. Sample with valid exposure data.

Characteristic	N	%	BMI Trajectory Low	Moderate	High
N			8375 (64.3)	3783 (29.0)	867 (6.7)
Cohort member sex at birth					
Male	6612	50.8	67.6	26.5	5.9
Female	6413	49.2	60.9	31.6	7.4
Cohort member ethnicity					
White	10968	84.4	64.6	29.2	6.2
Mixed	346	2.7	65.6	25.4	9.0
Indian	312	2.4	68.6	26.0	5.4
Pakistani or Bangladeshi	828	6.4	62.2	27.9	9.9
Black or Black British	383	3.0	52.0	36.0	12.0
Other, including Chinese or Arab	160	1.2	70.0	23.1	6.9
Family income at 9 months					
Most disadvantaged	2804	21.6	60.4	30.3	9.3
Second	2786	21.4	62.4	30.0	7.5
Third	2526	19.4	62.4	31.1	6.5
Fourth	2521	19.4	64.7	29.7	5.6
Least disadvantaged	2355	18.1	72.8	23.5	3.7
Highest parental education level at 9 months					
None	1403	10.8	60.2	29.8	10.0
NVQ Level 1 (GCSE grade D-G)	775	5.9	62.6	29.9	7.5
NVQ Level 2 (GCSE grade A*-C)	3199	24.6	60.6	31.4	8.0
NVQ Level 3 (A Level)	2151	16.5	63.6	29.2	7.2
NVQ Level 4 (One year Undergraduate)	4593	35.3	67.2	27.9	4.9
NVQ Level 5 (Two years Undergraduate)	896	6.9	72.5	23.9	3.6
Highest parental occupational class at 9 months					
Not in work	2924	22.5	60.5	30.6	8.9
Routine or semi-routine	1900	14.6	60.7	30.5	8.8
Lower supervisory or technical	1043	8.0	59.2	33.2	7.6
Small employers or self-employed	863	6.7	63.6	29.8	6.6
Intermediate occupations	1199	9.2	66.3	27.5	6.2
Managerial or professional	5050	38.9	68.5	27.1	4.4
Cohort member birthweight					
Low birthweight (≤2.5kg)	890	6.8	68.7	24.9	6.4
Birthweight >2.5kg	12106	93.2	64.0	29.3	6.7
Maternal pre-pregnancy BMI					
BMI <25	8416	70.3	71.4	24.6	4.0
BMI 25 – 29.9	2465	20.6	53.6	36.7	9.7
BMI ≥30	1083	9.1	38.2	43.1	18.7
Cohort member was breastfed					
No	3870	29.8	60.8	31.0	8.2
Yes	9135	70.2	65.8	28.2	6.0
Mother smoked in pregnancy					
No	11057	84.9	65.3	28.6	6.1
Yes	1962	15.1	58.7	31.5	9.8
Mother drank alcohol in pregnancy					
No	9020	69.4	63.0	29.8	7.3
Yes	3982	30.6	67.4	27.3	5.3
Any parent psychological distress at 3 years					
No	7965	65.5	64.8	29.1	6.2
Yes	4192	34.5	62.9	29.8	7.3

Characteristic	N	%	BMI Trajectory		
			Low	Moderate	High
Cohort member SDQ Score at 3 years[a]					
Average / Slightly raised (<17)	10870	89.5	64.4	29.2	6.4
High / Very High (≥17)	1271	10.5	62.5	28.8	8.7
Cohort member experienced bullying					
No	5061	51.2	62.9	30.8	6.3
Yes	4833	48.9	62.9	30.1	7.0
Cohort member experienced cyber bullying					
No	7026	71.0	63.3	30.2	6.5
Yes	2871	29.0	62.2	31.0	6.8
Cohort member sMFQ Score at 14 years[a]					
No depression (<12)	8267	84.5	64.3	29.7	6.0
Depression indicated (≥12)	1513	15.5	55.7	34.4	9.9

[a] Scores dichotomised for descriptive purposes only. Continuous scores used in analysis.

A greater proportion of those with complete exposures but missing outcome data were male and from socioeconomically disadvantaged backgrounds (**Appendix for Chapter 7, Table 3**). More cohort members who were missing outcome data were not breastfed, had a mother who smoked during pregnancy and reported being bullied by their peers. Those missing outcome data at 17 had higher mean SDQ scores at age 3, but there were minimal differences in depressive symptoms (sMFQ scores) or body satisfaction at age 14.

7.3.3 Is childhood weight trajectory associated with depressive symptoms at age 17?

Overall mean Kessler K6 score at 17 was 7.28 (SD 4.9, range 0 to 24). Results of linear regression modelling of the association between childhood BMI and adiposity trajectory and depressive symptoms at age 17 are shown in **Table 7-3**. Results from unadjusted models suggested strong evidence of an association between BMI trajectory and depressive symptoms. Compared to those with low BMI trajectories, cohort members with moderate trajectories had 0.41 (95% CI 0.16, 0.65) higher mean depressive symptom scores, while those with high trajectories had 0.98 (95% CI 0.41, 1.55) higher mean depressive symptom scores (**Table 7-3**). The associations were attenuated after adjustment for each block of confounders. After adjusting for all confounders, there was weak evidence for an association in those with moderate (mean difference 0.16, 95% CI -0.10, 0.41) and high trajectories (mean difference 0.54, 95% CI -0.03, 1.11), compared to those with low trajectories of BMI.

Table 7-3. Univariable and multivariable regression models estimating the association between childhood body composition trajectory and depressive symptoms. Participants with valid trajectory data and imputed outcomes and confounders (sampling weights applied).

		Depressive Symptoms at 17 years					
Whole sample N=13025	N	**Model 0 - unadjusted**	**Model 1 – 0 + sociodemographic factors**	**Model 2 – 0 + perinatal factors**	**Model 3 – 0 + mental health**	**Model 4 – fully adjusted**	**Exposure * Sex interaction**
		Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	P value
BMI Trajectory							
Low	8375	ref	ref	ref	ref	ref	ref
Moderate	3783	0.41 (0.16, 0.65)	0.24 (-0.00, 0.48)	0.34 (0.08, 0.60)	0.39 (0.14, 0.64)	0.16 (-0.10, 0.41)	0.703
High	867	0.98 (0.41, 1.55)	0.77 (0.21, 1.33)	0.76 (0.18, 1.34)	0.92 (0.35, 1.49)	0.54 (-0.03, 1.11)	0.251
Adiposity Trajectory							
Low	9306	ref	ref	ref	ref	ref	ref
Moderate	3024	0.97 (0.67, 1.24)	0.45 (0.17, 0.72)	0.91 (-0.63, 1.19)	0.95 (0.68, 1.23)	0.38 (0.09, 0.66)	0.765
High	695	1.67 (1.08, 2.27)	0.99 (0.41, 1.57)	1.52 (0.91, 2.12)	1.60 (1.00, 2.20)	0.78 (0.18, 1.38)	0.786

Model 0 – Unadjusted
Model 1 – Model 0 + sex at birth, age at interview, ethnicity, family income, parent education level, parent occupation.
Model 2 – Model 0 + maternal pre-pregnancy BMI, child birthweight, breastfeeding status, antenatal consumption of cigarettes and alcohol.
Model 3 – Model 0 + parent mental health at 3 years, child SDQ score at 3 years.

There was no evidence that the association varied by sex (moderate BMI* sex p=0.703; high BMI*sex p=0.251). When measuring trajectories of adiposity specifically, the association with depressive symptoms appeared to be stronger. In unadjusted analysis, cohort members with moderate adiposity trajectories had 0.97 higher mean depressive symptom scores (95% CI 0.67, 1.24) compared to those with low trajectories. Those with high adiposity trajectories had 1.67 higher mean depressive symptom scores (95% CI 1.08, 2.27). The magnitudes of the mean differences were attenuated after adjusting for confounders, however there remained strong evidence for an association in the fully adjusted model. Fully adjusted results suggested that compared to those with low trajectories of adiposity, those with moderate adiposity had 0.38 higher mean depressive symptom scores (95% CI 0.09, 0.66) and those with high adiposity had 0.78 higher mean depressive symptom scores (95% CI 0.18, 1.38) at age 17. As with BMI trajectory, there was no evidence that this association varied by sex (moderate adiposity*sex p=0.765; high adiposity*sex p=0.786). These results are largely consistent with the initial hypothesis that higher trajectories are associated with higher depressive symptoms, with a greater magnitude of association when using adiposity-specific trajectories (**Hypothesis 5**).

7.3.4 Is body satisfaction at age 14 associated with depressive symptoms at age 17?

Results of regression analysis also suggested strong evidence of an association between body satisfaction at age 14 and depressive symptoms at age 17 (**Table 7-4**). In unadjusted analyses, each one-point increase in body satisfaction score was associated with a greater than one-point reduction in subsequent depressive symptoms (coefficient -1.11, 95% CI -1.18, -1.04). Adjustment for sociodemographic factors, perinatal factors and BMI and bullying resulted in minor attenuation to the estimated coefficients. A large attenuation was observed when controlling for existing depressive symptoms at age 14, though the association persisted (coefficient -0.44, 95% CI -0.52, -0.36). After adjusting for all confounding variables, there remained strong evidence for an association, with each one-point increase in body satisfaction score associated with a 0.34 point reduction in depressive symptom score at age 17 (95% CI -0.42, -0.26). This was in line with initial hypotheses (**Hypothesis 6**). There was no evidence that this association varied by sex (p=0.391).

Table 7-4. Univariable and multivariable regression models estimating the association between body satisfaction and depressive symptoms. Participants with valid trajectory data and imputed outcomes and confounders (sampling weights applied).

	Depressive Symptoms at 17 years						
Whole sample N=13025	**Model 0 - unadjusted**	**Model 1 – 0 + sociodemographic factors**	**Model 2 – 0 + perinatal factors**	**Model 3 – 0 + mental health**	**Model 4 – 0 + BMI, bullying**	**Model 5 – fully adjusted**	**Exposure * Sex interaction**
	Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	P value
Body Satisfaction							
Per one unit increase in body satisfaction	-1.11 (-1.18, -1.04)	-0.98 (-1.05, -0.91)	-1.09 (-1.16, -1.02)	-0.44 (-0.52, -0.36)	-0.91 (-0.99, -0.84)	-0.34 (-0.42, -0.26)	0.391

Model 0 – Unadjusted
Model 1 – Model 0 + sex at birth, age at interview, ethnicity, family income, parent education level, parent occupation.
Model 2 – Model 0 + maternal pre-pregnancy BMI, child birthweight, breastfeeding status, antenatal consumption of cigarettes and alcohol.
Model 3 – Model 0 + parent mental health at 3 years, child MFQ score at 14 years.
Model 4 – Model 0 + BMI trajectory and bullying
Model 5 – All confounders in models 1-4

7.3.5 Does body satisfaction mediate the association between childhood weight trajectory and depressive symptoms?

As there was no evidence for sex interactions in any of the exposure–outcome, exposure–mediator, or mediator–outcome associations, mediation analyses were run on the whole sample of cohort members (**Error! Not a valid bookmark self-reference.**). Compared to those with low BMI trajectories, the total mean difference in depressive symptoms in those with moderate trajectories was 0.27 (95% CI 0.02, 0.53). This was not dissimilar to the fully adjusted estimate from regression analysis. There was weak evidence of a direct effect (0.15, 95% CI -0.10, 0.41), and strong evidence of an indirect effect (0.12, 95% CI 0.08, 0.16). The proportion of the association between moderate BMI trajectory and depressive symptoms that was explained by body satisfaction was estimated to be 45%, although there was high uncertainty in this estimate (proportion mediated 0.45, 95% CI -4.36, 5.25).

In those with high BMI trajectories, the total effect was 0.55 (95% 0.05, 1.04), meaning the mean difference in depressive symptoms in the high BMI group compared to the low group was 0.55. This was very similar to the fully adjusted estimate from regression analyses. There was weak evidence of a direct effect (0.30, 95% CI -0.20, 0.79) and strong evidence of an indirect effect via body satisfaction (0.25, 95% CI 0.16, 0.34). The proportion of the association between the high BMI trajectory and depressive symptoms that was explained by body satisfaction was 45% (95% CI -2.37, 3.27). This was consistent with initial hypotheses (**Hypothesis 7**).

When using a measure of adiposity, the total effect on depressive symptoms was increased in magnitude compared to the total effect of BMI, which was consistent with **Hypothesis 5**. In those with moderate trajectories, the total mean difference in depressive symptoms was 0.44 (95% CI 0.17, 0.71). There was strong evidence of a direct effect (0.32, 95% CI 0.05, 0.58), which was not seen using BMI trajectory. There was also strong evidence of an indirect effect, which was highly similar to that seen in the moderate BMI group (0.12, 95% CI 0.07, 0.17). The proportion of the association between moderate adiposity trajectory and depressive symptoms that was mediated by body satisfaction was 28% and there was greater certainty in this estimate compared to the moderate BMI results (95% CI -0.18,0.75).

Table 7-5. Mediation analysis. Marginal mean difference in depressive symptoms among those with moderate and high trajectories compared to those with a low trajectory of BMI and adiposity. Estimates from a sample with valid trajectories and missing data on other variables imputed (N=13,025).

Estimand	BMI	Adiposity
Moderate Trajectory		
Total Causal Effect	0.27 (0.02, 0.53)	0.44 (0.17, 0.71)
Natural Direct Effect	0.15 (-0.10, 0.41)	0.32 (0.05, 0.58)
Natural Indirect Effect	0.12 (0.08, 0.16)	0.12 (0.07, 0.17)
Proportion mediated	0.45 (-4.36, 5.25)	0.28 (-0.18, 0.75)
High Trajectory		
Total Causal Effect	0.55 (0.05, 1.04)	0.62 (0.07, 1.17)
Natural Direct Effect	0.30 (-0.20, 0.79)	0.36 (-0.17, 0.91)
Natural Indirect Effect	0.25 (0.16, 0.34)	0.25 (0.16, 0.35)
Proportion mediated	0.45 (-2.37, 3.27)	0.41 (-4.30, 5.12)

In those with high adiposity trajectories, the total effect was 0.62 (95% CI 0.07, 1.17). There was weak evidence of a direct effect (0.36, 95% CI -0.17, 0.91). As with prior results, there was strong evidence of an indirect effect via body satisfaction, which was estimated was very similar to the high BMI group (0.25, 95% CI 0.16, 0.35). The proportion of the association between high adiposity trajectory and depressive symptoms that was explained by body satisfaction was 41% (95% CI -4.30, 5.12). This was similar to the results of the high BMI trajectory and had similarly high levels of uncertainty around the estimate. Therefore, there was no evidence in support of the final hypothesis (**Hypothesis 8**) that body satisfaction would mediate a greater proportion of the association between adiposity and depressive symptoms relative to the BMI–depressive symptom association.

7.3.6 Sensitivity analysis

Regression and mediation analyses were repeated on samples with complete data on all variables of interest (**Appendix for Chapter 7, Table 4-6**). Results of the complete case analysis were highly similar to those in the main analysis.

The explanatory power of BMI trajectories compared to a single continuous measure of BMI at age 11 was also investigated in a sensitivity check. Results of the sensitivity analysis suggested that for each one-unit increase in BMI at age 11, there was a 0.04 increase in mean depressive symptoms at age 17 (95% CI 0.00, 0.08). R-squared values were very similar for both measures of BMI, with 6.7% of variation in depressive symptoms explained by BMI trajectory and baseline confounders, compared to 6.9% variation explained by BMI as a continuous measure and other confounders. Together, estimates of the association and R-squared values suggest that the use of BMI trajectories may result in reduced statistical power to detect differences between groups. Results are shown in **Appendix for Chapter 7, Table 7**.

7.4 Discussion

7.4.1 Summary of main findings

This study aimed to investigate the extent to which body satisfaction at age 14 mediates the association between childhood BMI and adiposity trajectories with depressive symptoms at 17. Consistent with initial hypotheses, results suggested that children with moderate and high trajectories of adiposity across childhood had higher depressive symptom scores at age 17 (**Hypothesis 5**) and that those with higher body satisfaction scores at age 14 had lower depressive symptom scores (**Hypothesis 6**). Furthermore, there was evidence of a dose-response relationship between childhood weight trajectory and depressive symptoms in late adolescence, with higher trajectories of adiposity associated with higher depressive symptom scores at age 17. Associations between adiposity trajectory and depressive symptoms remained after adjustment for mental health scores measured prior to adiposity trajectories, reflecting changes in depressive symptoms over time. There was no evidence that these associations differed by sex.

Mediation analysis suggested strong evidence of an indirect effect of childhood weight, indicated by BMI or adiposity, on later depressive symptoms through body satisfaction in early adolescence. It was estimated that almost half of the association between BMI trajectory and depressive symptoms was mediated by body satisfaction (45%). This was similar in children with high adiposity trajectories (41%), though there were high levels of uncertainty in all estimates, indicated by wide confidence intervals around estimates of the proportion mediated. It was initially hypothesised that the proportion mediated by body satisfaction would be greater in analyses of adiposity trajectory relative to BMI trajectory analyses (**Hypothesis 8**), but results did not provide evidence in support of this. Assuming a causal interpretation, these results suggest that an intervention improving body satisfaction in early adolescence may have the potential to reduce depressive symptoms in children with higher weights.

7.4.2 Comparison with previous literature

Few longitudinal studies have investigated the mediating role of body satisfaction in the association between weight and depressive symptoms. The findings of this study are consistent with some of these (134,219), however not all (220). Particularly, a study of children in Canada found a desire to be thinner mediated the association between childhood BMI trajectories and depressive symptoms in adolescence (238). The societal stigmatization of overweight may be similar in the UK and Canada, giving strength to the hypothesis that mental ill-health in adolescence may arise in response to weight- and appearance-related societal pressures. In contrast, a study of young people in the UK did not find evidence of mediation (220). However, this prior study analysed data from ALSPAC participants born in the 1990s and entering adolescence in the early 2000s. Therefore, the differences in results may also be attributed to cohort effects; body dissatisfaction and depressive symptoms appear to have increased in the last few decades (9,112) and so the associations examined may be stronger in more contemporary cohorts of adolescents.

In contrast to the results in this thesis, some studies found evidence of sex differences in the associations between weight and depression, and in the mediating effect of body satisfaction. These prior studies investigated depressive symptoms in early adolescence, at which point depression is rare in boys. Additionally, this is likely to precede the pubertal transition in most boys. It may be that the social and physiological changes of puberty are a catalyst for the development of body image concerns and depressive symptoms, and that sex differences in the timing of puberty explain the associations observed with depressive symptoms at age 14. In the current study, there was no evidence that the associations with depressive symptoms at 17 differed by sex. It is possible that children approaching physical maturation are more susceptible to societal weight stigma, which disfavours overweight in both boys and girls.

The evidence in this thesis relating to adiposity trajectories is novel and suggests that cumulative exposure to higher adiposity across the early lifecourse increases the risk of depressive symptoms in adolescence, via lower body satisfaction scores. This is consistent with evidence from experimental studies, which have demonstrated that interventions aimed at improving body image also have secondary effects of reducing depressive symptoms (135). Successful interventions have been delivered in schools, focusing on increasing media literacy and criticality of body-related messaging in media (239). Results suggest that these effects may dwindle over time, as shown in an intervention study of 11–14-year-old children in Australia (N=1316), where reductions in eating disorder symptoms immediately post-intervention had returned to baseline levels by six- or 12-months of follow-up. This could indicate that integration of body positive messaging into wider school activities and other aspects of young people's lives would be beneficial. This approach may have far-reaching benefits, as some body image interventions have also shown positive effects on physical activity (239). This is consistent with evidence that body weight, body image and depressive symptoms are bidirectionally associated and that, rather than being a motivator for weight loss, body dissatisfaction may be associated with greater weight gain over time (137).

Sustained benefits may not be seen in these interventions due to the ubiquitousness of societal messaging stigmatising overweight. For example, young people are some of the biggest consumers of highly visual social media, such as Instagram and TikTok, where popular content commonly reinforces messaging that health is only possible at lower weights (99). Diet culture is also rife. Similarly, UK obesity policy centres overweight as an issue of individual responsibility and the curriculum in primary schools includes "healthy lifestyle" education, including the importance of calorie awareness and exercise to maintain healthy weight. The overlap between these concepts and disordered eating behaviours is concerning in the context of this study's findings.

7.4.3 Limitations

In this study, body satisfaction was measured using a single item that captured overall satisfaction with appearance. Therefore, reported dissatisfaction by this measure could in fact relate to other aspects of physical appearance besides body shape and size. However, it was demonstrated in the previous chapter that this measure was strongly correlated with weight (**6.3.4**), which suggests it is a valid measure of weight-related satisfaction.

As discussed in the previous chapter (**6.4.3**), societal body ideals favour lean muscularity in men, and as this sample of adolescent boys are likely to be going through the pubertal transition, this could be an age at which muscularity becomes more important in the development of body image concerns and could therefore be associated with depressive symptoms also. However, due to the limitations of the muscularity measure available in this cohort, which captures not just lean mass but bone and organ mass also, this was not investigated. It would be anticipated that a measure of lean mass would be associated with depressive symptoms, but with higher lean mass associated with lower depressive symptoms. This may likely only be observed in boys, with no association expected between lean mass and depressive symptoms in girls. Future studies with specific measures of lean mass, such as using dual x-ray absorptiometry, should investigate this further.

A further limitation was the potentially limited statistical power of BMI trajectories, as suggested by a sensitivity analysis showing a modest linear association between BMI as a continuous measure at age 11 and depressive symptoms at age 17 by regression modelling. BMI trajectories showed evidence of a dose-response relationship by estimated coefficients with depressive symptoms but with confidence intervals spanning zero in the main analysis. However, the results of the mediation analysis suggested strong evidence of a total causal effect of BMI trajectory on depressive symptoms, which indicates that this analysis was not impacted by reduced statistical power. Nevertheless, the modelled trajectories did not differentiate between children with BMI values in the healthy and underweight groups, which means that any differences between these groups' body satisfaction and depressive symptom scores could not be investigated. Prior evidence from cross-sectional studies has suggested that boys in particular with low BMI values have lower body satisfaction than their healthy BMI peers (130,195); future research should investigate pathways between low BMI, body satisfaction and depressive symptoms.

Finally, causal interpretation of these results relies on several assumptions, including no residual confounding. Although a range of potential confounding variables in the early lifecourse and intermediate confounders were adjusted for, it was not possible to account for the child's genetic predisposition to mental health concerns. However, it is hoped that this was mitigated to some extent by adjusting for measures of parental BMI and mental health. A clear temporal sequence is also required to assess causal associations, and there was some potential overlap between the trajectories of body composition modelled and the measurement of body satisfaction. This could introduce bias as these could be bidirectionally associated and cohort members with lower body satisfaction across childhood could have tried to alter their weight. However, the trajectories included several time points prior to the measurement of body satisfaction, and showed stability across the early lifecourse, which suggests that they are unlikely to be impacted by body satisfaction to a great extent. In addition, previous studies using genetic instruments associated with body composition have provided strong evidence to support the assumption that body weight is causally associated with subsequent body satisfaction (209).

7.4.4 Interim conclusions

This study found strong evidence that higher weight across childhood is associated with higher symptoms of depression in adolescence and that just under half of this association is mediated via body satisfaction. This is important as body satisfaction is potentially modifiable, with several successful interventions improving both body satisfaction and depressive symptoms demonstrated in the wider literature. However, weight-based messaging, which includes making thinness analogous to healthiness, is pervasive in society and may make prevention of body dissatisfaction challenging. It is necessary to consider whether some childhood obesity strategies in the UK may have unintended consequences on adolescent mental health due to the evidence for this mediating pathway between weight and depressive symptoms.

8 Parental Concern about their Child’s Future Weight and Control of their Child’s Diet at Age 5: Associations with Trajectories of BMI and Body Satisfaction

8.1 Introduction

Reducing childhood obesity is a major public health priority in the UK, which has led to the introduction of a number of policies and strategies to track and target it. In 2006, the UK government launched the National Child Measurement Programme to be carried out in state schools. The National Child Measurement Programme measures the heights and weights of all children aged four to five and ten to eleven years old in England. The collection of these data was initially intended as public health surveillance to monitor the prevalence and time trends in childhood obesity. However, in 2008 the programme also incorporated feedback letters to parents, aiming to engage the families of children with overweight BMIs and encourage them to make healthy lifestyle changes (240). Feedback letters include information about the health risks associated with higher weights, the importance of healthy eating and physical activity and, where available, local weight management services.

Evaluations of this feedback process suggest that it may lead to an increase in parental awareness of their child’s weight classification, as well as short-term increases in self-reported dietary restriction (241). This is concerning as parental dietary restriction may be associated with subsequent weight gain, although the evidence for this is mixed. In a 2015 systematic review of this association, the majority (17 out of 22) of studies were cross-sectional and unable to distinguish whether dietary restriction predicts child weight or vice versa, as restriction is likely to occur in response to the child’s BMI (242). In the few longitudinal studies that have been conducted, some find no longitudinal association between restriction and changes in BMI (145,243–245), while others find evidence of increasing (246,247), and others decreasing (248), BMI values over time. This mixed evidence arises from relatively small samples (median N=358, range 57 to 2,021). Predominantly, this research has been conducted in settings outside the UK, with only one small UK study (N=113) finding no association between parental dietary restriction and change in child BMI over time (244).

At present, there is therefore equivocal evidence for an association between early childhood dietary restriction and subsequent BMI development. However, parental dietary restriction or control is of potential concern as it may also influence the development of body image concerns in their children. This could occur by moralizing certain foods as "good" or "bad" or by using food to reward or punish behaviours, which may promote unhealthy relationships with food and increase the risk of disordered eating behaviours (147). Additionally, parental dietary restriction, and other aspects of dietary control, could contribute to the perpetuation of societal ideals around thinness as attractive and symbolic of healthiness, which could encourage internalisation of the thin ideal and fear of weight gain (249), which are central conditions in many eating disorders (250).

Recent analyses of twins in England and Wales (the Gemini Study, N=2,094) found that parental pressure to eat, but not restrictive practices, was associated with small increases in disordered eating behaviours (e.g., fasting and purging) at 13 years old (148). At this age, disordered eating behaviours may be uncommon (251), whereas body dissatisfaction is observed at earlier ages (151). Therefore, the association between parental dietary control and body satisfaction in early adolescence warrants further investigation in a general population-representative sample, particularly as differences in early life circumstances in twins may limit the generalisability of findings to the wider population (148). This knowledge may elucidate opportunities for intervention to promote mental wellbeing, as low body satisfaction is associated with symptoms of depression and eating disorders (151,252). Given that childhood obesity strategies often rely on parents making changes to their child's diet, this study aims to investigate the associations between parental concern about their child's weight and control of their child's diet with both child BMI and body satisfaction trajectory. The following hypotheses were tested:

> ***Hypothesis 9:*** *Higher parental concern about their child's future weight and control of their child's diet for weight-related reasons are not associated with differences in adolescent BMI trajectories to age 17 after adjusting for prior BMI.*
>
> ***Hypothesis 10:*** *Higher parental concern about their child's future weight and control of their child's diet for weight-related reasons are associated with lower body satisfaction at ages 11 and 14 after adjusting for prior BMI.*

8.2 Methods

8.2.1 Sample

Millennium Cohort Study participants with valid data on the exposures of interest (parental concern about future weight and control of their child's diet at age 5) were included in analyses (N=14,588 and 14,577, respectively). Missing data on outcomes and confounders were imputed using multiple imputation by chained equations (described further in **8.2.7 Analysis**).

8.2.2 Parental concern about future overweight

When the cohort members were around 5 years old, their parent was asked "How concerned are you about your child becoming overweight in the future?". In 97% of cases, the parent completing the questionnaire was the cohort member's natural mother. Response options were: unconcerned; a little concerned; concerned; fairly concerned; very concerned. Within different levels of concern, groups were small and therefore were dichotomized into unconcerned versus concerned about future overweight (including a little; concerned; fairly and very concerned) (

Appendix for Chapter 8, Table 1).

8.2.3 Parental control of their child's diet

When the child was around 5 years old, their parent was also asked "During the past 12 months, have you controlled the type or amount your child eats or drinks for any of these reasons?". The parent could select any number of suggested responses or specify others. Responses included behaviour or hyperactivity, vegetarian diets, and for religious reasons. All responses are reported in **Appendix for Chapter 8, Table 2**. Responses were coded to investigate the presence of the following potentially weight-related reasons: to give a healthy, balanced diet (which included parents who reported limiting snacks so their child eats their main meal); to put on or maintain weight; to lose or control weight; or as a reward or punishment. Due to perceived overlap in concepts of weight maintenance and weight control, the two weight management responses were initially grouped into one response, also in addition to concerns around statistical power due to these being less commonly reported.

Three dummy variables were derived to capture cohort members whose parents reported controlling their diet: to give a healthy, balanced diet (yes versus no); to manage their weight (yes versus no); or as a reward or punishment (yes versus no). For each dummy variable, the no category included all cohort members whose parent did not report controlling their diet, those who did control their diet for any reason other than the one under investigation (i.e., those coded 'no' for healthy, balanced diet could have their diet control for multiple other reasons). As such, these dummy variables captured the presence or absence of diet control for each of the three hypothesised weight-related reasons.

8.2.4 Child BMI

Child's subsequent BMI was measured at ages 7, 11, 14, and 17 years. Procedures used in the Millennium Cohort Study to measure height and weight have previously been described in **4.5.1**. BMI was age- and sex-standardised using the *zanthro* package in Stata. Trajectories of BMI were modelled using multilevel modelling, separate to trajectories from latent class growth analysis used in prior empirical chapters, and described below (**8.2.7 Analysis**).

Other measures of body composition were not included (e.g. adiposity-specific measures) as it is intended that the findings are relevant to the current National Child Measurement Programme, which only collects data on, and categorises children according to, BMI.

8.2.5 Child body satisfaction

When the cohort member was aged approximately 11 and 14 years, they completed their own questionnaires, which included the question "On a scale of 1 to 7, where 1 means completely happy and 7 means not at all happy, how do you feel about the way you look?". This was reverse coded such that higher scores indicated greater satisfaction. Body satisfaction was not included in the cohort member questionnaire at age 17. Trajectories of body satisfaction were modelled using multilevel modelling, described below (**8.2.7 Analysis**).

8.2.6 Confounders

The following variables were identified as potential confounders, based on existing evidence of their associations with the exposures and outcomes under investigation and are not on the causal pathway. As the questionnaire item capturing parental dietary control at age 5 covered behaviour in the past 12 months, confounders were selected from data collection sweeps that occurred prior to this period, to ensure that these cannot be a consequence of the exposure. Confounding variables are described below.

Child characteristics

These were child sex assigned at birth and ethnic group, as previously described in **5.2.5,** reported by parents when the child was aged 9 months. Additionally, child emotional symptoms and peer problems at age 3 were considered as confounders. These were measured at the sweep prior to the measurement of the exposures, when the child's parent completed the Strengths and Difficulties Questionnaire (SDQ), a well-validated questionnaire that captures internalizing and externalizing symptoms on a three-point Likert scale (0= Not true, to 2= Certainly true) (231). Five items comprising the emotional symptom subscale were summed to give a total score for emotional symptoms (range 0 – 10), with higher scores indicating greater emotional symptoms. For descriptive purposes, a binary variable was created to indicate whether the emotional symptom score was above existing thresholds (≥5) for high emotional problems (253).

Using the same SDQ scale at age 3, five items comprising the peer problems subscale were summed to give a total score for peer problems (range 0 – 10), with higher scores indicating more problems with peers. For descriptive purposes, a binary variable was created to indicate whether the peer problem score was above existing thresholds for high peer problems (≥4) (253). The peer problems sub-scale was included as it was hypothesised that parental concerns around peer bullying may be associated with the child's weight status and could increase the parent's concern about their weight or their likelihood of controlling the child's diet.

Family socioeconomic position

Information was collected from parents when their child was aged 9 months. Measures of socioeconomic position were household income as OECD equivalized income quintiles, which account for household size; parental education level, as NVQ Level equivalents (None to Level 5, previously described in **5.2.5**); and parental occupational class, according to the NS-SEC five group classification. In two-parent households, the highest reported educational level and occupational class in the household was used.

Child BMI

Child height and weight at age 3 was used to derive BMI, which was then age- and sex-standardised in the same way as above. BMI at age 3 was used as parental feeding practices have been shown to be a response to child BMI. For descriptive purposes only, standardised BMI was categorized as underweight, healthy weight, overweight and obese according to International Obesity Taskforce thresholds (64).

Maternal pre-pregnancy BMI

Maternal pre-pregnancy height and weight was self-reported when their child was 9 months old, from which BMI was calculated in kilograms per metre squared. For descriptive purposes only, BMI was categorised into underweight, healthy weight, overweight and obese, according to World Health Organisation cut offs (197).

8.2.7 Analysis

Missing data

Among participants with valid exposure data, frequencies and proportions of missing data on outcomes and confounders were investigated. For those with valid exposure data, proportions and characteristics of participants missing outcome data at all ages were compared to those with at least one valid outcome measurement. Missing data on outcomes and confounders was imputed using multiple imputation by chained equations, assuming that data are missing at random. A total of 50 datasets were imputed using all variables included in the analysis and auxiliary variables included to improve predictions. Auxiliary variables were measures of the cohort member's mental health (parent-reported SDQ scores at ages 5, 7, 11, and 14; short Moods and Feelings Questionnaire at age 14; Kessler K6 scale at age 17), parental mental health when the cohort member was aged 3 (maternal and paternal Kessler K6 score), and whether the cohort member lived in a one- or two-parent household.

Descriptive statistics

The prevalence of parental concern about the child's future weight and of dietary control was examined, and prevalence according to confounding variables were described using proportions.

Multilevel modelling

The longitudinal associations of parent-reported concern about their child's future weight and control of their child's diet (healthy diet, weight management, reward/punishment; each as exposed versus unexposed) at age 5 with zBMI (ages 7, 11, 14, and 17) and body satisfaction (ages 11 and 14) were estimated using multilevel modelling. This statistical approach models repeated BMI and body satisfaction measurements, while accounting for their within-individual correlation, emerging from the repeated nature of the measure over time. For each combination of exposure and outcome, multilevel models were estimated with random intercepts at the child level and random slopes on linear time. This allows for children having different intercepts and outcome slopes over time.

When modelling BMI, age was centred at age 7 years. The association between age and BMI was first modelled in unconditional models, first with age as a linear term and then including a quadratic term, as BMI was measured at four unequally spaced time points. Unconditional modelling suggested that including both linear and quadratic terms for age resulted in improved model fit according to Akaike Information Criterion;

in addition, the p value for the quadratic age term was <0.0001. For body satisfaction, change in body satisfaction with age was modelled linearly, as body satisfaction was available at two time points. In these models, age was centred at 11 years.

Model specification is summarized in **Table 8-1**. For each combination of exposure and outcome, an unadjusted model first investigated the association between each of the exposure and the outcomes, while including the age indicator(s) (Model 0). Multivariable Model 1 adjusted for child characteristics (sex at birth, ethnicity, and emotional and peer problems at age 3) and family socioeconomic position. Subsequent models included separate adjustment for maternal pre-pregnancy BMI (Model 2) and child BMI at age 3 (Model 3), before both were included together (Model 4). As multiple reasons for diet control could be reported, an additional model was run which adjusted for the number of other diet control reasons reported. After including all putative confounding variables, models were repeated including an

Table 8-1. Specification of confounders in multilevel modelling.

Model	**Specification of confounders**	
0	Unadjusted	
1	Model 0 + child characteristics and family socioeconomic position (Child sex, ethnicity, emotional and peer problems at age 3, indicators of socioeconomic position at 9 months)	
2	Model 1 + maternal pre-pregnancy BMI	
3	Model 2 + child BMI at age 3	
4	Model 1 + maternal BMI and child BMI	
	Parental diet control	**Parental concern about future weight**
5	Model 4 + number of other diet control reasons	Model 4 + exposure*sex interaction
	Model 5 + exposure*sex interaction	Model 4 + exposure*age interaction (including sex interaction if significant)
	Model 5 + exposure*age interaction (including sex interaction if significant)	

exposure*sex interaction to investigate whether there were sex differences in the associations under investigation (evidence of interaction if $p \leq 0.05$). Finally, an exposure*age (and exposure*age^2 in BMI models) interaction term was included to investigate whether there was a differential rate of change in exposed and unexposed participants (evidence of interaction if $p \leq 0.05$). Trajectories of BMI and body satisfaction from final models, with any interaction terms as appropriate, were predicted using the margins command and plotted graphically. Where there was evidence of sex and/or interactions, intercepts (sex-specific) and slopes are reported. All modelling was performed in Stata MP 18 and used sampling weights to account for the stratified sampling frame used.

Negative exposure

A negative exposure was used to explore whether any potential differences in BMI and body satisfaction observed could be explained by unobserved confounding (i.e., not due to the weight-related reasons for diet control that were hypothesised). This negative exposure should have no hypothesised association with the outcomes under investigation but be susceptible to the same unmeasured confounding as the exposures under investigation (254). Conceptually, it was considered that, of all other diet control reasons, “digestive problems, e.g., constipation” was unlikely to be related to the parent’s perception of child’s weight and had a sufficient number of responses to be used in multilevel modelling. The characteristics of those whose parents had reported controlling their diet due to digestive problems were explored descriptively and multilevel modelling was repeated.

Post-hoc investigation of dietary control for weight management

Due to small sample sizes and potential overlap in the concepts of dietary control to maintain weight and to control weight, both weight management dietary control responses were grouped together initially. However, it was considered that dietary control to gain weight and to lose weight may exert different effects on BMI and body satisfaction. Therefore, these were disaggregated and their associations with BMI and body satisfaction were investigated.

Sensitivity analyses

<u>Missing data</u>

To assess the impact of missing data, models were repeated on a sample of participants with complete data on the exposure, confounders and at least one measurement of BMI and body satisfaction outcome data (as multilevel modelling uses maximum likelihood estimation to account for missing outcome data). Sampling and attrition weights at the age 7 and age 11 sweep were applied to BMI and body satisfaction models, respectively.

Parental BMI

Further analysis of the potential confounding role of parental BMI was performed, adjusting for maternal BMI measured at age 3 in lieu of pre-pregnancy BMI, which may capture potential dynastic effects. Additionally, in a sub-sample of children from two-parent households, paternal BMI at age 3 was included as a confounder. These were both self-reported.

Selection of weight- or appearance-related reasons for diet control

Conceptually, parents reporting diet control due to the reason “teeth” could be similar to those doing so to give a healthy, balanced diet. It is possible that altering the diet for the former reason could constitute reducing sugar intake to promote oral health. Therefore, this could be distinct from, but related to, a healthy, balanced diet and discussion of oral health could include a focus on appearance (for example, reinforcing the negative perception of decaying or missing teeth). Therefore, the characteristics of those who reported diet control related to teeth were examined, and multilevel modelling was repeated combining those who reported diet control either for a healthy, balanced diet or for teeth to investigate whether this affected results.

8.3 Results

8.3.1 Sample

Of the total 18,540 cohort members (taking one cohort member at random in cases of multiple births as outlined in **4.3**) who participated in the first wave of data collection at 9 months of age, 14,588 (78.7%) and 14,577 (78.6%) had valid data on parental concern about their child becoming overweight and parent-reported control of their child’s diet, respectively. Among those with valid exposure data, valid BMI data was available for 11,507 participants at age 7 (78.9%), 10,701 at age 11 (73.4%), 9,254 at age 14 (63.4%), and 7,953 at age 17 (54.5%). Valid body satisfaction data was available for 10,706 (73.4%) participants at age 11 and 9,438 at age 14 (64.7%).

Among those with valid exposure data, 7,142 (49.0%) were female and 12,249 (87.1%) were White (**Table 8-2**). Nearly 60% of children had parents with qualifications equivalent to A levels (NVQ Level 3) or higher and 40.4% had parents working in a managerial or professional occupation. Few children had high scores for emotional symptoms (3.8%), while 11.8% had high scores for peer problems. Most cohort members were born to mothers with pre-pregnancy BMI values in the healthy range (65.6%), and this was similar for child BMI at age 3 (72.3% healthy weight).

In total, 27.3% of parents had concerns about their child being overweight in the future, and this was more prevalent if their child was female compared to male (30.5% versus 24.2%), and less prevalent if their child was of Bangladeshi or Pakistani background compared to White children (21.6% versus 27.7%) (**Table 8-2**). Broadly, concern about future weight was less common in parents from the most disadvantaged socioeconomic backgrounds, however there were not clear social gradients observed among this indicator. Concern was higher among parents of children with high

Table 8-2. Sample characteristics and exposure status by characteristics.

Characteristic			Parent concerned about future weight		Diet control: healthy diet		Diet control: weight management		Diet control: reward or punishment	
	N	%	No	Yes	No	Yes	No	Yes	No	Yes
N			10687	3901	8269	6309	13646	931	12827	1751
%			72.7	27.3	55.1	44.9	93.6	6.4	87.1	12.9
Cohort member sex at birth										
Male	7446	51.0	75.8	24.2	55.4	44.6	91.2	5.8	86.2	13.8
Female	7142	49.0	69.5	30.5	54.7	45.3	93.1	6.9	88.0	12.0
Cohort member ethnicity										
White	12249	87.1	72.3	27.7	53.7	46.3	94.0	6.0	86.3	13.7
Mixed	410	3.2	75.3	24.7	59.0	41.0	91.3	8.7	87.9	12.1
Indian	357	1.8	70.6	29.4	61.8	38.2	94.0	6.0	93.5	6.5
Pakistani / Bangladeshi	892	4.0	78.4	21.6	72.1	27.9	90.3	9.7	94.4	5.6
Black or Black British	464	2.7	75.3	24.7	59.5	40.5	89.6	10.4	92.6	7.4
Other	182	1.1	75.6	24.4	64.4	35.6	92.6	7.4	96.3	3.7
Family income fifth at 9 months										
Most disadvantaged	3295	20.0	76.0	24.0	69.7	30.3	93.2	6.8	92.1	7.9
Second	3181	20.0	73.2	26.8	63.6	36.4	93.6	6.4	89.5	10.5
Third	2821	20.2	70.2	29.8	53.6	46.4	94.1	5.9	86.6	13.4
Fourth	2733	20.1	70.8	29.2	46.0	54.0	94.0	6.0	84.7	15.3
Least disadvantaged	2513	19.7	73.0	27.0	42.2	57.8	93.4	6.6	82.3	17.7
Parental education level at 9 months										
None	1701	10.0	76.8	23.2	72.8	27.2	93.3	6.7	95.2	4.8
NVQ Level 1 (GCSE grade D-G)	848	5.6	73.0	27.0	70.5	29.5	95.5	4.5	92.1	7.9
NVQ Level 2 (GCSE grade A*-C)	3633	25.2	71.6	28.4	62.6	37.4	93.2	6.8	89.3	10.7
NVQ Level 3 (A Level)	2401	16.1	72.8	27.2	57.1	42.9	94.5	5.5	86.3	13.7
NVQ Level 4 (One year Undergraduate)	5014	36.2	71.9	28.1	44.5	55.5	93.7	6.3	83.6	16.4
NVQ Level 5 (Two years Undergraduate+)	979	6.8	74.4	25.6	39.2	60.8	92.0	8.0	83.0	17.0

Characteristic	N	%	Parent concerned about future weight		Diet control: healthy diet		Diet control: weight management		Diet control: reward or punishment	
	N	%	No	Yes	No	Yes	No	Yes	No	Yes
Parental occupational class at 9 months										
Not in work	3502	22.2	76.8	23.2	65.8	34.2	93.5	6.5	91.7	8.3
Semi-routine/routine	2162	13.6	70.8	29.2	65.4	34.6	92.5	7.5	89.0	11.0
Lower supervisory/technical	1171	7.9	71.2	28.8	61.6	38.4	95.1	4.9	89.2	10.8
Small employers/self-employed	950	6.8	73.1	26.9	55.6	44.4	92.2	7.8	88.3	11.7
Intermediate	1316	9.0	70.8	29.2	53.2	46.8	94.7	5.3	86.5	13.5
Managerial/professional	5437	40.4	71.7	28.3	44.7	55.3	93.9	6.1	83.3	16.7
Cohort member baseline emotional symptoms at 3 years										
Close to average (<5)	12049	96.2	72.4	27.6	53.2	46.8	93.8	6.2	86.5	13.5
High (5-10)	526	3.8	68.3	31.7	65.3	34.7	89.9	10.1	88.1	11.9
Child's baseline peer problems at 3 years										
Close to average (<4)	10947	88.2	72.7	27.3	52.7	47.3	93.9	6.1	86.8	13.2
High (4-10)	1548	11.8	69.2	30.8	60.7	39.3	91.7	8.3	87.7	12.3
Maternal pre-pregnancy BMI										
<18.5	784	5.8	82.6	17.4	64.6	35.4	93.6	6.4	89.4	10.6
18.5 – 24.9	8682	65.6	76.5	23.5	52.3	47.7	94.2	5.8	86.2	13.8
25 – 29.9	2731	19.8	67.4	32.6	56.8	43.2	92.9	7.1	87.2	12.8
30+	1188	8.8	53.1	46.9	59.6	40.4	91.2	8.8	88.4	11.6
Cohort member BMI at 3 years										
Underweight	606	4.7	85.4	14.6	58.5	41.5	85.8	14.2	90.1	9.9
Healthy weight	8694	72.3	77.0	23.0	54.3	45.7	95.6	4.4	86.5	13.5
Overweight	2187	17.6	56.6	40.4	51.5	48.5	92.8	7.2	85.6	14.1
Obese	687	5.4	40.7	59.3	57.4	42.6	76.5	23.5	87.3	12.8

emotional symptoms and peer problem scores, and strongly correlated with both maternal and child BMI.

Control of their child's diet to give a healthy, balanced diet was reported by 44.9% of parents (**Table 8-2**). This did not appear to differ according to child sex but was most common in parents of White children (46.3%) and least common in parents of Pakistani and Bangladeshi children (27.9%). The proportion of parents who reported this type of dietary control increased with increasing socioeconomic advantage. Control to give a healthy diet was less common in parents of children with high emotional symptoms, peer problem scores and BMIs, and if the child's mother had a higher pre-pregnancy BMI.

Diet control for weight management was reported by 6.4% of parents. This was slightly more common in parents of girls (6.9% versus 5.8%), most common in parents of Black children (10.4%) and least common in parents of White or Indian children (6.0%). There did not appear to be differences in the prevalence of control for weight management by family socioeconomic position. More parents of children with high emotional symptom and peer problem scores reported controlling for weight management compared to those with close to average scores. There were few differences according to maternal pre-pregnancy BMI, however control for weight management at age 5 was strongly correlated with child BMI at age 3 and most common in children with underweight (14.2%) or obese BMIs (23.5%) compared to those with BMIs in the healthy range (4.4%).

Diet control as a reward or punishment was reported by 12.9% of parents and was slightly more common in parents of boys compared to girls (13.8% versus 12.0%) and children of White or Mixed ethnicity (13.7% and 12.1%, respectively), whereas it was least common in children from Pakistani and Bangladeshi backgrounds (5.6%). The proportion of parents reporting control as a reward or punishment increased with increasing socioeconomic advantage. It did not appear to differ by child emotional or peer problems, or by child or maternal BMI.

8.3.2 Missing data

Among participants with valid exposure data, missing data on confounders was low (less than 1%) for those measured at 9 months of age, with the exception of maternal pre-pregnancy BMI where 8.2% of participants had missing data (**Appendix for Chapter 8, Table 3.** Comparing characteristics of samples with valid exposure data; valid exposure data, complete confounders and at least one measure of BMI data from age 7; and valid exposure and imputed outcome and confounder data.). The proportion of missing data was higher for confounders measured when the child was aged 3; approximately 14% of participants had missing data for emotional or peer problem scores and 17.2% for child BMI.

Among participants with valid exposure data, the majority had complete or near-complete (i.e., missing only one wave) data on outcome measures (62.9% for BMI and 77.1% for body satisfaction, see **Appendix for Chapter 8, Table 4**). The proportion of participants with missing outcome data at all timepoints included in the analysis was 15.9% for BMI and 22.9% for body satisfaction. Among those with valid data on exposures, missing outcome data was more common in boys, children of mixed or Black ethnic groups, and those from more socioeconomically disadvantaged backgrounds (**Appendix for Chapter 8, Table 5**). Missing outcome data was also more common in children with high emotional, but not peer problems, and in children whose mother had an underweight pre-pregnancy BMI. The proportion of participants with missing outcome data was slightly lower among those whose parents restricted their diet to give them a healthy diet or as a reward or punishment.

8.3.3 Association of parental concern about weight and parental diet control with child BMI

Unconditional multilevel modelling suggested that BMI z score increased with each timepoint by 0.019 units (95% CI 0.013, 0.025), but this was not linear (p value for quadratic age term $p<0.0001$), as BMI z score began to decrease after age 11. Mean BMI at each time point is shown in **Table 8-3**. To aid interpretation of effect sizes, standard deviations are also reported.

Parental concern about their child being overweight in the future

In the unadjusted model (Model 0), children whose parents were concerned about their future weight at age 5 had higher BMI z scores at age 7 compared to those whose parents were not concerned (mean difference 0.67, 95% CI 0.62, 0.71; see **Appendix for Chapter 8, Table 6** for all model results). This did not change after adjusting for child characteristics and family socioeconomic position but was attenuated on adjustment for both maternal pre-pregnancy BMI and child BMI at age 3 (Model 4

Table 8-3. Change in BMI and body satisfaction with age. Results from multilevel modelling. Standard deviations reported for sample with at least one measurement of outcome.

	Age (Years)			
	7	11	14	17
Mean BMI z score (95% CI)	0.49 (0.47, 0.52)	0.53 (0.51, 0.55)	0.51 (0.48, 0.53)	0.44 (0.41, 0.47)
BMI z score SD	1.1	1.2	1.2	1.2
Mean body satisfaction score (95% CI)	-	5.49 (5.46, 5.53)	4.76 (4.73, 4.80)	-
Body satisfaction score SD	-	1.6	1.6	-

mean difference in BMI at age 7: 0.29, 95% CI 0.25, 0.32). There was no evidence of an interaction between parental concern about weight and sex (p=0.639), but there was strong evidence of an interaction between the parental concern and time (p<0.0001). Compared to children whose parents were not concerned about their future weight, in children whose parents were concerned mean BMI reduced more over time (exposure*age coefficient -0.009, 95% CI -0.013, -0.004, further details in **Appendix for Chapter 8, Table 7**). By age 17, children whose parents were concerned about their future weight had a mean BMI z score 0.23 units higher than children whose parents were not concerned about their future weight (95% CI 0.18, 0.28). This is shown in **Figure 8-1, A**.

Parental diet control: to give a healthy, balanced diet

There was no evidence that parental diet control with the goal of providing a healthy diet was associated with BMI at age 7 years in the unadjusted model (mean difference -0.03, 95% CI -0.06, 0.01). This was not altered by adjusting for confounders or the number of other control reasons reported (Model 4 mean difference -0.00, 95% -0.04, 0.03, see **Appendix for Chapter 8, Table 6** for all model results). There was no evidence for an interaction between dietary control to give a healthy diet and sex (p=0.874) or between dietary control to give a healthy diet and time (p=0.091). Results are shown in **Figure 8-1, B**).

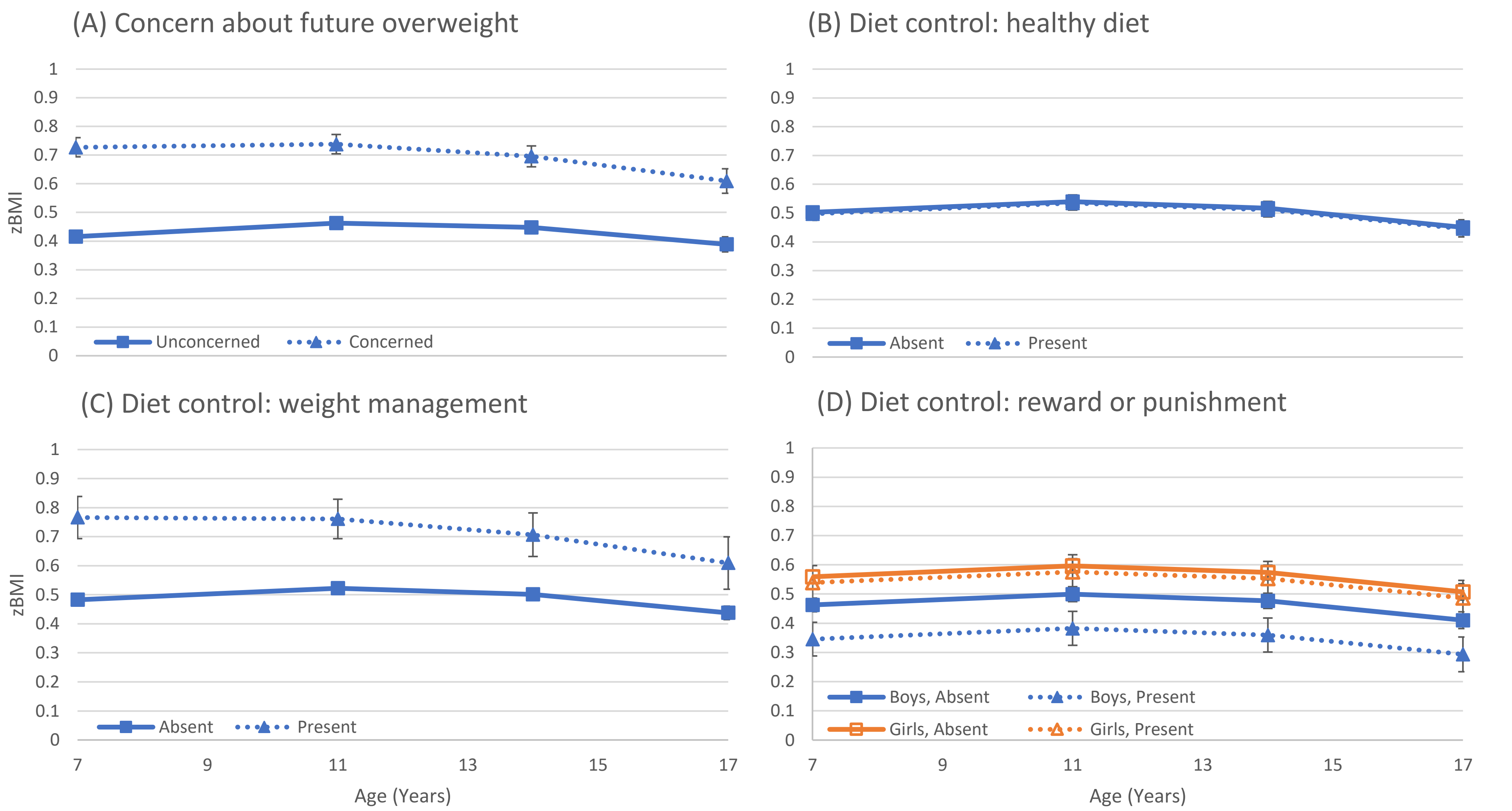

Figure 8-1. Trajectories of young people's BMI z score according to parent-reported concern about their child's future weight or diet control for specified reasons. Results from multilevel modelling of cohort members with valid exposure data and imputed outcomes.

Parental diet control: for weight management

In the unadjusted model, children whose parents controlled their diet for weight management had higher BMI z scores at age 7 compared to children whose parents did not control for this reason (mean difference 0.46, 95% CI 0.36, 0.56; see **Appendix for Chapter 8, Table 6** for all model results). The association did not change after adjusting for child characteristics or family socioeconomic position but was attenuatedby adjustment for maternal and child BMI (fully adjusted mean difference 0.25, 95% CI 0.18, 0.32). The association was not further attenuated by controlling for the number of other reasons for dietary control parents reported. There was no evidence for sex differences (p for interaction=0.439), but there was evidence for an interaction between dietary control for weight management and time (p=0.019). Over time, the BMIs of children whose parents controlled their diet for weight management reduced more compared to that of children whose parents did not control their diet for this reason (exposure*age coefficient -0.01, 95% CI -0.021, -0.002, see **Appendix for Chapter 8, Table 7** for further details). By age 17, children whose parents had controlled their diet for weight management had BMI z scores 0.19 units higher than those whose parents did not control their diet for this reason (95% CI 0.09, 0.29). Trajectories of BMI over time by exposure status are shown in **Figure 8-1, C.**

Parental diet control: as a reward or punishment

There was some evidence in the unadjusted model that dietary control as a reward or punishment for the child was associated with lower BMIs at age 7 compared to children whose parents did not control for this reason (mean difference -0.06, -0.12, -0.01; see **Appendix for Chapter 8, Table 6** for all model results). This did not change after adjusting for all confounders and the number of other reasons for control reported (fully adjusted mean difference -0.07, 95% CI -0.12, -0.03). There was evidence that this association varied by sex (p for interaction=0.027); there was no evidence of an association between the exposure and BMI in girls (mean difference -0.02, 95% CI -0.08, 0.04), whereas diet control as a reward or punishment was associated with lower BMIs in boys (mean difference -0.12, 95% CI -0.19, -0.06, **Appendix for Chapter 8, Table 7** for further details). There was no evidence for an interaction between the exposure and time (p=0.454). Sex-specific BMI trajectories in those whose parents did and did not control their diet as a reward or punishment are shown in **Figure 8-1, D**.

8.3.4 Association of parental concern about weight and parental diet control with child body satisfaction

Results of unconditional multilevel modelling suggested that body satisfaction score decreased from age 11 to 14. Mean body satisfaction score, on a scale 1 to 7, was 5.49 at age 11 and 4.76 at age 14 (**Table 8-3**).

Parental concern about their child being overweight in the future

In the unadjusted model, there was strong evidence that children whose parents were concerned about their future weight had lower body satisfaction scores at age 11 (mean difference -0.30, 95% CI -0.36, -0.25). This was slightly attenuated when adjusting for child characteristics and family socioeconomic position (mean difference -0.26, 95% CI -0.32, -0.20; see **Appendix for Chapter 8, Table 8** for all model results). This was further attenuated on adjustment for maternal and child BMI, but there remained strong evidence that children whose parents are concerned about their future weight have lower body satisfaction across early adolescence compared to those whose parents were not concerned (fully adjusted mean difference -0.18, 95% CI -0.24, -0.12). There was no evidence that the association between exposure and body satisfaction varied by sex (p for interaction=0.276), nor that parental concern with child's weight was associated with differential changes in body satisfaction over time (p for interaction=0.541). Final model results are shown in **Figure 8-2, A**.

Parental diet control: to give a healthy, balanced diet

In the unadjusted model, there was no evidence that diet control with a goal of providing a healthy, balanced diet was associated with differences in body satisfaction score at age 11 (mean difference 0.02, 95% CI -0.03, 0.07; see **Appendix for Chapter 8, Table 8** for all model results). This was not altered after adjusting for all confounding variables or the number of other reasons for diet control reported (fully adjusted mean difference 0.00, 95% CI -0.05, 0.06). There was no evidence that the association between control with the goal of providing a healthy diet and body satisfaction varied by sex (p for interaction=0.744). However, there was some evidence that the exposure was associated with differential changes in body satisfaction from age 11 to 14 (p for interaction=0.007), with body satisfaction scores reducing more across early adolescence in children whose parents controlled their diet for the purpose of providing a healthy diet, compared to children whose parents did not control for this reason

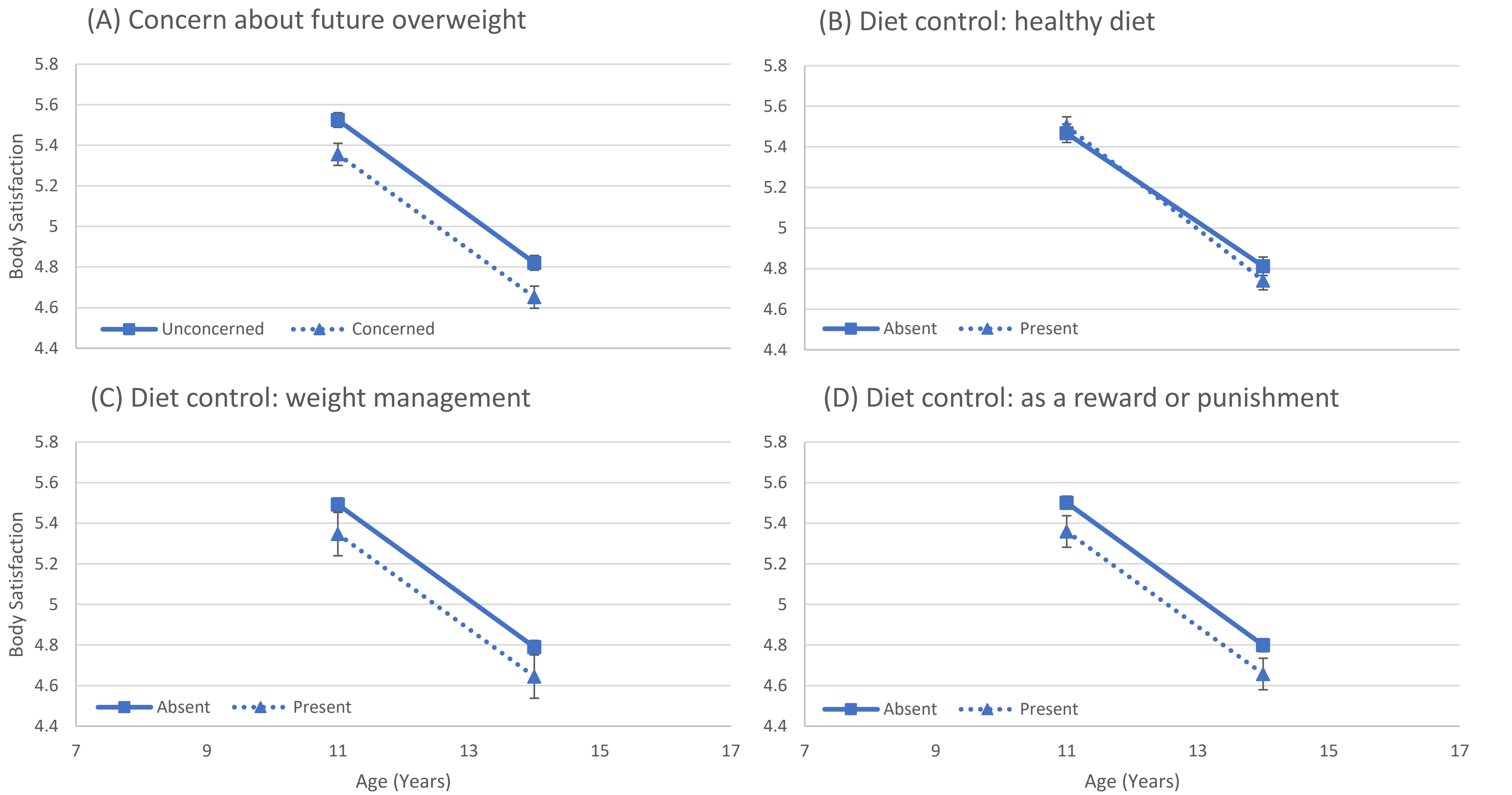

Figure 8-2. Trajectories of young people's body satisfaction score according to parent-reported concern about their child's future weight or diet control for specified reasons. Results from multilevel modelling of cohort members with valid exposure data and imputed outcomes and confounders.

(exposure*age coefficient -0.04, -0.06, -0.01, see **Appendix for Chapter 8, Table 9** for further details). This is shown in **Figure 8-2, B**.

Parental diet control: for weight management

There was strong evidence in the unadjusted model that diet control for weight management was associated with lower body satisfaction at age 11 (mean difference -0.21, 95% CI -0.32, -0.09). This was slightly attenuated by adjustment for confounding variables, mostly driven by child BMI at age 3 (fully adjusted mean difference -0.15, 95% CI -0.26, -0.04, see **Appendix for Chapter 8, Table 8** for all model results). There was no evidence that this association changed according to child sex (p for interaction=0.587) or that diet control for weight management was associated with differential changes in body satisfaction over time (p for interaction=0.733). Results are shown in **Figure 8-2, C**

Parental diet control: as a reward or punishment

In the unadjusted model, there was strong evidence that children whose parents controlled their diet as a reward or punishment had lower body satisfaction scores at age 11 compared to those whose parents did not control for this reason (mean difference -0.14, 95% CI -0.22, -0.06). This did not change after adjusting for all confounding variables and the number of diet control reasons reported (fully adjusted mean difference -0.14, 95% CI -0.22, -0.06, see **Appendix for Chapter 8, Table 8** for all model results). There was no evidence that this association varied by child sex (p for interaction=0.753) or differentially over time (p for interaction=0.117). Plotted results are shown in **Figure 8-2, D**.

8.3.5 Negative control

Parental diet control due to digestive problems including constipation was reported by 6.3% of parents. Similar proportions of diet control for digestive problems were reported by parents of girls and boys. It was less common in parents of children from Pakistani, Bangladeshi or other ethnic backgrounds including Chinese and Arab, compared to White children. Proportions of parents reporting diet control for digestive problems were higher in more advantaged socioeconomic families and in parents of children with high emotional problems at age 3. It did not appear to be associated with maternal or child BMI. A descriptive table showing the distribution of this exposure in the sample and across confounders is provided in **Appendix for Chapter 8, Table 10**.

BMI

In multilevel regression models, there was no evidence that diet control for digestive problems was associated with differences in zBMI at age 7 in either the unadjusted (mean difference -0.04, 95% CI -0.12, 0.04) or the fully adjusted models (mean difference -0.01, 95% CI -0.07, 0.05; see **Appendix for Chapter 8, Table 11** for all model results). There was no evidence that this association varied by sex (p for interaction=0.136), but there was strong evidence that the exposure was associated with differential changes in BMI over time (p for interaction=0.004). Diet control for digestive problems was associated with decreasing BMI trajectories over time (exposure*age coefficient -0.01, 95% CI -0.02, -0.00).

Body satisfaction

Similarly, there was no evidence that this type of diet control was associated with differences in body satisfaction at age 11 in unadjusted (mean difference -0.06, 95% CI -0.17, 0.06) or fully adjusted models (mean difference -0.03, 95% CI -0.14, 0.07; all model results in **Appendix for Chapter 8, Table 13**). There was no evidence for sex differences in this association (p for interaction=0.577) or differential changes over time (p for interaction=0.373). Trajectories of BMI and body satisfaction in children whose parents did and did not control their diet for digestive problems is shown in **Figure 8-3**.

8.3.6 Post-hoc analysis

To investigate whether diet control to gain weight and to lose weight were differentially associated with BMI and body satisfaction, these two responses were disaggregated. Diet control to gain or maintain weight was reported by 3.8% of parents, while control to lose or control weight was reported by 2.7%.

Parental diet control to gain or maintain weight

In the fully adjusted model, there was weak evidence that children whose parents controlled their diets to gain or maintain weight had lower BMI z scores at age 7 compared to those whose parents did not control for this reason (mean difference -0.05, 95% CI -0.13, 0.03). There was no evidence this association varied by child sex

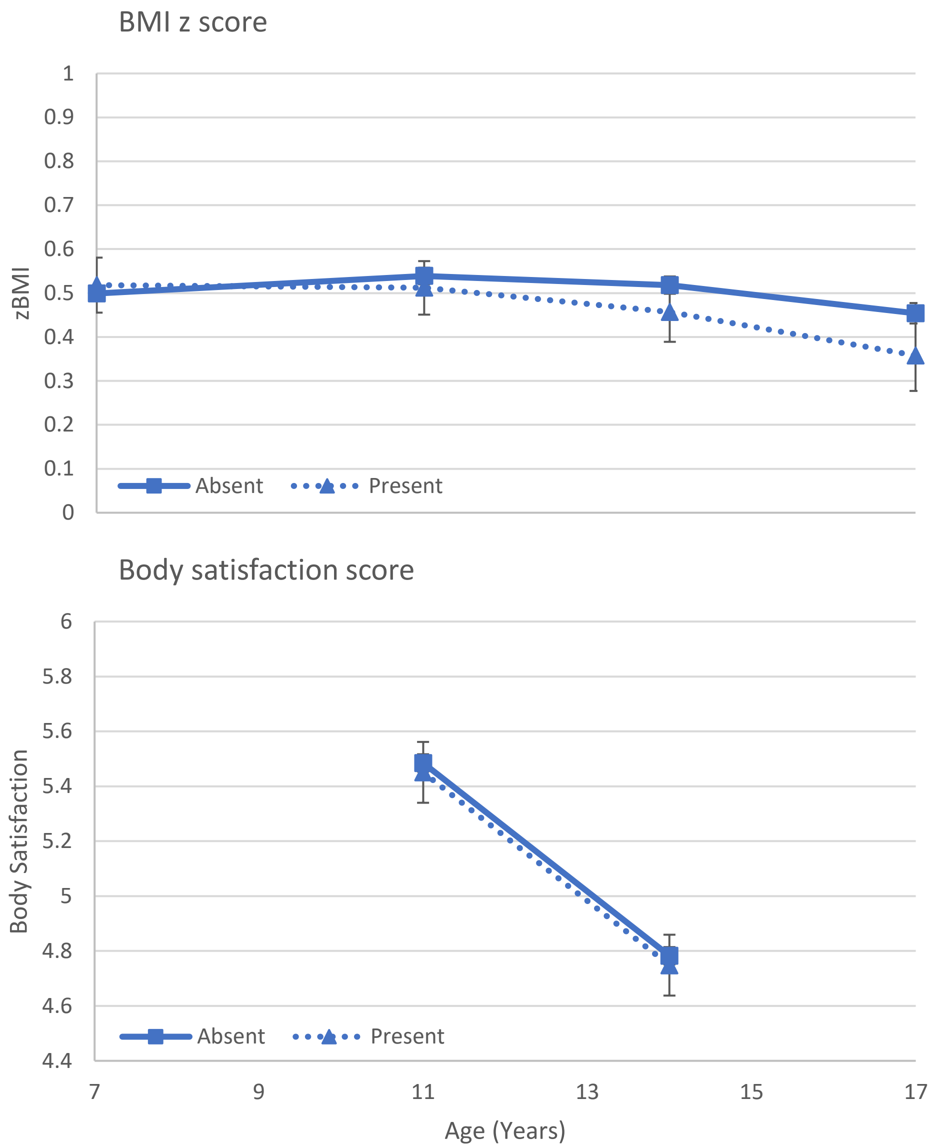

Figure 8-3. Results of a negative exposure control: Trajectories of child BMI z score and body satisfaction according to whether their parent reported controlling their diet for digestive problems.

(p for interaction=0.861), but there was evidence that diet control to gain or maintain weight was associated with increasing BMI trajectories over time (p for interaction=0.012, exposure*age coefficient 0.01, 95% CI 0.00, 0.03). All model results are detailed in **Appendix for Chapter 8, Table 14-15**.

There was no evidence that diet control to gain weight was associated with differences in body satisfaction score in adolescence (fully adjusted mean difference -0.03, 95% CI -0.16, 0.10). There was no evidence that the association varied by sex (p for interaction=0.920) or across time (p for interaction=0.617, see **Appendix for Chapter 8, Table 16**). BMI and body satisfaction trajectories among children whose parents did and did not control their diet with the goal of helping them gain weight are shown in **Figure 8-4, A and B**.

Parental diet control to lose or control weight

In the fully adjusted model, there was strong evidence that children whose parents controlled their diet with the goal of losing or controlling their weight had higher BMI z scores at age 7 compared to those whose parents did not control for this reason (mean difference 0.72 (95% CI 0.62, 0.82, see **Appendix for Chapter 8, Table 14** for model results). However, this association appeared to vary according to child sex (p for interaction=0.032) and also differentially across time (p for interaction <0.0001), with mean zBMI decreasing by approximately 0.52 in boys and by 0.48 in girls. Among boys whose parents controlled their diet to help them lose weight, mean zBMIs were higher at age 7 by 1.09 units (95% CI 0.91, 1.26) and by age 17 mean zBMIs were 0.57 units higher (95% CI 0.34, 0.80) compared to those whose parents did not control their diet to lose weight. Among girls whose parents controlled their diet, mean zBMIs were 0.77 units higher (95% CI 0.64, 0.91) at age 7 and 0.29 units higher (95% CI 0.10, 0.48) by age 17.

There was strong evidence in the fully adjusted model that control of the child's diet to lose weight was associated with lower body satisfaction scores at age 11 (mean difference -0.30, 95% CI -0.46, -0.14). There was no evidence that this association varied by child sex (p for interaction=0.596) or differentially across time (p for interaction=0.878). Trajectories of BMI and body satisfaction among children whose parents did and did not control their diet to help them lose weight are shown in **Figure 8-4, C and D**.

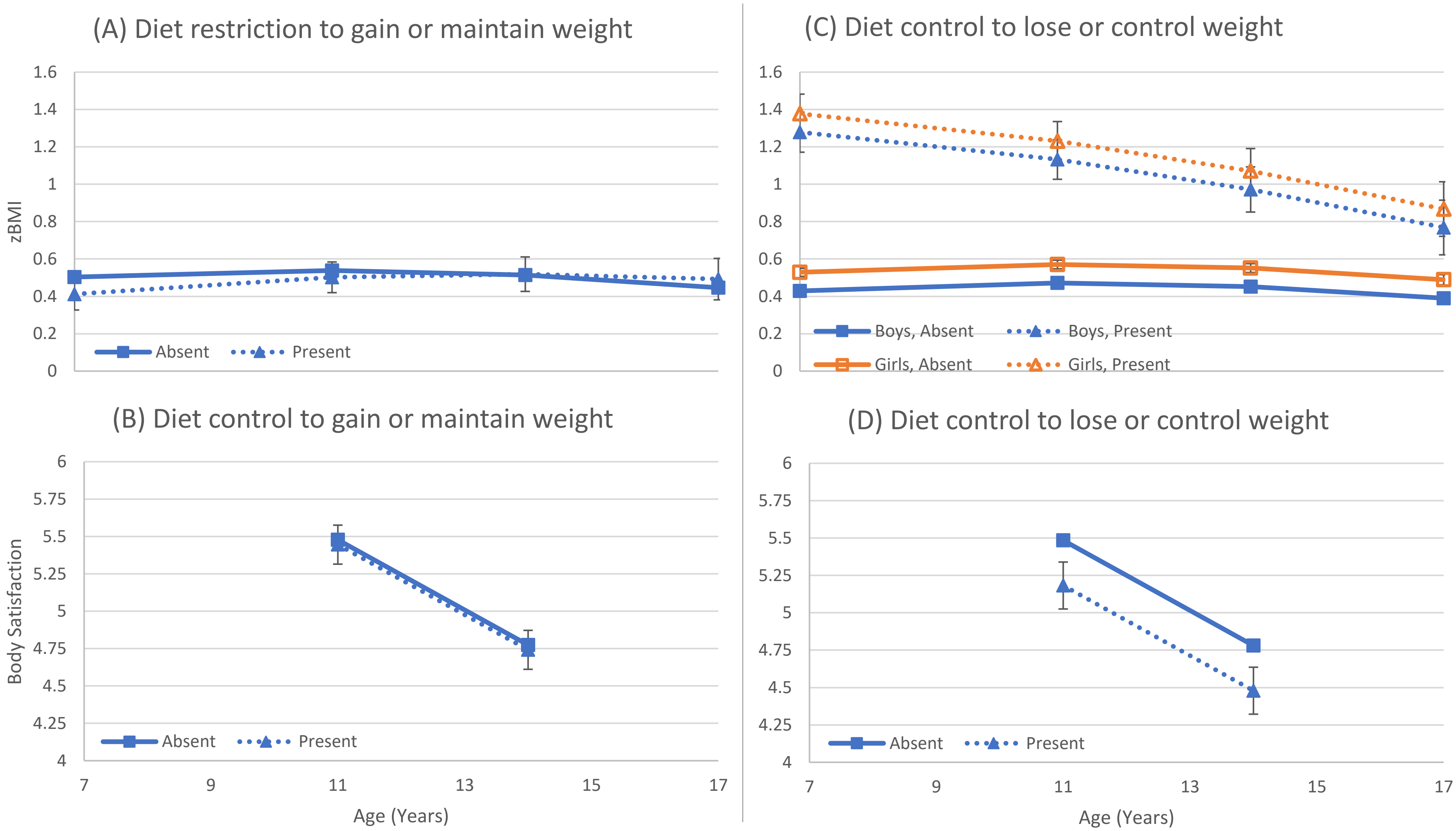

Figure 8-4. Post-hoc analysis: Disaggregating diet control for weight management. Trajectories of child BMI z score and body satisfaction score according to parent reported diet control to gain or manage weight and diet control to lose or control weight.

8.3.7 Sensitivity analyses

Analyses of the longitudinal associations of parental concern about future weight and control of their child's diet with BMI and body satisfaction were repeated in a sample with complete data on exposure and confounders, and with at least one valid measure on outcomes (N for BMI= 9,447; N for body satisfaction= 8,848). Results did not vary

from those in the main analyses, but confidence intervals were slightly wider and some p values for interactions were larger, which could indicate lower statistical power in this smaller sample size. Results can be found in **Appendix for Chapter 8, Table 17-19**.

Further exploration of potential confounding by parental BMI in early childhood was conducted. Results were repeated using maternal BMI when the child was aged 3 in lieu of pre-pregnancy BMI, which did not alter estimates (**Appendix for Chapter 8, Table 21-23**). Similarly, in a sub-sample of children from two-parent households, additional adjustment for paternal BMI at age 3 did not result in further attenuation of estimates (**Appendix for Chapter 8, Table 25-26**).

A final sensitivity analysis investigated whether including parents who controlled their child's diet for their teeth with those who did so to give a healthy diet would affect results. These groups were similar in terms of demographics (see **Appendix for Chapter 8, Table 10**) and multilevel regression model results including diet control for teeth were similar to those of healthy diet alone (**Appendix for Chapter 8, Table 11-13**).

8.4 Discussion

8.4.1 Summary of main findings

This study aimed to investigate the associations of parental concern about their child's future weight and control of their child's diet at age 5 years with child BMI and body satisfaction trajectory into adolescence. There was limited evidence that parental concern about future weight or diet control for weight-related reasons was associated with meaningful differences in BMI trajectory across 12 years of follow-up, largely consistent with initial hypotheses (**Hypothesis 9**); even after controlling for the child's prior BMI, children whose parents were concerned about their future weight or who had controlled their diet to lose weight had higher BMI z scores at all ages from 7 to 17 years. Although there was evidence that these children lost more weight over time, this did not correspond with improved body satisfaction; these children had significantly lower body satisfaction trajectories across early adolescence, which was in line with initial hypotheses (**Hypothesis 10**). There was some evidence that body satisfaction decreased more over time in children whose parents controlled their diet with the goal of providing a healthy, balanced diet, compared to those whose parents did not, although these differences were small.

These findings are strengthened by the use of a negative control to investigate potential residual confounding of the associations observed. The results suggested that associations observed among the exposures of interest were not likely to be due to unmeasured factors associated with diet control generally. This supports the underlying theory that diet control practices such as restriction, moralising of certain foods as “good” and “bad”, and a focus on thinness over healthiness may not be helpful to reducing childhood obesity and may be harmful for children’s emotional wellbeing.

8.4.2 Comparison with previous literature

Few longitudinal studies have investigated the association of parental dietary control practices on children’s weight in the UK. These broadly find that parental feeding practices arise in response to child BMI and are unlikely to exert change on subsequent weight, with the latter being largely consistent with the findings of the current study (144,244). This is also in line with evidence from experimental studies of family-based weight loss interventions, which suggests that reductions in BMI may be non-significant and not sustained in the long-term (255,256).

The finding that parental dietary control to reduce their child’s weight or as a reward or punishment is associated with lower body satisfaction in early adolescence is consistent with associations with disordered eating behaviours in a prospective cohort study of children in the Netherlands (Generation R), but not in a cohort of twins in the UK (Gemini) (148). In the latter, parental pressure to eat was associated with disordered eating (148). This practice may be captured by the measure of dietary control used in the current study, which captures parental control of the type or amount their child eats. Additionally, the inconsistent findings in the current and the twin study may be attributable to differences in early life feeding between singletons and twins, with the latter more likely to be born prematurely and at low birthweights (148), which may influence weight development and feeding practices in childhood. Findings in the current study are also consistent with wider evidence that familial pressure to lose weight is associated with increased weight-stigmatised beliefs (249), which are closely linked with body image and mental health concerns (257).

UK childhood obesity policies place families at the heart of their action and largely place responsibility upon individuals to make behaviour changes (53). For example, parents of children identified through the National Child Measurement Programme as having BMI values in the overweight or very overweight range receive a letter that encourages the family to eat more healthily (258). Where the Local Authority has family weight management services, families are also referred to these; though a recent survey found that one in five Local Authorities does not have such services due to fiscal constraints (259). Furthermore, analysis by The Food Foundation suggests that the most deprived fifth of UK families would need to spend half of their disposable income on food in order to achieve the Government-recommended healthy diet (260). In contrast, the least deprived fifth would spend just 11%. This highlights the economic barriers that may prevent families from achieving recommended healthy diets, regardless of National Child Measurement Programme advice. More interventionist policies which target the social determinants of obesity may be more effective and equitable than signposting parents to dietary advice (53).

The findings of the current study are particularly relevant to the National Child Measurement Programme, as studies suggest that weight feedback from the programme may increase parents' use of dietary restriction (241). Notably, there has been no long-term evaluation of the National Child Measurement Programme on children's BMI. However, a randomised controlled trial of a similar programme in one US state suggested that weight feedback did not lead to changes in BMI two years later but did decrease body satisfaction, which is consistent with the current study (261). If these associations are causal, these findings suggest that existing policies that rely on parents to control their child's diet to curb childhood overweight might not have the desired consequences in terms of BMI and could potentially lead to lower body satisfaction. Although further research is needed to confirm these findings, this suggests that further evaluation of the impacts of the National Child Measurement Programme on child BMI and wellbeing is needed.

It was interesting that there was some limited evidence that parental dietary control with the goal of providing their child with a healthy, balanced diet was associated with a greater reduction in body satisfaction from age 11 to 14 compared to children whose parents did not control their diet in this way. Although the decrease was small and may not translate into a meaningful difference, this was surprising and may have important implications for public health strategies aimed at reducing childhood overweight, though further investigation is required. Within the UK's childhood obesity strategy, children learn about the importance of healthy eating, including monitoring calorie intake, and preventing obesity, which is part of the statutory curriculum. Children's knowledge of healthy eating and lifestyles are also part of assessment criteria during Ofsted inspections. It is possible that this messaging, from parents or from schools, may contribute to children internalising weight stigma and feeling shame or fear, perhaps particularly as their bodies change during the pubertal transition, which is approximately the ages at which body satisfaction was measured in the current study.

In the current study it is not possible to investigate the mechanisms by which parental dietary control in childhood is associated with lower body satisfaction in adolescence. Previous studies have suggested that how the control is implemented may be important (146). Dietary control has been conceptualised as being either overt, where the child is aware of dietary restrictions or restraints, or covert, where the child is unaware (262). An example of the latter may be avoiding having foods high in sugar, salt, or fat in the house. It is plausible that the mechanisms by which dietary control is carried out may vary by the parents' motivation; for example, dietary control as a reward or punishment may be more overt than control to give a healthy, balanced diet, which may be more covert. Evidence from eating disorder research suggests that parental messaging around weight, as well as what to eat and what not to eat can contribute to body shame, disordered eating, and depression (147,263,264). Further research should investigate the mechanisms linking parental dietary control and body satisfaction in adolescence, the findings of which could also be relevant to family-based weight loss interventions, as well as how the National Child Measurement Programme provides weight feedback.

8.4.3 Limitations

Measures of dietary control were self-reported by parents and broadly measured the reasons why parents may control their child’s diet. However, it was not possible to investigate how these behaviours were carried out and whether and how they were perceived by the child. These may be important potentially moderating factors of the associations observed and it should be noted that it is not possible to disentangle what factors may be driving the associations found in this study.

Furthermore, parents could report multiple reasons for dietary control. This study attempted to isolate the main effects of specific weight-related reasons by adjusting for other reported ones. Count variables of the number of other reasons for control that parents reported were generated, but this may not have been sufficient to adjust for other control reasons.

In addition, parental dietary control as a reward or punishment was included together as one potential response option in the age 5 questionnaire in the Millennium Cohort Study. However, it is likely that control as a punishment for the child is experienced very differently from restriction as a reward. Further research should be conducted to understand how these two potentially contrasting behaviours are practiced and by whom. In addition, these may be differentially associated with BMI and body satisfaction; although it was not possible to differentiate between them in the current analysis, their measurement together may blur their true associations.

Additionally, some reasons for dietary control were reported by a relatively small proportion of parents, which may limit the statistical power of analyses, particularly where interactions between the exposure and both child sex and age were tested. In post-hoc analyses, dietary control for weight management was disaggregated into that with the goal of the child gaining weight and the goal of the child losing weight. The latter was reported by 2.7% of parents and therefore tests of interactions in these analyses may be underpowered.

Longitudinal studies are prone to attrition, which is more likely to occur among more disadvantaged and less healthy participants (218). In this study, a slightly greater proportion of cohort members with BMIs in the underweight or very overweight ranges at age 3 were missing outcome data, compared to those with healthy BMIs, suggesting that attrition was more likely to affect families who may be more prone to use dietary control or be concerned about their child's weight. However, multiple imputation of missing outcome and confounder data was employed to mitigate the risk of attrition bias. Nevertheless, attrition prior to age 5, when the exposure was measured, may reduce the generalisability of findings to the wider population.

Finally, a number of putative confounders were adjusted for, and methodological approaches were used to investigate the potential for residual confounding (i.e., a negative control). However, as with any observational study, there may be residual confounding, which may bias estimates of the association. In particular, it was not possible to account for genetic confounding, although parental BMI was controlled for which could be a marker of shared genetic and environmental factors within families. Additionally, previous research has suggested that parental feeding practices (including diet control or restriction) may occur as a response to the child's earlier growth and appetite (144,265). Although adjustment was made for the child's birthweight and BMI at age 3, there may be residual confounding by the child's appetite in early life, for which it was not possible to control in the study due to a lack of data in the Millennium Cohort Study. Recent evidence from Generation R in the Netherlands and the Gemini study in the UK suggests that aspects of appetite at age 4-5 (for example, emotional overeating) are associated with some disordered eating symptoms in adolescence (266). However, it is not known whether the association is mediated by parental feeding practices in response to the child's appetite, and therefore further research is needed.

8.4.4 Interim conclusions

This study investigated the association between parental concern about their child being overweight in the future and control of their child's diet for weight related reasons at age 5 with trajectories of BMI to age 17 and body satisfaction to age 14. Results suggested that regardless of their BMI at age 3, children whose parents were concerned about future weight and controlled their diet to lose weight had higher trajectories of BMI and lower trajectories of body satisfaction across adolescence. Dietary control as a reward or punishment also appeared to be associated with reductions in body satisfaction across adolescence. These findings are important as dietary changes are a common response to the National Child Measurement

Programme in England and invite further investigation of the potential unintended consequences on mental wellbeing of childhood obesity policies.

9 Discussion

This thesis aimed to understand the role that body image concerns play in the association between childhood weight and adolescent depressive symptoms, and explore potentially modifiable early life family factors that may be associated with the development of weight and body image concerns. In this chapter, the main findings of the thesis are summarized, and their limitations and implications are discussed.

9.1 Summary of main findings

Four objectives were identified and addressed through analysis of Millennium Cohort Study data. These were:

1. To model childhood trajectories of body composition and explore their early life correlates.
2. To investigate the association between childhood body composition trajectories and adolescent body image concerns.
3. To investigate the extent to which body satisfaction in early adolescence mediates the association between childhood body composition trajectories and depressive symptoms in later adolescence.
4. To investigate the association of parent-reported concern about their child's weight and control of their child's diet in early childhood with trajectories of BMI and body satisfaction into adolescence.

For the first objective (**Childhood Body Composition Trajectories and their Early Life Correlates**), distinct trajectories of BMI from age 3 to 14, and of adiposity and a proxy for muscularity from age 7 to 14, were observed, in line with initial hypotheses (**Hypothesis 1**). In similarity to prior studies of childhood BMI trajectories, three groups were found, representing low, moderate, and high trajectories of weight development. These three groups were mirrored when using markers of adiposity (FMI and FM/FFM) and a proxy for muscularity (FFMI). Descriptive analyses of early life correlates of body composition trajectories revealed that indicators of early life socioeconomic disadvantage were associated with higher trajectories of BMI and adiposity. Body composition trajectories were generally stable across childhood and early adolescence. Although these analyses were descriptive and therefore no adjustment for potential confounders was performed, this could suggest that public health measures aimed at reducing the prevalence of childhood overweight should focus on reducing early life socioeconomic inequalities.

Addressing Objective 2 (**Association of Childhood Body Composition Trajectories and Body Image Concerns in Adolescence**), findings suggested that higher trajectories of BMI and adiposity were associated with lower body satisfaction scores and increased odds of using dieting or exercise to lose weight, which was consistent with **Hypothesis 2**. There was some evidence to suggest that the magnitude of association between adiposity measures and body satisfaction was greater than for BMI, in line with **Hypothesis 3**, although this was not seen with other indicators of body image concerns. There was some evidence that differences in body image outcomes across muscularity trajectory groups were smaller than differences seen across BMI and adiposity trajectories, though there was no evidence to support the hypothesis that higher muscularity trajectories would be associated with higher body satisfaction scores (**Hypothesis 4**). In contrast to initial hypotheses, there was little evidence of sex differences in the association of childhood adiposity and body image concerns in adolescence, suggesting that boys and girls may be equally susceptible to negative societal messaging that stigmatises people with higher weights.

In Objective 3 (**Investigating the Mediating Role of Body Satisfaction in the Association of Childhood Body Composition Trajectory and Adolescent Depressive Symptoms**), higher body satisfaction was associated with lower depressive symptoms, even after adjusting for baseline mental health (**Hypothesis 6**) and results suggested that almost half of the association between childhood body composition trajectory and late adolescent depressive symptoms was mediated via body satisfaction in early adolescence, in line with **Hypothesis 7**. Assuming a causal interpretation, this suggests that an intervention aimed at improving body satisfaction by age 14 could reduce later adolescent depressive symptoms in young people with higher weights. Consistent with **Hypothesis 5**, children with higher trajectories of adiposity across childhood had higher depressive symptoms in late adolescence, while the evidence for an association between BMI trajectory and depressive symptoms was weaker. This highlights the importance of considering adiposity-specific measures when investigating potential health outcomes associated with weight. Yet, in contrast to **Hypothesis 8**, there was no evidence to suggest that the proportion mediated was greater when using adiposity trajectory as the exposure compared to BMI trajectory. No sex differences were observed in associations, using either BMI or adiposity, providing further evidence that girls and boys are equally exposed to societal weight stigma, at least by age 14. These findings are important as there are effective body image interventions and they have also been shown to reduce depressive symptoms. Findings invite further investigation of the sources of weight stigma, including whether childhood obesity strategies may be contributing to rising body dissatisfaction and depressive symptoms.

Finally, in Objective 4 (**Parental Concern about their Child's Future Weight and Control of their Child's Diet at Age 5: Associations with Trajectories of BMI and Body Satisfaction**), children whose parents were concerned about their future weight, or controlled their diet to help them lose weight or as a reward or punishment, had higher BMI trajectories across adolescence compared to their peers. These children also had lower body satisfaction scores across early adolescence. These findings were irrespective of the child's prior BMI and were consistent with initial hypotheses (**Hypothesis 9 and 10**). Interestingly, there was some evidence that children whose parents controlled their diet with the goal of providing a healthy, balanced diet may have greater reductions in body satisfaction score across early adolescence, compared to children whose parents did not restrict their diet in this way, although the differences appeared small in magnitude and might not, therefore, translate to meaningful differences overall. Findings were strengthened by the use of a negative control, which suggested that results were unlikely to be affected by residual confounding associated with dietary control practices generally, although it was not possible to take account of some potentially important early life factors such as the child's growth or appetite. Policies aimed at reducing childhood overweight in the UK often rely on parents to make lifestyle changes, including controlling or restricting their child's diet. However, these results suggest that this may not have the desired benefit to children's BMIs and may, in fact, be detrimental to their mental wellbeing. One possible explanation for this is that focusing on weight as a marker of health and attaching morals or emotions to certain foods as 'good' and 'bad' may foster feelings of shame and fear in children and increase the risk of internalising weight stigma. It is crucial that when developing policies aimed at reducing childhood overweight, the potential for unintended consequences on mental wellbeing are considered.

9.2 Limitations

Methodological limitations relating to specific studies have previously been discussed in each analytical chapter. Therefore, this section focuses only on those relevant across the thesis.

9.2.1 Measurement of body composition

This thesis used measures of different aspects of body composition, alongside BMI which is used ubiquitously as a proxy for adiposity in research. Investigations of the associations between body composition measures and body satisfaction and depressive symptoms were novel. There was some evidence that different body composition measures were differentially associated with body image concerns and depressive symptoms. Adiposity results were at times different to those seen using BMI, suggesting that, particularly in relation to body image and weight stigma, body composition measures may reflect different mechanisms than BMI. This has implications for the research field, which will be discussed in more depth in **9.5** below.

Body composition measures were derived from percentage body fat which was captured using bioelectrical impedance analysis. As a low-cost and non-invasive way to accurately estimate percentage body fat, it is an ideal method in large, longitudinal studies such as the Millennium Cohort Study. While dual x-ray absorptiometry scans are considered the gold standard method of body compositional analysis, these are more expensive, require attendance at a clinic and may require a specialist to interpret, which limit their feasibility for inclusion in cohort studies. Evidence demonstrates that bioelectrical impedance analysis and dual x-ray absorptiometry provide similar estimates at a population level (189–191), suggesting that bioelectrical impedance analysis is a suitable alternative for estimating adiposity measures in general population studies.

The advantage of dual x-ray absorptiometry over bioelectrical impedance analysis, however, is its ability to distinguish lean mass from other fat-free mass. Measures of fat-free mass in this thesis have included any mass that is not estimated to be fat, which includes mass from muscle, bones and organs. This may limit the interpretation of findings in **Chapter 6** relating to the role that muscularity plays in the development of body image concerns, as FFMI measures could be capturing differences in bone density, as has been suggested in other research (170), or be acting as a general marker of larger body size or taller stature. Additionally, other studies using FFMI have controlled for levels of fat mass (171), as it has been documented that with increases in fat mass there are adaptive increases in muscle mass to support a heavier frame (192,193). Due to the longitudinal nature of the trajectories used in this thesis, it was not possible to include this adjustment, and therefore it is not possible to assume that FFMI is a valid proxy measure of muscularity, as individuals with higher FFMI trajectories may have so as a consequence of their higher FMI trajectories. Therefore, the results of the association between FFMI and body image concerns may be in part still reflecting the association of FMI trajectories.

Another limitation of the FMI and FFMI measures used in this thesis relates to their derivation. It is standard practice to calculate BMI as weight divided by height squared, which is considered in adults to appropriately account for the correlation between weight and height (67). As such, where FMI and FFMI measures are used, they are also generally calculated using height squared, to similarly account for their association with height. However, recent research has suggested that indexing height to two (height squared) is not sufficient to remove the correlation between weight and height in children (67). In order to fully account for this correlation in BMI for example, height should be indexed to a number between 2 and 3, dependent on the age of the children, while for FMI height should in fact be indexed to >4 at certain ages (171). It is possible for these numbers to be calculated in the sample, for example using Benn parameters. However, this is not yet established practice, even in research of children. As there is very limited research investigating the role of different aspects of body composition in the development of body image concerns, it was considered appropriate to first examine these measures using the standard height squared equations, while further analysis with Benn parameters to index height could follow as future research to address this limitation. Nevertheless, using the present calculations in this thesis, it is possible that there may be residual confounding by height in the investigated associations, particularly as greater height is socially desirable in men.

A final limitation in relation to these body composition measures is the use of trajectories across childhood. Taking a lifecourse approach is advantageous as it may be overly simplistic to select a single timepoint at which weight may begin to influence a young person’s body image. However, the trajectories modelled were very stable over childhood, with no trajectories crossing one another. In BMI, for example, the three trajectories generally represented children who spent most of their childhood with BMIs that could be categorised into the healthy weight, overweight and very overweight/obese categories. Therefore, it is questionable whether the use of trajectories provides any additional explanatory value, for example, over a continuous measurement of body composition at one time point. This may be particularly limiting in respect to young boys, who have been shown to be at risk of negative body image at both high and low values of BMI (130). In the trajectory analysis, those with underweight BMI values were likely grouped into the low trajectory and could not therefore be investigated as a potentially vulnerable group. However, these young people may be represented in the low FFMI trajectory group, albeit with the limitations to FFMI measures discussed above. Additionally, in sensitivity analyses for Chapter 7 (**7.3.6**), substituting BMI trajectories for BMI as a continuous variable measured at age 11 explained only an additional 0.2% of the variation in depressive symptoms at 17 (as measured by the R squared value), although effect estimates suggested that BMI trajectories may be limited in statistical power.

9.2.2 Measurement of body image concerns

A number of measures of body image concerns were included in this thesis, which capture different theoretical aspects of body image. Due to methodological considerations associated with measures of weight perception and intention, and behaviours to alter weight, the thesis mostly used a single item measure of body satisfaction. This may be viewed as a limitation as body image is considered a multidimensional construct. Additionally, the measure of body satisfaction used throughout the thesis broadly measures satisfaction with looks, and is therefore not specific to, for example, weight and shape. However, satisfaction is highly correlated with cohort member body weight and pubertal status, which would be expected to be associated with weight concerns. This suggests convergent validity of the single item measure of appearance satisfaction with aspects relevant to weight-related concerns.

Measures of other body image concerns were used in **Chapter 6**, including behaviours used in an attempt to lose weight. Importantly, these measures help to capture behaviour change in response to body dissatisfaction, which could be viewed as an escalation of concerns. However, the items included in the Millennium Cohort Study measured broadly dieting and exercise with the intent to lose weight. This does not capture frequency or severity of either behaviour, or a compulsive element of exercise which has been measured in similar cohort studies, such as Growing Up In Ireland. Others, such as the Avon Longitudinal Study of Parents and Children collect data on disordered eating behaviours such as binge eating and purging. There exist validated questionnaires to measure disordered eating or other eating disorder symptoms, such as fear of gaining weight or distorted body perception, but these are not included in the Millennium Cohort Study. This is understandable as the design of each data collection sweep must balance the desire to collect rich, in-depth data with a responsibility to manage the burden on participants. Nevertheless, the measures of dieting and exercise for weight loss that are available in the Millennium Cohort Study capture subclinical behaviours that are increasingly prevalent in the general population (112). Furthermore, from a lifecourse perspective, this presents an opportunity to understand developing body image concerns at a potentially sensitive period when it might be possible to intervene to prevent clinical depression or eating disorders from occurring.

A further limitation that must be acknowledged in relation to the measures of body image concerns utilised is their framing around weight loss. Body image as a developmental concept arises in response to cultural norms and values and is therefore context dependent. In the UK, body ideals have changed over time, even in the last three decades. In the 1990s and early 2000s, celebrities and fashion models helped to glorify ultra-thin female body types, as seen in the rise of size 0 and 00 models. Yet there has been movement away from this, through both European regulation banning size 0 models and a cultural shift toward embracing diversity in media and advertising. However, while the idealised body type may have changed, the cultural value of appearance has not. Therefore, while Millennium Cohort Study participants have reached adolescence in what may be an outwardly more body positive culture, the rise of social media and the embrace of a Kardashian-esque, thin-but-curvy body type suggests young female participants are unlikely to avoid experiencing pressures to look a certain way. However, while body image concerns have been rising over time in young men (111,112), it is not clear how fully these measures, framed around weight loss, may capture such concerns in men (126). The socially desirable body type in men is an athletic and muscular build (267,268), and so adolescent boys wanting to gain muscle may not report, for example, exercising to lose weight. However, the prevalence in late adolescent boys in the Millennium Cohort Study is concordant with estimates from studies measuring muscle-building behaviours specifically, suggesting its validity in boys (267). Nevertheless, this is an important consideration given that men have historically been overlooked in eating disorder-related research.

9.2.3 Sample and generalisability

Longitudinal studies are prone to attrition and despite efforts to over-sample populations from disadvantaged areas, attrition remained higher among participants from ethnically and socioeconomically disadvantaged areas (157). Patterns of missing data were explored in all analytical studies and multiple imputation was used to address missing data on outcomes and confounders. However, samples were restricted to those with valid exposure data, which may reduce the generalisability of findings to the UK population and could contribute to biased estimates, as those with missing exposure data may be more disadvantaged and less healthy than those with complete data (218). Nevertheless, amongst those from ethnic and disadvantaged strata, response rates were sufficient (above 60% in all UK nations) (156,157). In tandem with multiple imputation of missing data and sampling weights, it is likely that findings are generalisable to the UK population of young people.

9.2.4 Causality

It is challenging to infer causality from observational data, and particularly challenging in the associations investigated in this thesis is the temporal order of exposure and outcome. The existing literature on the relationships between weight, body image, and depressive symptoms demonstrates the bidirectionality in associations between all three (89,132,137). In an effort to address this, the potential for reverse causality was mitigated where possible, by including a baseline measurement of the outcome as a confounding variable, measured at the same time point or a prior time point to the measurement of the exposure variable; for example, in **Chapter 7**, adjustment is made for baseline internalising and externalising symptoms, and in **Chapter 8**, multilevel models control for BMI and emotional symptoms prior to the measurement of exposures. This approach strengthens the underlying causal assumptions of hypotheses tested.

In **Chapter 6 and 7**, there was some temporal overlap between the final measure of body composition in trajectories and the measurement of body image concerns at age 14. However, the trajectories, in particular BMI trajectories which are measured from age 3, are likely to predate a child's self-concept of their body image, even though internalised fatphobia has been demonstrated in pre-school aged children (105).

Finally, as relates to all analysis of observational data, it is not possible to rule out biases arising from residual or unmeasured confounding. Using extensive searching of the literature, existing theory, and directed acyclic graphs, a wide range of putative confounders were considered and accounted for in analyses, including factors known to be associated with the development of eating disorders. However, it was not possible to consider genetic confounding, such as genetic predisposition to mental ill-health. To mitigate this, in all studies, parental phenotypic data were included, such as parental BMI and/or mental health, which may to some extent account for shared genetic or environmental factors. Additionally in **Chapter 8**, a negative control was used to investigate potential residual confounding. Yet, the categorisation of some confounding variables may have resulted in more limited statistical adjustment, such as the decision to dichotomise parental psychological distress scores. This was done in an attempt to avoid ignoring fathers, exclude single parent households, or impute missing paternal psychological distress scores inappropriately (such as where they are missing due to the father not being present in the child's life). Nevertheless, this data handling decision may have increased the risk of residual confounding by parental mental health. Furthermore, some child characteristics considered as confounders were reported by their parents when the child was aged approximately 9 months. Parent-reported data were selected to minimise missing data, but this precluded investigation of child-reported ethnicity and gender identity. There are small numbers within the sample who report a different ethnicity to that reported by their parents and also small numbers of cohort members who gender identity does not match the sex they were assigned at birth. These potential changes in identity across childhood or adolescence may be important for the development of body image concerns or depressive symptoms, but this was beyond the scope of this thesis.

9.3 Implications for mental health policy

The results of this thesis provide strong evidence to suggest that promoting positive body image may contribute to reduced depressive symptoms in later adolescence. While these findings relate specifically to body image in mid adolescence (as body satisfaction at age 14 was modelled in mediation analyses in **Chapter 7**), similar studies in early adolescence suggests that intervening by age 11 may also be beneficial to depressive symptoms (219). Wider evidence that pre-school aged children show weight stigmatised beliefs indicates that interventions targeting body image in childhood may be advantageous (105). Additionally, although results of mediation analyses speak to the potential reduction in depressive symptoms among adolescents with higher weights, more broadly, this thesis has also shown that body image concerns are highly prevalent in young people with BMIs in the healthy range. This highlights the importance of universal body image intervention programmes, in addition to interventions targeting only those with higher weights.

Major strengths of this work include the use of a large, socially and ethnically diverse cohort, which is representative of young people across the UK. The use of causal inference methods strengthens the conclusions that can be drawn from observational data. Crucially, the results from causal mediation analyses in this thesis (**Chapter 7**) are consistent with those from meta-analytic studies of randomised controlled trials showing that interventions targeting body image concerns also improve depressive symptoms in adolescents (135). These body image interventions are commonly designed to be delivered in schools by teachers and have been demonstrated to be effective at reducing body image concerns, at least in the short-term (239,269–271). Interventions often involve critiquing appearance-related societal ideals and the overvaluation of thinness, or improving media literacy through discussion of image-enhancement practices in advertising and on social media (135). This wider evidence to support school-based body image interventions is valuable as recent UK health policy focuses on schools as key sources of mental health support in a wider goal of preventing mental ill-health (31,32).

It should be noted that body image interventions have been predominantly developed targeting girls in adolescence (135,269,270). Fewer have been evaluated in both boys and girls (239,271), although this thesis has generated evidence suggesting that both are at risk of body image concerns. School-based interventions delivered by teachers are unlikely to segregate by gender, so there is room for further development in this area. Furthermore, it is important to explore whether interventions delivered at an earlier age are effective at preventing body image concerns from arising across childhood and adolescence, given that weight stigma may be present in children starting school (105). Nevertheless, the results of this thesis highlight the potential benefits of interventions aimed at improving or preventing body image concerns and call for increased and protected funding for schools to deliver them. Given the wider evidence that body image concerns may lead to greater weight gain and act as a barrier to physical activity (107,137), this may have lifelong benefits to physical health and wellbeing, in addition to improving mental health.

9.4 Implications for childhood obesity policy

Reducing the prevalence of childhood overweight is a major public health target in the UK. Strategies introduced include increasing knowledge of healthy choices through education in schools, nutritional labelling in shops and calorie labelling in restaurant and takeaway menus. Furthermore, the National Child Measurement Programme provides health surveillance on the BMIs of 4–5-year-olds and 10–11-year-olds with feedback to parents to encourage behaviour change if their child's BMI is above the healthy range. Although evaluation of this programme suggests that many parents do intend to make changes to their child's diet following this feedback (241,272), the results of this thesis suggest that parental dietary control for weight-related reasons may have negative impacts on body image in early adolescence (**Chapter 8**). This is concerning as it raises the question of whether policies which encourage parents to control or restrict their child's diet could have unintended consequences on their child's emotional wellbeing across the young lifecourse. More so, as this thesis has shown that approximately half of the association between childhood weight and later adolescent depressive symptoms is mediated via body dissatisfaction, this thesis calls for urgent consideration and evaluation of the impact of childhood obesity strategies on young people's mental health, including the National Child Measurement Programme.

Furthermore, this thesis has discussed major limitations of BMI as a measure of adiposity in young people and investigated whether these limitations have implications for understanding the association between weight and body image concerns or depressive symptoms at the population level. There was some evidence that a greater magnitude of association was observed using adiposity-specific measures with both body dissatisfaction and depressive symptoms in adolescence. This suggests that even at the population level, which is the intended application of BMI, it may be preferable to use adiposity-specific measures. Bioelectrical impedance analysis provides an easy method to estimate adiposity, such as through body fat percentage, as it uses the same equipment as would be needed to measure BMI; an individual would have their height measured and stand on a set of scales with bioelectrical impedance analysis functionality. Using the same calculations as applied in this thesis (**4.5.1**), FMI could be calculated, preferably using Benn parameters to appropriately control for the correlation between weight and height. The relative proportions of fat and fat-free mass could also be easily calculated (i.e., FM/FFM). Therefore, these measures could be incorporated into the National Child Measurement Programme to provide better identification of children at risk of obesity-related health consequences. Although on the whole BMI is considered to perform well as a measure of adiposity at the population level, this is due to high correlations at the extremes of BMI (214). As the majority of children have BMIs in the middle ranges, where BMI may not be a good proxy for adiposity (69), bioelectrical impedance analysis measures of adiposity specifically could provide better identification of children who are overweight. This is particularly important given that BMI is applied and interpreted at an individual level in the National Child Measurement Programme, although this is not advised, and family behaviour change is encouraged based on the categorisation of BMI.

This also raises a broader question around the meaning of BMI in the National Child Measurement Programme. Here, BMI or thinness seems to function as an indicator of health. Based on the categorisation of BMI, families are advised to adopt or increase healthy lifestyle behaviours. Feedback letters advise the benefits of healthy eating and physical activity. In this sense, BMI is potentially acting as a proxy for these healthy behaviours, which could in fact be measured directly, with further support provided to those who are not meeting the recommended guidelines. Instead, the use of BMI as a marker of health may be contributing to weight stigma by valuing thinness over actual healthy habits. Qualitative studies of the National Child Measurement Programme have shown that parents often reject the programme’s categorisation of their child’s weight for this reason (273). Instead, some parents appear to take a more holistic view of their child's health, considering their diet, activity levels and emotional wellbeing, which can reduce their perceived credibility of weight feedback (273). Therefore, incorporating measures of health behaviours into annual National Child Measurement Programme data collection may provide a better understanding of children's risk of negative health outcomes, help to improve parental acceptance of weight feedback, and prevent further perpetuation in society that thinness is analogous with health.

However, it is important to also consider the potential negative impacts of parental dietary control on children's emotional development across adolescence, as suggested in this thesis. This calls into question the reliance in childhood obesity strategies on individual behaviour change, which some have stated is likely to be ineffective and increase social inequalities (53). Although some families of children identified as overweight will receive referrals to weight management services, access to this support is inequitable due to fiscal pressures on local authorities (259). Behaviour change requires families to draw on their own resources, which may be limited in more socioeconomically disadvantaged families. For example, more healthy foods are much more expensive than less healthy foods per calorie (260). To meet government guidelines for a healthy diet, the most disadvantaged families would need to spend 50% of their disposable income on food, compared to 11% in the most advantaged families (260). In addition, there are substantial differences in the personal time resources needed to prepare a meal from fresh, raw ingredients compared to a more processed meal. Financial and time resource constraints are likely to also impact children's access to physical activities.

Therefore, this thesis calls for further action on the social determinants of childhood overweight. Strong social gradients in the prevalence of childhood overweight should prompt action to reduce poverty and social inequalities (38,274), as this may provide more families with the means to eat healthily and be physically active. By facilitating access to healthy lifestyles, rather than focusing on weight as a marker of health, this may reduce weight stigma, body dissatisfaction and potentially depressive symptoms in young people, promoting lifelong health and wellbeing.

9.5 Implications for future research

Several areas for further research have been identified in discussing the limitations and implications of findings in this thesis.

First, further investigation of the role of muscularity in the development of body dissatisfaction is needed. This should utilise methods that specifically measure lean mass, such as dual x-ray absorptiometry scanning, which could help elucidate risk factors for body dissatisfaction in young men, who have historically been excluded from body image and eating disorder research. These data are available in the Avon Longitudinal Study of Parents and Children, which could facilitate exploration of this association. However, as the study is limited to one region in England, it has limited generalisability to the wider UK population of young people, including those from ethnic minority backgrounds. Therefore, this thesis also calls for the inclusion of dual x-ray absorptiometry scanning in other longitudinal, general population-representative UK datasets.

Furthermore, the body image research field has evolved over the last 20 years to recognise that body image concerns also affect men and boys and are experienced and expressed in different ways to women and girls (275). Although male body dissatisfaction is predominantly characterised by a drive for muscularity (and a more muscular physique may be presently desirable among women also) (275,276), this aspect of body dissatisfaction is poorly captured in large, longitudinal UK datasets and warrants further investigation. This would allow for better understanding of changing body ideals over time and of body image concerns that manifest mostly in young men. This should be combined with measures of body composition so that associations with adiposity and muscularity can be investigated to better understand those at risk. As this thesis has shown that adolescent boys and young people of all weight statuses are at risk of body image concerns, further research is needed to develop effective and sustainable universal body image interventions in young people. This should also consider targeting children in primary schools.

Given the importance of body satisfaction in the links between weight and depressive symptoms in young people, both being major public health priorities, measurements of body image concerns should be included in new and ongoing cohort studies so that changes over time and with age can be understood. Additionally, it was not possible to investigate differences in the associations of weight, body dissatisfaction and depressive symptoms in marginalised populations in this thesis. Further research should explore experiences of body dissatisfaction among ethnic minority and gender diverse young people.

Finally, further research should be conducted to evaluate the impact of National Child Measurement Programme weigh-ins and weight feedback on children's BMIs and body image. This should include longitudinal measures to investigate whether any intended changes to BMI are sustained, and whether there may be any unintended consequences to children's mental wellbeing. Such studies should also include detailed repeated measures of parental behaviour change, including dietary and physical activity changes and whether the parents discuss the child's weight with them following feedback. This could help to highlight potential mechanisms by which body image may be impacted.

9.6 Concluding remarks

Rising overweight and depressive symptoms in young people are major public health challenges in the UK. A large proportion of the association between weight and depressive symptoms is mediated by body satisfaction in early adolescence. This presents a considerable opportunity, as body image concerns are modifiable and there exist effective interventions.

This thesis has shown that cumulative exposure to higher levels of adiposity across childhood is associated with body image concerns in adolescence. However, body image concerns are also highly prevalent in young people with healthy weights, suggesting that universal interventions may be beneficial. In young boys, levels of muscularity may also be important in the development of body image concerns, although further research is needed to investigate this using measurements of lean mass and questionnaires that explore the drive for muscularity. Such research could also further the development of positive body image interventions targeting boys.

UK strategies to reduce the prevalence of overweight often rely on families changing their behaviour to succeed, such as by altering their child's diet. However, this thesis has provided evidence that parental control of their child's diet may lead to lower body satisfaction scores across adolescence. Therefore, in developing policies to reduce childhood overweight, it is crucial to consider the potential for unintended consequences on young people's mental wellbeing and whether the policies may perpetuate weight stigma. This thesis calls for policies to target the structural factors that prevent families from achieving healthy lifestyle recommendations to reduce social inequalities, rather than relying on individual behaviour change.

Given the wider evidence of bidirectional associations between weight, body image concerns and depressive symptoms, it is possible that interventions promoting positive body image may act in support of efforts to reduce the prevalence of overweight in the UK.

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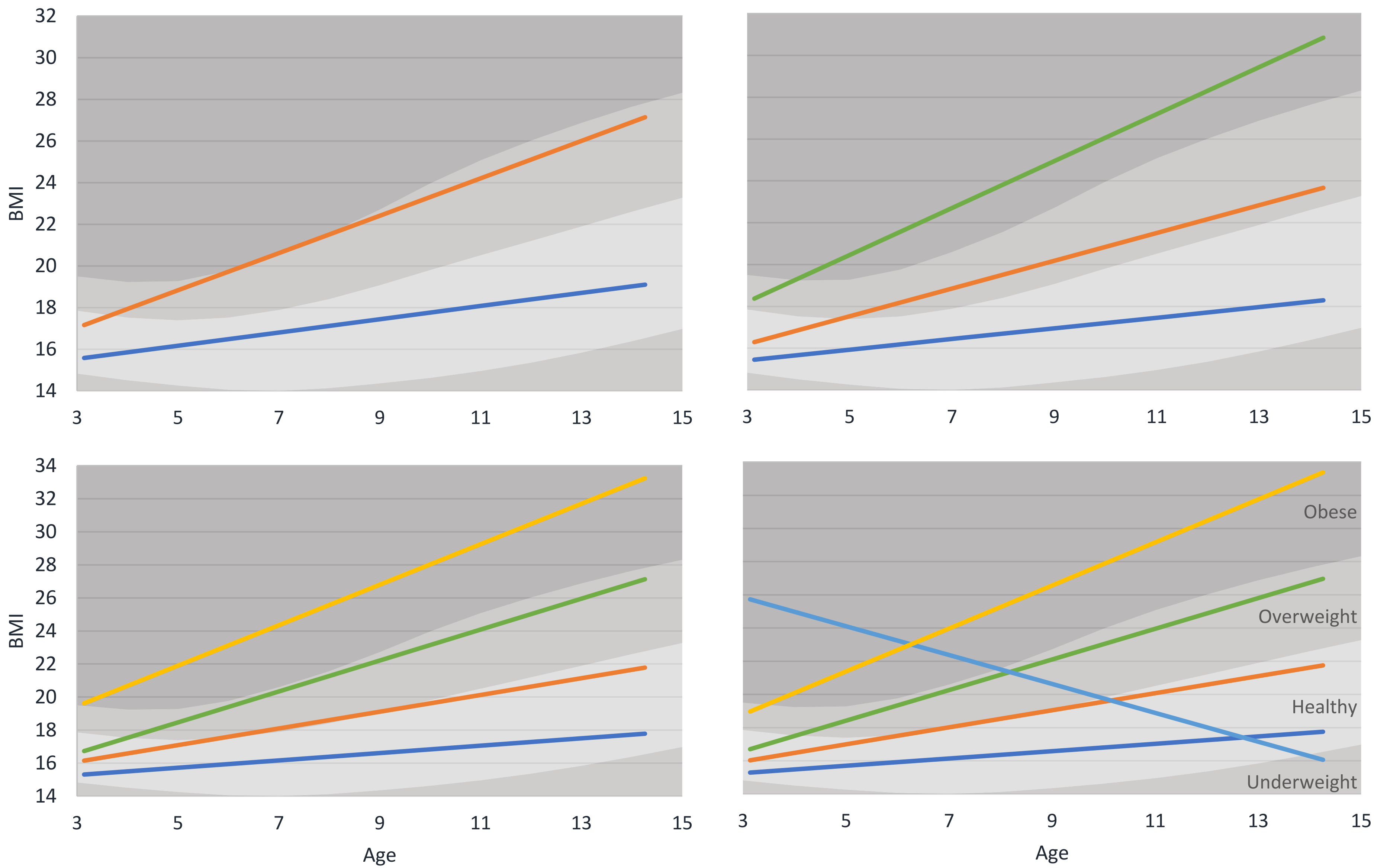
Appendix for Chapter 5, Table 1. Characteristics of sample with BMI data. Sample with valid data (N=14,675). Unweighted proportions.

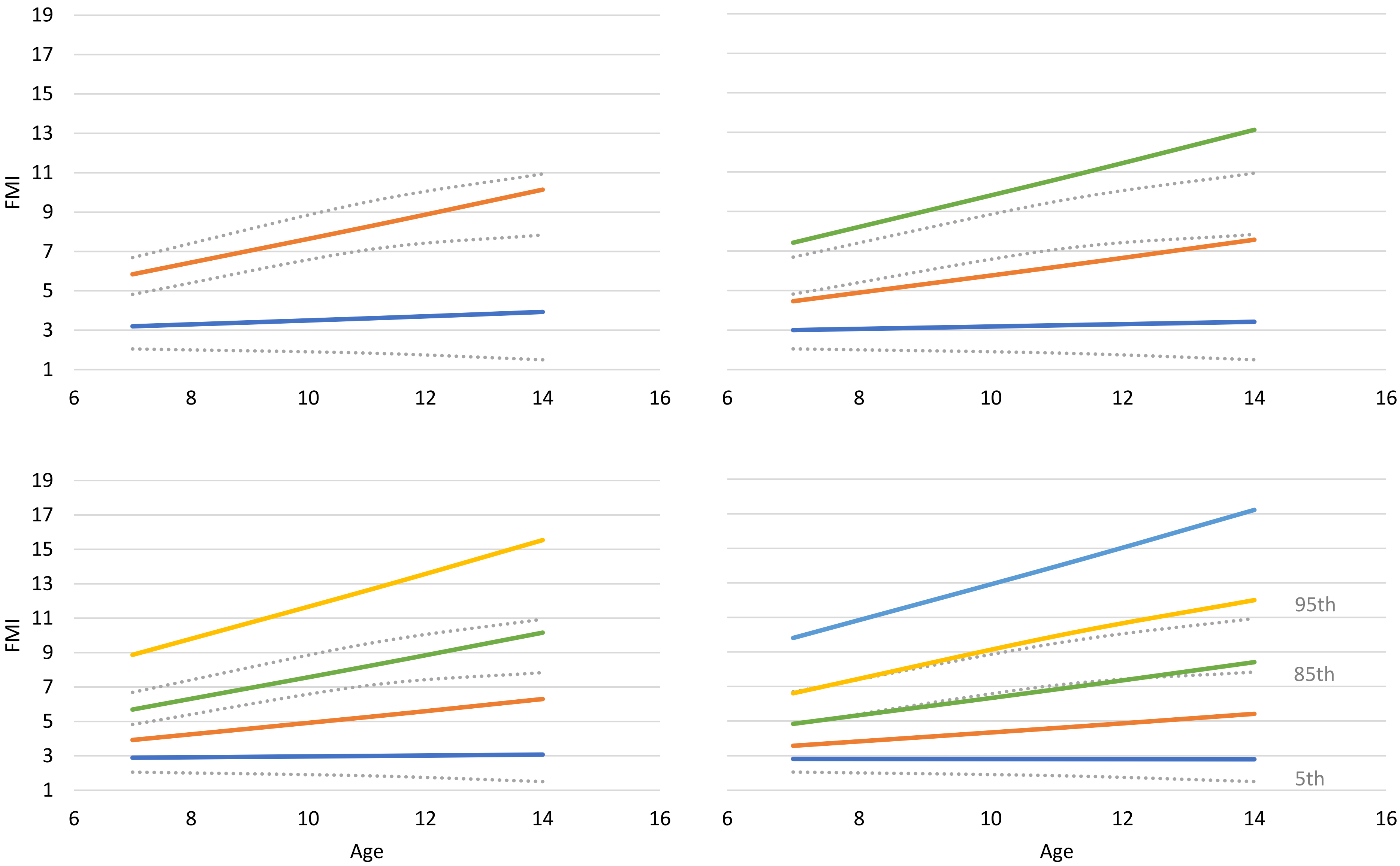
Characteristic	**Sample with BMI data (N=14,675)**	
	N	%
Cohort member mean age in years (SD)		
3	3.14	0.2
5	5.22	0.2
7	7.24	0.3
11	11.17	0.3
14	14.26	0.3
Cohort member sex at birth		
Male	7476	51.9
Female	7199	48.1
Cohort member ethnicity		
White	12322	84.0
Mixed	403	2.8
Indian	367	2.5
Pakistani and Bangladeshi	931	6.3
Black and Black British	438	3.0
Other ethnic group	183	1.2
Fifth of household income at 9 months		
Most disadvantaged	3269	22.3
Second	3179	21.7
Third	2849	19.4
Fourth	2766	18.8
Least disadvantaged	2571	17.5
Highest parental education qualification at 9 months		
None	1689	11.5
NVQ Level 1 (GCSE grade D-G)	886	6.0
NVQ Level 2 (GCSE grade A*-C)	3627	24.7
NVQ Level 3 (A Level)	2416	16.5
NVQ Level 4 (Higher education)	5056	34.4
NVQ Level 5 (Foundation degree)	991	6.8
Highest parental occupational class at 9 months		
Not in work	3467	23.6
Semi-routine or routine	2183	14.9
Lower supervisory or technical	1165	7.9
Small employers or self-employed	964	6.6
Intermediate occupations	1335	9.1
Managerial or professional	5505	37.5

Characteristic	Sample with BMI data (N=14,675)	
	N	%
Cohort member birthweight		
Low birthweight (≤2.5kg)	1008	6.9
Birthweight >2.5kg	13667	93.1
Cohort member gestation		
Pre-term (<37 weeks)	1037	7.1
Term	13638	92.9
Maternal pre-pregnancy BMI		
BMI <25	9496	64.7
BMI 25-29.9	2740	18.7
BMI 30+	2439	16.6
Cohort member was breastfed		
No	4489	30.6
Yes	10160	69.4
Mother smoked in pregnancy		
No	12411	85.6
Yes	2256	15.4
Mother drank alcohol in pregnancy		
No	10228	69.8
Yes	4418	30.2
Maternal age at child's birth		
Under 20	1106	7.5
20 to 29	6617	45.1
30 to 39	6613	45.1
40 plus	337	2.3
Maternal psychological distress at 3 years		
Low	9626	74.9
Moderate	2788	21.7
Severe	443	3.4
Paternal age at child's birth [a]		
Under 20	168	1.4
20 to 29	3942	32.1
30 to 39	6902	56.2
40 plus	1262	10.3
Paternal psychological distress at 3 years [a]		
Low	7429	78.1
Moderate	1927	20.3
Severe	151	1.6

[a] In subsample of two-parent families (N=12,456)



Appendix for Chapter 5, Figure 1. BMI trajectory modelling: visualising different class numbers.



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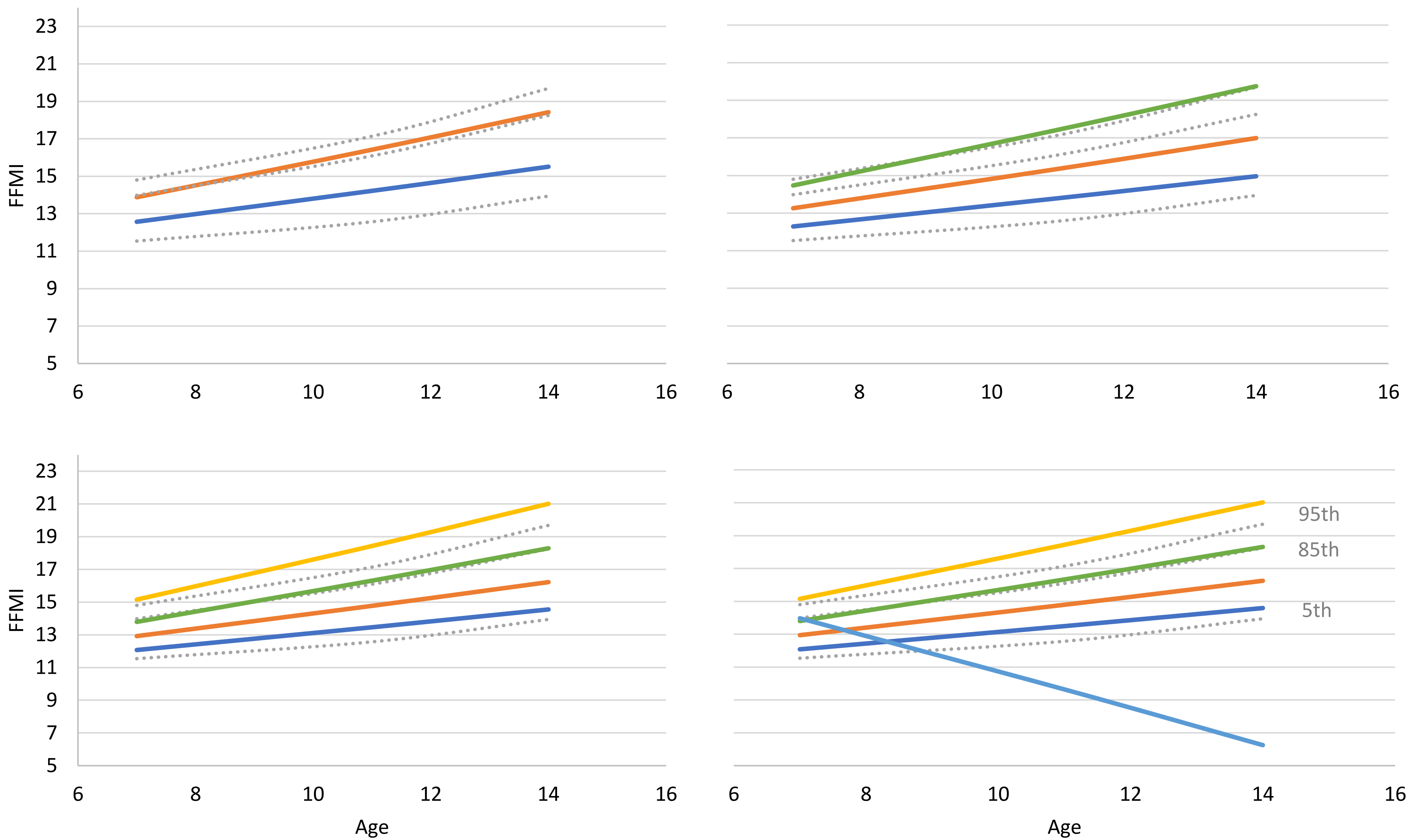
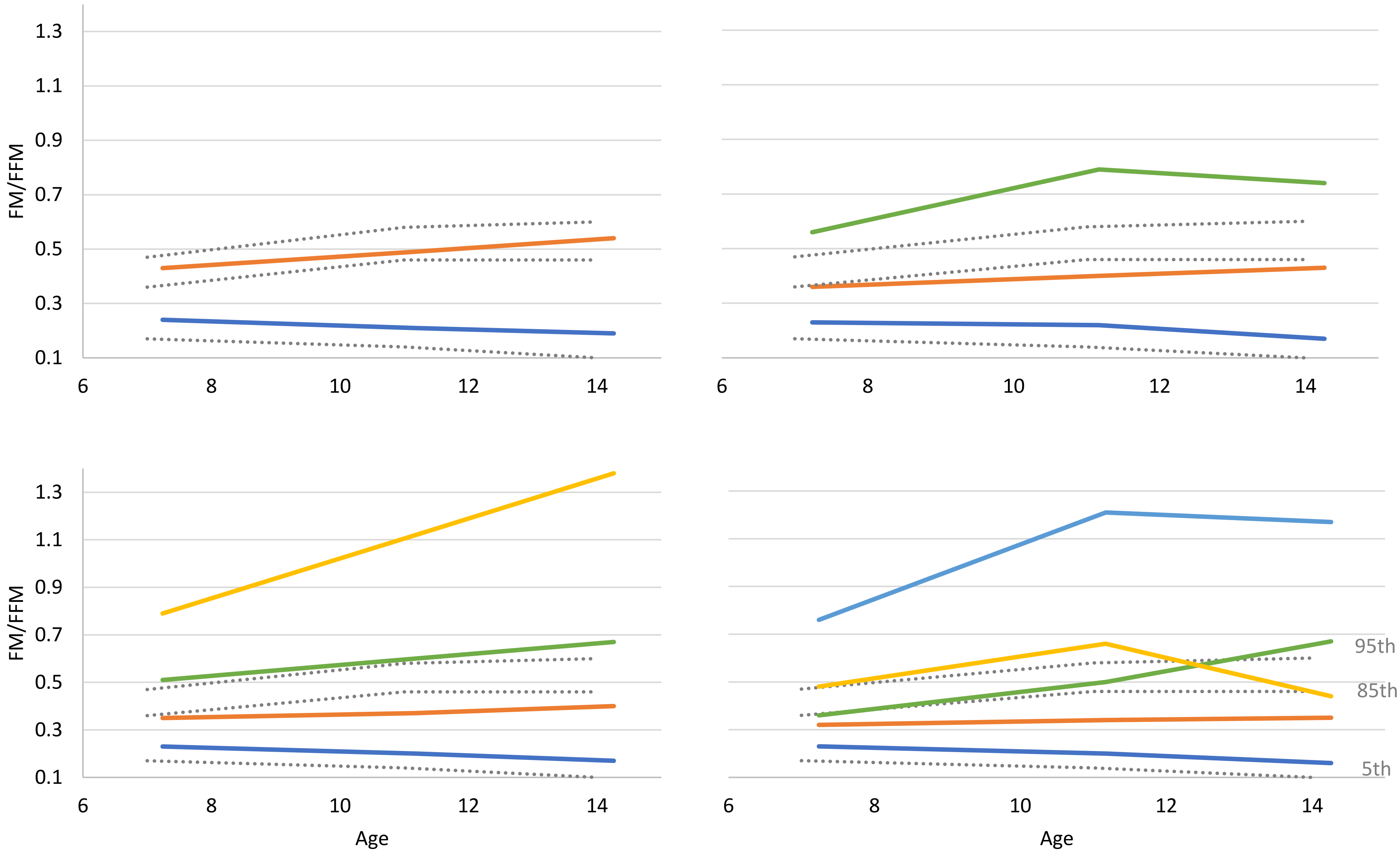
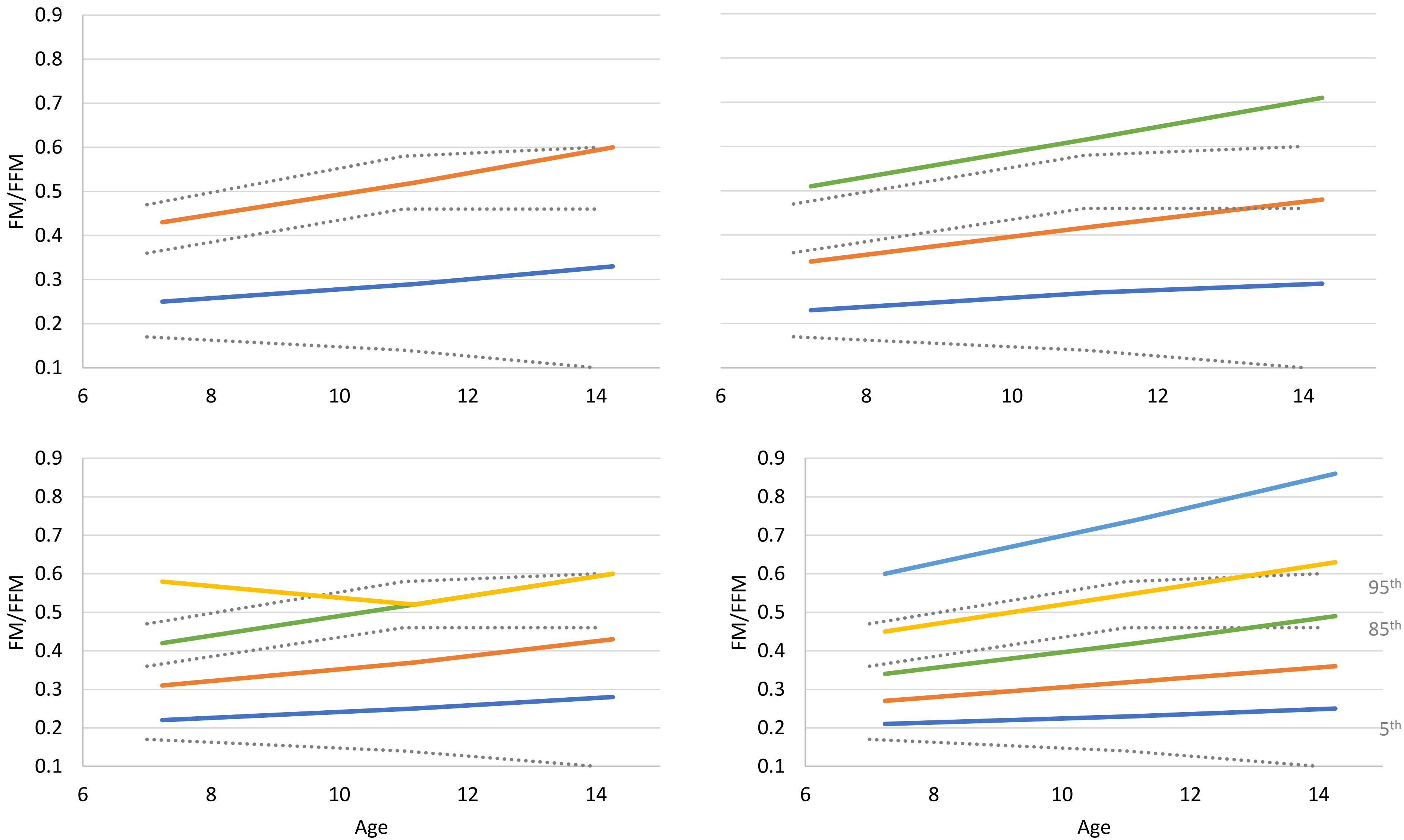


Appendix for Chapter 5, Figure 3. FFMI trajectory modelling: visualising different class numbers.



Appendix for Chapter 5, Figure 4. FM/FFM trajectory modelling in boys: visualising different class numbers.



Appendix for Chapter 5, Figure 5. FM/FFM trajectory modelling in girls: visualising different class numbers.

Appendix for Chapter 5, Table 2. Results of BMI trajectory modelling using different polynomial shapes.

Number of Classes	Polynomials	Akaike Information Criterion	Entropy Index	Group Membership %
3	0 0 0	-152649.55	0.834	81.2 16.4 2.4
3	**1 1 1**	**-133965.65**	**0.786**	**63.0 30.0 7.0**
3	1 1 2	-133722.76	0.770	60.7 30.6 8.7
3	1 1 3	-133548.29	0.762	59.5 31.0 9.5
3	1 2 1	-132312.8	0.749	52.6 38.6 8.7
3	1 2 2	-132040.07	0.735	49.5 40.1 10.4
3	1 2 3	-131837.78	0.727	47.7 41.0 11.2
3	1 3 1	-131824.4	0.761	53.3 38.4 8.3
3	1 3 2	-131582.87	0.749	50.8 39.5 9.7
3	1 3 3	-131401.42	0.741	49.2 20.3 10.5
3	2 1 1	-132312.8	0.749	38.6 52.6 8.7
3	2 1 2	-132040.07	0.735	40.1 49.5 10.4
3	2 1 3	-135303.08	0.882	23.4 76.1 0.5
3	2 2 1	-129823.04	0.802	61.7 31.4 6.9
3	2 2 2	-129616.51	0.795	60.4 31.8 7.8
3	2 2 3	-132502.84	0.899	77.6 21.8 0.5
3	2 3 1	-129315.13	0.805	61.3 32.0 6.7

Number of Classes	Polynomials	Akaike Information Criterion	Entropy Index	Group Membership %
3	2 3 2	-129458.34	0.790	59.5 8.4 32.1
3	2 3 3	-128980.11	0.794	59.2 32.7 8.1
3	3 1 1	-131824.4	0.761	38.4 53.3 8.3
3	3 1 2	-130794.49	0.823	67.6 25.8 6.6
3	3 1 3	-131401.42	0.741	40.3 49.2 10.5
3	3 2 1	-129735.77	0.804	62.3 30.9 6.8
3	3 2 2	-129533.71	0.797	61.1 31.3 7.6
3	3 2 3	-129378.8	0.792	60.2 31.6 8.2
3	3 3 1	-129242.11	0.807	61.8 31.5 6.6
3	3 3 2	-129051.9	0.802	60.9 31.8 7.3
3	3 3 3	-128914.83	0.797	59.9 32.2 7.9

Appendix for Chapter 5, Table 3. Results of FMI trajectory modelling using different polynomial shapes.

Number of Classes	Polynomials	Akaike Information Criterion	Entropy Index	Group Membership %
3	0 0 0	-68700.65	0.863	75.9 20.4 3.7
3	**1** **1** **1**	**-63993.01**	**0.841**	**26.9** **66.7** **6.4**
3	1 1 2	-63972.24	0.840	66.5 27.0 6.5
3	1 2 1	-63916.66	0.844	66.9 26.9 6.2
3	1 2 2	-63897.1	0.844	66.7 27.0 6.3
3	2 1 1	-63993.29	0.841	66.7 26.9 6.4
3	2 1 2	-63891.1	0.844	27.0 66.7 6.3
3	2 2 1	-63947.27	0.845	26.9 66.9 6.2
3	2 2 2	-63897.72	0.844	66.7 27.0 6.3

Appendix for Chapter 5, Table 4. Results of FFMI trajectory modelling using different polynomial shapes.

Number of Classes	Polynomials	Akaike Information Criterion	Entropy Index	Group Membership %
3	0 0 0	-68448.03	0.400	67.8 26.7 5.5
3	**1** **1** **1**	**-52132.05**	**0.701**	**44.9** **44.9** **10.1**
3	1 1 2	-52085.95	0.599	44.3 45.1 10.6
3	1 2 1	-53666.27	0.823	70.4 29.5 0.2
3	1 2 2	-51969.71	0.698	42.9 46.2 10.8
3	2 1 1	-52011.56	0.700	46.0 43.6 10.4
3	2 1 2	-51854.58	0.708	45.2 9.9 44.9
3	2 2 1	-51854.58	0.708	45.2 44.9 9.9
3	2 2 2	-51813.22	0.706	44.6 45.0 10.4

Appendix for Chapter 5, Table 5. Results of FM/FFM trajectory modelling in boys using different polynomial shapes.

Number of Classes	Polynomials	Akaike Information Criterion	Entropy Index	Group Membership %
Boys				
3	0 0 0	13629.23	0.906	15.9 81.9 2.2
3	1 1 1	14417.29	0.900	16.9 80.3 2.8
3	**1** **1** **2**	**14494.46**	**0.900**	**17.0** **80.2** **2.8**
3	1 2 1	14732.54	0.897	79.0 18.3 2.7
3	1 2 2	14580.72	0.905	16.4 80.9 2.7
3	2 1 1	14732.54	0.897	18.3 79.0 2.7
3	2 1 2	14807.57	0.896	18.4 78.8 2.8
3	2 2 1	14804.91	0.901	79.6 17.7 2.6
3	2 2 2	14879.72	0.900	17.9 79.4 2.7

Appendix for Chapter 5, Table 6. Results of FM/FFM trajectory modelling in girls using different polynomial shapes.

Number of Classes	Polynomials	Akaike Information Criterion	Entropy Index	Group Membership %
Girls				
3	0 0 0	12707.65	0.797	66.6 27.8 5.6
3	**1 1 1**	**14797.75**	**0.805**	**59.1 32.4 8.4**
3	1 1 2	14813.81	0.802	58.7 32.6 8.7
3	1 2 1	14834.17	0.812	59.9 32.0 8.0
3	1 2 2	14847.59	0.809	59.5 32.2 8.3
3	2 1 1	14834.17	0.812	32.0 59.9 8.0
3	2 1 2	14900.75	0.803	58.0 33.1 8.9
3	2 2 1	14924.45	0.812	32.6 59.2 8.2
3	2 2 2	14938.74	0.809	58.8 32.7 8.5

Appendix for Chapter 5, Table 7. Proportions of missing data in analytical sample.

Characteristic	**Sample with BMI and body composition data (N=13,025)**	
	N	**%**
Cohort member sex at birth		
Male	6612	50.8
Female	6413	49.2
Missing	*0*	*0.0*
Cohort member ethnicity		
White	10968	84.4
Mixed	346	2.7
Indian	312	2.4
Pakistani and Bangladeshi	828	6.4
Black and Black British	383	3.0
Other ethnic group	160	1.2
Missing	*28*	*0.2*
Fifth of household income at 9 months		
Most disadvantaged	2804	21.6
Second	2786	21.4
Third	2526	19.4
Fourth	2521	19.4
Least disadvantaged	2355	18.1
Missing	*33*	*0.3*
Highest parental education qualification at 9 months		
None	1403	10.8
NVQ Level 1 (GCSE grade D-G)	775	5.9
NVQ Level 2 (GCSE grade A*-C)	3199	24.6
NVQ Level 3 (A Level)	2151	16.5
NVQ Level 4 (One year Undergraduate)	4593	35.3
NVQ Level 5 (Two years Undergraduate)	896	6.9
Missing	*8*	*0.1*
Highest parental occupational class at 9 months		
Not in work	2924	22.5
Semi-routine or routine	1900	14.6
Lower supervisory or technical	1043	8.0
Small employers or self-employed	863	6.7
Intermediate occupations	1199	9.2
Managerial or professional	5050	38.9
Missing	*46*	*0.4*

Characteristic	Sample with BMI and body composition data (N=13,025)	
	N	%
Cohort member birthweight		
Low birthweight (≤2.5kg)	890	6.8
Birthweight >2.5kg	12106	93.2
Missing	*29*	*0.2*
Cohort member gestation		
Pre-term (<37 weeks)	915	7.0
Term	12110	93.0
Missing	*0*	*0.0*
Maternal pre-pregnancy BMI		
BMI <25	8416	70.3
BMI 25-29.9	2465	20.6
BMI 30+	1083	9.1
Missing	*1061*	*8.2*
Cohort member was breastfed		
No	3870	29.8
Yes	9135	70.2
Missing	*20*	*0.2*
Mother smoked in pregnancy		
No	11057	84.9
Yes	1962	15.1
Missing	*6*	*0.1*
Mother drank alcohol in pregnancy		
No	9020	69.4
Yes	3982	30.6
Missing	*23*	*0.2*
Maternal age at child's birth		
Under 20	938	7.2
20 to 29	5843	44.9
30 to 39	5941	45.6
40 or older	302	2.3
Missing	*1*	*0.0*
Maternal psychological distress at 3 years		
Low	8591	75.0
Moderate	2472	21.6
Severe	388	3.4
Missing	*1574*	*12.1*

Characteristic	Sample with BMI and body composition data (N=13,025)	
	N	**%**
Paternal age at child's birth [a]		
Under 20	146	1.3
20 to 29	3505	31.9
30 to 39	6180	56.3
40 or older	1150	10.5
Missing	*154*	*1.4*
Paternal psychological distress at 3 years [a]		
Low	6716	78.2
Moderate	1739	20.2
Severe	136	1.6
Missing	*2918*	*26.2*

[a] In a subsample of cohort members from two-parent households (N=11,135)

Appendix for Chapter 5, Table 8. Sensitivity analysis: BMI trajectory membership according to early life correlates in a sample with valid trajectory data on all body composition measures (N=13,025) and a full sample with BMI trajectory data (N=14,675).

Characteristic	Restricted Sample (N=13025) Trajectory Membership			Full Sample (N=14675) Trajectory Membership		
	Low	Mod ǂ	High	Low	Mod ǂ	High
N	8375	3783	867	9799	3977	949
%	62.4	30.8	6.9	62.6	30.5	6.9
Cohort member sex at birth						
Male	66.0	27.8	6.2	66.2	27.7	6.1
Female	58.6	33.8	7.6	58.6	33.6	7.8
Cohort member ethnicity						
White	62.9	30.8	6.3	63.0	30.6	6.4
Mixed	64.6	25.5	9.9	65.1	25.2	9.8
Indian	67.9	25.7	6.4	67.9	25.7	6.4
Pakistani and Bangladeshi	59.0	30.0	11.0	59.1	29.9	11.0
Black and Black British	51.9	36.6	11.5	51.9	36.6	11.5
Other ethnic group	64.0	27.0	9.0	63.7	26.9	9.4
Fifth of household income at 9 months						
Most disadvantaged	57.0	33.2	9.8	57.2	32.8	10.0
Second	59.2	32.9	7.9	59.2	32.9	7.9
Third	62.4	31.2	6.4	62.7	30.9	6.4
Fourth	63.7	30.8	5.5	63.7	30.8	5.5
Least disadvantaged	73.7	23.1	3.2	73.7	23.1	3.2
Highest parental education level at 9 months						
None	54.7	35.1	10.2	55.7	34.4	9.9
NVQ Level 1 (GCSE grade D-G)	62.3	29.1	8.6	62.1	29.3	8.6
NVQ Level 2 (GCSE grade A*-C)	58.7	33.6	7.7	58.8	33.5	7.7
NVQ Level 3 (A Level)	63.4	28.9	7.7	63.1	28.6	8.3
NVQ Level 4 (One year Undergraduate)	66.8	28.5	4.7	66.8	28.5	4.7
NVQ Level 5 (Two years Undergraduate)	73.0	24.5	2.5	73.1	24.4	2.5
Highest parental occupational class at 9 months						
Not in work	57.2	33.9	8.9	57.6	33.5	8.9
Semi-routine or routine	59.4	31.5	9.2	59.4	31.3	9.3
Lower supervisory or technical	57.7	34.3	7.9	57.9	34.2	7.9
Small employers or self-employed	61.4	32.2	6.4	61.4	32.1	6.0
Intermediate occupations	69.0	24.9	6.0	69.1	24.9	6.0
Managerial or professional	67.5	28.2	4.3	67.5	28.2	4.3
Cohort member birthweight						
Low birthweight (≤2.5kg)	66.6	27.0	6.4	66.3	27.4	6.3
Birthweight >2.5kg	62.1	31.0	6.9	62.2	30.8	7.0

Characteristic	Restricted Sample (N=13025) Trajectory Membership			Full Sample (N=14675) Trajectory Membership		
	Low	Mod ˡ	High	Low	Mod ˡ	High
Cohort member gestation						
Pre-term (<37 weeks)	63.2	28.9	7.9	62.9	29.3	7.8
Term	62.4	30.8	6.8	62.5	30.6	6.9
Maternal pre-pregnancy BMI						
BMI <25	70.0	25.8	4.2	70.1	25.6	4.3
BMI 25-29.9	50.1	39.8	10.1	50.2	39.8	10.0
BMI 30+	35.0	46.7	18.3	35.4	46.2	18.4
Cohort member was breastfed						
No	58.4	33.4	8.2	58.5	33.1	8.4
Yes	64.6	29.2	6.2	64.7	29.1	6.2
Mother smoked in pregnancy						
No	63.7	30.0	6.2	63.9	29.8	6.3
Yes	56.3	33.7	10.0	56.4	33.7	9.9
Mother drank alcohol in pregnancy						
No	60.9	31.7	7.4	61.0	31.5	7.5
Yes	66.1	28.2	5.7	66.2	28.2	5.6
Maternal age at child's birth						
Under 20	59.7	33.4	6.9	60.6	32.6	6.8
20 to 29	61.8	31.0	7.2	61.9	30.9	7.2
30 to 39	64.0	29.5	6.5	64.0	29.4	6.6
40 or older	58.9	32.5	8.6	58.9	32.5	8.6
Maternal psychological distress at 3 years						
Low	63.3	30.4	6.3	63.3	30.3	6.4
Moderate	59.6	32.3	8.1	60.0	31.8	8.2
Severe	59.1	32.1	8.8	59.2	32.1	8.7
Paternal age at child's birth [a]						
Under 20	56.5	42.0	1.5	56.5	42.0	1.5
20 to 29	62.6	30.6	6.8	62.8	30.4	6.8
30 to 39	65.0	29.1	5.9	65.0	29.0	6.0
40 or older	59.5	33.2	7.4	59.5	33.1	7.4
Paternal psychological distress at 3 years [a]						
Low	64.7	29.6	5.7	64.7	29.6	5.7
Moderate	63.3	29.0	7.7	63.3	29.0	7.7
Severe	68.3	27.6	4.0	68.3	27.6	4.0

[a] In a sub-sample of two-parent households.

ˡ Mod = Moderate.

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Appendix for Chapter 6, Table 1. Comparison of characteristics and missing data of sample with exposure data, sample with complete data on exposures, outcomes and confounders, and sample with valid exposure data and imputed outcomes and confounders (unweighted).

Variable	Valid Exposure Data N (%)	Complete Data N (%)	Imputed Data %
N	13025	8573	13025
Cohort member sex at birth			
Male	6612 (50.8)	4225 (51.0)	50.8
Female	6413 (49.2)	4354 (49.0)	49.2
Missing[a]	0	-	-
Cohort member age at interview (14 year)			
Mean (SD)	14.3 (0.3)	14.3 (0.3)	14.3
Missing	2735	-	-
Cohort member ethnicity			
White	10968 (84.4)	7564 (89.2)	84.4
Mixed	346 (2.7)	215 (3.1)	2.7
Indian	312 (2.4)	191 (1.6)	2.4
Pakistani or Bangladeshi	828 (6.4)	360 (2.7)	6.4
Black or Black British	383 (2.9)	160 (2.4)	2.9
Other, including Chinese or Arab	160 (1.2)	89 (1.0)	1.2
Missing	28 (0.2)	-	-
Family income at 9 months			
Most disadvantaged	2804 (21.6)	1400 (20.4)	21.6
Second	2786 (21.4)	1683 (20.9)	21.5
Third	2526 (19.4)	1748 (20.6)	19.4
Fourth	2521 (19.4)	1915 (19.7)	19.4
Least disadvantaged	2355 (18.1)	1833 (18.5)	18.1
Missing	33 (0.3)	-	-
Highest parent education attainment at 9 months			
None	1403 (10.8)	566 (9.6)	10.8
NVQ Level 1 (GCSE grade D-G)	775 (5.9)	407 (6.7)	5.9
NVQ Level 2 (GCSE grade A*-C)	3199 (24.6)	4970 (26.7)	24.6
NVQ Level 3 (A Level)	2151 (16.5)	1455 (16.5)	16.5
NVQ Level 4 (One year Undergraduate)	4593 (35.3)	3463 (34.4)	35.3
NVQ Level 5 (Two years Undergraduate)	896 (6.9)	718 (6.1)	6.9
Missing	8 (0.1)	-	-
Highest parent occupational class at 9 months			
Not in work	2924 (22.5)	1452 (21.6)	22.5
Routine or semi-routine	1900 (14.6)	1129 (14.8)	14.6
Lower supervisory or technical	1043 (8.0)	679 (8.2)	8.0
Small employers or self-employed	863 (6.6)	568 (7.0)	6.6
Intermediate occupations	1199 (9.2)	835 (9.2)	9.2
Managerial or professional	5050 (38.9)	3916 (39.2)	39.0
Missing	46 (0.4)	-	-
Cohort member birthweight			
Low birthweight (≤2.5kg)	890 (6.9)	533 (6.8)	6.9
Birthweight >2.5kg	12106 (93.1)	8046 (93.2)	93.1
Missing	29 (0.2)	-	-
Maternal pre-pregnancy BMI			
BMI <25	8416 (70.3)	6062 (71.6)	69.5
BMI 25 – 29.9	2465 (20.6)	1758 (19.4)	21.4
BMI ≥30	1083 (9.1)	759 (9.0)	9.0
Missing	1061 (8.2)	-	-
Cohort member was breastfed			
No	3870 (29.8)	2274 (33.5)	29.8
Yes	9135 (70.2)	6305 (66.5)	70.2
Missing	20 (0.2)	-	-
Mother smoked in pregnancy			
No	11057 (84.9)	7356 (82.5)	84.9
Yes	1962 (15.1)	1223 (17.5)	15.1
Missing	6 (0.1)	-	-

Variable	Valid Exposure Data N (%)	Complete Data N (%)	Imputed Data %
Mother smoked in pregnancy			
No	11057 (84.9)	7356 (82.5)	84.9
Yes	1962 (15.1)	1223 (17.5)	15.1
Missing	6 (0.1)	-	-
Mother drank alcohol in pregnancy			
No	9020 (69.4)	5727 (66.7)	69.4
Yes	3982 (30.6)	2852 (33.3)	30.6
Missing	23 (0.2)	-	-
Any parent psychological distress at 3 years			
No	7965 (65.5)	5686 (65.1)	64.0
Yes	4192 (34.5)	2863 (34.9)	36.0
Missing	868 (6.7)	-	-
Cohort member pubertal status at 11 years			
Not yet started	10339 (93.6)	7520 (93.5)	93.3
Started puberty	709 (6.4)	498 (6.5)	6.7
Missing	1977 (15.2)		-
Cohort member pubertal status at 14 years			
Not yet started	2249 (23.0)	1935 (22.7)	23.3
Started puberty	7519 (77.0)	6528 (77.3)	76.7
Missing	3257 (25.0)	-	-
Outcomes reported by cohort member			
Appearance satisfaction at 14 years			
Mean (SD)	4.79 (1.6)	4.73 (1.6)	4.80 (2.1)
Missing	3151 (24.2)	-	-
Weight perception at 14 years			
Underweight	696 (7.0)	588 (7.0)	7.3
About the right weight	5902 (59.8)	5190 (60.2)	59.8
Slightly overweight	2823 (28.6)	2406 (28.3)	28.3
Very overweight	451 (4.6)	364 (4.5)	4.6
Missing	3153 (24.2)	-	-
Weight intention at 14 years			
Lose weight	4124 (41.7)	3531 (41.2)	41.4
Gain weight	817 (8.3)	679 (8.4)	8.6
Stay the same weight	2548 (25.8)	2250 (26.3)	25.8
Doing nothing about weight	2398 (24.2)	2100 (24.2)	24.2
Missing	3138 (24.1)	-	-
Exercise for weight loss at 14 years			
No	3932 (39.8)	3400 (39.8)	39.5
Yes	5954 (60.2)	5162 (60.2)	60.5
Missing	3139 (24.1)	-	-
Dieting for weight loss at 14 years			
No	5483 (55.5)	4754 (55.8)	55.5
Yes	4389 (44.5)	3795 (44.2)	44.5
Missing	3153 (24.2)	-	-
Weight perception at 17 years[b]			
Underweight	565 (9.4)	488 (10.0)	10.2
About the right weight	3263 (54.2)	2925 (53.9)	54.5
Slightly overweight	1773 (29.4)	1554 (29.2)	28.2
Very overweight	424 (7.0)	352 (6.9)	7.0
Missing	7000 (53.7)	-	-
Weight intention at 17 years[b]			
Lose weight	2869 (47.7)	2520 (47.1)	44.5
Gain weight	772 (12.8)	677 (12.9)	14.7
Stay the same weight	1074 (17.8)	958 (17.5)	18.6
Doing nothing about weight	1305 (21.7)	1162 (22.5)	22.2
Missing	7005 (53.8)	-	-
No	2247 (37.3)	1971 (38.0)	40.2
Yes	3780 (62.7)	3348 (62.0)	59.8
Missing	6998 (53.7)	-	-
Dieting for weight loss at 17 years[b]			
No	2907 (48.2)	2563 (48.7)	51.1
Yes	3120 (51.8)	2756 (51.3)	48.9
Missing	6998 (53.7)	-	-

a Proportions of non-missing data add up to 100% for comparisons to be made across samples.

b Complete case sample at 17 years N=5323.

Appendix for Chapter 6, Table 2. Comparison of characteristics in participants with missing and available body image data at 14 and 17 years among participants with complete body composition trajectory data (n=13025).

Variable	Missing body image data at 14 years		Missing body image data at 17 years	
	No (n= 9788, 75.2%)	Yes (n= 3237, 24.8%)	No (n= 6013, 46.2%)	Yes (n= 7012, 53.8%)
Cohort member sex at birth				
Male	73.2	26.8	40.3	59.7
Female	77.2	22.8	52.2	47.8
Cohort member ethnicity				
White	74.7	25.3	46.2	53.8
Mixed	71.7	28.3	44.5	55.5
Indian	82.1	17.9	51.6	48.4
Pakistani or Bangladeshi	80.6	19.4	43.8	56.2
Black or Black British	71.5	28.5	41.8	58.2
Other, including Chinese and Arab	81.3	18.7	56.9	43.1
Family income at 9 months				
Most disadvantaged	66.4	33.6	33.2	66.8
Second	72.0	28.0	42.6	57.4
Third	75.6	24.4	46.6	53.4
Fourth	80.8	19.2	53.6	46.4
Least disadvantaged	82.9	17.1	57.5	42.5
Highest parental education level at 9 months				
None	66.5	33.5	33.0	67.0
NVQ Level 1 (GCSE grade D-G)	66.6	33.4	32.4	67.6
NVQ Level 2 (GCSE grade A*-C)	69.8	30.2	39.9	60.1
NVQ Level 3 (A Level)	73.3	26.7	43.4	56.6
NVQ Level 4 (One year Undergraduate)	81.6	18.4	54.6	45.4
NVQ Level 5 (Two years Undergraduate)	86.9	13.1	63.9	36.1
Highest parental occupational class at 9 months				
Not in work	65.9	34.1	32.7	67.3
Routine or semi-routine	71.2	28.8	39.8	60.2
Lower supervisory or technical	71.4	28.6	43.1	56.9
Small employers or self-employed	74.7	25.3	45.0	55.0
Intermediate occupations	76.1	23.9	45.9	54.1
Managerial or professional	82.5	17.5	57.1	42.9
Cohort member birthweight				
Low birthweight (≤2.5kg)	72.8	27.2	43.6	56.4
Birthweight >2.5kg	75.4	24.6	56.4	53.6
Maternal pre-pregnancy BMI				
BMI <25	75.5	24.5	46.5	53.5
BMI 25 – 29.9	75.5	24.5	46.2	53.8
BMI ≥30	74.6	25.4	48.4	51.6
Cohort member was breastfed				
No	68.4	31.6	37.3	62.7
Yes	78.1	21.9	50.0	50.0
Mother smoked in pregnancy				
No	76.2	23.8	48.1	51.9
Yes	69.0	31.0	35.5	54.5
Mother drank alcohol in pregnancy				
No	74.5	25.5	44.7	55.3
Yes	76.9	23.1	49.6	50.4
Any parent psychological distress at 3 years				
No	75.8	24.2	48.0	52.0
Yes	74.6	25.4	44.9	55.1
Cohort member pubertal status at 11 years				
Not yet started	81.7	18.3	51.0	49.0
Started puberty	79.4	20.6	50.5	49.5
Cohort member pubertal status at 14 years				
Not yet started	98.7	1.3	56.5	43.5
Started puberty	99.2	0.8	57.7	42.3

Variable	Missing body image data at 14 years		Missing body image data at 17 years	
	No (n= 9788, 75.2%)	Yes (n= 3237, 24.8%)	No (n= 6013, 46.2%)	Yes (n= 7012, 53.8%)
Cohort member BMI Trajectory				
Low	64.1	35.9	45.3	54.7
Moderate	68.2	31.8	48.7	51.3
High	61.7	38.3	43.6	56.4

Appendix for Chapter 6, Table 3. Results of univariable and multivariable multinomial logistic regression analysis of the association between body composition and weight perception at 14 years old in participants with complete data (sampling and attrition weights applied). Reports the risk ratio of seeing themselves as underweight, slightly overweight, or very overweight compared to the reference outcome – seeing themselves as about the right weight.

Whole sample (N=8542)	**N**	**Model 0 – unadjusted Risk Ratio (95% CI)**			**Model 1 – fully adjusted[a] Risk Ratio (95% CI)**			**Exposure * Sex Interaction P value**		
		Underweight	Slightly overweight	Very overweight	Underweight	Slightly overweight	Very overweight	Underweight	Slightly overweight	Very overweight
BMI Trajectory										
Low	2850	ref	ref	ref	ref	ref	ref	ref	ref	ref
Moderate	1142	0.16 (0.08, 0.32)	8.31 (7.20, 9.59)	13.01 (8.54, 19.82)	0.17 (0.08, 0.33)	8.11 (7.02, 9.37)	12.00 (7.75, 18.59)	0.795	0.001	0.170
High	233	0.14 (0.04, 0.54)	51.77 (33.57, 79.84)	324.20 (196.99, 533.57)	0.14 (0.04, 0.55)	52.35 (33.26, 82.39)	286.17 (167.07, 490.17)	<0.001	0.283	0.099
FMI Trajectory										
Low	3444	ref	ref	ref	ref	ref	ref	ref	ref	ref
Moderate	642	0.11 (0.04, 0.31)	9.79 (8.47, 11.32)	17.02 (11.49, 25.22)	0.12 (0.05, 0.35)	9.75 (8.35, 11.38)	15.72 (10.17, 24.30)	0.188	<0.001	<0.001
High	139	0.00 (0.00, 0.00)	54.16 (32.39, 90.55)	457.17 (268.61, 778.10)	0.00 (0.00, 0.00)	53.61 (31.48, 91.32)	386.42 (216.18, 690.71)	<0.001	0.137	0.001
FFMI Trajectory										
Low	1361	ref	ref	ref	ref	ref	ref	ref	ref	ref
Moderate	2207	0.25 (0.18, 0.35)	3.53 (3.09, 4.03)	5.45 (3.56, 8.34)	0.18 (0.13, 0.24)	5.49 (4.69, 6.42)	10.18 (6.56, 15.81)	0.917	0.002	0.551
High	657	0.10 (0.04, 0.27)	10.51 (8.30, 13.30)	38.91 (23.83, 63.53)	0.06 (0.02, 0.16)	25.97 (19.80, 34.05)	176.85 (98.34, 318.05)	<0.001	0.073	0.039
FM/FFM Trajectory										
Low	3531	ref	ref	ref	ref	ref	ref	ref	ref	ref
Moderate	605	0.11 (0.03, 0.38)	9.94 (8.63, 11.44)	22.08 (15.36, 31.75)	0.12 (0.04, 0.42)	9.38 (8.07, 10.90)	19.95 (13.42, 29.65)	-[b]	-	-
High	89	0.00 (0.00, 0.00)	46.23 (25.65, 83.34)	464.46 (249.90, 863.23)	0.00 (0.00, 0.00)	42.34 (22.73, 78.89)	375.86 (196.07, 720.53)	-	-	-

[a] Adjusting for sex at birth, age at interview, ethnicity, family income, parental education, parental occupational class at 9 months old, birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy, and parent psychological distress at 3 years old.
[b] Unable to compute due to highly singular variance matrix.

Appendix for Chapter 6, Table 4. Sex-stratified results from fully adjusted analyses[a] of the association between body composition trajectory and body satisfaction at age 14.

Whole sample N=13025	Body Satisfaction at 14 Years	
	Boys (n= 6612)	**Girls (n= 6413)**
	Mean Difference (95% CI)	Mean Difference (95% CI)
FFMI Trajectory		
Low	ref	ref
Moderate	-0.06 (-0.16, 0.04)	-0.40 (-0.51, -0.28)
High	-0.29 (-0.44, -0.14)	-0.80 (-1.11, -0.48)

Appendix for Chapter 6, Table 5. Sex-stratified results from fully adjusted analyses[a] of the association between body composition trajectory and exercise for weight loss in the past year at age 17.

Whole sample N=13025	Exercise for Weight Loss at 17 Years	
	Boys (n= 6612)	**Girls (n= 6413)**
	Odds Ratio (95% CI)	Odds Ratio (95% CI)
BMI Trajectory		
Low	ref	ref
Moderate	3.77 (3.04, 4.67)	2.49 (2.05, 3.02)
High	4.75 (3.16, 7.14)	3.63 (2.34, 5.62)
FMI Trajectory		
Low	ref	ref
Moderate	3.80 (2.96, 4.89)	2.45 (2.01, 2.98)
High	4.53 (2.82, 7.29)	3.81 (2.58, 5.63)
FM/FFM Trajectory		
Low	ref	ref
Moderate	3.71 (2.89, 4.77)	2.55 (2.07, 3.16)
High	4.18 (2.18, 7.99)	3.62 (2.47, 5.32)

[a] Adjusting for age at interview, ethnicity, family income, parental education, parental occupational class at 9 months old, birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy, and parent psychological distress at 3 years old.

Appendix for Chapter 6, Table 6. Sex-stratified results from fully adjusted analyses[a] of the association between body composition trajectory and lifetime dieting for weight loss reported at age 14.

	Dieting for Weight Loss at 14 Years	
Whole sample N=13025	**Boys (n= 6612)**	**Girls (n= 6413)**
	Odds Ratio (95% CI)	Odds Ratio (95% CI)
BMI Trajectory		
Low	ref	ref
Moderate	4.09 (3.48, 4.81)	3.20 (2.74, 3.73)
High	8.27 (6.09, 11.24)	7.57 (5.33, 10.75)
FMI Trajectory		
Low	ref	ref
Moderate	4.48 (3.65, 5.50)	3.18 (2.75, 3.68)
High	7.13 (4.80, 10.60)	8.01 (5.83, 11.00)
FM/FFM Trajectory		
Low	ref	ref
Moderate	4.29 (3.51, 5.25)	3.20 (2.71, 3.77)
High	7.31 (4.49, 11.88)	8.31 (5.90, 11.68)

[a] Adjusting for age at interview, ethnicity, family income, parental education, parental occupational class at 9 months old, birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy, and parent psychological distress at 3 years old.

Appendix for Chapter 6, Table 7. Sex-stratified results from fully adjusted analyses[a] of the association between body composition trajectory and dieting for weight loss in the past year at age 17.

Whole sample N=13025	Dieting for Weight Loss at 17 Years	
	Boys (n= 6612)	Girls (n= 6413)
	Odds Ratio (95% CI)	Odds Ratio (95% CI)
BMI Trajectory		
Low	ref	ref
Moderate	3.99 (3.22, 4.94)	2.98 (2.48, 3.57)
High	6.78 (4.51, 10.21)	4.92 (3.21, 7.54)
FMI Trajectory		
Low	ref	ref
Moderate	4.06 (3.17, 5.20)	2.96 (2.47, 3.55)
High	6.57 (4.11, 10.50)	5.27 (3.54, 7.84)
FFMI Trajectory		
Low	ref	ref
Moderate	4.19 (3.28, 5.36)	3.14 (2.55, 3.86)
High	8.26 (4.29, 15.87)	4.95 (3.35, 7.33)

[a] Adjusting for age at interview, ethnicity, family income, parental education, parental occupational class at 9 months old, birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy, and parent psychological distress at 3 years old.

Appendix for Chapter 6, Table 8. Results of univariable and multivariable linear regression analysis of the association between body composition trajectory and body satisfaction at 14 years in participants with complete data (sampling and attrition weights applied).

		Body Satisfaction at 14 Years					
Whole sample N=8547	N	**Model 0 - unadjusted**	**Model 1 – 0 + sociodemographic factors[a]**	**Model 2 – 0 + perinatal factors[b]**	**Model 3 – 0 + parent mental health[c]**	**Model 4 – fully adjusted[d]**	**Exposure * Sex interaction**
		Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	P value
BMI Trajectory							
Low	5405	ref	ref	ref	ref	ref	ref
Moderate	2602	-0.40 (-0.49, -0.1)	-0.31 (-0.39, -0.22)	-0.38 (-0.47, -0.29)	-0.40 (-0.49, -0.31)	-0.29 (-0.37, -0.20)	0.168
High	540	-0.93 (-1.13, -0.72)	-0.83 (-1.02, -0.64)	-0.86 (-1.07, -0.65)	-0.92 (-1.12, -0.72)	-0.77 (-0.97, -0.58)	0.992
FMI Trajectory							
Low	5826	ref	ref	ref	ref	ref	ref
Moderate	2246	-0.65 (-0.75, -0.54)	-0.39 (-0.49, -0.28)	-0.62 (-0.73, -0.51)	-0.64 (-0.75, -0.54)	-0.36 (-0.47, -0.25)	0.888
High	475	-1.12 (-1.33, -0.91)	-0.88 (-1.09, -0.67)	-1.07 (-1.28, -0.86)	-1.11 (-1.32, -0.90)	-0.82 (-1.03, -0.60)	0.727
FFMI Trajectory							
Low	3869	ref	ref	ref	ref	ref	ref
Moderate	3860	-0.06 (-0.15, 0.04)	-0.27 (-0.36, -0.18)	-0.01 (-0.10, 0.08)	-0.05 (-0.15, 0.04)	-0.23 (-0.32, -0.14)	<0.001
High	818	-0.16 (-0.30, -0.01)	-0.61 (-0.75, -0.46)	-0.05 (-0.21, 0.11)	-0.15 (-0.30, -0.01)	-0.53 (-0.68, -0.38)	0.010
FM/FFM Trajectory							
Low	6173	ref	ref	ref	ref	ref	ref
Moderate	1970	-0.59 (-0.70, -0.49)	-0.37 (-0.47, -0.26)	-0.57 (-0.67, -0.46)	-0.59 (-0.70, -0.49)	-0.34 (-0.45, -0.23)	0.355
High	404	-1.23 (-1.45, -1.01)	-0.94 (-1.15, -0.72)	-1.17 (-1.39, -0.94)	-1.22 (-1.44, -1.00)	-0.85 (-1.07, -0.64)	0.657

[a] Adjusting for sex, age at interview, ethnicity, family income, parental education, and parental occupational class at 9 months old.

[b] Adjusting for birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy.

[c] Adjusting for parent psychological distress at 3 years old.

[d] Adjusting for all confounding variables in models 1 to 3.

Appendix for Chapter 6, Table 9. Results of univariable and multivariable logistic regression analysis of the association between body composition trajectory and having ever exercised for weight loss at 14 years in participants with complete data (sampling and attrition weights applied).

Whole sample N=8556	N	Exercise for Weight Loss at 14 Years					
		Model 0 - unadjusted	**Model 1 – 0 + sociodemographic factors[a]**	**Model 2 – 0 + perinatal factors[b]**	**Model 3 – 0 + parent mental health[c]**	**Model 4 – fully adjusted[d]**	**Exposure * Sex interaction**
		Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	P value
BMI Trajectory							
Low	5421	ref	ref	ref	ref	ref	ref
Moderate	2597	4.20 (3.71, 4.75)	4.09 (3.61, 4.64)	4.10 (3.61, 4.67)	4.20 (3.71, 4.76)	3.97 (3.50, 4.51)	0.213
High	538	6.24 (4.72, 8.25)	6.10 (4.59, 8.10)	5.97 (4.51, 7.90)	6.24 (4.72, 8.25)	5.75 (4.32, 7.67)	0.228
FMI Trajectory							
Low	5840	ref	ref	ref	ref	ref	ref
Moderate	2244	4.17 (3.62, 4.80)	3.92 (3.38, 4.54)	4.05 (3.51, 4.68)	4.17 (3.62, 4.80)	3.77 (3.25, 4.37)	0.122
High	472	6.21 (4.56, 8.45)	5.90 (4.33, 8.04)	5.79 (4.23, 7.93)	6.21 (4.56, 8.45)	5.39 (3.93, 7.39)	0.568
FFMI Trajectory							
Low	3879	ref	ref	ref	ref	ref	ref
Moderate	3860	2.26 (2.03, 2.51)	2.93 (2.62, 3.28)	2.18 (1.95, 2.44)	2.26 (2.03, 2.51)	2.84 (2.52, 3.19)	0.094
High	817	4.73 (3.78, 5.90)	7.65 (5.99, 9.77)	4.39 (3.49, 5.52)	4.73 (3.78, 5.91)	7.20 (5.62, 9.23)	0.056
FM/FFM Trajectory							
Low	6187	ref	ref	ref	ref	ref	ref
Moderate	1966	4.03 (3.44, 4.74)	3.80 (3.22, 4.48)	3.90 (3.32, 4.58)	4.04 (3.44, 4.74)	3.62 (3.07, 4.28)	0.111
High	403	6.16 (4.43, 8.57)	5.64 (4.06, 7.84)	5.69 (4.05, 7.97)	6.16 (4.43, 8.57)	5.08 (3.62, 7.12)	0.615

[a] Adjusting for sex, age at interview, ethnicity, family income, parental education, and parental occupational class at 9 months old.

[b] Adjusting for birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy.

[c] Adjusting for parent psychological distress at 3 years old.

[d] Adjusting for all confounding variables in models 1 to 3.

Appendix for Chapter 6, Table 10. Results of univariable and multivariable logistic regression analysis of the association between body composition trajectory and having ever dieted for weight loss at 14 years in participants with complete data (sampling and attrition weights applied).

		Dieting for Weight Loss at 14 Years					
Whole sample N=8543	N	**Model 0 - unadjusted**	**Model 1 – 0 + sociodemographic factors[a]**	**Model 2 – 0 + perinatal factors[b]**	**Model 3 – 0 + parent mental health[c]**	**Model 4 – fully adjusted[d]**	**Exposure * Sex interaction**
		Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	P value
BMI Trajectory							
Low	5411	ref	ref	ref	ref	ref	ref
Moderate	2593	3.94 (3.48, 4.45)	3.89 (3.43, 4.40)	3.88 (3.41, 4.41)	3.94 (3.48, 4.45)	3.79 (3.34, 4.31)	0.011
High	539	8.27 (6.33, 10.79)	8.25 6.29, 10.82)	7.98 (6.11, 10.42)	8.25 (6.32, 10.76)	7.87 (5.98, 10.35)	0.490
FMI Trajectory							
Low	5830	ref	ref	ref	ref	ref	ref
Moderate	2239	4.59 (4.00, 5.27)	3.96 (3.45, 4.54)	4.49 (3.91, 5.16)	4.59 (4.00, 5.27)	3.82 (3.33, 4.39)	0.001
High	474	7.88 (6.03, 10.28)	6.83 (5.23, 8.94)	7.46 (5.69, 9.78)	7.85 (6.02, 10.24)	6.31 (4.79, 8.30)	0.639
FFMI Trajectory							
Low	3868	ref	ref	ref	ref	ref	ref
Moderate	3858	1.97 (1.76, 2.19)	2.92 (2.56, 3.32)	1.90 (1.70, 2.12)	1.96 (1.76, 2.19)	2.80 (2.46, 3.19)	0.076
High	817	3.72 (3.04, 4.57)	7.99 (6.40, 9.96)	3.41 (2.77, 4.21)	3.72 (3.03, 4.56)	7.42 (5.92, 9.30)	0.812
FM/FFM Trajectory							
Low	6177	ref	ref	ref	ref	ref	ref
Moderate	1963	4.29 (3.69, 4.98)	3.75 (3.22, 4.37)	4.15 (3.56, 4.84)	4.29 (3.69, 4.98)	3.59 (3.08, 4.20)	0.019
High	403	9.55 (6.99, 13.03)	7.78 (5.69, 10.95)	8.87 (6.47, 12.17)	9.49 (6.96, 12.94)	6.99 (5.07, 9.65)	0.620

[a] Adjusting for sex, age at interview, ethnicity, family income, parental education, and parental occupational class at 9 months old.

[b] Adjusting for birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy.

[c] Adjusting for parent psychological distress at 3 years old.

[d] Adjusting for all confounding variables in models 1 to 3.

Appendix for Chapter 6, Table 11. Results of univariable and multivariable logistic regression analysis of the association between body composition trajectory and having ever exercised for weight loss at 17 years in participants with complete data (sampling and attrition weights applied).

Whole sample N=5317	N	**Exercise for Weight Loss at 17 Years**					
		Model 0 - unadjusted	**Model 1 – 0 + sociodemographic factors[a]**	**Model 2 – 0 + perinatal factors[b]**	**Model 3 – 0 + parent mental health[c]**	**Model 4 – fully adjusted[d]**	**Exposure * Sex interaction**
		Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	P value
BMI Trajectory							
Low	3374	ref	ref	ref	ref	ref	ref
Moderate	1621	3.16 (2.71, 3.69)	3.19 (2.72, 3.73)	3.21 (2.75, 3.76)	3.16 (2.71, 3.69)	3.18 (2.71, 3.73)	<0.001
High	322	4.87 (3.35, 7.08)	5.31 (3.50, 8.06)	5.06 (3.43, 7.47)	4.85 (3.34, 7.04)	5.27 (3.44, 8.08)	0.028
FMI Trajectory							
Low	3584	ref	ref	ref	ref	ref	ref
Moderate	1439	3.34 (2.84, 3.93)	3.02 (2.56, 3.58)	3.35 (2.84, 3.95)	3.34 (2.83, 3.93)	2.95 (2.48, 3.50)	<0.001
High	294	4.81 (3.35, 6.92)	4.83 (3.24, 7.21)	4.88 (3.32, 7.19)	4.79 (3.33, 6.89)	4.66 (3.07, 7.07)	0.058
FFMI Trajectory							
Low	2514	ref	ref	ref	ref	ref	ref
Moderate	2330	1.93 (1.72, 2.17)	2.63 (2.30, 3.01)	1.93 (1.70, 2.18)	1.93 (1.71, 2.17)	2.62 (2.29, 3.01)	0.161
High	473	4.08 (3.01, 5.53)	7.98 (5.74, 11.11)	4.11 (3.02, 5.59)	4.06 (3.00, 5.51)	8.04 (5.76, 11.22)	0.072
FM/FFM Trajectory							
Low	3816	ref	ref	ref	ref	ref	ref
Moderate	1241	3.55 (2.95, 4.28)	3.26 (2.69, 3.96)	3.53 (2.93, 4.26)	3.54 (2.94, 4.27)	3.15 (2.60, 3.83)	<0.001
High	260	4.15 (2.82, 6.09)	3.95 (2.60, 6.00)	4.19 (2.80, 6.25)	4.13 (2.81, 6.06)	3.77 (2.46, 5.80)	0.135

[a] Adjusting for sex, age at interview, ethnicity, family income, parental education, and parental occupational class at 9 months old.

[b] Adjusting for birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy.

[c] Adjusting for parent psychological distress at 3 years old.

[d] Adjusting for all confounding variables in models 1 to 3.

Appendix for Chapter 6, Table 12. Results of univariable and multivariable logistic regression analysis of the association between body composition trajectory and having ever dieted for weight loss at 17 years in participants with complete data (sampling and attrition weights applied).

		Dieting for Weight Loss at 17 Years					
Whole sample N=5317	N	**Model 0 - unadjusted**	**Model 1 – 0 + sociodemographic factors[a]**	**Model 2 – 0 + perinatal factors[b]**	**Model 3 – 0 + parent mental health[c]**	**Model 4 – fully adjusted[d]**	**Exposure * Sex interaction**
		Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	P value
BMI Trajectory							
Low	3375	ref	ref	ref	ref	ref	ref
Moderate	1620	3.47 (3.00, 4.01)	3.62 (3.08, 4.25)	3.45 (2.95, 4.04)	3.47 (3.00, 4.01)	3.51 (2.96, 4.15)	0.002
High	322	5.39 (3.68, 7.91)	6.59 (4.31, 10.06)	5.35 (3.58, 8.00)	5.40 (3.68, 7.91)	6.17 (4.01, 9.50)	0.031
FMI Trajectory							
Low	3585	ref	ref	ref	ref	ref	ref
Moderate	1438	4.11 (3.51, 4.81)	3.56 (3.01, 4.21)	4.06 (3.44, 4.79)	4.11 (3.51, 4.82)	3.39 (2.85, 4.04)	<0.001
High	294	5.34 (3.67, 7.76)	5.34 (3.63, 7.87)	5.22 (3.55, 7.69)	5.34 (3.68, 7.76)	4.88 (3.30, 7.22)	0.288
FFMI Trajectory							
Low	2513	ref	ref	ref	ref	ref	ref
Moderate	2331	1.75 (1.54, 2.00)	2.76 (2.39, 3.18)	1.69 (1.48, 1.93)	1.75 (1.54, 2.00)	2.65 (2.29, 3.07)	0.160
High	473	2.62 (2.01, 3.40)	6.97 (5.14, 9.46)	2.42 (1.85, 3.16)	2.62 (2.01, 3.40)	6.46 (4.75, 8.77)	0.081
FM/FFM Trajectory							
Low	3817	ref	ref	ref	ref	ref	ref
Moderate	1242	4.33 (3.59, 5.22)	3.88 (3.17, 4.74)	4.26 (3.48, 5.21)	4.33 (3.59, 5.23)	3.68 (2.97, 4.55)	<0.001
High	258	5.18 (3.39, 7.91)	4.86 (3.16, 7.46)	5.06 (3.30, 7.76)	5.19 (3.40, 7.91)	4.42 (2.89, 6.77)	0.138

[a] Adjusting for sex, age at interview, ethnicity, family income, parental education, and parental occupational class at 9 months old.

[b] Adjusting for birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy.

[c] Adjusting for parent psychological distress at 3 years old.

[d] Adjusting for all confounding variables in models 1 to 3.

Appendix for Chapter 6, Table 13. Comparison of unadjusted results in (a) a sample with valid BMI trajectory and (b) the sample restricted to those with other trajectory data (collected from age 7 onward). Missing outcome data imputed, sampling weights applied.

BMI Trajectory	**Full sample with BMI data (n= 14,675)**	**Restricted sample in main analysis (n= 13,025)**
Body satisfaction at age 14	Mean Difference (95% CI)	Mean Difference (95% CI)
Low	ref	ref
Moderate	-0.41 (-0.48, -0.33)	-0.41 (-0.49, -0.33)
High	-0.84 (-0.99, -0.69)	-0.85 (-1.01, -0.69)
Lifetime exercise for weight loss at age 14	Odds Ratio (95% CI)	Odds Ratio (95% CI)
Low	ref	ref
Moderate	3.83 (3.83, 4.29)	3.88 (3.46, 4.36)
High	5.78 (4.40, 7.59)	5.94 (4.53, 7.78)
Lifetime dieting for weight loss at age 14	Odds Ratio (95% CI)	Odds Ratio (95% CI)
Low	ref	ref
Moderate	3.69 (3.33, 4.08)	3.73 (3.37, 4.13)
High	7.99 (6.46, 9.88)	8.24 (6.63, 10.23)
Past year exercise for weight loss at age 17	Odds Ratio (95% CI)	Odds Ratio (95% CI)
Low	ref	ref
Moderate	3.08 (2.67, 3.55)	3.06 (2.66, 3.52)
High	3.85 (2.86, 5.17)	3.90 (2.90, 5.24)
Past year dieting for weight loss at age 17	Odds Ratio (95% CI)	Odds Ratio (95% CI)
Low	ref	ref
Moderate	3.38 (2.98, 3.83)	3.39 (2.98, 3.86)
High	5.39 (4.13, 7.03)	5.49 (4.16, 7.24)

Appendix for Chapter 6, Table 14. Results of a sensitivity analysis adjusting for pubertal status in the association between body composition trajectory and body satisfaction at 14 years in participants with valid exposure data and imputed outcome and confounder data (sampling weights applied).

Whole sample N=13025	N	Body Satisfaction at 14 Years			
		Model 0 - unadjusted	**Model 1 – 0 + pubertal status[a]**	**Model 2 – fully adjusted[b]**	**Exposure * Sex interaction**
		Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	P value
BMI Trajectory					
Low	8375	ref	ref	ref	ref
Moderate	3783	-0.41 (-0.49, -0.33)	-0.36 (-0.44, -0.28)	-0.31 (-0.39, -0.23)	0.192
High	867	-0.85 (-1.01, -0.69)	-0.79 (-0.95, -0.63)	-0.69 (-0.84, -0.53)	0.146
FMI Trajectory					
Low	8930	ref	ref	ref	ref
Moderate	3288	-0.59 (-0.67, -0.51)	-0.54 (-0.62, -0.45)	-0.33 (-0.42, -0.24)	0.980
High	807	-1.00 (-1.17, -0.83)	-0.94 (-1.10, -0.77)	-0.70 (-0.87, -0.53)	0.195
FFMI Trajectory					
Low	5851	ref	ref	ref	ref
Moderate	5977	-0.09 (-0.17, -0.01)	-0.05 (-0.13, 0.03)	-0.23 (-0.31, -0.15)	<0.001
High	1197	-0.16 (-0.29, -0.03)	-0.12 (-0.25, 0.01)	-0.46 (-0.60, -0.32)	0.003
FM/FFM Trajectory					
Low	9306	ref	ref	ref	ref
Moderate	3024	-0.57 (-0.66, -0.49)	-0.52 (-0.61, -0.44)	-0.33 (-0.41, -0.24)	0.684
High	695	-1.12 (-1.30, 0.94)	-1.04 (-1.22, -0.86)	-0.75 (-0.93, -0.57)	0.575

a Adjusting for pubertal status at 11 and 14 years

b Adjusting for puberal status at 11 and 14 years, sex at birth, age at interview, ethnicity, family income, parental education, parental occupational class at 9 months old, birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy, and parent psychological distress at 3 years old.

Appendix for Chapter 6, Table 15. Results of a sensitivity analysis adjusting for pubertal status in the association between body composition trajectory and having ever exercised for weight loss at 14 years in participants with valid exposure data and imputed outcome and confounder data (sampling weights applied).

		Exercise for Weight Loss at 14 Years			
Whole sample N=13025	N	**Model 0 - unadjusted**	**Model 1 – 0 + pubertal status[a]**	**Model 2 – fully adjusted[b]**	**Exposure * Sex interaction**
		Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	P value
BMI Trajectory					
Low	8375	ref	ref	ref	ref
Moderate	3783	3.88 (3.46, 4.36)	3.72 (3.31, 4.19)	3.66 (3.24, 4.14)	0.130
High	867	5.94 (4.53, 7.78)	5.70 (4.34, 7.50)	5.52 (4.18, 7.30)	0.572
FMI Trajectory					
Low	8930	ref	ref	ref	ref
Moderate	3288	3.91 (3.46, 4.42)	3.70 (3.27, 4.20)	3.48 (3.06, 3.96)	0.044
High	807	6.21 (4.75, 8.13)	5.90 (4.51, 7.71)	5.44 (4.15, 7.14)	0.965
FFMI Trajectory					
Low	5851	ref	ref	ref	ref
Moderate	5977	2.22 (2.03, 2.44)	2.15 (1.96, 2.36)	2.63 (2.37, 2.92)	0.062
High	1197	4.37 (3.51, 5.42)	4.26 (3.42, 5.30)	6.04 (4.75, 7.98)	0.135
FM/FFM Trajectory					
Low	9306	ref	ref	ref	ref
Moderate	3024	3.78 (3.31, 4.30)	3.62 (3.16, 4.13)	3.40 (2.96, 3.90)	0.008
High	695	6.38 (4.70, 8.67)	5.84 (4.33, 7.89)	5.23 (3.86, 7.07)	0.657

a Adjusting for pubertal status at 11 and 14 years

b Adjusting for puberal status at 11 and 14 years, sex at birth, age at interview, ethnicity, family income, parental education, parental occupational class at 9 months old, birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy, and parent psychological distress at 3 years old.

Appendix for Chapter 6, Table 16. Results of a sensitivity analysis adjusting for pubertal status in the association between body composition trajectory and having ever dieted for weight loss at 14 years in participants with valid exposure data and imputed outcome and confounder data (sampling weights applied).

		Dieting for Weight Loss at 14 Years			
Whole sample N=13025	N	**Model 0 - unadjusted**	**Model 1 – 0 + pubertal status[a]**	**Model 2 – fully adjusted[b]**	**Exposure * Sex interaction**
		Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	P value
BMI Trajectory					
Low	8375	ref	ref	ref	ref
Moderate	3783	3.73 (3.37, 4.13)	3.55 (3.20, 3.94)	3.55 (3.18, 4.97)	0.012
High	867	8.24 (6.63, 10.23)	7.87 (6.30, 9.83)	7.71 (6.13, 9.69)	0.431
FMI Trajectory					
Low	8930	ref	ref	ref	ref
Moderate	3288	4.35 (3.85, 4.91)	4.10 (3.62, 4.63)	3.57 (3.15, 4.05)	<0.001
High	807	9.08 (7.19, 11.47)	8.56 (6.75, 10.85)	7.57 (5.75, 9.38)	0.846
FFMI Trajectory					
Low	5851	ref	ref	ref	ref
Moderate	5977	1.98 (1.81, 2.17)	1.90 (1.74, 2.09)	2.65 (2.38, 2.95)	0.050
High	1197	3.79 (3.18, 4.52)	3.68 (3.07, 4.41)	6.66 (5.42, 8.19)	0.617
FM/FFM Trajectory					
Low	9306	ref	ref	ref	ref
Moderate	3024	4.26 (3.74, 4.85)	4.03 (3.54, 4.59)	3.52 (3.07, 4.03)	0.001
High	695	10.10 (7.77, 13.12)	9.35 (7.17, 12.20)	7.54 (5.73, 9.92)	0.785

a Adjusting for pubertal status at 11 and 14 years

b Adjusting for puberal status at 11 and 14 years, sex at birth, age at interview, ethnicity, family income, parental education, parental occupational class at 9 months old, birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy, and parent psychological distress at 3 years old.

Appendix for Chapter 6, Table 17. Results of a sensitivity analysis adjusting for pubertal status in the association between body composition trajectory and having exercised for weight loss in the past 12 months at 17 years in participants with valid exposure data and imputed outcome and confounder data (sampling weights applied).

		Exercise for Weight Loss at 17 Years			
Whole sample N=13025	N	**Model 0 - unadjusted**	**Model 1 – 0 + pubertal status**[a]	**Model 2 – fully adjusted**[b]	**Exposure * Sex interaction**
		Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	P value
BMI Trajectory					
Low	8375	ref	ref	ref	ref
Moderate	3783	3.06 (2.66, 3.52)	2.97 (2.58, 3.42)	3.09 (2.66, 3.58)	0.002
High	867	3.90 (2.90, 5.24)	3.83 (2.84, 5.16)	4.17 (3.07, 5.67)	0.230
FMI Trajectory					
Low	8930	ref	ref	ref	ref
Moderate	3288	3.22 (2.78, 3.74)	3.12 (2.96, 3.63)	2.89 (2.47, 3.38)	0.001
High	807	4.14 (3.11, 5.52)	4.05 (3.04, 5.40)	4.03 (2.99, 5.43)	0.300
FFMI Trajectory					
Low	5851	ref	ref	ref	ref
Moderate	5977	1.93 (1.73, 2.16)	1.89 (1.68, 2.11)	2.59 (2.27, 2.95)	0.534
High	1197	3.90 (3.00, 5.07)	3.83 (2.94, 4.99)	6.92 (5.24, 9.15)	0.107
FM/FFM Trajectory					
Low	9306	ref	ref	ref	ref
Moderate	3024	3.21 (2.73, 3.77)	3.11 (2.65, 3.65)	2.92 (2.48, 3.45)	0.003
High	695	4.01 (2.95, 5.45)	3.88 (2.85, 5.28)	3.67 (2.66, 5.06)	0.415

a Adjusting for pubertal status at 11 and 14 years

b Adjusting for puberal status at 11 and 14 years, sex at birth, age at interview, ethnicity, family income, parental education, parental occupational class at 9 months old, birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy, and parent psychological distress at 3 years old.

Appendix for Chapter 6, Table 18. Results of a sensitivity analysis adjusting for pubertal status in the association between body composition trajectory and having dieted for weight loss in the past 12 months at 17 years in participants with valid exposure data and imputed outcome and confounder data (sampling weights applied).

Whole sample N=13025	N	Dieting for Weight Loss at 17 Years			
		Model 0 - unadjusted	**Model 1 – 0 + pubertal status[a]**	**Model 2 – fully adjusted[b]**	**Exposure * Sex interaction**
		Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	P value
BMI Trajectory					
Low	8375	ref	ref	ref	ref
Moderate	3783	3.39 (2.98, 3.86)	3.25 (2.84, 3.71)	3.44 (2.98, 3.97)	0.021
High	867	5.49 (4.16, 7.24)	5.31 (3.99, 7.06)	5.88 (4.27, 8.09)	0.152
FMI Trajectory					
Low	8930	ref	ref	ref	ref
Moderate	3288	4.07 (3.55, 4.66)	3.86 (3.36, 4.43)	3.35 (2.90, 3.89)	0.009
High	807	6.47 (4.92, 8.52)	6.20 (4.68, 8.22)	5.75 (4.21, 7.86)	0.227
FFMI Trajectory					
Low	5851	ref	ref	ref	ref
Moderate	5977	1.74 (1.56, 1.93)	1.67 (1.50, 1.86)	2.55 (2.24, 2.91)	0.747
High	1197	2.89 (2.33, 3.58)	2.80 (2.25, 3.50)	6.10 (4.71, 7.90)	0.353
FM/FFM Trajectory					
Low	9306	ref	ref	ref	ref
Moderate	3024	4.14 (3.55, 4.83)	3.95 (3.38, 4.61)	3.52 (2.98, 4.15)	0.010
High	695	7.02 (5.15, 9.58)	6.62 (4.82, 9.10)	5.73 (4.03, 8.15)	0.059

a Adjusting for pubertal status at 11 and 14 years

b Adjusting for puberal status at 11 and 14 years, sex at birth, age at interview, ethnicity, family income, parental education, parental occupational class at 9 months old, birthweight, maternal pre-pregnancy BMI, breastfeeding, cigarette and alcohol use in pregnancy, and parent psychological distress at 3 years old.

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```
**Set baseline confounders for all analyses
global confs "AHCSEX00 age17 ethnicitybl incomebl highestnvq composite_nssec
matprebmi birthwgt anysmok anyalc breastfed parentmh sdq3"

**Create vars for mediation
gen y = c_cmkess17
gen m = c_bodysat14
gen l4 = c_mfq6
gen l3 = cyberbully2
gen l2 = peerbully2
gen l1 = puberty14

**Mediation analysis, complete case
preserve
keep if miss==0
#delimit;
gformula y modbmi m l2 l3 l4 $confs,
mediation
outcome(y) exposure(modbmi) mediator(m) post_confs(l2 l3 l4)
base_confs($confs)
commands(y: regress, m: regress, l2: logit, l3: logit, l4: regress)
equations
        (
        y       : modbmi m l4 l3 l2  $confs  ,
        m       : modbmi   l4 l3 l2  $confs  ,
        l4      : modbmi      l3 l2  $confs  ,
        l3      : modbmi         l2  $confs  ,
        l2      : modbmi             $confs  ,
        )
control(m:0) obe
samples(1000) moreMC simulations(20000) replace seed(79)
;
#delimit cr
restore
```

Appendix for Chapter 7, Table 2. Comparison of sample characteristics among those with valid exposure data, complete data and imputed data.

Variable	Valid exposure N (%)	Complete data %	Imputed %
N	13025	6663	13025
Cohort member sex at birth			
Male	6612 (50.8)	47.9	50.8
Female	6413 (49.2)	52.1	49.2
Missing[a]	0	-	-
Cohort member ethnicity			
White	10968 (84.4)	88.5	84.4
Mixed	346 (2.7)	2.5	2.7
Indian	312 (2.4)	2.2	2.4
Pakistani or Bangladeshi	828 (6.4)	3.8	6.4
Black or Black British	383 (2.9)	1.9	2.9
Other, including Chinese or Arab	160 (1.2)	1.0	1.2
Missing	28 (0.2)	-	-
Family income at 9 months			
Most disadvantaged	2804 (21.6)	13.8	21.6
Second	2786 (21.5)	18.3	21.5
Third	2526 (19.4)	20.6	19.4
Fourth	2521 (19.4)	23.5	19.4
Least disadvantaged	2355 (18.1)	23.8	18.1
Missing	33 (0.3)	-	-
Highest parental education level at 9 months			
None	1403 (10.8)	5.2	18.8
NVQ Level 1 (GCSE grade D-G)	775 (5.9)	3.8	5.9
NVQ Level 2 (GCSE grade A*-C)	3199 (24.6)	21.5	24.6
NVQ Level 3 (A Level)	2151 (16.5)	16.6	16.5
NVQ Level 4 (One year Undergraduate)	4593 (35.3)	43.4	35.3
NVQ Level 5 (Two years Undergraduate)	896 (6.9)	9.6	6.9
Missing	8 (0.1)	-	-
Highest parental occupational class at 9 months			
Not in work	2924 (22.5)	14.1	22.5
Routine or semi-routine	1900 (14.6)	12.2	14.6
Lower supervisory or technical	1043 (8.0)	7.7	8.0
Small employers or self-employed	863 (6.6)	6.4	6.6
Intermediate occupations	1199 (9.2)	9.4	9.2
Managerial or professional	5050 (38.9)	50.1	38.9
Missing	46 (0.4)	-	-
Cohort member birthweight			
Mean (SD)	3.36 (0.6)	3.39 (0.6)	3.36 (0.6)
Missing	29 (0.2)	-	-
Maternal pre-pregnancy BMI			
Mean (SD)	23.8 (4.5)	23.8 (4.4)	23.8 (4.6)
Missing	1061 (8.2)	-	-
Cohort member was breastfed			
No	3870 (29.8)	23.6	29.8
Yes	9135 (70.2)	76.4	70.2
Missing	20 (0.2)	-	-
Mother smoked in pregnancy			
No	11057 (84.9)	87.1	84.9
Yes	1962 (15.1)	12.9	15.1
Missing	6 (0.1)	-	-
Mother drank alcohol in pregnancy			
No	9020 (69.4)	65.5	69.4
Yes	3982 (30.6)	34.5	30.6
Missing	23 (0.2)	-	-
Any parent psychological distress at 3 years			
No	7965 (65.5)	66.9	64.0
Yes	4192 (34.5)	33.1	36.0
Missing	868 (6.7)	-	-

Variable	Valid exposure N (%)	Complete data %	Imputed %
Mean (SD)	9.54 (5.2)	8.88 (4.9)	9.70 (5.4)
Missing	884 (6.8)	-	-
Cohort member experienced bullying at 14 years			
No	5061 (51.2)	48.4	51.2
Yes	4833 (48.9)	51.6	48.9
Missing	3131 (24.0)	-	-
Cohort member experienced cyber bullying at 14 years			
No	7026 (71.0)	70.4	70.5
Yes	2871 (29.0)	29.6	29.5
Missing	3128 (24.0)	-	-
Cohort member sMFQ Score at 14 years			
Mean (SD)	5.53 (5.8)	5.67 (5.9)	5.53 (6.7)
Missing	3245 (24.9)	-	-
Cohort member body satisfaction at 14 years			
Mean (SD)	4.79 (1.6)	4.76 (1.6)	4.79 (1.8)
Missing	3151 (24.2)	-	-
Cohort member depressive symptoms at 17 years			
Mean (SD)	7.27 (4.9)	7.30 (4.8)	7.27 (6.0)
Missing	4257 (32.7)	-	-

[a] Proportions of non-missing data add up to 100% for comparisons to be made across samples.

Appendix for Chapter 7, Table 3. Characteristics of samples with valid and missing outcome data at 17 years.

Variable	Missing depressive symptom data at age 17	
	No (n= 8768, 67.3%)	Yes (n= 4257, 32.7%)
Cohort member sex at birth		
Male	64.7	35.3
Female	70.0	30.0
Cohort member ethnicity		
White	66.3	33.7
Mixed	66.2	33.8
Indian	77.9	22.1
Pakistani or Bangladeshi	75.9	24.1
Black or Black British	66.1	33.9
Other, including Chinese and Arab	78.1	21.9
Family income at 9 months		
Most disadvantaged	57.1	42.9
Second	63.8	36.2
Third	67.4	32.6
Fourth	72.7	27.3
Least disadvantaged	77.8	22.2
Highest parental education level at 9 months		
None	58.9	41.1
NVQ Level 1 (GCSE grade D-G)	54.1	45.9
NVQ Level 2 (GCSE grade A*-C)	61.4	38.6
NVQ Level 3 (A Level)	63.7	36.3
NVQ Level 4 (One year Undergraduate)	74.9	25.1
NVQ Level 5 (Two years Undergraduate)	82.5	17.5
Highest parental occupational class at 9 months		
Not in work	55.6	44.4
Routine or semi-routine	63.0	37.0
Lower supervisory or technical	63.8	36.2
Small employers or self-employed	67.8	32.2
Intermediate occupations	65.8	34.2
Managerial or professional	76.6	23.4
Cohort member birthweight		
Low birthweight (≤2.5kg)	66.8	33.2
Birthweight >2.5kg	67.4	32.6
Maternal pre-pregnancy BMI		
BMI <25	67.6	32.4
BMI 25 – 29.9	66.6	33.4
BMI ≥30	67.8	32.2
Cohort member was breastfed		
No	57.6	42.4
Yes	71.5	28.5
Mother smoked in pregnancy		
No	69.0	31.0
Yes	58.1	41.9
Mother drank alcohol in pregnancy		
No	66.4	33.6
Yes	69.6	30.4
Any parent psychological distress at 3 years		
No	67.6	32.4
Yes	67.4	32.6
Cohort member SDQ score at 3 years		
Mean (SD)	9.17 (5.1)	10.30 (5.4)

Variable	Missing depressive symptom data at age 17	
	No (n= 8768, 67.3%)	Yes (n= 4257, 32.7%)
Cohort member experienced bullying at 14 years		
No	79.0	21.0
Yes	84.4	15.6
Cohort member experienced cyber bullying at 14 years		
No	82.0	18.0
Yes	80.7	19.3
Cohort member sMFQ Score at 14 years		
Mean (SD)	5.59 (5.9)	5.30 (5.8)
Cohort member body satisfaction at 14 years		
Mean (SD)	4.78 (1.6)	4.80 (1.6)
Cohort member BMI trajectory		
Low	66.6	33.4
Moderate	69.6	30.4
High	64.6	35.4

Appendix for Chapter 7, Table 4. Univariable and multivariable regression models estimating the association between childhood body composition trajectory and depressive symptoms in participants with complete data on exposures, outcomes and confounders (sampling and attrition weights applied).

		Depressive Symptoms at 17 years					
Complete case sample N=7244	N	**Model 0 - unadjusted**	**Model 1 – 0 + sociodemographic factors**	**Model 2 – 0 + perinatal factors**	**Model 3 – 0 + mental health**	**Model 4 – fully adjusted**	**Exposure * Sex interaction**
		Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	P value
BMI Trajectory							
Low		ref	ref	ref	ref	ref	ref
Moderate		0.41 (0.12, 0.70)	0.23 (-0.05, 0.51)	0.37 (0.06, 0.67)	0.39 (0.10, 0.68)	0.17 (-0.12, 0.47)	0.689
High		1.13 (0.45, 1.81)	0.87 (0.19, 1.54)	1.00 (0.34, 1.65)	1.06 (0.38, 1.73)	0.72 (0.07, 1.38)	0.525
Adiposity Trajectory							
Low		ref	ref	ref	ref	ref	ref
Moderate		0.98 (0.64, 1.31)	0.47 (0.14, 0.80)	0.93 (0.58, 1.28)	0.95 (0.62, 1.28)	0.41 (0.06, 0.75)	0.899
High		1.62 (0.84, 2.39)	0.96 (0.18, 1.75)	1.52 (0.78, 2.26)	1.54 (0.76, 2.31)	0.83 (0.07, 1.59)	0.762

Model 0 – Unadjusted
Model 1 – Model 0 + sex at birth, age at interview, ethnicity, family income, parent education level, parent occupation.
Model 2 – Model 0 + maternal pre-pregnancy BMI, child birthweight, breastfeeding status, antenatal consumption of cigarettes and alcohol.
Model 3 – Model 0 + parent mental health at 3 years, child SDQ score at 3 years.

Appendix for Chapter 7, Table 5. Univariable and multivariable regression models estimating the association between body satisfaction and depressive symptoms in participants with complete data on exposures, outcomes and confounders (sampling and attrition weights applied).

	Depressive Symptoms at 17 years						
Complete case sample N=6600	**Model 0 - unadjusted**	**Model 1 – 0 + Sociodemographic factors**	**Model 2 – 0 + perinatal factors**	**Model 3 – 0 + mental health**	**Model 4 – 0 + BMI, bullying**	**Model 5 – fully adjusted**	**Exposure * Sex interaction**
	Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	Mean Difference (95% CI)	P value
Body Satisfaction							
Per one unit increase in body satisfaction	-1.13 (-1.22, -1.04)	-1.01 (-1.10, -0.92)	-1.11 (-1.20, -1.02)	-0.44 (-0.54, -0.34)	-0.93 (-1.02, -0.84)	-0.35 (-0.45, -0.25)	0.329

Model 0 – Unadjusted
Model 1 – Model 0 + sex at birth, age at interview, ethnicity, family income, parent education level, parent occupation.
Model 2 – Model 0 + maternal pre-pregnancy BMI, child birthweight, breastfeeding status, antenatal consumption of cigarettes and alcohol.
Model 3 – Model 0 + parent mental health at 3 years, child MFQ score at 14 years.
Model 4 – Model 0 + BMI trajectory and bullying
Model 5 – All confounders in models 1-4.

Appendix for Chapter 7, Table 6. Mediation analysis: marginal mean difference in depressive symptoms among those with moderate and high trajectory compared to those with a low trajectory of BMI and adiposity. Estimates from a sample with complete data on all variables of interest (N=6,600).

Estimand	**BMI**	**Adiposity**
Moderate Trajectory		
Total Causal Effect	0.18 (-0.09, 0.45)	0.34 (0.02, 0.65)
Natural Direct Effect	0.08 (-0.18, 0.34)	0.23 (-0.08, 0.54)
Natural Indirect Effect	0.10 (0.05, 0.15)	0.11 (0.06, 0.15)
Proportion mediated	0.55 (-1.12, 2.22)	0.31 (-0.18, 0.81)
High Trajectory		
Total Causal Effect	0.55 (0.00, 1.10)	0.59 (0.00, 1.18)
Natural Direct Effect	0.30 (-0.25, 0.85)	0.35 (-0.22, 0.91)
Natural Indirect Effect	0.25 (0.14, 0.36)	0.24 (0.13, 0.35)
Proportion mediated	0.45 (-1.03, 1.94)	0.41 (-7.50, 8.32)

Appendix for Chapter 7, Table 7. Comparing the explanatory power of BMI trajectory compared to BMI as a continuous variable at one time point. Fully adjusted[a] regression models repeated on a sample with valid data on BMI and adiposity trajectory and imputed data on outcomes and confounders (N=13,025).

Whole sample (N=13,025)	**Mean difference in depressive symptoms at age 17 (95% CI)**	
	BMI Trajectory (3 to 14 years)	BMI at age 11 (continuous)
Moderate BMI	0.16 (-0.10, 0.41)	-
High BMI	0.54 (-0.03, 1.11)	-
Per one unit increase in BMI	-	0.04 (0.00, 0.08)
Adjusted R^2	6.7%	6.9%
+ exposure*sex interaction p value	Moderate = 0.703 High = 0.251	0.114

[a] Controls for sex at birth, age at outcome measurement, ethnicity, family income, parents' educational qualifications and occupational class, maternal pre-pregnancy BMI, cohort member birthweight, breastfeeding, maternal smoking and alcohol consumption in pregnancy, parental mental health, child SDQ score at age 3.

Appendix for Chapter 8

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Appendix for Chapter 8, Table 1. Categorisation of parent-reported concern about their child becoming overweight. Initial response categories in Millennium Cohort Study Sweep 3 (Age 5) and dichotomised responses for analysis.

Responses	**N (%)**	**Unconcerned N (%)**	**Concerned N (%)**
Unconcerned	10687 (73.3)	10687 (73.3)	
A little concerned	2591 (17.8)		3901 (26.7)
Concerned	522 (3.6)		
Fairly concerned	381 (2.6)		
Very concerned	407 (2.8)		

Appendix for Chapter 8, Table 2. Parent-reported reasons for controlling their child's diet at age 5, grouped according to categories used in analysis. Total responses are greater than N=14,577 due to multiple responses.

Diet control reasons	**N**
Healthy, balanced diet	
To give a healthy, balanced diet	6,497
Limit snacks so child eats main meal	18
Weight management	
To put on or maintain weight	591
To lose or control weight	402
As a reward or punishment	
As a reward or punishment	1,805
Other responses	
Behaviour/hyperactivity	1,892
Vegetarian / vegan diet	215
Teeth	3,715
Digestive problems (e.g. constipation)	877
Allergies/sensitivities	602
Religious reasons (e.g., no pork)	185
Limit drinks to prevent bed-wetting	39
Diabetes	16
No restriction for any of these reasons	5,470

Appendix for Chapter 8, Table 3. Comparing characteristics of samples with valid exposure data; valid exposure data, complete confounders and at least one measure of BMI data from age 7; and valid exposure and imputed outcome and confounder data.

Characteristic	**Valid exposure** N=14,588	**Complete confounders** N=9960	**Imputed outcomes and confounders** N=14,588
Cohort member sex at birth			
Male	7446 (51.0)	4961 (49.8)	51.0
Female	7142 (49.0)	4999 (50.2)	49.0
Missing	0	-	-
Cohort member ethnicity			
White	12249 (84.1)	8787 (88.2)	84.1
Mixed	410 (2.8)	257 (2.6)	2.8
Indian	357 (2.5)	215 (2.2)	2.5
Pakistani / Bangladeshi	892 (6.1)	408 (4.1)	6.1
Black or Black British	464 (3.2)	189 (1.9)	3.2
Other	182 (1.2)	104 (1.0)	1.3
Missing	34 (0.2)	-	-
Family income fifth at 9 months			
Most deprived	3295 (22.6)	1764 (17.7)	22.7
Second	3181 (21.8)	2019 (20.3)	21.9
Third	2821 (19.3)	2015 (20.2)	19.4
Fourth	2733 (18.7)	2141 (21.5)	18.8
Least deprived	2513 (17.2)	2021 (20.3)	17.2
Missing	45 (0.3)	-	-
Parental education level at 9 months			
None	1701 (11.7)	779 (7.8)	11.7
NVQ Level 1 (GCSE grade D-G)	848 (5.8)	498 (5.0)	5.8
NVQ Level 2 (GCSE grade A*-C)	3633 (24.9)	2374 (23.8)	24.9
NVQ Level 3 (A Level)	2401 (16.5)	1699 (17.1)	16.5
NVQ Level 4 (One year Undergraduate)	5014 (34.4)	3848 (38.6)	34.4
NVQ Level 5 (Two years Undergraduate)	979 (6.7)	762 (7.7)	6.7
Missing	12 (0.1)	-	-
Parental occupational class at 9 months			
Not in work	3502 (24.0)	1880 (18.9)	24.1
Semi-routine/routine	2162 (14.8)	1350 (13.6)	14.9
Lower supervisory/technical	1171 (8.0)	795 (8.0)	8.0
Small employers/self-employed	950 (6.5)	659 (6.6)	6.6
Intermediate	1316 (9.0)	967 (9.7)	9.0
Managerial/professional	5437 (37.3)	4309 (43.3)	37.4
Missing	50 (0.3)	-	-
Cohort member emotional symptoms at 3 years			
Mean (SE)	1.35 (0.01)	1.29 (0.02)	1.40 (0.01)
Missing	2013 (13.8)	-	-
Cohort member peer problems at 3 years			
Mean (SE)	1.53 (0.01)	1.46 (0.02)	1.18 (0.01)
Missing	2093 (14.4)	-	-
Mother's pre-pregnancy BMI (mean-centred)			
Mean (SE)	0.13 (0.04)	0.17 (0.04)	0.19 (0.04)
Missing	1203 (8.2)	-	-
Cohort member BMI at 3 years (mean-centred)			
Mean (SE)	0.88 (0.01)	0.88 (0.01)	0.63 (0.01)
Missing	2514 (17.2)	-	-

Appendix for Chapter 8, Table 4. Patterns of missing outcome data across data collection waves of interest, among a sample of participants with valid exposure data.

Number of waves missing BMI data, ages 7-17	**N (%)**
0 (data at all waves)	8341 (57.2)
1	830 (5.7)
2	1758 (12.1)
3	1346 (9.2)
4 (no data at any wave)	2313 (15.9)
Number of waves missing body satisfaction data, ages 11-14	**N (%)**
0 (data at all waves)	8889 (60.9)
1	2366 (16.2)
2 (no data at any wave)	3333 (22.9)

Appendix for Chapter 8, Table 5. Proportions missing outcome data by sample characteristics, among those with valid exposure data.

Characteristic	Missing BMI data (<1 valid BMI 7-17)		Missing body satisfaction data (<1 valid body satisfaction 11-14)	
	No (N= 12,275 84.1%)	Yes (N= 2,313 15.9%)	No (N=11,255 77.1%)	Yes (N= 3,333 22.9%)
Cohort member sex at birth				
Male	83.4	16.6	75.8	24.2
Female	84.9	15.1	78.6	21.4
Cohort member ethnicity				
White	85.2	14.8	78.1	21.9
Mixed	77.1	22.9	70.5	29.5
Indian	81.8	18.2	78.2	21.8
Pakistani / Bangladeshi	80.6	19.4	75.7	24.3
Black or Black British	73.1	26.9	62.9	37.1
Other	81.9	18.1	75.3	24.7
Family income fifth at 9 months				
Most deprived	75.6	24.4	67.0	33.0
Second	81.9	18.1	73.8	26.2
Third	85.9	14.1	79.0	21.0
Fourth	89.4	10.6	83.9	16.1
Least deprived	90.9	9.1	85.6	14.4
Parental education level at 9 months				
None	73.7	26.3	65.2	34.8
NVQ Level 1 (GCSE grade D-G)	81.5	18.5	72.5	27.5
NVQ Level 2 (GCSE grade A*-C)	82.0	18.0	73.9	26.1
NVQ Level 3 (A Level)	84.4	15.6	76.7	23.3
NVQ Level 4 (One year Undergraduate)	88.8	11.2	83.3	16.7
NVQ Level 5 (Two years Undergraduate)	88.2	11.8	84.1	15.9
Parental occupational class at 9 months				
Not in work	74.9	25.1	66.8	33.2
Semi-routine/routine	81.4	18.6	73.8	26.2
Lower supervisory/technical	84.2	15.8	74.7	25.3
Small employers/self-employed	86.2	13.8	78.0	22.0
Intermediate	86.9	13.1	80.3	19.7
Managerial/professional	90.2	9.8	84.8	15.2
Cohort member emotional symptoms at 3 years				
Close to average (<5)	93.4	6.6	80.4	29.6
High (5-10)	91.6	8.4	75.9	24.1
Cohort member peer problems at 3 years				
Close to average (<4)	93.3	6.7	80.5	19.5
High (4-10)	93.2	6.8	78.5	21.5
Mother's pre-pregnancy BMI				
<18.5	80.4	19.6	72.5	27.5
18.5 – 24.9	84.4	15.6	77.5	22.5
25 – 29.9	85.4	14.6	78.8	21.2
30+	85.7	14.3	78.8	21.2
Cohort member BMI at 3 years				
Underweight	91.4	8.6	80.9	19.1
Healthy weight	93.7	6.3	80.5	19.5
Overweight	93.6	6.4	80.2	19.8
Obese	90.8	9.2	77.8	22.2

Characteristic	Missing BMI data (<1 valid BMI 7-17)		Missing body satisfaction data (<1 valid body satisfaction 11-14)	
	No (N= 12,275 84.1%)	Yes (N= 2,313 15.9%)	No (N=11,255 77.1%)	Yes (N= 3,333 22.9%)
Parental concern about future overweight				
Unconcerned	83.8	16.2	76.6	23.4
Concerned	85.0	15.0	78.7	21.3
Parental diet control: healthy diet				
No	82.6	17.4	75.0	25.0
Yes	86.2	13.8	80.0	20.0
Parental diet control: weight management				
No	84.2	15.8	77.2	22.8
Yes	83.4	16.6	76.6	23.4
Parental diet control: reward or punishment				
No	83.6	16.4	76.4	23.6
Yes	88.5	11.5	82.9	17.1

Appendix for Chapter 8, Table 6. Association of parental concern about their child's future weight and control of their child's diet at age 5 with trajectories of BMI from age 7 to 17. Results from multilevel modelling of participants with valid exposure data and imputed outcomes and confounders.

Exposure and model	Mean difference in BMI z score at age 7 (Intercept)			Final model interaction test p values	
Parental concern about child's future weight (N=14,588)	Unconcerned	Concerned (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 0 (age, age^2)	ref	0.67 (0.62, 0.71)	<0.001	-	-
Model 1 (0 + confounders[a])	ref	0.67 (0.63, 0.72)	<0.001	-	-
Model 2 (1 + mother's BMI)	ref	0.56 (0.52, 0.60)	<0.001	-	-
Model 3 (1 + child's BMI at 3y)	ref	0.35 (0.31, 0.39)	<0.001	-	-
Model 4 (1 + mother and child BMI)	ref	0.29 (0.25, 0.32)	<0.001	-	-
Model 4 + sex interaction	ref	[b]		0.639	-
Model 4 + age interaction	ref	0.31 (0.27, 0.35)	<0.001	-	<0.001
Parental diet control for healthy diet (N=14,578)	Absent	Healthy diet (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 0 (age, age^2)	ref	-0.03 (-0.06, 0.01)	0.171	-	-
Model 1 (0 + confounders[a])	ref	0.01 (-0.03, 0.04)	0.637	-	-
Model 2 (1 + mother's BMI)	ref	0.02 (-0.02, 0.05)	0.424	-	-
Model 3 (1 + child's BMI at 3y)	ref	-0.01 (-0.04, 0.02)	0.425	-	-
Model 4 (1 + mother and child BMI)	ref	-0.01 (-0.04, 0.02)	0.649	-	-
Model 5 (4 + no. other restriction reasons)	ref	-0.00 (-0.04, 0.03)	0.754	-	-
Model 5 + sex interaction	ref	[b]		0.874	-
Model 5 + age interaction	ref	0.01 (-0.03, 0.04)	0.749	-	0.091
Parental diet control for weight management (N=14,578)	Absent	For weight (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 0 (age, age^2)	ref	0.46 (0.36, 0.56)	<0.001	-	-
Model 1 (0 + confounders[a])	ref	0.46 (0.37, 0.56)	<0.001	-	-
Model 2 (1 + mother's BMI)	ref	0.42 (0.33, 0.52)	<0.001	-	-
Model 3 (1 + child's BMI at 3y)	ref	0.27 (0.20, 0.34)	<0.001	-	-
Model 4 (1 + mother and child BMI)	ref	0.25 (0.18, 0.32)	<0.001	-	-
Model 5 (4 + no. other restriction reasons)	ref	0.25 (0.18, 0.32)	<0.001	-	-
Model 5 + sex interaction	ref	[b]		0.439	-
Model 5 + age interaction	ref	0.28	<0.001	-	0.019

		(0.21, 0.36)			
Parental diet control as reward or punishment (N=14,578)	Absent	Reward/Punish (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 0 (age, age^2)	ref	-0.06 (-0.12, -0.01)	0.026	-	-
Model 1 (0 + confounders[a])	ref	-0.03 (-0.09, 0.02)	0.228	-	-
Model 2 (1 + mother's BMI)	ref	-0.03 (-0.08, 0.02)	0.264	-	-
Model 3 (1 + child's BMI at 3y)	ref	-0.06 (-0.11, -0.02)	0.006	-	-
Model 4 (1 + mother and child BMI)	ref	-0.06 (-0.10, -0.01)	0.009	-	-
Model 5 (4 + no. other restriction reasons)	ref	-0.07 (-0.12, -0.03)	0.002	-	-
Model 5 + sex interaction	ref	[b]		0.027	
Model 5 + age interaction	ref	[b]		0.027	0.454

[a] Model 1 confounders: child sex at birth and ethnicity; family income, educational level and occupational class at 9 months; child emotional and peer problems at age 3.
[b] Coefficient not reported when sex interaction included in model, see table 5 for sex-stratified results where evidence of sex differences.

Appendix for Chapter 8, Table 7. Final BMI multilevel model results.

Exposure	Mean difference in BMI at age 7 (Intercept)	Change in BMI differential over time (Exposure*Age Interaction)
Parental concern about child's future weight (N=14,588)		
Unconcerned	Concerned (95% CI)	Mean Difference (95% CI)
ref	0.312 (0.273, 0.351)	-0.009 (-0.013, -0.004)
Parental diet control for weight management (N=14,578)		
Absent	For weight (95% CI)	Mean Difference (95% CI)
ref	0.283 (0.209, 0.357)	-0.011 (-0.021, -0.002)
Parental diet control as reward or punishment (N=14,578)		
Boys (N=7,441)		
Absent	Reward/Punish (95% CI)	Mean Difference (95% CI)
ref	-0.121 (-0.185, -0.058)	-
Girls (N=7,137)		
Absent	Reward/Punish (95% CI)	Mean Difference (95% CI)
ref	-0.020 (-0.083, 0.044)	-

Appendix for Chapter 8, Table 8. Association of parental concern about their child's future weight and control of their child's diet at age 5 with trajectories of body satisfaction from age 11 to 14. Results from multilevel modelling of a sample with valid exposure data and impute outcomes and confounders.

Exposure and model	Mean difference in body satisfaction at age 11 (Intercept)			Final model interaction test p values	
Parental concern about child's future weight (N=14,588)	Unconcerned	Concerned (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 0 (age, age^2)	ref	-0.30 (-0.36, -0.25)	<0.001	-	-
Model 1 (0 + confounders[a])	ref	-0.26 (-0.32, -0.20)	<0.001	-	-
Model 2 (1 + mother's BMI)	ref	-0.22 (-0.28, -0.16)	<0.001	-	-
Model 3 (1 + child's BMI at 3y)	ref	-0.20 (-0.26, -0.15)	<0.001	-	-
Model 4 (1 + mother and child BMI)	ref	-0.18 (-0.24, -0.12)	<0.001	-	-
Model 4 + sex interaction	ref	[b]		0.279	-
Model 4 + age interaction	ref	-0.23 (-0.40, -0.05)	0.011	-	0.541
Parental diet control for healthy diet (N=14,578)	Absent	Healthy diet (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 0 (age, age^2)	ref	0.02 (-0.03, 0.07)	0.447	-	-
Model 1 (0 + confounders[a])	ref	0.01 (-0.04, 0.06)	0.756	-	-
Model 2 (1 + mother's BMI)	ref	0.00 (-0.05, 0.05)	0.999	-	-
Model 3 (1 + child's BMI at 3y)	ref	0.01 (-0.05, 0.06)	0.803	-	-
Model 4 (1 + mother and child BMI)	ref	0.00 (-0.05, 0.06)	0.884	-	-
Model 5 (4 + no. other restriction reasons)	ref	-0.00 (-0.06, 0.05)	0.965	-	-
Model 5 + sex interaction	ref	[b]		0.744	-
Model 5 + age interaction	ref	0.17 (0.02, 0.33)	0.023	-	0.007
Parental diet control for weight management (N=14,578)	Absent	For weight (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 0 (age, age^2)	ref	-0.21 (-0.32, -0.09)	0.001	-	-
Model 1 (0 + confounders[a])	ref	-0.18 (-0.30, -0.07)	0.001	-	-
Model 2 (1 + mother's BMI)	ref	-0.17 (-0.28, -0.06)	0.002	-	-
Model 3 (1 + child's BMI at 3y)	ref	-0.15 (-0.26, -0.04)	0.008	-	-
Model 4 (1 + mother and child BMI)	ref	-0.15 (-0.26, -0.04)	0.010	-	-
Model 5 (4 + no. other restriction reasons)	ref	-0.15 (-0.26, -0.04)	0.010	-	-
Model 5 + sex interaction	ref	[b]		0.587	-
Model 5 + age interaction	ref	-0.10	0.579	-	0.733

		(-0.43, 0.24)			
Parental diet control as reward or punishment (N=14,578)	Absent	Reward/Punish (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 0 (age, age^2)	ref	-0.14 (-0.22, -0.06)	0.001	-	-
Model 1 (0 + confounders[a])	ref	-0.15 (-0.23, -0.07)	<0.001	-	-
Model 2 (1 + mother's BMI)	ref	-0.15 (-0.23, -0.07)	<0.001	-	-
Model 3 (1 + child's BMI at 3y)	ref	-0.15 (-0.22, -0.07)	<0.001	-	-
Model 4 (1 + mother and child BMI)	ref	-0.15 (-0.22, -0.07)	<0.001	-	-
Model 5 (4 + no. other restriction reasons)	ref	-0.14 (-0.22, -0.06)	<0.001	-	-
Model 5 + sex interaction	ref	[b]		0.753	-
Model 5 + age interaction	ref	-0.29 (-0.51, -0.07)	0.009	-	0.117

[a] Model 1 confounders: child sex at birth and ethnicity; family income, educational level and occupational class at 9 months; child emotional and peer problems at age 3.
[b] Intercept coefficient not reported when sex interaction included in model, see table 5 for sex-stratified results where evidence of sex differences.

Appendix for Chapter 8, Table 9. Results of final body satisfaction multilevel models.

Exposure	Difference in body satisfaction at age 11 (Intercept)	Change in body satisfaction with age (Slope)
Diet control for healthy, balanced diet (N=14,578)		
Absent	Healthy diet (95% CI)	Healthy diet (95% CI)
ref	0.035 (-0.031, 0.101)	-0.035 (-0.060, -0.010)

Appendix for Chapter 8, Table 10. Characteristics of children whose parents report controlling their diet for specified reasons.

Characteristic			Diet control: healthy diet + teeth		Diet control: digestive problems	
	N	%	No	Yes	No	Yes
N			7020	7558	13732	845
%			46.9	53.1	93.7	6.3
Cohort member sex at birth						
Male	7446	51.0	47.0	53.0	93.5	6.5
Female	7142	49.0	47.0	53.0	94.0	6.0
Cohort member ethnicity						
White	12249	87.1	45.6	54.4	93.4	6.6
Mixed	410	3.2	48.3	51.7	93.4	6.6
Indian	357	1.8	54.9	45.1	94.8	5.2
Pakistani / Bangladeshi	892	4.0	63.9	36.1	97.5	2.5
Black or Black British	464	2.7	52.0	48.0	95.6	4.4
Other	182	1.1	59.6	40.4	98.9	1.1
Family income fifth at 9 months						
Most deprived	3295	20.0	58.5	41.5	95.7	4.3
Second	3181	20.0	53.0	47.0	94.5	5.5
Third	2821	20.2	46.1	53.9	93.3	6.7
Fourth	2733	20.1	39.5	60.5	92.8	7.2
Least deprived	2513	19.7	37.4	62.6	92.6	7.4
Parental education level at 9 months						
None	1701	10.0	61.4	38.6	96.9	3.1
NVQ Level 1 (GCSE grade D-G)	848	5.6	59.5	40.5	95.9	4.1
NVQ Level 2 (GCSE grade A*-C)	3633	25.2	52.6	47.4	94.6	5.4
NVQ Level 3 (A Level)	2401	16.1	48.5	51.5	93.2	6.8
NVQ Level 4 (One year Undergraduate)	5014	36.2	38.6	61.4	92.3	7.7
NVQ Level 5 (Two years Undergraduate)	979	6.8	34.6	65.4	93.1	6.9
Parental occupational class at 9 months						
Not in work	3502	22.2	55.0	45.0	95.4	4.6
Semi-routine/routine	2162	13.6	54.6	45.4	94.9	5.1
Lower supervisory/technical	1171	7.9	51.9	48.1	93.5	6.5
Small employers/self-employed	950	6.8	47.6	52.4	95.0	5.0
Intermediate	1316	9.0	45.3	54.7	93.5	6.5
Managerial/professional	5437	40.4	39.2	60.8	92.4	7.6
Cohort member emotional symptoms at 3 years						
Close to average (<5)	13409	94.7	45.3	54.7	93.5	6.5
High (5-10)	779	5.3	54.8	45.2	90.2	9.8
Cohort member peer problems at 3 years						
Close to average (<4)	13084	92.7	45.0	55.0	93.5	6.5
High (4-10)	1092	7.3	50.6	49.4	92.9	7.1
Mother's pre-pregnancy BMI						
<18.5	784	5.8	54.7	45.3	96.1	3.9
18.5 – 24.9	8682	65.6	44.4	55.6	93.6	6.4
25 – 29.9	2731	19.8	48.6	51.4	93.7	6.3
30+	1188	8.8	50.1	49.9	92.4	7.6
Cohort member BMI at 3 years						
Underweight	606	4.7	50.9	49.1	93.8	6.2
Healthy weight	8694	72.3	46.2	53.8	93.4	6.6
Overweight	2187	17.6	43.7	56.3	94.3	5.7
Obese	687	5.4	50.7	49.3	94.0	6.0

Appendix for Chapter 8, Table 11. Association of parental control of their child's diet at age 5 with trajectories of BMI from age 7 to 17. (1) Dietary control for digestive problems as a negative exposure control; (2) Investigating the effect of including dietary control for "teeth" with "healthy diet". Results from multilevel modelling in a sample with valid exposure data and imputed outcomes and confounders.

Exposure and model	Difference in BMI z score at age 7 (Intercept)			Final model interaction test p values	
Parental diet control for digestive problems (N=14,578)	Unconcerned	Concerned (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 0 (age, age^2)	ref	-0.04 (-0.12, 0.04)	0.314	-	-
Model 1 (0 + confounders[a])	ref	-0.02 (-0.10, 0.06)	0.570	-	-
Model 2 (1 + mother's BMI)	ref	-0.04 (-0.11, 0.03)	0.297	-	-
Model 3 (1 + child's BMI at 3y)	ref	0.01 (-0.06, 0.07)	0.839	-	-
Model 4 (1 + mother and child BMI)	ref	-0.01 (-0.07, 0.05)	0.825	-	-
Model 5 (4 + no. other restriction reasons)		-0.01 (-0.07, 0.05)	0.700	-	-
Model 5 + sex interaction	ref	[b]		0.136	-
Model 5 + age interaction	ref	0.02 (-0.05, 0.08)	0.568	-	0.004
Parental diet control for healthy diet or teeth (N=14,578)	Absent	Healthy / Teeth (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 0 (age, age^2)	ref	-0.01 (-0.05, 0.02)	0.445	-	-
Model 1 (0 + confounders[a])	ref	0.01 (-0.03, 0.05)	0.601	-	-
Model 2 (1 + mother's BMI)	ref	0.02 (-0.02, 0.05)	0.404	-	-
Model 3 (1 + child's BMI at 3y)	ref	-0.01 (-0.04, 0.02)	0.574	-	-
Model 4 (1 + mother and child BMI)	ref	-0.00 (-0.03, 0.03)	0.808	-	-
Model 5 (4 + no. other restriction reasons)	ref	-0.00 (-0.03, 0.03)	0.780	-	-
Model 5 + sex interaction	ref	[b]		0.981	-
Model 5 + age interaction	ref	0.01 (-0.03, 0.04)	0.703	-	0.072

Appendix for Chapter 8, Table 12. Results of final BMI multilevel models.

Exposure	Difference in BMI at age 7 (Intercept)	Change in BMI with age (Slope)
Parental concern about child's future weight (N=14,588)		
Unconcerned	Concerned (95% CI)	Concerned (95% CI)
ref	0.019 (-0.046, 0.084)	-0.012 (-0.019, -0.004)

Appendix for Chapter 8, Table 13. Association of parental control of their child's diet at age 5 with trajectories of body satisfaction from age 11 to 14. (1) Dietary control for digestive problems as a negative exposure control; (2) Investigating the effect of including dietary control for “teeth” with “healthy diet”. Results from multilevel modelling of a sample with valid exposure data and imputed outcomes and confounders.

Exposure and model	Difference in body satisfaction at age 11 (Intercept)			Final model interaction test p values	
Parental diet control for digestive problems (N=14,578)	Unconcerned	Concerned (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 0 (age, age^2)	ref	-0.06 (-0.17, 0.06)	0.315	-	-
Model 1 (0 + confounders[a])	ref	-0.04 (-0.15, 0.07)	0.457	-	-
Model 2 (1 + mother’s BMI)	ref	-0.04 (-0.15, 0.07)	0.508	-	-
Model 3 (1 + child’s BMI at 3y)	ref	-0.05 (-0.16, 0.06)	0.374	-	-
Model 4 (1 + mother and child BMI)	ref	-0.04 (-0.15, 0.06)	0.415	-	-
Model 5 (4 + no. other restriction reasons)		-0.03 (-0.14, 0.07)	0.536	-	-
Model 5 + sex interaction	ref	[b]		0.577	-
Model 5 + age interaction	ref	0.09 (-0.23, 0.42)		-	0.373
Parental diet control for healthy diet or teeth (N=14,578)	Absent	Healthy / Teeth (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 0 (age, age^2)	ref	0.01 (-0.04, 0.06)	0.679	-	-
Model 1 (0 + confounders[a])	ref	-0.02 (-0.07, 0.03)	0.431	-	-
Model 2 (1 + mother’s BMI)	ref	-0.02 (-0.07, 0.03)	0.526	-	-
Model 3 (1 + child’s BMI at 3y)	ref	-0.01 (-0.06, 0.04)	0.710	-	-
Model 4 (1 + mother and child BMI)	ref	-0.01 (-0.06, 0.04)	0.626	-	-
Model 5 (4 + no. other restriction reasons)	ref	-0.01 (-0.06, 0.04)	0.675	-	-
Model 5 + sex interaction	ref	[b]		0.974	-
Model 5 + age interaction	ref	0.16 (0.00, 0.32)	0.047	-	0.025

Appendix for Chapter 8, Table 14. Post-hoc analysis: disaggregating children whose parents control their diet to put on or maintain weight and to lose or control weight. Model 5 includes adjustment for baseline confounders, maternal pre-pregnancy BMI, child BMI at age 3 and number of other diet control reasons endorsed.

Exposure and model	Difference in BMI z score at age 7 (Intercept)			Final model interaction test p values	
Parental diet control to gain or maintain weight (N=14,577)	Absent	Gain weight (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 5 (4 + no. other restriction reasons)		-0.05 (-0.13, 0.03)	0.199	-	-
Model 5 + sex interaction	ref	b		0.861	-
Model 5 + age interaction	ref	-0.09 (-0.18, -0.01)	0.036	-	0.012
Parental diet control to lose or control weight (N=14,577)	Absent	Lose weight (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 5 (4 + no. other restriction reasons)	ref	0.72 (0.62, 0.82)	<0.001	-	-
Model 5 + sex interaction	ref	b		0.032	-
Model 5 + age interaction	ref	b		0.034	<0.001

Appendix for Chapter 8, Table 15. Results for BMI from multilevel models disaggregating diet control to put on or maintain weight and to lose or control weight.

Exposure	Difference in BMI at age 7 (Intercept)	Change in BMI with age (Slope)
Parental diet control to gain or maintain weight (N=14,577)		
Absent	Gain weight (95% CI)	Gain weight (95% CI)
ref	-0.092 (-0.178, -0.006)	0.014 (0.003, 0.025)
Parental diet control to lose or control weight (N=14,577)		
Boys (N=7,440)		
Absent	For weight (95% CI)	For weight (95% CI)
ref	0.970 (0.801, 1.138)	-0.049 (-0.070, -0.029)
Girls (N=7,137)		
Absent	For weight (95% CI)	For weight (95% CI)
ref	0.756 (0.620, 0.893)	-0.048 (-0.065, -0.032)

Appendix for Chapter 8, Table 16. Post-hoc analysis: disaggregating children whose parents control their diet to put on or maintain weight and to lose or control weight. Model 5 includes adjustment for baseline confounders, maternal pre-pregnancy BMI, child BMI at age 3 and number of other diet control reasons endorsed.

Exposure and model	Difference in body satisfaction at age 11 (Intercept)			Final model interaction test p values	
Parental diet control to gain or maintain weight (N=14,577)	Absent	Gain weight (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 5 (4 + no. other restriction reasons)		-0.03 (-0.16, 0.10)	0.626	-	-
Model 5 + sex interaction	ref	[b]		0.920	-
Model 5 + age interaction	ref	-0.00 (-0.19, 0.18)	0.978	-	0.617
Parental diet control to lose or control weight (N=14,577)	Absent	Lose weight (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 5 (4 + no. other restriction reasons)	ref	-0.30 (-0.46, -0.14)	<0.001	-	-
Model 5 + sex interaction	ref	[b]		0.596	-
Model 5 + age interaction	ref	-0.31 (-0.52, -0.11)	0.003	-	0.878

Appendix for Chapter 8, Table 17. Association of parental concern about their child's future weight and control of their child's diet at age 5 with trajectories of BMI from age 7 to 17. Results from multilevel modelling of a sample with valid exposure data, complete data on confounders, and outcome data from at least one time point.

Exposure and model	Difference in BMI z score at age 7 (Intercept)			Final model interaction test p values	
Parental concern about child's future weight (N=9,447)	Unconcerned	Concerned (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 0 (age, age^2)	ref	0.66 (0.61, 0.71)	<0.001	-	-
Model 1 (0 + confounders[a])	ref	0.66 (0.62, 0.71)	<0.001	-	-
Model 2 (1 + mother's BMI)	ref	0.56 (0.51, 0.61)	<0.001	-	-
Model 3 (1 + child's BMI at 3y)	ref	0.34 (0.30, 0.39)	<0.001	-	-
Model 4 (1 + mother and child BMI)	ref	0.29 (0.24, 0.33)	<0.001	-	-
Model 4 + sex interaction	ref	[b]		0.763	-
Model 4 + age interaction	ref	0.31 (0.26, 0.35)	<0.001	-	0.001
Parental diet control for healthy diet (N=9,447)	None	Healthy diet (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 0 (age, age^2)	ref	-0.04 (-0.08, 0.03)	0.072	-	-
Model 1 (0 + confounders[a])	ref	-0.01 (-0.05, 0.04)	0.779	-	-
Model 2 (1 + mother's BMI)	ref	0.00 (-0.04, 0.05)	0.843	-	-
Model 3 (1 + child's BMI at 3y)	ref	-0.01 (-0.04, 0.03)	0.608	-	-
Model 4 (1 + mother and child BMI)	ref	-0.00 (-0.04, 0.03)	0.914	-	-
Model 5 (4 + no. other restriction reasons)	ref	-0.00 (-0.04, 0.03)	0.965		
Model 5 + sex interaction	ref	[b]		0.859	-
Model 5 + age interaction	ref	0.00 (-0.03, 0.04)	0.886	-	0.521
Parental diet control for weight management (N=9,447)	None	For weight (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 0 (age, age^2)	ref	0.41 (0.28, 0.54)	<0.001	-	-
Model 1 (0 + confounders[a])	ref	0.42 (0.30, 0.55)	<0.001	-	-
Model 2 (1 + mother's BMI)	ref	0.38 (0.26, 0.50)	<0.001	-	-
Model 3 (1 + child's BMI at 3y)	ref	0.27 (0.18, 0.35)	<0.001	-	-
Model 4 (1 + mother and child BMI)	ref	0.25 (0.17, 0.33)	<0.001	-	-
Model 5	ref	0.25 (0.17, 0.33)	<0.001	-	-

(4 + no. other restriction reasons)					
Model 5 + sex interaction	ref	[b]		0.505	-
Model 5 + age interaction	ref	0.27 (0.18, 0.35)	<0.001	-	0.147
Parental diet control as reward or punishment (N=9,447)	None	Reward/Punish (95% CI)	p value	Exposure * Sex	Exposure * Age
Model 0 (age, age^2)	ref	-0.07 (-0.14, -0.01)	0.029	-	-
Model 1 (0 + confounders[a])	ref	-0.04 (-0.10, 0.02)	0.178	-	-
Model 2 (1 + mother's BMI)	ref	-0.03 (-0.09, 0.02)	0.248	-	-
Model 3 (1 + child's BMI at 3y)	ref	-0.06 (-0.11, -0.01)	0.014	-	-
Model 4 (1 + mother and child BMI)	ref	-0.05 (-0.10, -0.01)	0.023	-	-
Model 5 (4 + no. other restriction reasons)	ref	-0.07 (-0.12, -0.02)	0.007	-	-
Model 5 + sex interaction	ref	[b]		0.005	-
+ age interaction	ref	[b]		0.005	0.080

[a] Model 1 confounders: child sex at birth and ethnicity; family income, educational level and occupational class at 9 months; child emotional and peer problems at age 3.
[b] Intercept coefficient not reported when sex interaction included in model, see table 5 for sex-stratified results where evidence of sex differences.

Appendix for Chapter 8, Table 18. Results of final BMI multilevel models in a sample with complete data on exposure, outcomes and confounders.

Exposure	Difference in BMI at age 7 (Intercept)	Change in BMI with age (Slope)
Parental concern about child's future weight (N=9,447)		
Unconcerned	Concerned (95% CI)	Concerned (95% CI)
ref	0.306 (0.262, 0.349)	-0.009 (-0.014, -0.004)
Parental diet control as reward or punishment (N=9,447)		
Boys (N=4,677)		
None	Reward/Punish (95% CI)	Reward/Punish (95% CI)
ref	-0.133 (-0.202, -0.064)	-
Girls (N=4770)		
None	Reward/Punish (95% CI)	Reward/Punish (95% CI)
ref	0.008 (-0.061, 0.076)	-

Appendix for Chapter 8, Table 19. Association of parental concern about their child's future weight and control of their child's diet at age 5 with trajectories of body satisfaction from age 11 to 14. Results from multilevel modelling of a sample with valid exposure data, complete data on confounders, and outcome data from at least one time point, with sampling and attrition weights applied.

Exposure and model	Difference in body satisfaction at age 11 (Intercept)			Final model interaction tests	
Parental concern about child's future weight (N=8,848)	Unconcerned	Concerned (95% CI)	p value	Exposure * Sex p value	Exposure * Age p value
Model 0 (age)	ref	-0.29 (-0.35, -0.22)	<0.001	-	-
Model 1 (0 + confounders[a])	ref	-0.23 (-0.29, -0.17)	<0.001	-	-
Model 2 (1 + mother's BMI)	ref	-0.20 (-0.26, -0.14)	<0.001	-	-
Model 3 (1 + child's BMI at 3y)	ref	-0.18 (-0.24, -0.11)	<0.001	-	-
Model 4 (1 + mother and child BMI)	ref	-0.15 (-0.22, -0.10)	<0.001	-	-
Model 4 + sex interaction	ref	[b]		0.030	-
+ age interaction	ref	[b]		0.030	0.447
Parental diet control healthy diet (N=8,848)	None	Healthy diet (95% CI)	p value	Exposure * Sex p value	Exposure * Age p value
Model 0 (age)	ref	0.02 (-0.04, 0.07)	0.529	-	-
Model 1 (0 + confounders[a])	ref	-0.01 (-0.06, 0.05)	0.728	-	-
Model 2 (1 + mother's BMI)	ref	-0.01 (-0.07, 0.04)	0.648	-	-
Model 3 (1 + child's BMI at 3y)	ref	-0.01 (-0.06, 0.05)	0.755	-	-
Model 4 (1 + mother and child BMI)	ref	-0.01 (-0.07, 0.04)	0.684	-	-
Model 5 (4 + no. other restriction reasons)	ref	-0.02 (-0.07, 0.04)	0.494	-	-
Model 5 + sex interaction	ref	[b]		0.626	-
Model 5 + age interaction	ref	0.01 (-0.06, 0.08)	0.731	-	0.150
Parental diet control for weight management (N=8,848)	None	For weight (95% CI)	p value	Exposure * Sex p value	Exposure * Age p value
Model 0 (age)	ref	-0.21 (-0.33, -0.09)	0.001	-	-
Model 1 (0 + confounders[a])	ref	-0.16 (-0.28, -0.05)	0.006	-	-
Model 2 (1 + mother's BMI)	ref	-0.15 (-0.26, -0.03)	0.011	-	-
Model 3 (1 + child's BMI at 3y)	ref	-0.13 (-0.25, -0.02)	0.020	-	-
Model 4 (1 + mother and child BMI)	ref	-0.13 (-0.24, -0.01)	0.029	-	-

Model 5 (4 + no. other restriction reasons)	ref	-0.13 (-0.25, -0.02)	0.020	-	-
Model 5 + sex interaction	ref	[b]		0.740	-
Model 5 + age interaction	ref	-0.10 (-0.24, 0.05)	0.194	-	0.388
Parental diet control as reward or punishment (N=8,848)	None	Reward/Punish (95% CI)	p value	Exposure * Sex p value	Exposure * Age p value
Model 0 (age)	ref	-0.11 (-0.19, -0.02)	0.013	-	-
Model 1 (0 + confounders[a])	ref	-0.13 (-0.21, -0.05)	0.001	-	-
Model 2 (1 + mother's BMI)	ref	-0.14 (-0.22, -0.06)	0.001	-	-
Model 3 (1 + child's BMI at 3y)	ref	-0.13 (-0.21, -0.05)	0.002	-	-
Model 4 (1 + mother and child BMI)	ref	-0.13 (-0.21, -0.05)	0.001	-	-
Model 5 (4 + no. other restriction reasons)	ref	-0.12 (-0.20, -0.04)	0.004	-	-
Model 5 + sex interaction	ref			0.511	-
Model 5 + age interaction	ref	-0.18 (-0.28, -0.08)	0.001	-	0.057

[a] Model 1 confounders: child sex at birth and ethnicity; family income, educational level and occupational class at 9 months; child emotional and peer problems at age 3.
[b] Intercept coefficient not reported when sex interaction included in model, see Table 4 for sex-stratified results.

Appendix for Chapter 8, Table 20. Sex-stratified results from final multilevel models.

Exposure	Difference in body satisfaction at age 11 (Intercept)	Change in body satisfaction with age (Slope)
Parental concern about child's future weight (N=9,447)		
Boys (N=4,344)		
Unconcerned	Concerned (95% CI)	Concerned (95% CI)
ref	-0.09 (-0.18, 0.00)	-
Girls (N=4,504)		
Unconcerned	Concerned (95% CI)	Concerned (95% CI)
ref	-0.21 (-0.30, -0.12)	-
Parental diet control as reward or punishment (N=8,848)		
None	Reward/Punish (95% CI)	Reward/Punish (95% CI)
ref	-0.181 (-0.285, -0.077)	0.040 (-0.00, 0.082)

Appendix for Chapter 8, Table 21. Sensitivity analysis: BMI multilevel models adjusting for mother's BMI when their child was aged 3. Final multilevel models repeated (imputed dataset).

Exposure	Difference in BMI z score at age 7 (Intercept)			Final model interaction test p values	
Parental concern about child's future weight (N=14,588)	Unconcerned	Concerned (95% CI)	p value	Exposure * Sex	Exposure * Age
Final model	ref	0.31 (0.27, 0.35)	<0.001	-	<0.001
Parental diet control for healthy diet (N=14,578)	Absent	Healthy diet (95% CI)	p value	Exposure * Sex	Exposure * Age
Final model	ref	-0.00 (-0.03, 0.03)	0.997	-	-
Parental diet control for weight management (N=14,578)	Absent	For weight (95% CI)	p value	Exposure * Sex	Exposure * Age
Final model	ref	0.29 (0.21, 0.36)	<0.001	-	0.019
Parental diet control as reward or punishment (N=14,578)	Absent	Reward/punish (95% CI)	p value	Exposure * Sex	Exposure * Age
Final model	ref	[b]		0.040	-

Appendix for Chapter 8, Table 22. Results from BMI multilevel models adjusting for mother's BMI when their child was aged 3.

Exposure	Difference in BMI at age 7 (Intercept)	Change in BMI with age (Slope)
Parental concern about child's future weight (N=14,588)		
Unconcerned	Concerned (95% CI)	Concerned (95% CI)
ref	0.310 (0.271, 0.348)	-0.009 (-0.014, -0.004)
Parental diet control for weight management (N=14,578)		
Absent	For weight (95% CI)	For weight (95% CI)
ref	0.286 (0.212, 0.360)	-0.011 (-0.021, -0.002)
Parental diet control as reward or punishment (N=14,578)		
Boys (N=7,441)		
Absent	Reward/Punish (95% CI)	Reward/Punish (95% CI)
ref	-0.118 (-0.182, -0.055)	-
Girls (N=7,137)		
Absent	Reward/Punish (95% CI)	Reward/Punish (95% CI)
ref	-0.027 (-0.091, 0.038)	-

Appendix for Chapter 8, Table 23. Sensitivity analysis: body satisfaction multilevel models adjusting for mother's BMI when their child was aged 3. Final multilevel models repeated (imputed dataset).

Exposure	Difference in body satisfaction at age 11 (Intercept)			Final model interaction test p values	
Parental concern about child's future weight (N=14,588)	Unconcerned	Concerned (95% CI)	p value	Exposure * Sex	Exposure * Age
Final model	ref	-0.18 (-0.24, -0.12)	<0.001	-	-
Parental diet control for healthy diet (N=14,578)	Absent	Healthy diet (95% CI)	p value	Exposure * Sex	Exposure * Age
Final model	ref	0.03 (-0.03, 0.10)	0.324	-	0.007
Parental diet control for weight management (N=14,578)	Absent	For weight (95% CI)	p value	Exposure * Sex	Exposure * Age
Final model	ref	-0.15 (-0.26, -0.04)	0.009	-	-
Parental diet control as reward or punishment (N=14,578)	Absent	Reward/punish (95% CI)	p value	Exposure * Sex	Exposure * Age
Final model	ref	-0.14 (-0.22, -0.06)	<0.001	-	-

Appendix for Chapter 8, Table 24. Results from final body satisfaction multilevel models adjusting for mother's BMI when their child was aged 3.

Exposure	Difference in body satisfaction at age 11 (Intercept)	Change in body satisfaction with age (Slope)
Diet control for healthy weight (N=14,578)		
Absent	Healthy (95% CI)	Healthy (95% CI)
ref	0.033 (-0.033, 0.099)	-0.035 (-0.060, -0.010)

Appendix for Chapter 8, Table 25. Sensitivity analysis: BMI multilevel models with additional adjustment for father's BMI when their child was aged 3 in children from two-parent households. Final multilevel models repeated (imputed dataset).

Exposure	Difference in BMI z score at age 7 (Intercept)			Final model interaction test p values	
Parental concern about child's future weight (N=12,328)	Unconcerned	Concerned (95% CI)	p value	Exposure * Sex	Exposure * Age
Final model restricted to two parent households	ref	0.32 (0.27, 0.36)	<0.001	-	0.001
+ adjustment for father's BMI	ref	0.29 (0.25, 0.33)	<0.001	-	0.001
Parental diet control for healthy diet (N=12,320)	Absent	Healthy diet (95% CI)	p value	Exposure * Sex	Exposure * Age
Final model restricted to two parent households	ref	0.00 (-0.03, 0.04)	0.775	-	-
+ adjustment for father's BMI	ref	0.01 (-0.02, 0.04)	0.622	-	-
Parental diet control for weight management (N=12,320)	Absent	For weight (95% CI)	p value	Exposure * Sex	Exposure * Age
Final model restricted to two parent households	ref	0.28 (0.21, 0.36)	<0.001	-	0.041
+ adjustment for father's BMI	ref	0.27 (0.19, 0.35)	<0.001	-	0.041
Parental diet control as reward or punishment (N=12,320)	Absent	Reward/punish (95% CI)	p value	Exposure * Sex	Exposure * Age
Final model restricted to two parent households	ref	[b]		0.054	-
+ adjustment for father's BMI	ref	[b]		0.041	-

Appendix for Chapter 8, Table 26. Results from final BMI multilevel models with additional adjustment for father's BMI in children from two-parent households.

Exposure	Difference in BMI at age 7 (Intercept)	Change in BMI with age (Slope)
Parental concern about child's future weight (N=12,328)		
Unconcerned	Concerned (95% CI)	Concerned (95% CI)
ref	0.290 (0.249, 0.331)	-0.008 (-0.013, -0.003)
Parental diet control for weight management (N=12,320)		
Absent	For weight (95% CI)	For weight (95% CI)
ref	0.271 (0.192, 0.349)	-0.010 (-0.020, -0.000)
Parental diet control as reward or punishment (N=12,320)		
Boys (N=6,271)		
Absent	Reward/Punish (95% CI)	Reward/Punish (95% CI)
ref	-0.112 (-0.178, -0.046)	-
Girls (N=4770)		
Absent	Reward/Punish (95% CI)	Reward/Punish (95% CI)
ref	-0.022 (-0.087, 0.044)	-

Appendix for Chapter 8, Table 27. Sensitivity analysis: body satisfaction multilevel models with additional adjustment for father's BMI when their child was aged 3 in children from two-parent households. Final multilevel models repeated (imputed dataset).

Exposure	Difference in body satisfaction at age 11 (Intercept)			Final model interaction test p values	
Parental concern about child's future weight (N=12,328)	Unconcerned	Concerned (95% CI)	p value	Exposure * Sex	Exposure * Age
Final model restricted to two parent households	ref	-0.18 (-0.24, -0.12)	<0.001	-	-
+ adjustment for father's BMI	ref	-0.17 (-0.23, -0.11)	<0.001		
Parental diet control for healthy diet (N=12,320)	Absent	Healthy diet (95% CI)	p value	Exposure * Sex	Exposure * Age
Final model restricted to two parent households	ref	0.03 (-0.03, 0.10)	0.324	-	0.007
+ adjustment for father's BMI	ref	0.03 (-0.03, 0.10)	0.343	-	0.007
Parental diet control for weight management (N=12,320)	Absent	For weight (95% CI)	p value	Exposure * Sex	Exposure * Age
Final model restricted to two parent households	ref	-0.15 (-0.26, -0.04)	0.009	-	-
+ adjustment for father's BMI	ref	-0.14 (-0.25, -0.03)	0.012	-	-
Parental diet control as reward or punishment (N=12,320)	Absent	Reward/punish (95% CI)	p value	Exposure * Sex	Exposure * Age
Final model restricted to two parent households	ref	-0.14 (-0.22, -0.06)	<0.001	-	-
+ adjustment for father's BMI	ref	-0.14 (-0.22, -0.07)	<0.001	-	-