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Lifetime risk factors for leisure-time physical inactivity in mid-adulthood

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ABSTRACT

We aimed to identify factors from different life-stages that were associated with inactivity at two adult ages and stability and change between these ages. Leisure-time inactivity (activity frequency < 1/wk) was assessed at 33y and 50y in the 1958 British Birth cohort (N = 12,271). We created scores representing several domains, i.e. physical health, mental function, social, family and neighbourhood circumstances at different life-stages, and examined associations with adult inactivity. 31% were inactive at 33y and 50y with 17% deteriorating to, and 18% improving from, inactivity. Adjusting for all domains and life-stages, most concurrent factors were associated with inactivity: e.g. per 1-unit worsening physical status (score range:0–2) $OR_{adjusted}$ for 50y inactivity was 1.56(1.44,1.70). Physical status at 33y was associated with inactivity patterns 33y-to-50y (Relative risk ratios (RRRs) of inactivity persistence and deterioration (vs never inactive) per 1-unit worsening status (score:0–1) were 1.73(1.51,1.99) and 1.28(1.10,1.49) respectively; RRR for improvement (vs persistently inactive) was 0.75(0.63,0.88). Some early-life domain scores were associated with inactivity independent of concurrent factors: e.g. per 1-unit worsening early-life social score (range:0–3) $OR_{adjusted}$ for 50y inactivity was 1.12(1.05,1.19). Highly urbanised neighbourhood in early adulthood was associated with inactivity (e.g. RRRs for persistent inactivity and deterioration were 1.42(1.22,1.65) and 1.15(1.01,1.31) respectively; 0.82(0.68,0.98) for improvement). Concurrent physical and mental function were associated with adult inactivity at two ages; poorer physical status was associated with greater risk of inactivity persistence and deterioration and lower risk of improvement 33y-to-50y. Young adult neighbourhood and early-life social and family circumstances were independently associated with mid-life inactivity.

1. Introduction

Physical inactivity has high health (Lee et al., 2012) and economic (Ding et al., 2016) costs and prevention is a key public health goal. Accordingly, calls have been made for research on inactivity and its determinants (Telama, 2009), with the latter including macro- to individual-level factors (Bauman et al., 2012). Much has been done on correlates of (in)activity (Bauman et al., 2012); e.g. adult (in)activity has been linked to health, self-efficacy, socioeconomic and family circumstances (Trost et al., 2002), although whether these factors predate (in)activity is unclear given the cross-sectional design of many studies. Recent studies have examined health (Picavet et al., 2011) and economic (Barnett et al., 2008) circumstances at baseline and subsequent (in)activity several years later, but few take a life-course approach, whereby influences from different life-stages are considered (Power et al., 2013). This approach has the potential to identify the timing (i.e. life-stage) for interventions to promote physical activity in adulthood.

A recent systematic review (Elhakeem et al., 2015) of childhood socioeconomic position (SEP) and adult leisure-time (in)activity provided support for an influence of early-life on infrequent activity: of 36 predominantly high-income country studies, 22 found associations with lower childhood SEP; and, 9 of 16 studies that adjusted for adult SEP showed attenuated associations for childhood SEP. Such findings suggest that individual-level influences are likely to encompass the past life-course as well as more immediate influences; but, whether concurrent factors represent an accumulation of influences from earlier life-stages is unknown. For example, the influence of adult SEP may represent the accumulated effect of child and adult SEP or adult SEP alone. Possible life-course pathways to adult inactivity, and factors involved, are shown in Fig. 1. Early-life social circumstances could be associated with mid-adult inactivity independently (A in Fig. 1) or via continuity through early (Fig. 1D) and mid-adulthood (Fig. 1E). Likewise, the influence of mid-adult social circumstances on concurrent inactivity may represent an independent effect (Fig. 1C) or an accumulation from earlier life-stages (Fig. 1F). We have previously shown childhood height associations with adult inactivity, independent of adult height (Pinto Pereira et al., 2014a), suggesting a direct influence of early-life physical status on adult inactivity (Fig. 1A). Yet, more

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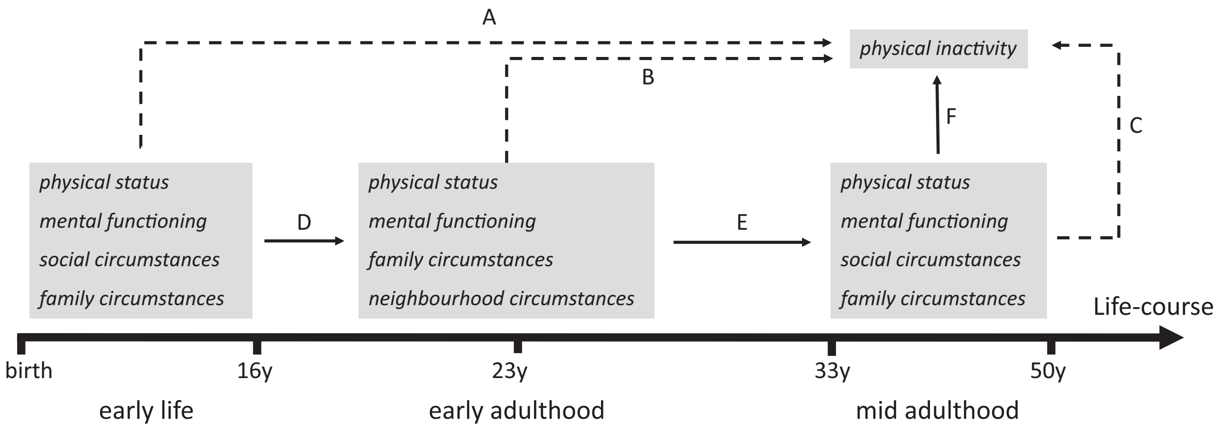

Fig. 1. Hypothesized relationships between early-life, early-adult and mid-adult factors with mid-adult physical inactivity.
Footnote: Early-life factors may influence later inactivity through subsequent (adult) factors and/or via a direct effect. Likewise, early adult factors may influence later inactivity through subsequent mid-adult factors and/or via a direct effect. The influence of mid-adult factors on concurrent inactivity may represent an independent effect or influences from earlier life-stages.
A: effect of early life factors that is not via continuity to early and mid-adulthood or other influence on later factors.
B: effect of influences during early-adulthood that is not via continuity to mid-adulthood or other influence on later factors.
C: effect of influences during mid-adulthood that does not represent accumulated effects from earlier life-stages.
D: effect of influences during early-life that operate via continuity to early adulthood.
E: effect of influences during early adulthood that operate via continuity to mid-adulthood.
F: accumulated effect of life-course factors on inactivity.

generally, it is unknown whether current physical, mental, social and family circumstances have independent effects on (in)activity (Fig. 1C) or whether they mainly reflect influences from earlier life (Fig. 1F) and such knowledge can shed light on when in the life-course interventions may be most effective.

Moreover, change in individual's (in)activity over time is common, with low to moderate tracking observed in several populations (Picavet et al., 2011; Morseth et al., 2011; Telama et al., 2005; Pinto Pereira et al., 2015). Programmes to prevent inactivity may benefit from understanding why some individuals sustain inactive lifestyles over long periods of life while others maintain their physical activity, and likewise what the determinants are of changing to, or from, inactivity. Notwithstanding previous research by ourselves (Pinto Pereira et al., 2014a; Pinto Pereira et al., 2015; Pinto Pereira and Power, 2017) and others (Elhakeem et al., 2015; Elhakeem et al., 2017; Seiluri et al., 2011; Uijtdewilligen et al., 2015; Xue et al., 2012), no study has *simultaneously* investigated a broad range of influences across a lifetime on adult inactivity.

In a UK general population sample, we aimed to identify associations of factors from different life-stages with inactivity at two mid-adult ages and with patterns of change between these ages. Building on our previous studies (Pinto Pereira et al., 2015; Pinto Pereira and Power, 2017), we considered potential factors in relation to inactivity, organised into 'domains': physical status (e.g. obesity), mental function (e.g. depression), social (e.g. employment) and family (e.g. children) circumstances and neighbourhood type (Table 1). We used domains primarily to represent related concepts, e.g., early-life social class and parental education represent early-life SEP and are likely to influence inactivity via similar pathways. We examined (i) associations of concurrent factors spanning the above domains with inactivity at 33y and 50y, (ii) whether concurrent associations persisted after accounting for factors from previous life-stages (and vice-versa) and (iii) life-course associations (concurrent and previous life-stages) with inactivity stability and change 33y-to-50y.

2. Methods

The 1958 British Birth Cohort is an ongoing longitudinal study of all born during one week in March 1958 across England, Scotland and Wales (N = 17,638) and a further 920 immigrants with the same birth week (Power and Elliott, 2006). Information was collected in childhood (birth, 7y, 11y, 16y) and adulthood (23y, 33y, 42y, 45y, 50y). Ethical approval was given, including at 50y, by the London Multi-centre Research Ethics Committee; informed consent was obtained from participants at various ages. Respondents in mid-adulthood are broadly representative of the total surviving cohort (Atherton et al., 2008); this study includes those living in Britain at 50y with information on inactivity at 33y or 50y (N = 12,271).

Physical inactivity at 33y and 50y was ascertained, using the same questions, asking participants about regular leisure-time activity frequency; 'regular' defined as ≥1/month for most of the year and, to aid recall, a list of example activities (e.g. swimming, walks) was provided. Those responding affirmatively, reported activity frequency ranging from every/most days to < 2–3 times/month (Parsons et al., 2006). Consistent with previous work (Pinto Pereira et al., 2014a; Pinto Pereira et al., 2015; Brown et al., 2013; Hamer et al., 2009; Vatten et al., 2006) low frequency was identified as < 1/week (including no 'regular' activity), hereafter referred to as inactivity. From 33y and 50y categories, we identified two stable groups: 'never inactive' (active ≥ 1/week at both ages), 'persistently inactive' (< 1/week at both ages); and two change groups: 'deteriorating' (≥1/week at 33y, < 1/week at 50y), 'improving' status (< 1/week at 33y, ≥1/week at 50y). Thus, deteriorating status refers to changing to inactivity; improving status refers to changing from inactivity. Inactivity measures available at other adult ages were not always comparable, and hence are not considered here for examining inactivity change.

Life-course factors identified from previous studies (Bauman et al., 2012; Pinto Pereira et al., 2015; Xue et al., 2012; Rhodes and Quinlan, 2015; Uijtdewilligen et al., 2014) were categorised into different life-stages: mid-adult (50y and 33y), early-adult (23y) and early-life (birth-16y). Variables representing different domains and data collection points are shown in Table S1, such that the exposed usually had higher odds of inactivity (Table 2). Neighbourhood represented a meso-level characteristic, other domains were mostly individual-level.

2.1. Statistical analysis

Our approach to establishing associations of life-course factors with

Table 1
Concurrent (50y and 33y), early adult (23y) and early-life (0-16y) factors from the 1958 British birth cohort.

Domain factors [ascertainment[a]]	Concurrent		Early adult		Early-life	
	33y	50y	23y		birth-16y	
	N(%)	N(%)		N(%)		N(%)
Physical status						
Poor-rated health [S]	1444 (13.3)	1789 (18.4)	Physical limiting illness [S]	372 (3.6)	Short pre-pubertal stature (7y) [M]	1161 (11.6)
Obesity [M;S]	1227 (11.5)	2395 (25.6)	Obesity [S]	271 (2.7)	Poor hand control/co-ordination (7y, 11y, 16y) [T]	1584 (14.4)
Mental function						
Depression [S]	1294 (11.8)	998 (10.4)	Depression [S]	1150 (11.2)		
Low cognitive ability [Tst]		930 (9.9)	Low level education[b] [S]	2677 (24.9)	Low cognitive ability (16y) [Tst]	1164 (9.6)
Low self-efficacy [S]	3036 (29.6)	2552 (26.6)				
Social circumstances						
Low social class [S]	4082 (40.1)	3063 (32.9)			Low social class (birth) [P]	8577 (72.1)
Not in paid employment [S]		1489 (15.3)			Minimal parental education (birth, 7) [P]	6334 (60.1)
Financial insecurity [S]		824 (8.5)			Poor household amenities (7y, 11y, 16y) [P]	939 (8.7)
Social isolation [S]		1283 (13.2)				
Family circumstances						
≥2 children [S]	5600 (55.5)	3129 (32.1)	≥1 child [S]	2510 (26.1)	Parental divorce [S at 33y]	1672 (15.4)
Neighbourhood type						
			Highly urbanised areas [A]	6707 (69.3)		

[a] S: self-report; M: measured; P: parent-report; T: teacher-rating; Tst: tested; A: addresses.
[b] Prospectively measured to 33y.

adult inactivity involved three main phases. First, we identified factors to represent different domains, for physical status, mental function, social and family circumstances and neighbourhoods at different life-stages (concurrent, early-adult and early-life). Organising factors into domains representing similar concepts was a pragmatic strategy to handle the large number of factors considered. We initially examined associations between each factor and inactivity separately at 50y and 33y. Next, we adjusted associations for all other factors from the same life-stage. Where associations remained for 50y or 33y inactivity, factors were carried forward to create domain scores, i.e. by summing the relevant factors (coded: 0/1) within a domain at a specific life-stage. Higher scores indicate a greater number of risk factors for inactivity. Scores with low prevalence (< 3%) were combined with other categories (details in Table S2).

Second, we conducted a series of analyses to shed light on whether concurrent factors (represented by domains) contributed to adult inactivity independent of factors at prior life-stages and vice-versa. Specifically, within each domain, we examined associations of concurrent scores with inactivity (e.g. 50y social score with 50y inactivity) (model 1). Next, we included additional adjustments for previous life-stages (e.g. 50y social score with 50y inactivity, adjusted for social scores from earlier life-stages) (model 2). We then examined associations for all domains at all life-stages (i.e. concurrent associations adjusted for all domains and life-stages) (model 3). We repeated models 1 to 3 for 33y inactivity. Differences in associations between domain scores and inactivity at 50y (or 33y) by sex were examined using an interaction term (sex ∗ score). There was little evidence of effect modification; hence, both sexes were combined in analyses.

Third, for inactivity patterns (33y-to-50y), we used a similar approach (models 1 to 3, as above) to examine whether domain scores at baseline (33y) or earlier (23y, birth-16y) were associated with subsequent inactivity stability and change. We applied multinomial logistic regression to estimate Relative Risk Ratios (RRRs) and 95% confidence intervals (CIs). We compared (i) persistently vs never inactive, (ii) deteriorating vs never inactive, and (iii) improving vs persistently inactive: i.e. we compared for (i) the most vs. least adverse behaviour, and for (ii) and (iii) changing behaviour vs. remaining the same.

We conducted two sensitivity analyses. First, because inactivity at prior life-stages could affect potential influences on later inactivity (e.g. adolescent activity could affect subsequent obesity (Bauman et al., 2012)) we conducted sensitivity analyses with further adjustment for 16y and 23y activity. Associations were little affected by additional adjustments (data not shown). Second, to ensure that reported associations were robust, we repeated analyses using more stringent cut-offs (defined in Table S3) for factors used in domain scores; the same factors were identified for domain scores and associations with adult inactivity were broadly similar to main analyses (Tables S3 and S4).

To minimise data loss, multiple imputation using chained equations was used to impute missing data on inactivity (11% at 33y; 21% at 50y), concurrent (11% (33y depression) to 24% (50y social class)), early-adult (16% (physical limiting illness) to 22% (children)) and early-life (2% (cognition) to 18% (pre-pubertal stature)) factors. Imputation models included all model variables and previously identified key predictors of missingness (Atherton et al., 2008) to create 20 imputed datasets. Imputed results were broadly similar to those using observed values; the former are presented.

3. Results

Inactivity prevalence was similar (~31%) at 33y and 50y. Across these ages, 51% were never inactive, 14% persistently inactive and 35% changed inactivity status (17% deteriorating; 18% improving).

3.1. Life-stage domain scores

Associations of factors at different life-stages (organised within domains) and inactivity at 50y and 33y, are shown as odds ratios (ORs) without and with adjustment for other factors at the same life-stage (Table 2). Factors associated concurrently with 50y inactivity after adjustment included poor-rated health, obesity (physical status); low self-efficacy and cognition (mental function), and low social class (social circumstances); these were used to construct concurrent (50y) domain scores. For example, the score for physical status, ranged 0 to 2, based on elevated, $ORs_{adjusted}$ for poor-rated health (1.98(1.76,2.24)) and obesity (1.54(1.40,1.70)). Factors at 33y associated with inactivity at either adult age were poor-rated health, obesity (physical status); depression, low self-efficacy (mental function); low social class (social circumstances) and ≥2 children (family circumstances); these were used to construct 33y domain scores. Factors from early-adulthood used for domain scores included limiting illness, obesity (physical status);

Table 2
Associations (ORs (95% CIs)) for factors at different life-stages and physical inactivity[a] at 50y or 33y.

	50y		33y	
	Unadjusted	Adjusted[b]	Unadjusted	Adjusted[b]
50y factors				
Physical status				
Poor-rated health	2.29 (2.04,2.58)	1.98 (1.76,2.24)		
Obesity	1.65 (1.50,1.82)	1.54 (1.40,1.70)		
Mental function				
Depression	1.54 (1.33,1.79)	0.99 (0.85,1.16)		
Low self-efficacy	1.67 (1.51,1.85)	1.36 (1.22,1.52)		
Low cognitive ability	1.56 (1.36,1.78)	1.34 (1.16,1.55)		
Social circumstances				
Low social class	1.46 (1.33,1.61)	1.31 (1.18,1.45)		
Not in paid employment	1.39 (1.24,1.56)	0.87 (0.77,1.00)		
Financial insecurity	1.47 (1.25,1.73)	1.06 (0.91,1.25)		
Social isolation	1.22 (1.08,1.39)	1.01 (0.88,1.15)		
Family circumstances				
≥2 children	0.89 (0.81,0.98)	0.95 (0.86,1.04)		
33y factors				
Physical status				
Poor-rated health	1.63 (1.43,1.85)	1.43 (1.25,1.64)	1.82 (1.62,2.04)	1.58 (1.40,1.79)
Obesity	1.48 (1.30,1.70)	1.40 (1.22,1.61)	1.23 (1.09,1.39)	1.17 (1.03,1.32)
Mental function				
Depression	1.35 (1.18,1.56)	1.09 (0.93,1.27)	1.60 (1.43,1.80)	1.29 (1.14,1.47)
Low self-efficacy	1.37 (1.24,1.52)	1.21 (1.08,1.35)	1.39 (1.27,1.51)	1.19 (1.08,1.31)
Social circumstances				
Low social class	1.46 (1.33,1.61)	1.36 (1.23,1.50)	1.34 (1.23,1.46)	1.20 (1.09,1.31)
Family circumstances				
≥2 children	1.00 (0.91,1.11)	0.96 (0.87,1.06)	1.26 (1.16,1.36)	1.22 (1.12,1.33)
Early adult (23y)[c]				
Physical status				
Physical limiting illness	1.41 (1.11,1.80)	1.31 (1.03,1.67)	1.33 (1.08,1.64)	1.23 (0.99,1.53)
Obesity	1.61 (1.25,2.08)	1.43 (1.11,1.85)	1.31 (1.02,1.69)	1.14 (0.88,1.48)
Mental function				
Depression	1.46 (1.27,1.67)	1.29 (1.12,1.48)	1.46 (1.28,1.66)	1.27 (1.11,1.46)
Low level education	1.55 (1.40,1.71)	1.40 (1.26,1.56)	1.65 (1.50,1.80)	1.49 (1.36,1.64)
Family circumstances				
≥1 child	1.34 (1.22,1.48)	1.17 (1.06,1.30)	1.40 (1.27,1.55)	1.21 (1.09,1.35)
Neighbourhood type				
Highly urbanised areas	1.31 (1.17,1.46)	1.26 (1.13,1.41)	1.28 (1.16,1.42)	1.24 (1.12,1.37)
Early-life (0-16y)[c]				
Physical status				
Short pre-pubertal stature	1.23 (1.06,1.41)	1.11 (0.96,1.28)	1.29 (1.13,1.47)	1.19 (1.04,1.36)
Poor hand control/co-ordination	1.41 (1.24,1.59)	1.28 (1.13,1.46)	1.35 (1.21,1.52)	1.23 (1.09,1.39)
Mental function				
Low cognitive ability	1.46 (1.27,1.67)	1.20 (1.04,1.38)	1.57 (1.37,1.81)	1.37 (1.18,1.59)
Social circumstances				
Low social class	1.48 (1.33,1.65)	1.29 (1.15,1.45)	1.23 (1.12,1.35)	1.10 (0.99,1.22)
Minimal parental education	1.39 (1.27,1.53)	1.21 (1.10,1.34)	1.24 (1.13,1.36)	1.13 (1.02,1.25)
Poor household amenities	1.39 (1.19,1.62)	1.23 (1.06,1.42)	1.23 (1.06,1.41)	1.12 (0.97,1.29)
Family circumstances				
Parental divorce	1.28 (1.14,1.45)	1.25 (1.11,1.41)	1.15 (1.03,1.28)	1.12 (1.01,1.25)

Unadjusted: adjusted for sex only.

[a] % inactive (averaged over twenty imputed datasets), at 33y: 31.4; at 50y: 30.8. NB: if participant was pregnant at time of questionnaire, physical inactivity status was based on activity frequency before pregnancy.

[b] Adjusted for all factors at the same life-stage.

[c] Identified from a larger number of early adult and early-life factors previously examined (see Pinto Pereira and Power, 2017 and Pinto Pereira et al., 2015). Several factors showed no association with inactivity at 33y or 50y and are not included here. These include, in early adulthood: adult height, employment status and social class at 23y and marital/cohabitation status at 33y; and in early-life: physical handicap/disabling condition at 7y or 11y, maternal smoking in pregnancy, maternal pre-pregnancy BMI, maternal age at birth, child neglect, institutional care, internalizing and externalizing behaviours at 16y.

depression, low-level education (mental function); ≥1 child (family circumstances) and highly urbanised areas (neighbourhood). Early-life factors used for domain scores included short pre-pubertal stature, poor hand-control/co-ordination (physical status); low cognition (mental function); low social class, parental education and household amenities (social circumstances) and parental divorce (family circumstances).

3.2. Life-stage domains and inactivity at 50y or 33y

Most life-stage domain scores were binary, except physical status (50y), mental function (23y, 33y, 50y) (range:0–2) and early-life social circumstances (range:0–3) (Table S2). As expected, all scores across the life-course were associated with 50y inactivity in sex-adjusted analysis, except for 33y family circumstances (model 1, Table S5). Associations for concurrent domains (physical status, mental function and social circumstances) remained when adjusted for prior life-stages within the same domain (model 2, Table 3). Associations also remained for previous life-stages for 33y social circumstances, 23y mental function and neighbourhood and early-life physical and social circumstances (model 2): e.g., odds of inactivity increased per 1-unit increase in mental

Table 3
Associations (ORs or Relative risk ratios (95% CIs)) between life-stage domain scores* (range) and physical inactivity at 50y or 33y or physical inactivity stability and change 33y to 50y.

	50y inactivity		33y inactivity		Inactivity stability and change 33y to 50y					
					Persistently inactive vs. never inactive	Deteriorating vs. never inactive	Improving vs. persistently inactive	Persistently inactive vs. never inactive	Deteriorating vs. never inactive	Improving vs. persistently inactive
	Model 2	Model 3	Model 2	Model 3	Model 2			Model 3		
Physical status										
50y (0–2)	1.69 (1.56,1.84)	1.56 (1.44,1.70)								
33y (0–1)	1.13 (0.99,1.27)	1.06 (0.94,1.19)	1.53 (1.39,1.69)	1.37 (1.24,1.53)	2.05 (1.79,2.35)	1.43 (1.24,1.66)	0.71 (0.60,0.83)	1.73 (1.51,1.99)	1.28 (1.10,1.49)	0.75 (0.63,0.88)
23y (0–1)	1.04 (0.86,1.27)	1.03 (0.84,1.25)	1.06 (0.89,1.26)	1.02 (0.86,1.22)	1.23 (0.95,1.58)	1.22 (0.95,1.57)	0.85 (0.63,1.13)	1.16 (0.90,1.50)	1.18 (0.92,1.52)	0.86 (0.65,1.16)
Early-life (0–1)	1.23 (1.10,1.37)	1.09 (0.97,1.22)	1.27 (1.15,1.40)	1.12 (1.01,1.24)	1.46 (1.28,1.67)	1.32 (1.14,1.51)	0.88 (0.75,1.04)	1.21 (1.05,1.39)	1.15 (0.99,1.33)	0.94 (0.79,1.11)
Mental function										
50y (0–2)	1.42 (1.30,1.54)	1.29 (1.18,1.41)								
33y (0–2)	1.05 (0.97,1.14)	0.99 (0.91,1.07)	1.20 (1.13,1.29)	1.15 (1.08,1.24)	1.31 (1.18,1.46)	1.15 (1.05,1.26)	0.92 (0.81,1.05)	1.20 (1.07,1.33)	1.08 (0.98,1.19)	0.97 (0.85,1.11)
23y (0–2)	1.26 (1.15,1.38)	1.09 (0.99,1.20)	1.33 (1.23,1.44)	1.23 (1.13,1.34)	1.59 (1.41,1.79)	1.33 (1.19,1.49)	0.84 (0.73,0.97)	1.34 (1.19,1.52)	1.14 (1.01,1.28)	0.92 (0.79,1.06)
Early-life (0–1)	1.02 (0.88,1.19)	0.91 (0.77,1.07)	1.19 (1.02,1.38)	1.09 (0.94,1.28)	1.25 (1.02,1.53)	1.17 (0.95,1.44)	1.00 (0.79,1.26)	1.06 (0.86,1.31)	1.00 (0.80,1.25)	1.07 (0.84,1.36)
Social circumstances										
50y (0–1)	1.24 (1.11,1.39)	1.12 (0.99,1.25)								
33y (0–1)	1.21 (1.08,1.35)	1.08 (0.96,1.21)	1.27 (1.16,1.39)	1.05 (0.96,1.16)	1.47 (1.29,1.68)	1.40 (1.22,1.60)	0.90 (0.77,1.05)	1.14 (0.99,1.32)	1.25 (1.08,1.44)	0.96 (0.81,1.13)
Early-life (0–3)	1.21 (1.14,1.28)	1.12 (1.05,1.19)	1.11 (1.06,1.17)	1.02 (0.96,1.07)	1.27 (1.18,1.37)	1.24 (1.16,1.33)	0.87 (0.79,0.95)	1.12 (1.04,1.21)	1.17 (1.09,1.26)	0.91 (0.83,1.01)
Family circumstances										
33y (0–1)	0.91 (0.81,1.01)	0.93 (0.83,1.03)	1.15 (1.05,1.26)	1.18 (1.08,1.29)	1.00 (0.86,1.16)	0.93 (0.82,1.05)	1.24 (1.04,1.48)	1.03 (0.89,1.19)	0.93 (0.82,1.06)	1.23 (1.03,1.46)
23y (0–1)	1.37 (1.23,1.53)	1.07 (0.94,1.20)	1.31 (1.18,1.46)	1.08 (0.97,1.22)	1.61 (1.38,1.87)	1.39 (1.20,1.62)	0.82 (0.68,0.98)	1.16 (0.99,1.36)	1.11 (0.95,1.30)	0.94 (0.77,1.14)
Early-life (0–1)	1.24 (1.10,1.41)	1.19 (1.05,1.34)	1.11 (0.99,1.24)	1.05 (0.94,1.18)	1.29 (1.10,1.51)	1.27 (1.08,1.48)	0.86 (0.71,1.04)	1.21 (1.03,1.42)	1.22 (1.05,1.43)	0.87 (0.72,1.06)
Neighbourhood type										
23y (0–1)	1.31 (1.17,1.46)	1.19 (1.06,1.33)	1.28 (1.16,1.42)	1.22 (1.10,1.34)	1.56 (1.35,1.81)	1.25 (1.10,1.43)	0.78 (0.66,0.93)	1.42 (1.22,1.65)	1.15 (1.01,1.31)	0.82 (0.68,0.98)

Model 2: adjusted for sex and all life-stages within a domain.
Model 3: adjusted for sex and all life-stages and domains.
**Physical status scores*: 50y: poor-rated health, obesity; 33y: poor-rated health, obesity; 23y: physically limiting illness, obesity; Early-life: short pre-pubertal stature, poor hand control/co-ordination.
Mental function scores: 50y: low self-efficacy, low cognitive ability; 33y: depression, low self-efficacy; 23y: depression, low level education; Early-life: low cognitive ability.
Social circumstances: 50y: low social class; 33y: low social class; Early-life: low social class at birth, minimal parental education, poor household amenities.
Family circumstances: 33y: ≥2 children; 23y: ≥1 child; Early-life: parental divorce.
Neighbourhood type: 23y: highly urbanised areas.
(See Table S2 for more details on life-stage domain score composition)

function score (range:0–2) at 50y: OR = 1.42(1.30,1.54) and at 23y: OR = 1.26(1.15,1.38), when adjusted for mental function at all life-stages (model 2). Family circumstances in early-life and at 23y were associated with 50y inactivity. Associations for concurrent (50y) physical status and mental function persisted when all life-stage domains were considered (model 3,Table 3): $ORs_{adjusted}$ were 1.56(1.44,1.70) and 1.29(1.18,1.41) respectively, per 1-unit higher score (0–2); associations also remained for 23y neighbourhood (1.19(1.06,1.33)) and early-life social (1.12(1.05,1.19)) and family (1.19(1.05,1.34)) circumstances.

Similarly for 33y inactivity, associations were observed for all domain scores across the life-course in model 1 (Table S5). Within-domains, associations for concurrent physical status, mental function, social and family circumstances remained after adjusting for prior life-stages (model 2, Table 3). Associations also remained for 23y mental function, family circumstances and neighbourhood and early-life physical status, mental function and social circumstances (model 2): e.g., for mental function, scores at all life-stages were associated with increased ORs of inactivity: 1.45(1.25,1.65) for lowest vs highest score at 33y (i.e. 1.20 ∗ 1.20), 1.78(1.50,2.06) at 23y (i.e. 1.33 ∗ 1.33) and 1.19(1.02,1.38) for early-life (model 2, Table 3). In models of all life-stage domains combined (model 3, Table 3), associations were observed for concurrent (33y) physical status, mental function and family circumstances; for 23y mental function and neighbourhood and early-life physical status.

3.3. Life-stage domains and inactivity patterns 33y-to-50y

Adjusting for all life-stage domains, 33y physical status and 23y neighbourhood were associated with all inactivity patterns (model 3, Table 3). Risk of inactivity persistence (vs never) increased per 1-unit in 33y physical status score: RRR = 1.73(1.51,1.99); the RRR for deterioration was 1.28(1.10,1.49) and for improvement (vs persistently inactive) was 0.75(0.63,0.88). RRRs for neighbourhood were 1.42(1.22,1.65) and 1.15(1.01,1.31) for persistent inactivity and deterioration respectively, and 0.82(0.68,0.98) for improvement. Mental function (23y) and early-life social and family circumstances were associated with persistent inactivity and deterioration but not with improvement. Other factors were related to persistence (33y mental function, early-life physical circumstances) or deterioration (33y social circumstances), but not improvement. Family circumstances (33y) was associated with an elevated RRR for improvement (1.23(1.03,1.46)).

4. Discussion

In a general mid-life population followed from birth, we identify four important findings. First, concurrent factors, particularly relating to physical status and mental function, were associated with inactivity at two adult ages after allowing for other domains and life-stages. For example, odds of inactivity associated with 1-unit physical score (vs. 0) were 56% higher at 50y and, 37% higher at 33y. Second, associations with inactivity observed for concurrent factors were often evident with measures within the same domain (e.g. physical status) that pre-date concurrent factors at least in simple analyses (model 1). This observation suggests that concurrent influences often reflect an accumulation over many years. Relatedly, poorer physical status was associated with greater risk of inactivity persistence and deterioration and lower risk of improvement 33y-to-50y. Third, in some instances, domains from previous life-stages were associated with inactivity in mid-adulthood independent of concurrent factors: early-life circumstances were associated with 50y inactivity, with increased odds of 19% for unfavourable family circumstances and 40% for poor social (OR 1.12^3 for score 3 vs 0) circumstances. Fourth, highly urbanised neighbourhood in early adulthood was associated with higher odds (~20%) of inactivity at both 50y and 33y, and with unfavourable inactivity patterns, notably, after allowing for several individual-level factors.

Given the study's ambitious scope, there were several methodological considerations. Our study has gone further than others in terms of the range of factors and time-frame considered and adds new knowledge on likely lifetime influences on inactivity. Study data are unique in prospectively capturing diverse factors birth to 50y; and inactivity at two ages almost 20y apart, with the same measure to examine stability and change. Study limitations are acknowledged. There is no consistent definition of inactivity; some studies use failure to meet recommended activity levels (Lee et al., 2012; Picavet et al., 2011), others identify the least active in a population (Kuh and Cooper, 1992). Our self-report measure of infrequent leisure-time activity (< 1/week) is similar to others (Brown et al., 2013; Hamer et al., 2009; Vatten et al., 2006; Aarnio et al., 2002), and has been found to be associated with psychological distress (Hamer et al., 2009) and mortality (Brown et al., 2013; Vatten et al., 2006). However, outstanding issues include reliability of inactivity measures and possible misclassification of inactivity change. Organisation of factors into domains afforded a structured and pragmatic approach, although improvements in this approach may be possible in future work; dichotomising factors, in some instances using arbitrary cut-offs, was necessary to create domain scores. Reassuringly, conclusions were broadly similar in sensitivity analysis using alternative cut-offs. Dichotomising factors could lead to reduced variation, possibly resulting in conservative estimated associations with inactivity. Some measures have limitations, e.g. we lack detailed information on non-person-level characteristics; our neighbourhood classification is general rather than specific to characteristics potentially relevant to inactivity (e.g. environmental convenience/access), and data are available for only one life-stage. Also, because the study is observational uncontrolled covariates or measurement error could account for some of the observed associations. Our findings for a sample that is broadly representative of the British population at a similar age (Atherton et al., 2008), are likely to be applicable to other high-income countries, but less so for low- and middle-income countries. As with any long-term study, sample attrition occurred, but we maximised available data by including participants with inactivity data at 33y or 50y and avoided sample reductions due to missing information via multiple imputation.

No other study has investigated such an extensive array of factors across a lifetime with adult inactivity. For example, previous studies, including our own (Pinto Pereira et al., 2014a; Pinto Pereira et al., 2015; Pinto Pereira and Power, 2017), focus on a few factors from particular life-stages (Elhakeem et al., 2017; Seiluri et al., 2011; Uijtdewilligen et al., 2015; Xue et al., 2012). We found that patterns of association of risk factors (domains and life-stages) were broadly similar for inactivity at both 33y and 50y, particularly in highlighting concurrent factors such as physical status and mental function. Organisation of factors into domains hampers comparison, but consistencies with other studies can be identified. Notably, our findings agree with previous literature on physical status being a correlate of adult (in)activity (Bauman et al., 2012). Here we extend such findings; first, by demonstrating that this association is robust after accounting for other domains and life-stages, with increased risks for substantial proportions in the population: e.g. at 50y, 31% had a physical score of one, associated with 56% higher odds; 8% had a score of 2 with over two-fold odds ($1.56 * 1.56$) of inactivity. Second, our findings suggest that the association of early-adult physical status with inactivity in mid-adulthood is via concurrent status (which reflects an individual's past status). The likely impact of poor physical status in early-adulthood is underscored by its association with subsequent inactivity persistence, deterioration (73% and 28% higher risk respectively per unit increase in 33y score) and improvement (25% lower risk). Third, the importance of physical status in early-life is highlighted by the increased odds of inactivity at both 33y and 50y of ~25%, independent of later physical status, but only for 33y inactivity when account was taken of other domains. Such findings agree with literature showing relationships between fewer child health problems and higher odds of activity at 36y (Kuh and Cooper, 1992); also, associations for early-life physical factors correspond to our previous study of specific factors (e.g. co-ordination) and inactivity (Pinto Pereira et al., 2015).

Likewise for mental functioning, spanning cognitive and psychological components, concurrent status was associated with inactivity at both ages with substantial proportions of the population in elevated risk groups. For example at 50y, 30% had a mental function score of one, associated with 29% higher odds of inactivity; 5% had a score of 2 with 66% (i.e. $1.29 * 1.29$) higher odds. Interestingly, there was an independent association of early-adult mental function with inactivity at 33y but not 50y. However, due to data limitations, the composition of domain scores varies; cognition or educational attainment were components at 50y and 23y but not at 33y, so an association between the early-adult domain and 33y inactivity could reflect an influence of cognitive ability not captured concurrently (at 33y). Early-adult mental functioning was associated with a 34% and 14% higher risk of inactivity persistence and deterioration 33y-to-50y respectively (per 1-unit increase, scale 0–2), but there was no association with improvement. Our findings agree with existing literature showing no association with improvement, while better-educated groups are more likely than others to be never inactive in their leisure-time (Picavet et al., 2011). Early-life (cognitive ability alone) associations did not remain after accounting for subsequent life-stages, suggesting that its impact on adult inactivity is via later educational attainment/or mid-adult cognition. Associations observed for depression in early (23y, 33y) but not mid-adulthood (50y) with inactivity agree with previous research in this cohort (Pinto Pereira et al., 2014b), while low self-efficacy and inactivity associations add to other studies (Bauman et al., 2012) by showing links (as a component of 33y mental function) with inactivity persistence 33y-to-50y.

Neighbourhood in early-adulthood was the only non-person level characteristic available. Highly urbanised areas were associated with ~20% higher odds of inactivity at 33y and 50y; 42% and 15% higher risks respectively for persistent inactivity and deterioration, and, 18% lower risk of improvement. Many (69%) study participants lived in high-risk neighbourhoods, highlighting the potential importance of this factor and supplementary analysis confirmed our findings using an alternative neighbourhood grouping. We are unaware of other studies using similar neighbourhood classifications and are unable to identify the characteristics underlying our associations. Nonetheless, findings were robust to adjustment for multiple individual-level factors from different life-stages, and were observed for inactivity almost three decades later. Hence, our study suggests that the neighbourhood lived-in during early-adulthood has important effects on later inactivity, or alternatively, could represent concurrent neighbourhood conditions.

As previously noted, early-life social and family circumstances are associated with inactivity at 50y but not 33y (Pinto Pereira et al., 2014a) and with inactivity persistence and deterioration but not improvement (Pinto Pereira et al., 2015). Our findings for parental divorce (early-life family) are novel in light of the limited evidence available, while findings for social background add to the sparse literature including recent research in children (Knuth et al., 2017). Previously, we hypothesized that parents' manual work may not be conducive to physical activity during leisure-time, with transmission of behaviour to offspring (Pinto Pereira et al., 2014a).

4.1. Public health implications

Overviews (Bauman et al., 2012) argue for multiple influences on physical (in)activity ranging from macro-level to meso- and individual-level factors. Focusing on the latter, our findings support the notion of multiple influences, from multiple life-stages, on adult leisure-time inactivity. Importantly, as well as associations of concurrent factors with inactivity we found that measures of similar characteristics at earlier life-stages were also associated with inactivity in adulthood, suggesting a likely cumulative influence over several years. Relationships with inactivity stability and change, are likely to be similarly affected by continuity or change in circumstances, as will be explored in future work. In conclusion, our findings support calls for action to reduce inactivity to be made at the neighbourhood level (Sallis et al., 2012). In addition, our study suggests that physical status and mental functioning over the life-course and disadvantage (low SEP and parental divorce) in childhood are important policy targets. For example, strategies to encourage activity in adulthood could include maintaining health and self-efficacy in adulthood and reducing childhood socioeconomic inequalities.

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The authors declare that they have no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2018.05.005.

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