Title: Early adulthood determinants of mid-life leisure-time physical inactivity stability and change: findings from a prospective birth cohort

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Abstract

Objectives: Physical inactivity is highly prevalent. Knowledge is needed of influences on inactive lifestyles. We aimed to establish whether early adult factors predict subsequent inactivity patterns in mid-adulthood.

Design: Leisure-time inactivity (activity frequency<1/wk) was assessed at 33y and 50y in the 1958 British Birth cohort (N=12,271).

Methods: We assessed associations of early adult (23-33y) physical status, mental function, social, family and neighbourhood circumstances with four 33-50y patterns (never inactive, persistently inactive, deteriorating or improving) using multinomial logistic regression with and without adjustment for childhood factors (e.g. social class).

Results: Inactivity prevalence was similar at 33y and 50y (~31%), but 17% deteriorated and 18% improved with age. Factors associated with persistent vs never inactive were: limiting illness (Relative risk ratio (RRR):1.21(1.04,1.42) per number of ages exposed (0,1 or 2 times across ages 23y and 33y), obesity (1.33(1.16,1.54) per number of ages exposed), height (0.93(0.89,0.98) per 5cm), depression (1.32(1.19,1.47) per number of ages exposed); education (1.28(1.20,1.38) per decrease on 5-point scale) and neighbourhood (1.59(1.37,1.86) in 'industrial/local authority housing areas' and 1.33(1.12,1.58) in 'growth/metropolitan inner areas' vs 'suburbs, service, rural or seaside areas'). Associations were broadly similar for inactivity deterioration. Industrial/local authority housing areas (0.75(0.61,0.91)) and longer obesity exposure (0.78(0.64,0.95)) were associated with lower RRRs for improvement. Number of children was associated with improvement, although associations varied by age. Associations remained after adjustment for childhood factors.

Conclusions: Several early adult factors are associated with inactivity persistence and deterioration; fewer with improvement. Obesity duration and neighbourhood lived in during young adulthood had long-lasting associations with inactivity patterns in mid-life.

27 Keywords: Leisure-time physical inactivity, life-course, birth cohort, Britain

Introduction

Physical inactivity is highly prevalent[1] and associated with substantial economic[2] and health burdens[3]. Inactivity, defined as activity frequency<1/week, is associated with unfavourable health outcomes such as psychological distress[4] and mortality[5, 6]. With such high costs, preventing inactivity is particularly important, especially given evidence suggesting that even low activity levels (i.e. avoidance of inactivity) protects against mortality[7]. An improved understanding of influences on inactivity is therefore needed.

Influences on physical (in)activity are many, and one challenge in interpreting current evidence is that most studies, being cross-sectional, examine contemporary correlates of physical activity[8]. Such studies do not take a life-course approach, and ignore the fact that factors specific to particular life-stages could be important for future inactivity levels. For example, life events typically occurring in early adulthood, such as family formation, may alter physical (in)activity levels[9, 10] and contribute to gender differences[10, 11] in subsequent inactivity patterns. Early adulthood is a life-stage of many important transitions such as parenthood and job entry and may be a pivotal period for developing lifestyles, both protective and risk-laden[12]. Within the context of macro- to micro-level influences, early adult physical factors (e.g. health status[13]), mental function (e.g. depression[14]), social circumstances (e.g. employment[13]), family circumstances (e.g. parenthood[10]) and neighbourhood characteristics (e.g. access to recreational facilities[15]) could influence subsequent inactivity status. However, few prospective studies examine whether early adulthood is a key life-stage when several influences may affect subsequent inactivity levels and patterns, including stability and changes. Moreover, it is important to account for putative influences from early-life, such as physical development and co-ordination[16]. In this respect, a life-course approach has the possibility to shed light on the added contribution of early adulthood influences over and above those from prior life-stages.

Therefore, in a nationwide general population sample we aimed to establish whether factors in early adulthood are associated with inactivity patterns subsequently in midlife. We examine inactivity patterns in terms of stability and change because adult inactivity is only moderately stable[16] and, knowledge of influences on these inactivity patterns may inform the development of intervention strategies. Specific objectives were to (i) examine whether physical, mental function, social, family and neighbourhood circumstances in early adulthood (at 23y and/or 33y) were associated with later inactivity stability and change 33y to 50y, and (ii) examine associations after accounting for potential influences from prior life-stages.

Methods

The 1958 British Birth Cohort is an ongoing longitudinal study of all babies born during one week, March 1958 across England, Scotland and Wales (N=17,638) and a further 920 immigrants with the same birth week[17]. Information was collected in childhood (birth, 7, 11 and 16y) and adulthood (23, 33, 42, 45 and 50y). Ethical approval was given for various sweeps, 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[18]; the sample for this study consists of those alive and living in Britain at 50y with information on inactivity at either 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' was defined as ≥1/month for most of the year (or over the part of the year when they did the activity) and, to aid recall, a list of example activities (e.g. swimming or going for walks) was provided. Those responding affirmatively, reported activity frequency ranging from every/most days to <2-3 times/month[19]. Participants reported frequency of all activities together. Consistent with previous work[4-6], low activity frequency was identified as <1/week (including no 'regular'

activity), hereafter referred to as inactivity. From binary inactivity measures at 33y and 50y, we identified four groups: (i) 'never inactive' (≥1/week at 33y and 50y) (ii) 'persistently inactive' (active <1/week at both ages) and two change groups, (iii) deteriorating status (≥1/week at 33y, <1/week at 50y) and (iv) improving status (<1/week at 33y, ≥1/week at 50y). Thus, deteriorating status refers to deterioration in activity (i.e. changing to inactivity); improving status refers to improvement in activity (i.e. changing from inactivity).

Early adult factors (main exposures), identified from previous studies[10, 20, 21], were assessed prospectively and categorised into five broad domains: physical status (limiting illness, obesity, height), mental function (depression, education level), social circumstances (social class, employment), family circumstances (co-habitation, number of children), and neighbourhood type. Neighbourhood represented a meso-level characteristic, whereas the physical, mental function, social and family domains mostly represented individual-level characteristics (details in Table 1).

Early-life factors (covariates) identified previously[16] include pre-pubertal stature, hand control/co-ordination problems, cognitive ability, social class at birth, household amenities, parental education, parental divorce and 16y activity (frequency and aptitude) (details in Table 1). Other factors, for sensitivity analyses, include 16y body mass index (BMI; from measured heights and weights), mental health (16y internalizing and externalising behaviours from the Rutter scale[22]) and 23y physical activity (self-reported frequency[19]).

Statistical analysis

We examined whether factors in early adulthood (23-33y) were associated with later inactivity stability and change (33-50y) by fitting two multinomial logistic regression models, which provided Relative Risk Ratios (RRRs) and 95% confidence intervals (CIs). We first compared the persistently inactive relative to the never inactive (i.e. most vs. least adverse behaviour 33-50y) and those with deteriorating status relative to the never inactive (i.e.

changing vs. remaining the same over the age range). Second, we compared those with improving status relative to the persistently inactive. Initially, associations between factors and inactivity patterns were examined separately and gender differences in associations were assessed using an interaction term (gender*factor); where interactions were found results are presented separately by gender. We conducted domain specific multivariable models including all factors (from each domain) in one model. Next, to assess associations for domains simultaneously, we combined all factors associated with inactivity patterns in the first stage of analysis into one model. Finally, we included adjustments for early-life factors. To account for potential bi-directional associations of inactivity with adiposity or mental health[14, 23, 24] and to further control for previous activity levels, we conducted sensitivity analyses that included further adjustment for 16y BMI and mental health and 23y activity. To minimize data loss, multiple imputation using chained equations was used to impute missing data on inactivity (11% at 33y; 21% at 50y), early adult factors (1% (33y height) to 22% (23y children)) and early-life factors (1% (cognition) to 30% (16y weight)). Imputation models included all model variables, including previously identified key predictors of missingness[18]. Regression analyses were run across 10 imputed datasets; overall estimates were attained using Rubin's rules. Imputed results (presented here) were broadly similar to those using observed values (Table S1). Analyses were conducted in STATA v13.1.

Results

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

Domain specific associations

In univariable analyses, all physical factors (limiting illness, obesity, height) were associated with persistent inactivity (versus never inactive); all except limiting illness were related to

deteriorating status (versus never inactive) and all except height were associated with improving status (vs persistent inactivity) (Table 2). Both mental function factors (depression, lower education level) were associated with persistent inactivity and deterioration, and, in the opposite direction, with improvement. For social factors, lower social class (23y and 33y) and not in paid employment at 23y (but not at 33y) were associated with inactivity persistence and deterioration. Social class (23y and 33y) were also associated, in the opposite direction, with improvement. In the family domain, higher number of children at 23y was associated with inactivity persistence and deterioration and, in the opposite direction, with improvement. Only one gender-interaction was found ($p_{interation}$=0.01): for children at 33y, the direction of association for inactivity deterioration differed by gender. Regarding neighbourhood, 'stable industrial or local authority dominated housing areas' was associated with a higher RRR (1.84(95% CI: 1.58,2.14)) for persistent inactivity and likewise for 'growth and metropolitan inner areas' (1.37(1.16,1.63)) versus 'suburbs, service centres; rural areas and seaside resorts'. Similar associations were observed for inactivity deterioration. Correspondingly, 'stable industrial/local authority housing' was associated with a lower RRR (0.71(0.59,0.87)) for improving. In multivariable domain specific models, associations attenuated, though remaining for several early adult factors (Table S2).

Combined domains and adjusting for early-life

In models that included all domains simultaneously, obesity and neighbourhood were associated with all inactivity patterns (Table 3). Per number of ages exposed to obesity (0,1, or 2 times across ages 23y and 33y), the RRR for persistent inactivity and deterioration was 1.33(1.16,1.54) and 1.26(1.08,1.47) respectively; for improvement the RRR was 0.78(0.64,0.95). RRRs for 'stable industrial/local authority dominated housing areas' were 1.59(1.37,1.86), and 1.30(1.14,1.49) for persistent inactivity and deterioration respectively and 0.75 (0.61,0.91) for improvement. Lower education level was associated with persistent inactivity and deterioration (RRR: 1.28(1.20,1.38) and 1.15(1.08,1.23) respectively per lower qualification on a five-point scale), but not with improvement. Other factors were

related to persistence (limiting illness, shorter stature, depression) or deterioration (33y social class), but not improvement. There were modest associations for number of children with improvement, albeit in opposite directions at 23y and 33y. At 23y, higher number of children was associated with a lower RRR for improvement (0.87(0.77,0.99)), whereas at 33y higher number of children was associated with an elevated RRR for improvement (1.16(1.05,1.28)), in women only. After adjustment for early-life factors most associations remained (Table S3) and likewise in sensitivity analysis including further adjustment for prior BMI, mental health and activity (data not shown).

Discussion

In a general population followed from birth to 50y, we identify two factors from young adulthood (obesity and neighbourhood) that were associated with subsequent inactivity persistence, deterioration and improvement during mid-life. Associations for these two factors remained even after accounting for several adult and early-life factors, such that those who were obese at both 23y and 33y had a 74% and 56% higher odds of persistent inactivity and deterioration respectively, and 38% lower odds of improvement. Neighbourhood was the only non-person level characteristic examined, with 'stable industrial/local authority dominated housing areas' associated with the least favourable inactivity patterns. While lower education level was associated with inactivity persistence and deterioration (though not with improvement), other young adult factors (limiting illness, shorter stature, depression, social class and children) showed less consistent associations with subsequent inactivity patterns.

Methodological considerations

Our sample enabled examination of several factors, such as duration of exposure to obesity over a 10y period in early adulthood and allowed us to account for prospectively assessed early-life factors. Identical inactivity measures at 33y and 50y facilitated investigation of adult inactivity stability and change.. To our knowledge, no other study has investigated such an extensive array of early adult factors with subsequent inactivity patterns, while simultaneously accounting for influences from early-life. Study limitations include self-report of leisure-time activity and potential reporting bias. However, reassuringly, previous findings of our activity measures (e.g. with blood pressure[25]) provides construct validity and elsewhere has been associated with important health outcomes including mortality[5, 6]. Misclassification of individuals remains a possibility and inactivity over a 17y period may not fully capture stability and change during the intervening period. Such measurement challenges may affect our finding that inactivity is only moderately stable in mid-adulthood.

We investigated several individual-level factors but only one representing the environment in which individuals lived in young adulthood. Some adult measures have limitations, e.g. data for our neighbourhood measure is available at one time-point and is non-specific in terms of dimensions potentially relevant to inactivity (e.g. access to recreation facilities). Also, there are differences in the timing of data collection (1981) and census (1971) from which the classification was derived, such that neighbourhood characteristics may have changed in the interim. One challenge in epidemiological studies is the potential for bi-directional associations, e.g. between activity and adiposity[23, 24] or depressive symptoms[14]. Potential bi-directional associations have been ignored previously[21], but our sensitivity analysis (i.e. adjustments for prior BMI, mental health and activity) suggest that observed associations were robust. Whilst our findings are consistent with the interpretation that obesity influences inactivity[23, 24], uncertainties remain on the direction of relationships or whether uncontrolled covariates could partially account for the associations. Such issues, including changes in exposures, will be explored in future work to strengthen causal inference. Organisation of early adult factors into domains is subjective, but such organisation afforded a structured and pragmatic approach. Finally, sample attrition occurred, although respondents in mid-adulthood were broadly representative of the surviving cohort[18]. Maximising available data, we included participants with an inactivity measure at either 33y or 50y and avoided sample reductions due to missing information by using multiple imputation.

Interpretation and comparison to other studies

Our finding of a robust association between neighbourhood and subsequent inactivity patterns is important. We found that living in ‘stable industrial/local authority housing dominated areas’ was associated with a 60% and 30% higher odds of inactivity persistence and deterioration respectively and a 25% lower odds of improving. Over a third of the population lived in this neighbourhood type, highlighting the high prevalence of this potentially important factor for subsequent inactivity patterns. Thus, our findings provide support for the growing consensus view that change in population levels of physical activity

will require major modifications in environments. Comparison with other studies is difficult because our categorisation of neighbourhood is not used elsewhere. However, the role of environmental factors such as accessibility, safety, and aesthetics on physical activity has been investigated previously[10]. Evidence is sometimes scarce or inconclusive, but appears to support a link between environmental convenience/access to recreation and activity maintenance[10]. In the US, more affluent neighbourhoods have more activity facilities[26] and thus we speculate that our findings may reflect such aspects of neighbourhood affluence[27] and point to potential inequality in the availability of activity facilities. We cannot discount the possibility of selection of inactive participants into particular neighbourhoods, but the robustness of associations with all inactivity patterns after adjusting for several person-level factors suggests that this is not a major concern.

Another main finding of our study was the observation that obesity exposure in early adulthood was related to all inactivity patterns in mid-adulthood. While there is considerable evidence on the cross-sectional association between adiposity and (in)activity, information on the longitudinal relationship is limited. Our finding adds to this literature[23, 24] by demonstrating that associations with detrimental activity patterns are maintained even after accounting for other adult and early-life factors including adolescent BMI and activity (the latter suggesting that our findings are unlikely to be due to a reverse association of inactivity to BMI). Such findings are plausible because increased body weight could hinder participation in physical activity due to musculoskeletal problems and exhaustion[24]. Also, although obesity prevalence at both 23y and 33y was low, reducing study power, findings highlight the potential detrimental consequences for physical activity of long exposure to obesity and resultant high level of adiposity. With secular trends in obesity, this factor may be of increasing importance for inactivity levels among more recent generations.

It is noteworthy also that educational attainment was associated with subsequent inactivity persistence and deterioration but not with improvement, and these results concur with our previously reported associations for early-life cognition[16]. 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[13]. However, for other factors it is interesting to note the lack of continuity of associations across the life-course. For example, we show here that depression in early adulthood was associated with persistent inactivity but not with inactivity change. This contrasts with the null-findings for mental health in early-life and adult inactivity persistence and change in this population[16]. Nonetheless, our findings extend and agree with previous findings in elderly women[20]. For height, which is a well-accepted indicator of health status due to its associations with adult morbidity and mortality risk[28], our study shows an association between shorter adult stature and inactivity persistence. Yet, this association was not evident in analyses that adjusted for pre-pubertal stature, which we have previously shown to be associated with adult inactivity persistence[16]. Such novel findings add to the limited literature on height and subsequent inactivity, and emphasises that associations between factors may vary with age. Interestingly, we found that number of children was not associated with inactivity persistence but it was associated with inactivity change. However, the direction of association differed with age; further highlighting the need to consider life-stage of potential influences on inactivity. The differences with age may reflect differences in the meaning of this factor, i.e. for disadvantaged groups early parenthood may be perceived as an alternative pathway into adulthood[29], whilst the link of disadvantage with parenthood may not apply at later ages. Finally, our finding that physical limiting illness was associated with persistent inactivity, agrees with previous findings on self-reported health and mobility disability[20]. Likewise, our findings for social class agree with the literature on a decrease in physical activity among manual workers[30] and, similar to a recent review[10], we found no evidence of relationships of either employment or marriage/co-habitation and inactivity change.

Conclusion

Moderate inactivity tracking may provide opportunities for improvements over the life-course[19]. Associations of early adult factors, particularly obesity in young adulthood and the environment in which individuals lived (‘stable industrial/local authority dominated housing

areas'), appeared to have long-lasting associations with inactivity stability and change in mid-life, even after accounting for potential influences from earlier life. These findings contribute to the identification of groups likely to benefit from interventions to prevent inactivity. They are relevant to recent UK policies that encourage engagement in physical activity with a focus on those who tend not to take part[31]. Obesity and neighbourhood showed pervasive associations with subsequent inactivity maintenance and both deterioration and improvement. Our findings therefore shed light on a potential pathway via inactivity by which factors such as neighbourhood may influence future health. Replication of such findings in different cohorts, generations and countries is needed to strengthen evidence on causal relationships between such factors and inactivity.

Practical Implications

- Moderate inactivity tracking provides opportunities for improvements over the life-course.
- Young adult obesity and neighbourhood show pervasive associations with subsequent inactivity maintenance and both deterioration and improvement, contributing to the identification of groups likely to benefit from interventions to prevent inactivity.
- Inactivity is a potential pathway via which factors such as neighbourhood may influence future health.

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References

1. Hallal PC, Andersen LB, Bull FC, et al. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet.* 2012; 380(9838):247-257.
2. Ding D, Lawson KD, Kolbe-Alexander TL, et al. The economic burden of physical inactivity: a global analysis of major non-communicable diseases. *Lancet.* 2016; 388(10051):1311-1324.
3. Lee IM, Shiroma EJ, Lobelo F, et al. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet.* 2012; 380(9838):219-229.
4. Hamer M, Stamatakis E, Steptoe A. Dose-response relationship between physical activity and mental health: the Scottish Health Survey. *Br. J. Sports Med.* 2009; 43(14):1111-1114.
5. Brown RE, Riddell MC, Macpherson AK, et al. The association between frequency of physical activity and mortality risk across the adult age span. *J. Aging Health.* 2013; 25(5):803-814.
6. Vatten LJ, Nilsen TI, Romundstad PR, et al. Adiposity and physical activity as predictors of cardiovascular mortality. *Eur J Cardiovasc Prev Rehabil.* 2006; 13(6):909-915.
7. Lee IM, Skerrett PJ. Physical activity and all-cause mortality: what is the dose-response relation? *Med. Sci. Sports Exerc.* 2001; 33(Supplement):S459-S471.
8. Bauman AE, Reis RS, Sallis JF, et al. Correlates of physical activity: why are some people physically active and others not? *Lancet.* 2012; 380(9838):258-271.
9. Engberg E, Alen M, Kukkonen-Harjula K, et al. Life events and change in leisure time physical activity: a systematic review. *Sports Med.* 2012; 42(5):433-447.
10. Rhodes RE, Quinlan A. Predictors of Physical Activity Change Among Adults Using Observational Designs. *Sports Med.* 2015; 45(3):423-441.
11. Oesterle S, Hawkins JD, Hill KG, et al. Men's and Women's Pathways to Adulthood and Their Adolescent Precursors. *J Marriage Fam.* 2010; 72(5):1436-1453.
12. Settersten RA. The New Landscape of Adult Life: Road Maps, Signposts, and Speed Lines. *Research in human development.* 2007; 4(3-4):239-252.
13. Picavet HS, Wendel-vos GC, Vreeken HL, et al. How stable are physical activity habits among adults? The Doetinchem Cohort Study. *Med. Sci. Sports Exerc.* 2011; 43(1):74-79.
14. Pinto Pereira SM, Geoffroy MC, Power C. Depressive Symptoms and Physical Activity During 3 Decades in Adult Life Bidirectional Associations in a Prospective Cohort Study. *JAMA Psychiat.* 2014; 71(12):1373-1380.
15. Ranchod YK, Roux AVD, Evenson KR, et al. Longitudinal Associations Between Neighborhood Recreational Facilities and Change in Recreational Physical Activity in the Multi-Ethnic Study of Atherosclerosis, 2000-2007. *Am. J. Epidemiol.* 2014; 179(3):335-343.
16. Pinto Pereira SM, Li L, Power C. Early Life Factors and Adult Leisure Time Physical Inactivity Stability and Change. *Med. Sci. Sports Exerc.* 2015; 47(9):1841-1848.
17. Power C, Elliott J. Cohort profile: 1958 British birth cohort (National Child Development Study). *Int. J. Epidemiol.* 2006; 35(1):34-41.
18. Atherton K, Fuller E, Shepherd P, et al. Loss and representativeness in a biomedical survey at age 45 years: 1958 British birth cohort. *J. Epidemiol. Community Health.* 2008; 62(3):216-223.
19. Parsons TJ, Power C, Manor O. Longitudinal physical activity and diet patterns in the 1958 British Birth Cohort. *Med. Sci. Sports Exerc.* 2006; 38(3):547-554.
20. Xue QL, Bandeen-Roche K, Mielenz TJ, et al. Patterns of 12-Year Change in Physical Activity Levels in Community-Dwelling Older Women: Can Modest Levels of Physical Activity Help Older Women Live Longer? *Am. J. Epidemiol.* 2012; 176(6):534-543.
21. Uijtdewilligen L, Twisk JW, Chinapaw MJ, et al. Longitudinal person-related determinants of physical activity in young adults. *Med. Sci. Sports Exerc.* 2014; 46(3):529-536.
22. Power C, Li L, Atherton K, et al. Psychological health throughout life and adult cortisol patterns at age 45 y. *Psychoneuroendocrinology.* 2011; 36(1):87-97.

23. Richmond RC, Smith GD, Ness AR, et al. Assessing Causality in the Association between Child Adiposity and Physical Activity Levels: A Mendelian Randomization Analysis. *PloS Med.* 2014; 11(3).
24. Golubic R, Ekelund U, Wijndaele K, et al. Rate of weight gain predicts change in physical activity levels: a longitudinal analysis of the EPIC-Norfolk cohort. *Int. J. Obes.* 2013; 37(3):404-409.
25. Pouliou T, Ki M, Law C, et al. Physical activity and sedentary behaviour at different life stages and adult blood pressure in the 1958 British cohort. *J. Hypertens.* 2012; 30(2):275-283.
26. Gordon-Larsen P, Nelson MC, Page P, et al. Inequality in the built environment underlies key health disparities in physical activity and obesity. *Pediatrics.* 2006; 117(2):417-424.
27. Webber R. Parliamentary constituencies: a socio-economic classification: Office of Population Censuses and Surveys; 1978.
28. Gunnell D, Whitley E, Upton MN, et al. Associations of height, leg length, and lung function with cardiovascular risk factors in the Midspan Family Study. *J. Epidemiol. Community Health.* 2003; 57(2):141-146.
29. Graham H. *Unequal Lives Health and Socioeconomic Inequalities*, Open University Press; 2007.
30. Seiluri T, Lahti J, Rahkonen O, et al. Changes in occupational class differences in leisure-time physical activity: a follow-up study. *Int J Behav Nutr Phys Act.* 2011; 8:14.
31. Cabinet Office London. Sporting Future: A New Strategy for an Active Nation2015.

Table 1: Adult (23-33y) and early-life (0-16y) factors in the 1958 birth cohort

	Ascertainment method (age)	Description	Categories/units	N(%) or Mean (SD)
Early adult factors (main exposures)				
Physical status				
Physically limiting illness	Self-report (23y, 33y)	Responses (yes/no) to a single question on any longstanding limiting illness, disability or infirmity (additional information was used to exclude mental illness)	Number of ages with a physical limiting illness: 0 (i.e. neither 23y or 33y), 1 (at either 23y or 33y), 2 (i.e. at both 23y and 33y)	0: 7896 (84.0) 1: 1324 (14.1) 2: 175 (1.9)
Obesity	Self-report (23y); measured (33y)	body mass index; (weight (kg) /height (m)²)≥30kg/m²	Number of ages: 0 (i.e. not obese at 23y or 33y), 1 (obese at 23y or 33y) 2 (i.e. obese at 23y and 33y)	0: 8018 (88.7) 1: 826 (9.1) 2: 195 (2.2)
Adult height	Measured (33y)	measured without shoes using a stadiometer reading to the nearest centimetre	cm	170 (9.7)
Mental function				
Depression	Self-report (23y, 33y)	15 (yes/no) items from psychological sub-scale of Malaise Inventory; top (gender-specific) 10% identified as 'depressed'[14]	Number of ages depressed: 0 (i.e. not depressed at 23y or 33y), 1 (depressed at either 23y or 33y), 2 (depressed at both 23y and 33y)	0: 7730 (82.6) 1: 1195 (12.8) 2: 437 (4.7)
Education level	Self-report to 33y	highest educational qualification	1. degree level 2. A-levels 3. O-levels 4. some 5. none	1: 1355 (12.6) 2: 3024 (28.2) 3: 3684 (34.3) 4: 1343 (12.5) 5: 1334 (12.4)
Social circumstances				
Social class	Self-report (23y, 33y)	categorized using the Registrar General's Classification	 1.professional/managerial 2.skilled non-manual 3.skilled manual 4.semiskilled/unskilled	23y / 33y 1: 2159 (21.9) / 3681 (36.1) 2: 3441 (34.8) / 2426 (23.8) 3: 2405 (24.3) / 2059 (20.2) 4: 1875 (19.0) / 2023 (19.9)
Not in paid employment	Self-report (23y, 33y)			23y / 33y 2551 (24.9) / 2281 (20.8)
Family circumstances				
Co-habitation	Self-report (33y)	living with spouse/live-in partner: derived from household composition data	Living with partner; other	Other: 2263 (20.5)
Number of children	Self-report (23y, 33y)	all children (natural/adopted/partner's/fostered) living in the household; identified from household composition data	0, 1, 2, 3, 4+	23y / 33y 0: 7113 (73.9) / 2526 (25.0) 1: 1610 (16.7) / 1974 (19.5) 2: 739 (7.7) / 3834 (38.0) 3: 142 (1.5) / 1372 (13.6) 4+: 19 (0.2) / 394 (3.9)
Neighbourhood type				
Neighbourhood characteristic	Addresses (23y)	local areas (based on participants constituency, from 1971 Census) allocated to one of 6 groups from CACI International data[27], collapsed into	1: suburbs, service centres; rural areas, seaside resorts 2: growth & metropolitan inner areas	1: 2970 (30.7) 2: 3113 (32.2) 3: 3594 (37.14)

		three groups.	3: stable industrial/local authority housing dominated areas	
Early-life factors (covariates)				
Pre-pubertal stature	Measured (7y)	measured by trained medical staff, to the nearest inch	cm	122.4 (5.9)
Hand control/ co-ordination problems	Teacher rating (7y, 11y, 16y)	at each age recorded as: no problems (score: 0); somewhat or certainly applies (score: 1); the three variables are summed across ages.	Number of ages with a problem: 0 (i.e. no problem at 7y, 11y and 16y), 1, 2, 3 (problems at 7y, 11y and 16y)	0: 6,388 (57.9) 1: 3,063 (27.8) 2: 1,276 (11.6) 3: 308 (2.8)
Cognitive ability	Reading and mathematics tests (16y)	derive age standardised score for tests & convert to 0-100 scale. average of tests used (if missing, average from 11/7y used). converted to internally standardised z-scores.	NA*	NA*
Social class	Parent report (birth)	father's occupation at birth (if missing at 7y); categorized using the Registrar General's (1951) Classification.	1.professional/managerial 2.skilled non-manual 3.skilled manual 4.semiskilled/unskilled/ single parent household	1: 2,141 (18.0) 2: 1,171 (9.9) 3: 5,817 (48.9) 4: 2,760 (23.2)
Household amenities	Parent report (7y, 11y, 16y)	three questions at each age on access to bathroom/indoor lavatory/hot water, scored as: sole use (0), shared (1), not available (2); the nine questions are summed across ages	Score range: 0-18	1.07 (2.6)
Parental education	Parent report (0y, 7y)	two questions on (i) mother and (ii) father having minimal schooling	No; Yes	Yes: 6,334 (60.1)
Parental divorce	Self-report (33y)	single question on parents ever permanently separating or divorced	No; Yes	Yes: 1,672 (15.4)
Physical activity	Self-report (16y)	frequency of playing outdoor and indoor games and sports, swimming or dancing. scores summed across questions; collapsed to four categories[19]	1.most active 2. very active 3. active 4. least active	1: 1,759 (19.1) 2: 1,365 (14.8) 3: 1,769 (19.2) 4: 4,324 (46.9)
Sports aptitude (≤average)	Self-report (16y)	single question on aptitude for sports and games	No; Yes	Yes: 6,754 (73.9)

N varies due to missing data. *non-standardised values are not available because measures for the combination of ages are not meaningful

Table 2: Relative Risk Ratio[a] (95%CI) of physical inactivity[b] 33y-50y associated with early adult factors: univariable[c] models in 12,271 men and women in the 1958 British Birth Cohort

		Persistently inactive vs. never inactive	Deteriorating vs. never inactive	Improving vs. persistently inactive
Physical status				
Physically limiting illness[d]		1.33(1.14,1.54)	1.14(0.98,1.31)	0.81(0.69,0.96)
Obesity[d]		1.52(1.33,1.75)	1.36(1.17,1.59)	0.74(0.61,0.90)
Height(per 5 cm) [d]		0.88(0.84,0.92)	0.94(0.91,0.98)	1.05(0.99,1.10)
Mental function				
Depression[d]		1.59(1.44,1.76)	1.28(1.12,1.45)	0.86(0.76,0.98)
Education[d]	(high-low)	1.44(1.36,1.51)	1.26(1.19,1.33)	0.88(0.83,0.94)
Social circumstances				
23y social class[d]	(high-low)	1.32(1.23,1.41)	1.18(1.12,1.25)	0.92(0.85,0.99)
33y social class[d]	(high-low)	1.26(1.20,1.33)	1.22(1.15,1.29)	0.91(0.86,0.97)
23y not in paid employment		1.32 (1.13,1.53)	1.23 (1.06,1.43)	0.95 (0.80,1.12)
33y not in paid employment		1.12 (0.96,1.30)	1.07 (0.91,1.25)	0.95 (0.79,1.14)
Family circumstances				
Cohabitation	(married/cohabiting)			
	other	1.11(0.95,1.30)	1.14(0.99,1.32)	0.78(0.64,0.94)
23y children[d]		1.37(1.23,1.52)	1.21(1.09,1.33)	0.88(0.80,0.98)
33y children[d]				
men		1.09(1.01,1.18)	0.92(0.85,0.99)	1.06(0.96,1.16)
women		1.08(0.99,1.17)	1.09(1.01,1.17)	1.07(0.97,1.17)
Neighbourhood type				
(suburbs, service centres; rural areas, seaside resorts)				
growth & metropolitan inner areas		1.37 (1.16,1.63)	1.11 (0.97,1.29)	0.81 (0.64,1.02)
stable industrial/local authority housing dominated areas		1.84 (1.58,2.14)	1.42 (1.25,1.62)	0.71 (0.59,0.87)

[a] for categorical factors the reference category is listed (in parentheses) [b] % inactive (average over ten imputed datasets), at 33y: 31.4; at 50y: 30.8. % inactive 33-50y: Never inactive: 51.3; persistently inactive: 13.6; deteriorating: 17.3; improving: 17.9 [c]gender adjusted or gender stratified (33y children $p_{interaction}$ =0.01) [d]per increase in scale

Table 3: Relative Risk Ratio[a] (95%CI) of physical inactivity 33y-50y associated with early adult factors: domains-combined models

		Persistently inactive vs. never inactive	Deteriorating vs. never inactive	Improving vs. persistently inactive
Physical status				
Physically limiting illness[b]		1.21 (1.04,1.42)	1.07 (0.92,1.24)	0.85 (0.72,1.01)
Obesity[b]		1.33 (1.16,1.54)	1.26 (1.08,1.47)	0.78 (0.64,0.95)
Height (per 5 cm) [b]		0.93 (0.89,0.98)	0.98 (0.94,1.02)	1.02 (0.97,1.08)
Mental function				
Depression[b]		1.32 (1.19,1.47)	1.13 (0.99,1.29)	0.93 (0.81,1.07)
Education[b]	(high-low)	1.28 (1.20,1.38)	1.15 (1.08,1.23)	0.93 (0.86,1.01)
Social circumstances				
23y social class[b]	(high-low)	1.04 (0.95,1.14)	0.99 (0.91,1.06)	1.02 (0.92,1.14)
33y social class[b]	(high-low)	1.02 (0.95,1.09)	1.10 (1.02,1.20)	0.96 (0.87,1.05)
Family circumstances				
23y children[b]		1.12 (0.99,1.26)	1.08 (0.96,1.20)	0.87 (0.77,0.99)
33y children[b]				
men		1.03 (0.95,1.12)	0.89 (0.82,0.96)	1.10 (0.99,1.21)
women		0.95 (0.86,1.03)	0.99 (0.91,1.07)	1.16 (1.05,1.28)
Neighbourhood type				
(suburbs, service centres; rural areas, seaside resorts)				
growth & metropolitan inner areas		1.33 (1.12,1.58)	1.10 (0.95,1.27)	0.81 (0.64,1.02)
stable industrial/local authority housing dominated areas		1.59 (1.37,1.86)	1.30 (1.14,1.49)	0.75 (0.61,0.91)

[a] for categorical factors the reference category is listed (in parentheses) [b]per increase in scale

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Supplementary Tables

Table S1: Relative Risk Ratio[a] (95%CI) of physical inactivity 33y-50y associated with early adult factors: univariable[b] models (complete case analysis)

		Persistently inactive vs. never inactive	Deteriorating vs. never inactive	Improving vs. persistently inactive
Physical status				
Physically limiting illness[c]		1.29(1.10,1.51)	1.15(0.99,1.33)	0.81(0.67,0.97)
Obesity[c]		1.65(1.41,1.94)	1.36(1.16,1.60)	0.66(0.54,0.81)
Height(per 5 cm) [c]		0.90(0.85,0.94)	0.96(0.92,1.01)	1.04(0.98,1.10)
Mental function				
Depression[c]		1.62(1.43,1.85)	1.29(1.13,1.47)	0.86(0.74,1.00)
Education[c]	(high-low)	1.43(1.35,1.52)	1.29(1.23,1.36)	0.89(0.83,0.95)
Social circumstances				
23y social class[c]	(high-low)	1.35(1.25,1.45)	1.20(1.12,1.28)	0.90(0.83,0.98)
33y social class[c] (high-low)		1.25(1.18,1.33)	1.26(1.20,1.34)	0.92(0.86,0.99)
23y not in paid employment		1.33(1.13,1.58)	1.26(1.08,1.47)	0.96(0.79,1.17)
33y not in paid employment		1.08 (0.91,1.29)	1.06(0.91,1.24)	0.95 (0.78,1.17)
Family circumstances				
Cohabitation	(married/co-habiting)			
	other	1.17(0.99,1.38)	1.19(1.02,1.38)	0.72(0.59,0.88)
23y children[c]		1.42(1.28,1.57)	1.23(1.12,1.36)	0.87(0.78,0.98)
33y children[c]				
men		1.07(0.98,1.17)	0.90(0.83,0.98)	1.06(0.95,1.17)
women		1.05(0.96,1.15)	1.13(1.04,1.22)	1.10(0.99,1.22)
Neighbourhood type				
	(suburbs, service centres; rural areas, seaside resorts)			
	growth & metropolitan inner areas	1.42(1.17,1.71)	1.03(0.87,1.22)	0.81(0.65,1.01)
	stable industrial/local authority housing dominated areas	1.77(1.47,2.13)	1.31(1.12,1.54)	0.74(0.59,0.91)

[a] for categorical factors the reference category is listed (in parentheses) [b]gender adjusted for all but 33y children [c]per increase in scale

Table S2: Relative Risk Ratio[#] (RRR, 95% CI) of adult physical inactivity persistence and change 33y-50y associated with early adult factors in multivariable domain-specific models

		Persistently inactive vs. never inactive	Deteriorating vs. never inactive	Improving vs. persistently inactive
Physical status				
Physically limiting illness*		1.30 (1.12,1.51)	1.12 (0.97,1.30)	0.82 (0.70,0.97)
Obesity*		1.47 (1.27,1.68)	1.34 (1.15,1.57)	0.75 (0.62,0.91)
Height (per 5 cm)*		0.88 (0.85,0.92)	0.95 (0.91,0.99)	1.04 (0.99,1.10)
Mental function				
Depression*		1.37 (1.23,1.53)	1.16 (1.02,1.32)	0.91 (0.79,1.04)
Education*	(high-low)	1.39 (1.31,1.46)	1.24 (1.18,1.31)	0.90 (0.84,0.96)
Social circumstances				
23y social class*	(high-low)	1.19 (1.10,1.30)	1.05 (0.97,1.13)	0.96 (0.86,1.06)
33y social class*	(high-low)	1.15 (1.08,1.23)	1.18 (1.10,1.27)	0.93 (0.85,1.01)
23y not in paid employment		1.12 (0.96,1.30)	1.13 (0.96,1.32)	1.02 (0.85,1.21)
33y not in paid employment		0.96 (0.83,1.12)	0.98 (0.83,1.14)	1.01 (0.84,1.21)
Family circumstances				
Cohabitation	(married/cohabiting)			
	Other	1.19 (0.99,1.41)	1.11 (0.95,1.31)	0.82 (0.67,1.01)
23y children*		1.37 (1.22,1.54)	1.22 (1.10,1.36)	0.82 (0.73,0.92)
33y children*				
	men	1.05 (0.96,1.15)	0.90 (0.83,0.99)	1.07 (0.96,1.18)
	women	0.98 (0.90,1.07)	1.03 (0.95,1.11)	1.13 (1.02,1.24)
Neighbourhood type				
(suburbs, service centres; rural areas, seaside resorts)				
growth & metropolitan inner areas		1.37 (1.16,1.63)	1.11 (0.97,1.29)	0.81 (0.64,1.02)
stable industrial/local authority housing dominated areas		1.84 (1.58,2.14)	1.42 (1.25,1.62)	0.71 (0.59,0.87)

[#] for categorical factors the reference category is listed (in parentheses)
*per increase in scale

Table S3: Relative Risk Ratio[#] (RRR, 95% CI) of adult physical inactivity persistence and change 33y-50y associated with early adult factors in multivariable domains-combined models adjusted for early-life factors**

		Persistently inactive vs. never inactive	Deteriorating vs. never inactive	Improving vs. persistently inactive
Physical status				
Physically limiting illness*		1.20 (1.02,1.40)	1.06 (0.92,1.23)	0.86 (0.73,1.02)
Obesity*		1.32 (1.14,1.53)	1.25 (1.08,1.46)	0.79 (0.64,0.98)
Height (per 5 cm)*		0.94 (0.88,1.01)	1.02 (0.96,1.08)	1.03 (0.96,1.12)
Mental function				
Depression*		1.27 (1.14,1.41)	1.09 (0.96,1.25)	0.94 (0.82,1.08)
Education*	(high-low)	1.24 (1.15,1.35)	1.09 (1.01,1.19)	0.93 (0.85,1.02)
Social circumstances				
23y social class*	(high-low)	1.04 (0.95,1.15)	0.97 (0.89,1.05)	1.02 (0.91,1.14)
33y social class*	(high-low)	1.00 (0.93,1.08)	1.09 (1.01,1.18)	0.96 (0.88,1.06)
Family circumstances				
23y children*		1.11 (0.99,1.26)	1.06 (0.94,1.18)	0.87 (0.77,0.99)
33y children*				
	men	1.07 (0.98,1.16)	0.89 (0.82,0.97)	1.09 (0.99,1.19)
	women	0.96 (0.87,1.04)	0.99 (0.92,1.07)	1.16 (1.04,1.28)
Neighbourhood type				
(suburbs, service centres; rural areas, seaside resorts)				
growth & metropolitan inner areas		1.34 (1.14,1.59)	1.07 (0.93,1.24)	0.81 (0.64,1.02)
stable industrial/local authority housing dominated areas		1.60 (1.37,1.87)	1.25 (1.09,1.43)	0.75 (0.61,0.91)

[#] for categorical factors the reference category is listed (in parentheses)

*per increase in scale

**early-life factors: pre-pubertal stature, hand control/co-ordination problems, 16y cognition, social class at birth, parental education, parental divorce, household amenities, 16y activity and sports aptitude