Stability of balance performance from childhood to midlife

Joanna M Blodgett PhD [a], Rachel Cooper PhD [b], Snehal M Pinto Pereira PhD [a], Mark Hamer PhD [a]

Affiliations:

[a] Institute of Sport Exercise & Health, Division of Surgery & Interventional Science, University College London, 170 Tottenham Court Road, W1T 7HA, London, UK

[b] Department of Sport and Exercise Sciences, Musculoskeletal Science and Sports Medicine Research Centre, Manchester Metropolitan University, Oxford Road, M15 6BH, Manchester, UK

Address correspondence to:

Joanna M Blodgett
Institute of Sport Exercise & Health
Division of Surgery & Interventional Science
University College London
170 Tottenham Court Road
W1T 7HA
London, UK
Email: joanna.blodgett@ucl.ac.uk

ABSTRACT

Background: Balance ability underlies most physical movement across life, with particular importance for older adults. No study has investigated if balance ability is established in childhood nor if associations are independent of adult factors. We investigated associations between balance performance in early (age 10) and midlife (age 46), and whether associations were independent of known contributors to adult balance.

Methods: Up to 6024 individuals from the 1970 British Cohort Study were included. At age 10, static (one-legged stand) and dynamic (backwards toe-to-heel walk) balance were categorized as poor, medium or high. Eyes open and closed one-legged balance performance (max:30seconds), was assessed at age 46 with five categories.

Results: Poor static balance at age 10 was strongly associated with worse balance ability at age 46. Relative to the highest balance group at age 46 (i.e. eyes open and closed for 30s), those with poor static balance had a 7.07 (4.92,10.16) greater risk of being in the poorest balance group (i.e. eyes open <15s). Associations were robust to adjustment for childhood illness, cognition and socioeconomic position and adult measures of height, BMI, education, exercise, word recall and grip strength (adjusted relative risk (RR): 5.04 (95% CI: 3.46,7.37)). Associations between dynamic balance at age 10 and balance at age 46 were weaker (adjusted RR of poorest balance group: 1.84 (1.30,2.62)).

Conclusion: Early childhood may represent an important period for maturation of postural strategies involved in balance, indicating the potential for early intervention and policy changes alongside existing interventions that currently target older adults.

KEYWORDS

balance, early life, life course, birth cohort

INTRODUCTION

From infancy to old age, the ability to balance is a fundamental skill underlying most daily physical activities. Balance ability, a marker of healthy ageing[1, 2], is associated with falls, disability, and premature mortality in mid and later life[3-7]. The importance of balance is globally recognized, with recent physical activity guidelines recommending that adults aged 65+ undertake regular balance and strength training exercises[8-10]. Although factors that contribute to better balance performance in mid and later life have been identified[11-14], the role of early life factors is not well-established[12, 15-17], and there has been no consideration of childhood balance.

The Developmental Origins of Health and Disease hypothesis suggests that early life exposures during critical periods of development and growth have significant consequences for subsequent health[18]. Consistent with this, basic neural developmental processes may play an important role in determining adult balance[15, 16, 19] given the cerebellum is responsible for most physical movement, including coordination of balance and posture[20], and undergoes continual maturation throughout childhood and adolescence[21, 22]. This may explain why better early cognitive ability and motor development are associated with better midlife balance performance[15-17]. Furthermore, balance performance plateaus in early adolescence (e.g. 12-14 years), where it is largely equivalent to average adult performance[23-25]. This early attainment of peak balance ability, in combination with neurological mechanisms involved in balance, provides further plausibility that balance ability may be largely established during early life.

No study has examined if childhood balance is associated with adulthood balance nor if associations are independent of pertinent adult factors. For example, physical inactivity, poor musculoskeletal function, low cognition and low SEP in adulthood are known contributors to poor balance[11-14], and thus may explain associations between childhood and adulthood balance. Lower childhood balance may contribute to a sequelae of reduced participation in physical activity and subsequent weaker muscular strength[26-29]. Childhood balance could also reflect existing disparities in cognitive function or SEP, both of which track strongly across life[30-33] and contribute to adult balance[11, 13, 34]. The 1970 British Birth Cohort study is the first population-based study to have prospectively ascertained measures of balance performance in childhood and midlife. This presents a unique opportunity to study balance across the life course. We investigated if balance ability in childhood contributes to balance ability in adulthood and whether associations were independent of physical activity, strength, SEP or cognitive function in adulthood.

METHODS

Study sample

The 1970 British Cohort Study comprises over 16000 individuals born in England, Scotland or Wales during the same week in 1970[35]. Data collection has occurred at ten waves, from birth to the most recent follow-up at age 46, which consisted of home visit interviews and a biomedical assessment. At age 46, 8,581 study members participated; the remaining individuals had either died, emigrated, withdrawn from the study, could not be contacted or did not consent to participate. To be included in the analytical sample, individuals needed to have balance data at ages 10 and 46. Data at age 10 were available for those who completed a medical examination and were able to understand and perform the motor coordination tests (87.3%; 12,984/14,870 who participated in age 10 wave). Balance data was available for 85.8% (n=7,363/8,581) of those participating at age 46. Reasons for non-participation in balance assessments at age 46 included: recent injury on preferred standing leg, lower back problems, hip problems, did not feel that it was safe to attempt the test or refusal(n=228). A total of 5,990 and 6,024 had data at both ages for static and dynamic balance scores, respectively.

Measures of balance

Static balance (age 10): Participants were asked to balance for 30 seconds on each leg, with their suspended foot against the knee of their standing leg and their hands on their hips. As balance times were heavily left skewed (>60% of the cohort could balance for 30s), a categorical variable was derived from additional observations made by the assessors. One point was given if the foot did not move and one point if the hand did not move, for a maximum of 4 points across both legs. Those with 3 or 4 points were categorised as high balance, those with 2 points medium balance and those with 0 or 1 low balance[28].

Dynamic balance (age 10): Participants were asked to place their hands on their hips and walk backwards along a straight line by placing their feet toe to heel for 20 steps. Assessors recorded the number of steps before an error occurred (i.e. deviation from line, movement of hands from the hips or failure to maintain the toe-to-heel movement). If an error occurred in the first 5 steps, nurses counted the number of steps before the next error instead. As the number of steps were also heavily left skewed (>45% of the cohort completed 20 steps), a categorical variable of high (20 steps), medium (10-19 steps) and low (<10 steps) balance was also derived[28].

Midlife balance (age 46): Participants were instructed to balance on their preferred leg for 30 seconds with eyes open, while keeping their other leg off the ground. They could use their arms, bend their knee or move their body during the trial. Timing stopped if the raised foot touched the ground or the standing foot moved. If successful in achieving 30s, the participant was asked to repeat the test with eyes closed. As balance times for both eyes open and closed were heavily skewed (>85% balanced for 30s with eyes open; >65% for <10s eyes closed), balance performance was considered in five ascending categories, following an approach from previously published analyses[36]. The five categories were: low (<15s eyes open), low-medium (15 to <30s eyes open), medium (30s eyes open, <15s eyes closed), medium-high (30s eyes open, 15 to <30s eyes closed) and high (30s eyes open, 30s eyes closed).

Covariates

Covariates were identified a priori based on known associations with balance performance across the life course[11, 15, 36, 37]. At age 10, *childhood cognition* (Edinburgh Reading Test standardised z-scores)[38], *childhood SEP* (categorized using the Registrar General's Social Classification of the father's occupational class: I Professional/II Intermediate, III Skilled non-manual/manual or IV Partly skilled/V Unskilled)[39], and *childhood illness* (number of overnight hospitalization admissions between ages 5 and 10) were ascertained. Highest academic qualification, as an indicator for *adulthood SEP*[39], was derived using records from all waves (categorized as none, General Certificate of Education (GCE) Ordinary Level- generally attained at age 16 years, GCE Advanced Level- generally attained at age 18 years, diploma or degree level, or higher degree). The remaining covariates were assessed at age 46. *Height (cm)* and *BMI* (kg/m^2; calculated with height and weight) were measured by research nurses; self-reported values were used where nurse measures were unavailable. Individuals reported how many days per week they *exercised* for 30+ minutes, working hard enough to raise their heart rate and break into a sweat. *Verbal memory* was assessed with a word recall test[11, 13, 40], where participants were played 10 words at 2 second intervals by a computer program and then asked to recall as many as they could within 2 minutes. *Grip strength* was assessed as the maximum score of 6 trials (3 in each hand) using a Smedley spring-gauge hand-held dynamometer.

Statistical analyses

Given sex differences in balance performance in childhood and adulthood, sample characteristics were described by sex across each category of static and dynamic balance at age 10. Chi-squared tests assessed the cross-tabbed proportions of balance at ages 10 and 46. The correlation between balance measures at age 10 was assessed using Spearman's rank correlation. Multinomial logistic regressions were used to assess associations between each measure of balance at age 10 with balance at age 46. The following steps were conducted for static balance and repeated for dynamic balance. First, an interaction between sex and childhood balance was assessed ($p<0.05$); if present, models would be stratified by sex. Second, preliminary sex-adjusted (or stratified) models were assessed. Finally, each covariate was added in turn, and the final-adjusted model of all covariates is presented using relative risk ratios (RR). Following a missing at random (MAR) assumption, covariate data were imputed using multiple imputation chained equations[41] and estimates from 20 imputed datasets were combined using Rubin's rules[42]. Supplementary analyses compared characteristics between: i) those with low static childhood balance and either high or low balance at age 46; ii) those with high static childhood balance and either high or low balance at age 46; iii) the main analytical sample and those excluded due to missing balance or covariate data. Sensitivity analyses repeated regression models using complete cases data. Analyses were performed in Stata MP 16 and RStudio 4.0.3.

RESULTS

Sample characteristics

Characteristics of the analytical sample are provided in ***Table 1***. Compared to those with low or medium static balance at age 10, those with high static balance had higher SEP and cognitive performance in childhood and adulthood, lower BMI, better grip strength and exercised more frequently. There were no differences in childhood hospital admissions or adult height. Associations between dynamic balance groups and sample characteristics were similar, however there were no associations with BMI or exercise frequency.

Balance performance at age 10 and 46

At age 10, females had better static (high: 51.2% vs 38.8%) and dynamic balance (high: 51.2% vs 47.2%) than males. Conversely at age 46, males had slightly better balance than females (high: 14.1% vs 11.6%; ***Table 2***). Spearman rank correlations between static and dynamic balance at age 10 were weak (0.25 in males, 0.20 in females); 27.8% had high performance on both tests while 5.0% had low performance on both.

Chi-square tests suggested that static and dynamic balance at age 10 tracked strongly to balance at age 46 (***Figure 1, Supplementary Table 1***). Of those with high static balance, 31.1% had high or medium-high balance at age 46, compared to 18.2% of those with poor static balance. Similarly, 22.1% of those with poor static balance continued to have low or low-medium balance at age 46, compared to 8.8% of those with high balance. Notably, tracking was weaker between childhood dynamic balance and balance at age 46; 28.2% and 21.4% of those with high and poor childhood dynamic balance, respectively, had high or medium-high balance at age 46.

Multinomial logistic regressions

There was no interaction between sex and either measure of childhood balance, thus males and females were included in the same model. Poor static balance at age 10 was consistently associated with poorer balance performance at age 46 (***Table 3***). Relative to the highest performing group (30s eyes open and closed), children with poor static balance had a greater risk of being in any of the lower four balance categories at age 46 and children with medium static balance had a greater risk of being in any of the lowest three categories. For example, in the sex-adjusted model, those with poor static balance had a 7.07 (95%CI: 4.92,10.16) greater risk of being in the worst performing balance group (<15s with eyes open). There was only minimal attenuation of estimates in the adjusted model (RR: 5.04 (3.46,7.37)), with no single covariate driving the attenuation.

Poor or medium dynamic balance was also associated with greater relative risks of poor midlife balance (***Table 3***). For example, relative to the highest performing group and in sex-adjusted models, those with poor dynamic balance at age 10 had 2.33 (1.66,3.26), 1.82 (1.31,2.52) and 1.27 (1.09,1.72) greater risk of having low, low-middle or middle balance at age 46, respectively. Adjustment for covariates somewhat attenuated the results, with poor or medium dynamic balance remaining associated with a lower relative risk of being in the poorest balance group only.

Supplementary analysis

Compared to those with consistently low balance (n=237), individuals who improved from low static balance at age 10 to high balance at age 46 (n=195) were more likely to be male, have higher childhood cognition and SEP, lower childhood illness, higher education, lower BMI, taller height, higher word recall, greater strength and exercise more frequently (***Supplementary Table 2***). Conversely, compared to those with consistently high balance (n=843), those who declined from high static balance at age 10 to low balance at age 46 (n=238) were more likely to be female, have lower childhood cognition and SEP, lower education, higher BMI, shorter height, lower word recall, lower strength and exercise less frequently.

Individuals who were missing balance data at age 46 due to attrition or not having a valid measurement were more likely to have poor static (55.8% vs 44.2%) and dynamic balance (55.2% vs 44.8%) at age 10 than the analytical sample. Compared with complete cases, those who were missing covariates performed worse on the balance test at age 46 (low group: 12.1% vs 5.9%), however there was no difference in age 10 balance. Results did not change when complete cases data was used (***Supplementary Table 3)***.

DISCUSSION

In a large prospective birth cohort study, poor childhood balance performance was strongly associated with poor balance performance in midlife. Specifically, children with poor static balance and, to a slighter lesser extent, poor dynamic balance were at greater risk of having poor one-legged balance ability at age 46. Associations were not explained by childhood SEP, cognition and illness nor adult indicators of exercise, strength, SEP or verbal memory. This suggests that the ability to balance in midlife largely depends on ability in childhood, reflecting an important period of development of postural strategies.

Strengths and limitations

Key strengths of this study include the prospective ascertainment of balance ability in childhood and adulthood, the large population representative sample, and the novel ascertainment of balance ability in mid-life before onset of major age-related disease. The study does have some limitations. Notably, balance performance could not be modelled continuously; there was a strong ceiling effect at age 10, while at age 46, only individuals who could balance with their eyes open for the full 30s performed the eyes closed trial. Although models are adjusted for potential adulthood factors, causal interpretation of the associations should be done with caution due to the observational nature of the data and the potential for residual confounding. Dynamic balance was not ascertained in midlife, limiting our ability to examine how dynamic balance tracks across life. Finally, as in any birth cohort, there was loss-to-follow; despite this attrition, the sample remains large and representative of the mainland UK population in many respects[43]. As those with missing data at age 46 had poorer childhood balance than the analytical sample, estimates may be underestimated. Finally, the lack of ethnic diversity (95.3% White British) is a limitation[44].

Comparison to other studies

This is one of the first studies to examine associations between childhood and adulthood balance ability, and as such, comparisons with previous studies are limited. However, other studies have identified a similar positive relationship between childhood cognition and standing balance in mid and later life[16, 17, 45]. This supports the hypothesis that establishment of early neural pathways may play a crucial role in balance across the life course via a sensorimotor integration mechanism[16, 46]. Advantageous early motor development, including better balance and coordination, is also associated with positive health outcomes in adulthood[15, 47]. For example, a recent study using 1958 British birth cohort data demonstrated that better childhood psychomotor coordination (e.g. balance, ball catching, dexterity, jumping) was associated with lower risk of death by age 60[47]. Possible mechanisms include direct tracking of coordination skills across life (e.g. minimizing risk of accidental death) and indirect life course pathways leading to high disease prevalence. As balance appears tracks strongly from childhood to adulthood, future research must explore if poor adulthood balance ability mediates the association between poor psychomotor coordination and premature mortality.

Mechanisms of associations

We tested two sets of factors that may explain the association between childhood and adulthood balance. First, it was hypothesized that better balance in childhood may reflect current and future cognitive and socioeconomic advantages, with evidence showing that better cognition and SEP across the life course contribute to better adult balance[11-13, 16, 34]. Second, children with better motor development tend be more physically active throughout life[26-28, 48] and, as a result, may demonstrate greater muscular strength in adulthood[29, 49]. As adults age, maintenance of muscle strength and power may facilitate the motor components of balance[50, 51]. However, neither set of factors explained the association between childhood and adulthood balance.

Instead, there was robust evidence of an association between childhood and adulthood balance ability, independent of the hypothesized adulthood factors, suggesting that the ability to balance is largely established in early life. Developmental balance curves demonstrate steep non-monotonic improvements in postural control between ages 8 and 13, at which age balance ability is nearly equivalent to adult-like performance[23, 52-55]. Stark improvements in balance performance during these ages are a result of both refined motor skills and changes in strategies used to maintain balance[56]. Early postural control strategies (e.g. <10 years) focus on relatively large and reactive adjustments to body position using an open-loop system of control[54], which does not incorporate somatosensory feedback. Around age 10, children learn to refine these strategies with smaller, more frequent postural adjustments[54, 57-59] using a closed-loop system of control, resulting from non-linear development of the three afferent sensory systems involved in balance: visual, proprioceptive and vestibular input[54-59]. As postural strategies are largely refined by mid-childhood, this provides further support that maturation of balance control occurs in early adolescence.

The mechanisms involved in static and dynamic balance differ, as demonstrated by the low correlation and overlap in performance at age 10, and may explain the stronger association between static balance measures at ages 10 and 46. Dynamic balance ability requires higher level cognitive processes to successfully respond to goal-oriented movement (e.g. stepping off a curb, avoiding an obstacle)[60]. Static and dynamic balance performance are both closely linked to fall risk in mid and later life[61, 62]. Therefore, when data becomes available, further research must examine if similar associations extend from dynamic balance in childhood to dynamic balance in adulthood and if childhood balance directly contributes to balance-related outcomes such as fall risk[63].

Translation to clinical settings

The maturation of balance control in childhood highlights the need and opportunity for early intervention in children with lower balance abilities. A systematic review of 17 studies has demonstrated a moderate to large effect of balance training on both static and dynamic balance performance in children and adolescents[64]. Associations were strong regardless of age, sex, training history, and intervention frequency or setting, highlighting the feasibility and potential impact of early intervention. This could manifest as clinical screening and subsequent referral to balance training during regular physician check-ups or as national public health policies that incorporate balance development into educational curricula and physical activity guidelines. Additionally, we identified characteristics of individuals with high childhood and low adulthood balance (e.g. declining) and those with low childhood and high adulthood balance (e.g. improving) that could inform evidence-based interventions. These included sex, cognition, SEP, BMI, strength and exercise frequency.

CONCLUSIONS

With a rapidly ageing population, public health efforts increasingly aim to minimise falls risk and improve physical function in older adults. Physical activity guidelines recommending balance exercises target only adults over the age of 65[8-10]. In addition to existing interventions targeting older adults, the strong continuity of balance from childhood to adulthood provides support for earlier integration of these health promotion strategies and guidelines. This could have an important impact in improving adulthood balance ability and reducing balance-related outcomes.

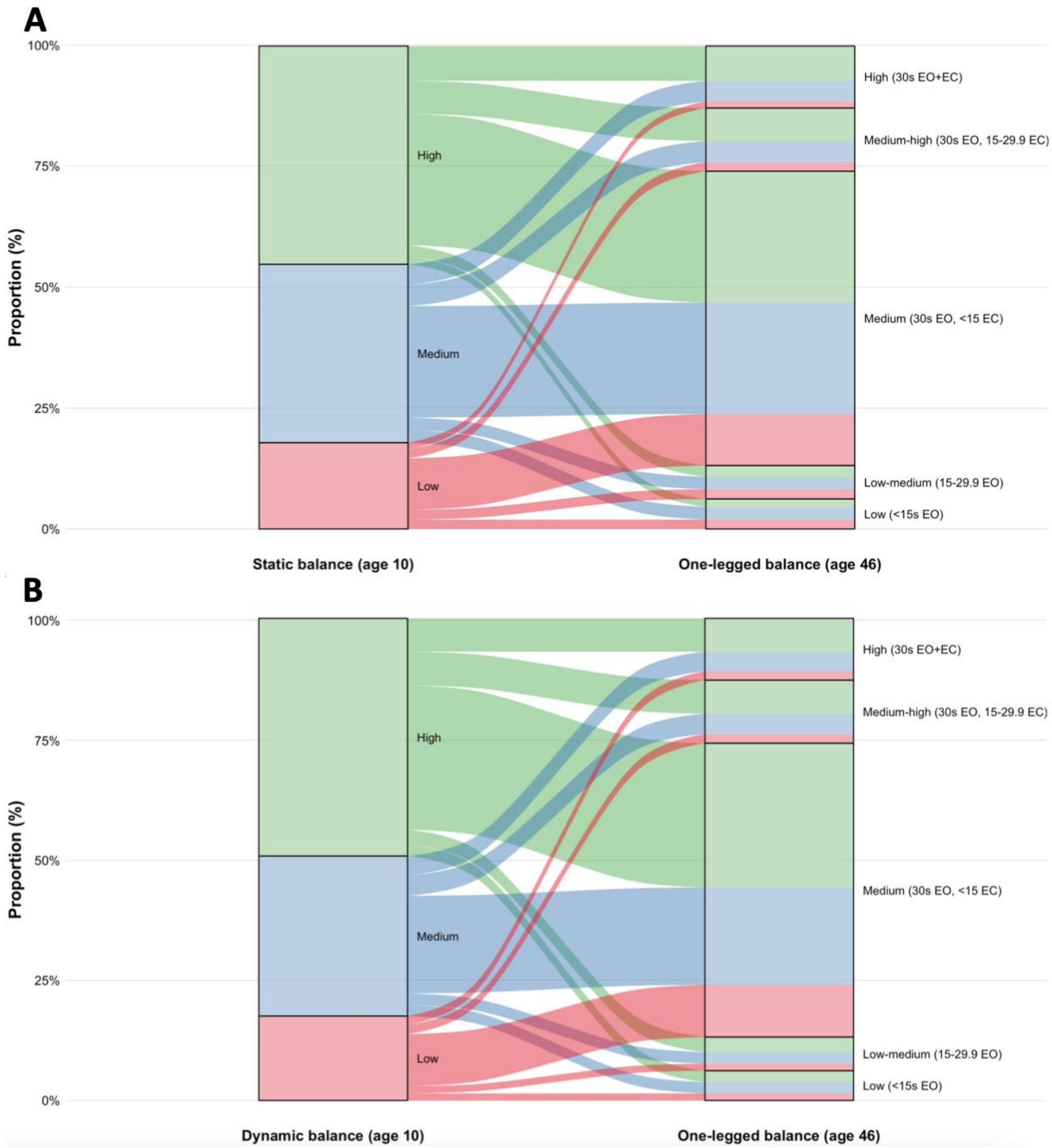

Figure 1. Tracking of A. static balance at age 10 and B. dynamic balance at age 10 to balance performance at age 46

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Table 1. Sample characteristics of the 1970 British Birth cohort analytical sample (up to n=5990) by age 10 static balance performance and sex

	STATIC BALANCE AGE 10					
	Males (n=3003)			**Females (n=3219)**		
	High (n=1 121)	Medium (n=1 147)	Low (n=623)	High (n=1 588)	Medium (n=1 064)	Low (n=447)
Ascertained at age 10:						
CHILDHOOD COGNITION[a], mean (SD)	0.27 (0.93)	0.15 (0.96)	-0.05 (1.01)	0.38 (0.86)	0.22 (0.90)	0.05 (0.93)
CHILDHOOD SEP[b], n(%)						
I Professional or II Managerial	401 (36.9)	386 (34.7)	175 (29.4)	545 (35.8)	333 (32.4)	126 (29.2)
III Skilled Non-manual or Manual	544 (50.1)	550 (49.5)	317 (53.3)	756 (49.7)	513 (49.9)	234 (54.3)
IV Partly Skilled or V Unskilled	142 (13.1)	176 (15.8)	103 (17.3)	220 (14.5)	182 (17.7)	71 (16.5)
CHILDHOOD ILLNESS[c], n (%)						
0 overnight hospital admissions	830 (77.1)	852 (76.7)	452 (75.8)	1254 (81.9)	850 (82.9)	347 (80.1)
1 overnight hospital admission	185 (17.2)	194 (17.5)	109 (18.3)	225 (14.7)	140 (13.7)	68 (15.7)
2+ overnight hospital admissions	62 (5.8)	64 (5.8)	35 (5.9)	52 (3.4)	36 (3.5)	18 (4.2)
Ascertained at age 46:						
HEIGHT (cm), mean (SD)	176.9 (7.0)	176.8 (6.8)	176.7 (7.0)	163.9 (6.0)	163.8 (6.4)	163.6 (6.9)
BMI (kg/m^2), mean (SD)	28.5 (4.9)	29.0 (4.9)	29.1 (5.1)	28.1 (6.5)	28.2 (6.2)	28.9 (6.6)
HIGHEST EDUCATIONAL ATTAINMENT, n (%)						
None	291 (26.3)	337 (29.8)	204 (33.2)	332 (21.1)	226 (21.4)	127 (28.7)
GSE O-level (usually attained at age 16)	336 (30.3)	355 (31.4)	206 (33.6)	477 (30.3)	371 (35.2)	148 (33.4)
GCE A-level (usually attained at age 18)	154 (13.9)	154 (13.6)	70 (11.4)	266 (16.9)	172 (16.3)	65 (14.7)
Diploma or degree	253 (22.8)	217 (19.2)	111 (18.1)	413 (26.3)	230 (21.8)	84 (19.0)
Higher degree	74 (6.7)	68 (6.0)	23 (3.8)	84 (5.3)	55 (5.2)	19 (4.30)
NUMBER OF DAYS EXERCISED 30+ MIN PER WEEK, median (Q1-Q3)	3 (1, 5)	3 (1, 5)	3 (1, 5)	3 (1, 5)	3 (0, 5)	2 (0, 4)
WORD RECALL (score out of 10), mean (SD)	6.7 (1.4)	6.6 (1.4)	6.4 (1.4)	6.8 (1.3)	6.7 (1.5)	6.5 (1.4)
MAXIMUM GRIP STRENGTH (kg), mean (SD)	47.0 (8.6)	46.0 (8.5)	44.2 (8.3)	28.4 (5.5)	27.8 (5.8)	27.2 (5.8)

N varies between characteristics due to missing covariate data ; GSE O-level: General Certificate of Education (GCE) Ordinary Level; GSE A-level: General Certificate of Education (GCE) Advanced Level

[a] standardised Edinburgh Reading Test scores

[b] Father's occupational class categorized using the Registrar General's Social Classification

Table 2. Balance performance at age 10 and 46 years by sex

		Males (n=3003)	Females (n=3219)
Static balance, age 10			
High		1 121 (38.8%)	1 588 (51.2%)
Medium		1 147 (39.7%)	1 064 (34.3%)
Low		623 (21.6%)	447 (14.4%)
Dynamic balance, age 10			
High		1367 (47.2%)	1 602 (51.2%)
Medium		1 013 (35.0%)	988 (31.6%)
Low		516 (17.8%)	538 (17.2%)
Static balance, age 46			
High	(30s EO, 30s EC)	424 (14.1%)	374 (11.6%)
Medium-high	(30s EO, 15-29.9s EC)	434 (14.5%)	376 (11.7%)
Medium	(30s EO, <15s EC)	1 799 (59.9%)	2 001 (62.2%)
Low-medium	(15-29.9 EO)	178(5.9%)	251 (7.8%)
Low	(<15s EO)	168 (5.6%)	217 (6.7%)

EO eyes open; EC eyes closed

Table 3. Relative Risk Ratios (95% CI) demonstrating associations of i) static balance and ii) dynamic balance at age 10 with balance performance at age 46, relative to the reference category of high balance at age 46 (30s EO, 30s EC)

		Age 10 balance category	Sex-adjusted model	Final adjusted model [a]
STATIC BALANCE (AGE 10)		Ref: High	n= 5,990[b]	
Age 46 balance	Medium-high (30s EO, 15-29.9s EC)	Medium	1.09 (0.88, 1.27)	1.06 (0.85, 1.33)
		Poor	**1.47 (1.07, 2.02)**	1.37 (1.00, 1.89)
	Middle (30s EO, <15s EC)	Medium	**1.50 (1.27, 1.78)**	**1.41 (1.18, 1.68)**
		Poor	**2.21 (1.71, 2.86)**	**1.89 (1.46, 2.46)**
	Low-middle (15-29.9 EO)	Medium	**2.03 (1.53, 2.68)**	**1.79 (1.35, 2.39)**
		Poor	**5.20 (3.69, 7.34)**	**3.74 (2.61, 5.34)**
	Low (<15s EO)	Medium	**2.95 (2.19, 3.98)**	**2.66 (1.95, 3.62)**
		Poor	**7.07 (4.92, 10.16)**	**5.04 (3.46, 7.37)**
DYNAMIC BALANCE (AGE 10)		Ref: High	n= 6,024[b]	
Age 46 balance	Medium-high (30s EO, 15-29.9s EC)	Medium	1.03 (0.82, 1.28)	1.02 (0.81, 1.27)
		Poor	1.03 (0.77, 1.38)	0.96 (0.71, 1.29)
	Middle (30s EO, <15s EC)	Medium	**1.17 (0.98, 1.39)**	1.14 (0.95, 1.37)
		Poor	**1.27 (1.09, 1.72)**	1.21 (0.96, 1.53)
	Low-middle (15-29.9 EO)	Medium	**1.35 (1.03, 1.76)**	1.25 (0.95, 1.65)
		Poor	**1.82 (1.31, 2.52)**	**1.42 (1.01, 1.99)**
	Low (<15s EO)	Medium	**1.69 (1.28, 2.25)**	**1.57 (1.17, 2.11)**
		Poor	**2.33 (1.66, 3.26)**	**1.84 (1.30, 2.62)**

[a] Adjusted for childhood cognition, SEP and illness (all collected at age 10) and adulthood height, BMI, highest academic qualification, exercise, word recall and grip strength (all collected at age 46)
[b] Multiple imputation by chained equations was used to impute any missing covariate data
Bolded scores indicate that estimates do not cross 1

Supplemental Table 1. Cross-tabulation of age 10 static or balance categories with age 46 balance categories (proportions correspond to Figure 1A and B)

	Balance age 46				
	High (30s EO, 30s EC)	**Medium-high** (30s EO, 15-29.9s EC)	**Medium** (30s EO, <15s EC)	**Low-medium** (15-29.9 EO)	**Low** (<15s EO)
Static balance age 10 (n(%))					
High	434 (16.0)	409 (15.1)	1628 (60.1)	140 (5.2)	98 (3.6)
Medium	255 (11.5)	262 (11.9)	1382 (62.5)	154 (7.0)	158 (7.2)
Low	82 (7.7)	113 (10.6)	638 (59.6)	121 (11.3)	116 (10.8)
Dynamic balance age 10 (n(%))					
High	417 (14.1)	420 (14.2)	1801 (60.7)	187 (6.3)	144 (4.9)
Medium	244 (12.2)	253 (12.6)	1220 (61.0)	144 (7.2)	140 (7.0)
Low	111 (10.5)	115 (10.9)	651 (61.8)	89 (8.4)	88 (8.4)

Supplemental Table 2. Sample characteristics of the 1970 British Birth cohort analytical sample by discordance on static balance tests from age 10 to age 46 (up to n=5990)

	Low static balance at age 10		**High static balance at age 10**	
	Low balance at age 46 (n=237)	High balance at age 46 (n=195)	High balance at age 46 (n=843)	Low balance at age 46 (n=238)
FEMALE, n(%)	116 (49.0)	61 (31.3)	448 (53.1)	161 (67.7)
Ascertained at age 10:				
CHILDHOOD COGNITION [a], mean (SD)	-0.24 (1.02)	0.13 (0.95)	0.47 (0.84)	0.19 (0.95)
CHILDHOOD SEP [b], n(%)				
I Professional or II Managerial	56 (25.3)	65 (34.6)	347 (42.5)	58 (25.6)
III Skilled Non-manual or Manual	127 (57.5)	98 (52.1)	398 (48.8)	121 (53.3)
IV Partly Skilled or V Unskilled	38 (17.2)	25 (13.3)	71 (8.7)	48 (21.2)
CHILDHOOD ILLNESS [c], n (%)				
0 overnight hospital admissions	162 (70.7)	147 (76.2)	651 (79.0)	183 (79.2)
1 overnight hospital admission	54 (23.6)	38 (19.7)	134 (16.3)	40 (17.3)
2+ overnight hospital admissions	13 (5.7)	8 (4.2)	39 (4.7)	8 (3.5)
Ascertained at age 46:				
HEIGHT (cm), mean (SD)	170 (9.8)	172.7 (9.8)	170.0 (9.0)	167.3 (9.2)
BMI (kg/m^2), mean (SD)	31.0 (7.4)	27.1 (4.2)	26.8 (4.5)	31.5 (8.3)
HIGHEST EDUCATIONAL ATTAINMENT[c], n (%)				
Up to GSE O-level (usually attained at age 16)	168 (72.1)	107 (55.2)	393 (47.0)	149 (64.2)
GCE A-level (usually attained at age 18)	23 (9.9)	29 (15.0)	129 (15.4)	36 (16.0)
Diploma or degree (including higher degree)	42 (18.0)	58 (29.9)	314 (37.6)	46 (19.8)
NUMBER OF DAYS EXERCISED 30+ MIN PER WEEK, median (Q1-Q3)	2 (0, 5)	3 (1, 5)	3 (2, 5)	2 (0, 5)
WORD RECALL (score out of 10), mean (SD)	6.1 (1.4)	6.7 (1.3)	7.0 (1.4)	6.6 (1.4)
MAXIMUM GRIP STRENGTH (kg), mean (SD)	33.7 (11.5)	40.0 (11.2)	37.5 (11.4)	32.4 (11.3)

N varies between characteristics due to missing covariate data ; GSE O-level: General Certificate of Education (GCE) Ordinary Level; GSE A-level: General Certificate of Education (GCE) Advanced Level

[a] standardised Edinburgh Reading Test scores

[b] Father's occupational class categorized using the Registrar General's Social Classification

[c] Educational attainment was collapsed into 3 categories due to small n

Supplementary Table 3. Relative Risk Ratios (95% CI) demonstrating associations of i) static balance and ii) dynamic balance at age 10 with balance performance at age 46, relative to the reference category of high balance at age 46 (30s EO, 30s EC) in complete cases

		Age 10 balance category	**Sex-adjusted model**	**Final adjusted model** [a]
STATIC BALANCE (AGE 10)		Ref: High	n= 4,455	
Age 46 balance	Medium-high (30s EO, 15-29.9s EC)	Medium	1.09 (0.84, 1.40)	1.05 (0.81, 1.38)
		Poor	**1.46 (1.02, 2.10)**	1.36 (0.94, 1.96)
	Middle (30s EO, <15s EC)	Medium	**1.54 (1.27, 1.88)**	**1.43 (1.16, 1.75)**
		Poor	**2.20 (1.65, 2.93)**	**1.88 (1.39, 2.52)**
	Low-middle (15-29.9 EO)	Medium	**1.84 (1.33, 2.54)**	**1.56 (1.12, 2.18)**
		Poor	**5.20 (3.52, 6.68)**	**3.56 (2.37, 5.34)**
	Low (<15s EO)	Medium	**3.11 (2.19, 4.44)**	**2.70 (1.87, 3.89)**
		Poor	**6.41 (4.17, 9.86)**	**4.40 (2.81, 6.90)**
DYNAMIC BALANCE (AGE 10)		Ref: High	n= 4,478	
Age 46 balance	Medium-high (30s EO, 15-29.9s EC)	Medium	1.06 (0.82, 1.38)	1.04 (0.81, 1.36)
		Poor	0.99 (0.70, 1.40)	0.91 (0.65, 1.29)
	Middle (30s EO, <15s EC)	Medium	1.20 (0.99, 1.47)	1.16 (0.94, 1.42)
		Poor	**1.47 (1.14, 1.81)**	1.27 (0.97, 1.67)
	Low-middle (15-29.9 EO)	Medium	**1.37 (1.00, 1.88)**	1.22 (0.88, 1.69)
		Poor	**1.91 (1.31, 2.78)**	1.40 (0.95, 2.08)
	Low (<15s EO)	Medium	**1.92 (1.37, 2.68)**	**1.71 (1.20, 2.41)**
		Poor	**2.58 (1.73, 3.85)**	**1.93 (1.27, 2.92)**

[a] Adjusted for childhood cognition, SEP and illness (all collected at age 10) and adulthood height, BMI, highest academic qualification, exercise, word recall and grip strength (all collected at age 46)

Bolded scores indicate that estimates do not cross 1