Factors associated with persistently high muscular power from childhood to adulthood

Short running title: Correlates of muscular power tracking groups

Brooklyn J. Fraser, BBiotechMedRes(Hons) [a*]

Leigh Blizzard, PhD [a]

Verity Cleland, PhD [a]

Michael D. Schmidt, PhD [b]

Kylie J. Smith, PhD [a]

Seana L. Gall, PhD [a]

Terence Dwyer, MD, MPH [a, c]

Alison J. Venn, PhD [a]

Costan G. Magnussen, PhD [a, d]

[a] *Menzies Institute for Medical Research, University of Tasmania, Hobart, Tasmania, Australia.*

[b] *Department of Kinesiology, University of Georgia, Athens, USA.*

[c] *George Institute for Global Health, Oxford Martin School and Nuffield Department of Obstetrics & Gynaecology, Oxford University, Oxford, UK.*

[d] *Research Centre of Applied and Preventive Cardiovascular Medicine, University of Turku, Turku, Finland.*

Correspondence to Brooklyn J. Fraser, Menzies Institute for Medical Research, University of Tasmania, Private Bag 23, Hobart 7001, Tasmania, Australia. E-mail: fraserbj@utas.edu.au

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Abstract

Purpose: Child and adult muscular power have been shown to associate with contemporary cardiometabolic health. Muscular power typically persists (tracks) between childhood and adulthood. Few studies span childhood to adulthood, so we aimed to identify modifiable and environmental factors associated with the persistence or change in muscular power across the life course.

Methods: Prospective study examining 1,938 participants who had their muscular power (standing long jump distance) measured in 1985 as children aged 7–15-years and again 20-years later in adulthood (aged 26–36-years). A selection of objectively measured anthropometric characteristics (adiposity and fat-free mass), cardiorespiratory fitness (CRF), self-reported physical activity, dietary (quality and fruit, vegetable, protein intake) and sociodemographic data were available at both time-points. Muscular power was separated into thirds and participants were reported as having persistently low, decreasing, persistently moderate, increasing, or persistently high muscular power.

Results: Higher adiposity, lower physical activity, diet quality and socioeconomic status (SES) across the life course, and lower adult CRF were associated with persistently low muscular power. Lower adult protein intake and an increase in adiposity over time were associated with decreasing muscular power. An increase in fat-free mass was associated with a reduced probability of decreasing or persistently high muscular power, and an increased probability of increasing muscular power. Higher adult fruit intake was associated with increasing muscular power. Lower adiposity across the life course, higher adult CRF and SES, and higher child protein intake were associated with persistently high muscular power.

Conclusion: A healthy weight, good CRF, greater protein intake and high SES are important correlates of high muscular power maintained from childhood to adulthood.

Keywords: Muscle Fitness, Muscle power, Epidemiology, Cohort

Introduction

The importance of muscular fitness in children and adults is increasingly highlighted in physical activity guidelines due to the associated independent health benefits (1, 2). Low muscular fitness associates with an increased risk of adverse cardiometabolic health outcomes and all-cause and cardiovascular mortality in adults (3-6). Low muscular fitness in childhood is shown to associate with higher levels of type 2 diabetes and cardiovascular disease risk factors, and an increased risk of metabolic syndrome and all-cause mortality in adulthood (7-10). Given these health benefits, the maintenance of high muscular fitness levels from childhood to adulthood is important.

Jumping performance is a reliable measure of muscular power. Of interest is how it changes between childhood and adulthood. We have shown children with low muscular power to be four times more likely to maintain their low muscular power status into adulthood, compared with having high adult muscular power (11). We found 53% of those with low jumping performance relative to their peers in childhood maintained this to adulthood, whereas only 14% were able to develop a high level by adulthood (11). Although correlates of muscular fitness have been identified (12-16), there is limited evidence of longitudinal predictors of persistence or change in muscular power from childhood to adulthood. Longitudinal data can potentially provide important insights (17). Given modifiable and sociodemographic factors are associated with childhood muscular fitness, these factors could influence muscular power across the life course. Identifying factors associated with persistence or change in muscular power could help inform intervention strategies aimed at promoting persistently high muscular power into adulthood.

No previous study has examined the association between a wide range of factors and the persistence or change in muscular power between childhood and adulthood. Using data from the Childhood Determinants of Adult Health (CDAH) Study that collected data in childhood and again 20-years later, we aimed to identify modifiable and environmental factors associated with persistence or change in muscular power.

Materials and methods

Participants

In 1985, health and fitness data on a nationally representative sample of 8,498 Australian schoolchildren (aged 7–15-years) was collected as part of the Australian Schools Health and Fitness Survey (ASHFS), with a subset of children aged 9, 12 and 15 years completing additional testing (e.g. skinfolds, CRF). Participants were followed-up in adulthood (2004–06), when their health and fitness was remeasured. Included in this study were 1,938 participants who had their standing long jump measured at both time points and who were not pregnant at follow-up (flow chart of participation presented in Figure S1 of the Supplemental Digital Content). In 1985, the State Directors General of Education approved the baseline study and the Southern Tasmania Health and Medical Human Research Ethics Committee approved the follow-up study. Participant consent was obtained from a parent and the child at baseline and participants provided written informed consent at follow-up.

Muscular power

Muscular power was measured from a standing long jump test. The standing long jump is commonly used in field settings and has previously demonstrated strong test-retest reliability (r=0.83 to 0.99) (18) and negligible test-retest differences (19, 20). Further, the standing long jump has previously displayed moderate to strong construct validity with different measures of lower and upper body muscular power and strength including the countermovement, squat and vertical jumps, basketball throw, isometric strength and one repetition maximum leg and chest press (16, 21). In both childhood and adulthood, a two-footed take-off and landing was required, and participants were encouraged to swing their arms to aid forward momentum. The farthest distance (cm) of two attempts was used in the analyses. Measures of jumping performance not attributable to body mass were created by regressing standing long jump distance on body mass and using the residuals added to the grand mean (7, 22).

Anthropometric measures

Body mass was measured using regularly calibrated scales to the nearest 0.5 kg in childhood and using Heine scales (Heine, Dover, NH) to the nearest 0.1 kg in adulthood. Height was measured to the closest 0.1 cm using a KaWe height tape (KaWe Kirchner & Wilhelm, Aspeg, Germany) in childhood and a Leicester height measure (Invicta, Leicester, UK) in adulthood. Body mass index (BMI) was calculated as body mass (kg) divided by height (m) squared. Using a constant tension tape, waist circumference was measured to the nearest 0.1 cm at the level of the umbilicus in childhood and at the narrowest point between the lower costal border and the iliac crest in adulthood. Holtain calipers (Holtain, Crymych, UK) were used to measure triceps, biceps, subscapular, and suprailiac skinfolds to the nearest 0.1 mm in childhood (aged 9, 12 and 15 years) and to the nearest 0.5 mm using Slim Guide Calipers in adulthood. Using age-specific regression estimates (23), body density and fat percentage were calculated using the log of the sum of four skinfolds. Body fat was calculated from body density, using the Siri formula (24) and fat-free mass was estimated as the difference between total body mass and fat mass.

Cardiorespiratory fitness

Cardiorespiratory fitness (CRF) was measured as physical work capacity at a heart rate of 170 beats per minute (PWC_{170}) for children aged 9, 12 and 15 years at baseline and for all eligible participants at follow-up. A Monark 818E bicycle ergometer (Monark Exercise AB, Vansbro, Sweden) was used in childhood and a Monark 828E bicycle ergometer (Monark Exercise AB, Vansbro, Sweden) was used in adulthood. This sub-maximal test included three successive 3-minute workloads (childhood) or three successive 4-minute workloads (adulthood) that incrementally increased resistance. Heart rate and workloads were recorded in the final minute of each workload and the regression lines were extrapolated to estimate PWC_{170}. Because muscle mass could influence the absolute work load achieved in these tests (25), we created measures of PWC_{170} not attributable to fat-free mass by regressing PWC_{170} on fat-free mass and using the residuals added to the grand mean (22).

Physical activity

For children aged 9–15-years, a questionnaire relating to sport and exercise participation was administered. Based on questionnaire responses, childhood physical activity levels were categorized (26, 27) and ‘total physical activity’ (the sum of all individual physical activity domains) levels were estimated (27). Adult physical activity levels were calculated using responses from the long version of the International Physical Activity Questionnaire (28). Total weekly leisure time physical activity (mins/week) was used as the measure of physical activity in adulthood, as it most closely aligned with the childhood measure (29).

Dietary intake

Children aged 10 years and over completed a 24-hour food diary. In groups of four or five, trained data collectors showed students how to measure and record their intake. Nutrient intake was calculated using a database that was compiled for the study. Using gram weight or kilojoule content, total daily intake of protein in grams and total daily servings of core food groups (fruit, vegetables, breads and cereals, dairy and alternatives, meat and alternatives) and discretionary foods (those that are high in saturated fat, sugar, salt or alcohol and not essential for a healthy diet. E.g. ice-cream, chocolate, soft drink) were calculated. In adulthood, responses from a 127-item food frequency questionnaire were used to calculate total daily servings of core food groups and discretionary foods. For these calculations, it was assumed that each eating occasion was equivalent to a standard serving. Serving sizes were based on the 2013 Australian Dietary Guidelines (30). For fruit and vegetable intake, adult servings were based on responses to two questions "How many serves of fruit/vegetables do you usually eat each day?". Responses were grouped into "1 serving or less", "2–3 servings" and "4 or more servings". For consistency, childhood fruit and vegetable servings were categorized the same way. In both childhood and adulthood, total daily servings of protein were calculated by summing the daily servings of meat and alternatives (lean and non-lean) with the daily servings of dairy and alternatives. Daily protein servings were grouped as "2 servings or less", "3–4 servings" and "5 or more servings". In both childhood and adulthood, a dietary guideline index (DGI) score was calculated, as a measure of diet quality, from the sum of nine individual dietary component scores (31). With the exception of discretionary food intake which was scored from 0 to 20, each individual component was scored from 0 to 10. The age- and sex-specific recommendations in the 2013 Australian Dietary Guidelines (30) were used to calculate the DGI score. A healthier diet is reflected by a larger DGI score.

Socioeconomic status

In adulthood, participants reported the highest level of education they had completed and also retrospectively recorded their parent's education level when they were aged 12 years. The highest combined parental education level of the participant and the participant's own education level were used to define education-based socioeconomic status (SES) at baseline and follow-up as low (secondary or primary education), medium (trade/vocation), or high (tertiary/college education).

Persistence or change in muscular power

Muscular power levels were age- and sex-standardized and categorized into thirds. Participants were reported as having "persistently low" (lowest third in both childhood and adulthood), "decreasing" (moved from highest third in childhood to middle or lowest third in adulthood, or from middle third to lowest third), "persistently moderate" (middle third in both childhood and adulthood), "increasing" (moved from bottom third in childhood to middle or highest third in adulthood, or from the middle third to highest third) or "persistently high" (highest third in both childhood and adulthood) muscular power. See Figure S2 of the Supplemental Digital Content for a visual representation.

Statistical analyses

All statistical analyses were performed using Stata (Version 15.0, StataCorp, College Station, Texas).

Sociodemographics

Participant characteristics are stratified by sex and presented as mean (standard deviation) or median (interquartile range) for continuous variables, and percentages (number of participants) for categorical variables.

Factors associated with persistence or change in muscular power from childhood to adulthood

Continuous variables were converted to age- and sex-specific z-scores. Log multinomial regression models (32) were used to estimate the relative risk (95% confidence intervals) of being in a muscular power group per one unit increase in the child and adult continuous variable z-score. The excluded muscular power group was the persistently moderate group. Initially, covariates for the measurements of exposure to a study factor in childhood and in adulthood were included in the same model. Their estimated coefficients allow assessment of whether the exposure in childhood or adulthood, or both, was associated with the risk of each other muscular power group:

(1) childhood effect dominant: if the effect estimate for the exposure in childhood was much greater in absolute size than the effect estimate for adult exposure, only the covariate for childhood exposure was retained in the model;

(2) adult effect dominant: if the effect estimate for the exposure in adulthood was much greater in absolute size than the effect estimate for childhood exposure, only the covariate for adult exposure was retained in the model;

(3) lifetime effect: if the effect estimates were similar in magnitude and of the same sign, the two covariates were replaced by a single covariate with values calculated as the numerical average of the standardized values of the measurements of childhood and adult exposure;

(4) change over time: if the effect estimates were similar in magnitude and of opposite sign, the two covariates were replaced by a single covariate with values calculated as the difference (adult z-score – child z-score) between the standardized values of the measurements of childhood and adult exposure.

Within all models, adjusting for length of follow-up did not change the estimates by more than 10%. Therefore, length of follow-up was not included in analyses. Adapting an approach by Seaman et al (33), inverse probability weighting with multiple imputation of incomplete baseline data was used to account for missing data at follow-up.

Results

Sociodemographics

Participant characteristics are presented in Table 1. Mean (standard deviation) length of follow-up was 19.9 (0.6) years. Males could jump further, had greater estimated CRF, and were taller and heavier, than females.

Factors associated with persistence or change in muscular power from childhood to adulthood

Factors associated with the persistence or change in muscular power are presented in Table 2. Separate but co-adjusted effect estimates for exposure in childhood and exposure in adulthood are presented in Table S1 of the Supplemental Digital Content. The percentage (numbers) of participants included in each regression model are presented in Table S2 of the Supplemental Digital Content. Higher BMI or waist circumference in childhood and higher skinfolds in both childhood and adulthood were associated with persistently low muscular power. Higher CRF in adulthood and higher physical activity, DGI and SES in both childhood and adulthood were associated with a reduced probability of persistently low muscular power. The results for BMI and fat-free mass differed by sex. Childhood BMI levels for males (RR=1.26, 95% CI=1.16, 1.38), and adulthood BMI levels for females (RR=1.23, 95% CI=1.08, 1.41) were associated with persistently low muscular power. Also associated with persistently low muscular power was any increase in fat-free mass between childhood and adulthood for females (RR=2.12, 95% CI=1.54, 2.90). For males, higher fat-free mass in adulthood was associated with a reduced probability of persistently low muscular power (RR=0.88, 95% CI=0.67, 1.14), although the effect was not statistically significant.

Factors associated with decreasing muscular power were any increase in waist circumference, skinfolds or fat-free mass between childhood and adulthood. Further, greater daily protein intake in adulthood was associated with decreasing muscular power.

Any increase in fat-free mass over time or greater daily fruit intake in adulthood was associated with increasing muscular power. The results for BMI, skinfolds and fat-free mass differed by sex. For females, higher BMI (RR=1.11, 95% CI=1.02, 1.21) and skinfolds in childhood (RR=1.30, 95% CI=1.08, 1.56) were associated with increasing muscular power. Effects were in the opposite direction for males (BMI: RR=0.85, 95% CI=0.77, 0.95; skinfolds: RR=0.81, 95% CI=0.58, 1.14). Any increase in fat-free mass between childhood and adulthood was more strongly associated with increasing muscular power for males (RR=1.72, 95% CI=1.48, 1.99) than for females.

Higher BMI or waist circumference in adulthood, higher skinfolds in both childhood and adulthood, and any increase in fat-free mass between childhood and adulthood, were associated with a reduced probability of persistently high muscular power. Higher CRF or SES levels in adulthood and greater daily intake of protein in childhood were associated also with persistently high muscular power.

When all statistically significant covariates were included in the same model, three factors – sum of skinfolds, fat-free mass and CRF – remained as important predictors of the muscular power groups (data not shown).

Discussion

We found adiposity, CRF, physical activity, dietary quality and education-based SES in both childhood and adulthood, adiposity and protein intake in childhood, adiposity, CRF, fruit and protein intake and education-based SES in adulthood, and the change in adiposity and fat-free mass between childhood and adulthood, as factors associated with persistence or change in muscular power from childhood to adulthood. Given muscular fitness typically persists between childhood and adulthood (11, 34) and long-term clinical trials are not appropriate in this setting, these observational findings reiterate the importance of obesity prevention and physical activity, CRF, dietary quality and education promotion strategies and highlight the additional benefits these strategies could provide for maintaining or improving muscular fitness levels.

Childhood and adulthood adiposity levels and a relative increase in adiposity between childhood and adulthood were associated with the persistence or change in muscular power. Higher levels of adiposity in childhood were associated with an increased probability of persistently low muscular power, and higher adiposity levels in adulthood were associated with a reduced probability of persistently high muscular power. Higher levels of sum of skinfolds in both childhood and adulthood were associated with an increased probability of persistently low muscular power and a reduced probability of persistently high muscular power. Further, an increase in sum of skinfolds between childhood and adulthood was associated with an increased probability of decreasing muscular power. These findings are plausible given adiposity has previously been shown to associate with muscular fitness levels in both child and adult populations (35, 36), with the association between low adiposity and high muscular fitness potentially explained by adiposity levels reflecting the overall health of one's lifestyle or lower adiposity being related to improved muscle quality (37). Participants who increased their fat-free mass between childhood and adulthood were more likely to have increasing muscular power and less likely to have decreasing or persistently high muscular power. These results highlight the positive association between fat-free mass and muscular power. Those who increased their fat-free mass into adulthood were less likely to have persistently high muscular power because they were more likely to be increasing their muscular power. Muscle mass, a large component of fat-free mass, positively associates with muscular power and that could explain these associations. Additionally, higher adulthood CRF and physical activity in both childhood and adulthood were associated with persistently low muscular power. Furthermore, CRF in both childhood and adulthood was associated with persistently high muscular power. This association could be explained by people who were physically active or had high aerobic fitness potentially participating in activities that were benefiting their muscular fitness levels. It suggests increased participation in aerobic exercises in childhood and maintaining these behaviors into adulthood could play a role in maintaining high muscular power between childhood and adulthood. These findings, although not surprising, collectively demonstrate that positive change is possible and highlight the detrimental effect of increased adiposity, and the beneficial effect of improved fat-free mass and CRF, on muscular power.

Dietary factors were associated with persistence and change in muscular power. Greater protein intake in childhood was associated with persistently high muscular power. The DGI in both childhood and adulthood, and fruit intake and protein intake in adulthood, were associated with persistence or change in muscular power, with effects suggesting greater intake was associated with higher muscular power. These associations could be explained by muscular fitness levels reflecting overall diet quality or nutritional status (38).

Higher levels of education-based SES across the life course were associated with a reduced probability of persistently low muscular power, and higher education-based SES in adulthood was associated with an increased probability of persistently high muscular power. These findings are supported by previous literature that highlighted the association between markers of SES and muscular fitness levels (39). Higher SES may reflect greater opportunities to be physically active or greater awareness of the importance of physical activity. Given that the highest level of education attained is amenable to intervention, strategies aimed to support people in their educational pursuits and provide equal educational opportunities could have favorable effects on muscular power.

Limitations of our study include the use of self-reported dietary and physical activity data and retrospective recall of parental education. Loss to follow-up is another potential limitation, although our statistical analyses, which included inverse probability weighting, aimed to take account of missingness (33) and to reduce the likelihood of bias. This statistical approach is appropriate if missing data were missing at random and we have no reason to believe that this was not the case. Furthermore, our results are based on only one measure of muscular power and we acknowledge that our groups defining persistence or change in muscular power were categorized based on jumping performance levels at a single time point in each of childhood and adulthood. We were unable to examine muscular power at other time-points. Our categorizations of muscular power were arbitrary and not based on thresholds that reflect ideally, a muscular power health risk, although to the best of our knowledge such thresholds do not exist. The measurements made at a single time-point in adulthood were treated as being representative of recent values of the exposure. Ideally, more comprehensive measurements of exposure preceding the eventual change in muscular power would have been included, but these data were not available. Furthermore, it is important to note that muscular fitness has both environmental and genetic components (40) that could influence how it persists or changes. Further research examining the association between genetics and the persistence or change in muscular fitness is required. Study strengths include the long follow-up of this large national sample and the use of the standing long jump test, a reliable field-based measure of muscular power that demonstrates very good test-retest reliability (19, 20) and good construct validity (16, 21). Additional strengths include the rich depth of information available for analysis on potential confounding and modifying factors.

In the absence of a long-term intervention spanning two decades, these findings could help identify potential targets for interventions aimed towards improving muscular power throughout the life course. Our findings suggest that maintaining or improving muscular power from childhood to adulthood could be an additional benefit of strategies aimed at obesity prevention by promotion of physical activity, CRF, dietary quality and education. Because low muscular power is a risk factor for adverse health outcomes, promoting strategies aimed at increasing muscular power could improve future health.

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Supplemental Digital Content

Supplemental Digital Content 1.doc

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Tables

Table 1. Characteristics of participants.

	Childhood			Adulthood		
		Male	Female		Male	Female
Characteristic	n	Mean (SD)*	Mean (SD)*	n	Mean (SD)*	Mean (SD)*
Standing long jump, cm	1938	153.5 (31.0)	137.2 (26.1)	1938	188.5 (24.8)	136.3 (25.8)
Standing long jump$_{adj}$, cm†	1938	153.4 (30.9)	137.1 (26.1)	1938	188.5 (24.1)	136.3 (23.5)
Body mass, kg	1938	40.9 (13.4)	38.9 (12.0)	1938	85.2 (14.6)	68.0 (14.2)
Height, cm	1937	148.3 (16.1)	144.9 (14.5)	1938	179.7 (6.8)	165.8 (6.3)
BMI, kg/m^2	1937	18.1 (2.7)	18.0 (2.7)	1938	26.4 (4.2)	24.7 (4.8)
Waist circumference, cm	1937	64.5 (8.0)	61.7 (7.8)	1938	89.1 (10.3)	77.4 (10.8)
Sum of skinfolds, mm	651	30.4 (15.8)	40.6 (18.0)	1927	65.5 (27.0)	77.2 (31.0)
Fat-free mass, kg	651	35.4 (10.2)	31.7 (7.3)	1927	64.0 (7.7)	44.5 (6.2)
PWC$_{170}$, watts	618	110.1 (44.3)	79.5 (28.2)	1921	198.0 (46.1)	130.4 (30.8)
PWC$_{170adj}$, watts‡	615	109.2 (39.9)	80.2 (26.8)	1910	198.2 (40.8)	130.3 (28.7)
Leisure time physical activity, mins/week: median (IQR)	1507	340 (200, 620)	303 (180, 525)	1743	120 (0, 243)	120 (30, 238)
Dietary Guidelines Index§	1213	45.8 (11.9)	43.9 (11.6)	1775	51.9 (10.8)	58.5 (10.7)
Fruit intake, servings per day	1213			1775		
1 serving or less		59.6% (380)	57.0% (328)		58.9% (527)	49.6% (436)
2-3 servings		23.8% (152)	28.7% (165)		37.7% (337)	45.8% (403)
4 or more servings		16.6% (106)	14.3% (82)		3.5% (31)	4.7% (41)
Vegetable intake, servings per day	1213			1775		
1 serving or less		42.8% (273)	51.1% (294)		41.7% (373)	27.4% (241)
2-3 servings		32.5% (207)	31.3% (180)		50.8% (455)	59.1% (520)
4 or more servings		24.8% (158)	17.6% (101)		7.5% (67)	13.5% (119)
Protein intake, servings per day	1213			1775		
2 servings or less		34.6% (221)	53.0% (305)		2.9% (26)	2.7% (24)
3-4 servings		39.8% (254)	33.4% (192)		23.2% (208)	21.9% (193)
5 or more servings		25.6% (163)	13.6% (78)		73.9% (661)	75.3% (663)
Education-based SES‖	1824			1919		

Low (school only)	42.6% (392)	44.9% (406)	24.5% (242)	25.8% (241)
Medium (trade/vocation)	30.7% (282)	30.4% (275)	36.5% (359)	24.5% (229)
High (tertiary/college)	24.6% (26.7)	24.7% (223)	39.0% (384)	49.7% (464)

* Mean (standard deviation) or median (interquartile range) for continuous variables, and % (n) for categorical variables.

† Measure of standing long jump not attributable to body mass created by regressing standing long jump distance on body mass and using the residuals added to the grand mean.

‡ Measure of PWC_{170} not attributable to fat-free mass created by regressing PWC_{170} on fat-free mass and using the residuals added to the grand mean.

§ The Dietary Guideline Index ranges from 0–100. A higher score indicates greater compliance with the Dietary Guidelines.

‖ Education based-SES in childhood was determined retrospectively based on parental education levels and based on individual education level in adulthood.

Abbreviations: BMI, body mass index; SD, standard deviation; IQR, interquartile range; PWC_{170}, physical work capacity at a heart rate of 170 beats per minute; SES, socioeconomic status.

Table 2. Factors associated with the persistence or change in muscular power from childhood to adulthood*.

		Muscular power group†			
		Persistently low	Decreasing	Increasing	Persistently high
Characteristic		RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)
BMI					
	Childhood	1.19 (1.11, 1.28) n=331			
	Adulthood				0.85 (0.78, 0.92) n=343
Waist circumference					
	Childhood	1.23 (1.12, 1.34) n=330			
	Adulthood				0.80 (0.73, 0.88) n=343
	Change over time		1.13 (1.04, 1.24) n=550		
Sum of skinfolds					
	Lifetime effect	1.65 (1.31, 2.07) n=113			0.53 (0.45, 0.63) n=119
	Change over time		1.19 (1.09, 1.30) n=204		

Fat-free mass					
	Change over time		0.85 (0.76, 0.96)	1.47 (1.27, 1.70)	0.74 (0.64, 0.86)
			n=204	n=140	n=119
Cardiorespiratory fitness					
	Adulthood	0.78 (0.70, 0.86)			
		n=108			
	Lifetime effect				1.25 (1.10, 1.42)
					n=111
Physical activity					
	Lifetime effect	0.75 (0.63, 0.88)			
		n=238			
Dietary guideline index					
	Lifetime effect	0.77 (0.64, 0.91)			
		n=200			
Fruit intake					
	Adulthood			1.12 (1.04, 1.24)	
				n=266	
Protein intake					
	Childhood				1.23 (1.10, 1.39)
					n=212
	Adulthood		0.89 (0.82, 0.97)		

			n=290		
Education-based SES					
	Adulthood				1.25 (1.08, 1.43) n=327
	Lifetime effect	0.69 (0.59, 0.81) n=304			

* Childhood and adulthood z-scores were included in analyses.

† Persistently moderate is the excluded muscular power group.

Abbreviations: BMI, body mass index; CI, confidence intervals; RR, relative risk; SES, socioeconomic status.

Supplementary Content

Table S1. Factors associated with the persistence or change in muscular power from childhood to adulthood*.

		Muscular power group†‡			
		Persistently low	Decreasing	Increasing	Persistently high
Characteristic		RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)
BMI					
	Childhood	1.14 (1.02, 1.28)	0.90 (0.81, 1.00)§	0.96 (0.86, 1.07)	1.04 (0.92, 1.17)
	Adulthood	1.08 (0.98, 1.20)	1.09 (0.99, 1.19)	1.03 (0.93, 1.14)	0.83 (0.74, 0.93)
Waist circumference					
	Childhood	1.15 (1.01, 1.33)	0.89 (0.80, 0.97)	0.98 (0.87, 1.11)	1.02 (0.89, 1.16)
	Adulthood	1.09 (0.94, 1.26)	1.13 (1.03, 1.25)	1.02 (0.91, 1.14)	0.79 (0.70, 0.89)
Sum of skinfolds					
	Childhood	1.46 (1.19, 1.78)	0.84 (0.72, 0.98)	1.15 (0.95, 1.38)	0.72 (0.57, 0.91)
	Adulthood	1.19 (1.05, 1.36)	1.16 (1.06, 1.27)	0.95 (0.83, 1.09)	0.72 (0.63, 0.83)
Fat-free mass					
	Childhood	0.82 (0.66, 1.01)	1.14 (1.01, 1.29)	0.71 (0.60, 0.84)	1.46 (1.25, 1.71)
	Adulthood	1.09 (0.84, 1.41)	0.83 (0.72, 0.96)	1.51 (1.29, 1.76)	0.84 (0.72, 0.99)
Cardiorespiratory fitness					
	Childhood	1.02 (0.82, 1.27)	1.00 (0.86, 1.17)	1.04 (0.87, 1.25)	1.15 (0.93, 1.43)
	Adulthood	0.75 (0.67, 0.85)	0.93 (0.84, 1.02)	1.12 (0.97, 1.30)	1.27 (1.08, 1.50)
Physical activity					
	Childhood	0.90 (0.78, 1.03)	1.00 (0.91, 1.09)	0.99 (0.89, 1.09)	1.07 (0.96, 1.19)
	Adulthood	0.83 (0.73, 0.96)	0.99 (0.91, 1.07)	1.07 (0.99, 1.15)	1.03 (0.94, 1.13)
Dietary guideline index					

	Childhood	0.88 (0.76, 1.01)	1.00 (0.89, 1.12)	1.09 (0.99, 1.20)	1.05 (0.93, 1.19)
	Adulthood	0.87 (0.77, 1.00)‖	0.94 (0.85, 1.05)	1.09 (0.97, 1.22)	1.13 (0.99, 1.28)
Fruit intake					
	Childhood	0.93 (0.80, 1.08)	1.09 (0.97, 1.22)	0.97 (0.86, 1.10)	1.08 (0.94, 1.24)
	Adulthood	0.93 (0.81, 1.07)	0.91 (0.81, 1.01)	1.13 (1.02, 1.25)	1.05 (0.92, 1.20)
Vegetable intake					
	Childhood	0.97 (0.84, 1.11)	0.96 (0.87, 1.07)	1.04 (0.93, 1.15)	1.03 (0.90, 1.17)
	Adulthood	0.90 (0.79, 1.03)	0.94 (0.85, 1.05)	1.10 (0.98, 1.24)	1.03 (0.91, 1.17)
Protein intake					
	Childhood	0.94 (0.83, 1.07)	0.96 (0.87, 1.07)	0.96 (0.87, 1.07)	1.23 (1.09, 1.39)
	Adulthood	1.14 (0.98, 1.32)	0.89 (0.82, 0.97)	0.98 (0.88, 1.08)	1.05 (0.92, 1.21)
Education-based SES					
	Childhood	0.89 (0.78, 1.02)	1.09 (0.99, 1.19)	1.02 (0.92, 1.13)	1.03 (0.91, 1.16)
	Adulthood	0.79 (0.67, 0.90)	0.93 (0.85, 1.03)	1.04 (0.93, 1.17)	1.24 (1.07, 1.43)

* Childhood and adulthood z-scores were included in analyses.

† Persistently moderate is the excluded muscular power group.

‡ Numbers for analysis: range 108–331 (persistently low), 191–550 (decreasing), 72–230 (persistently moderate), 129–484 (increasing), 111–343 (persistently high). See Table S2 of the Supplemental Digital Content.

§ p-value=0.053

‖ p-value=0.047

Abbreviations: BMI, body mass index; CI, confidence intervals; RR, relative risk; SES, socioeconomic status.

Table S2. Percentage and number of participants in each muscular power group for the analyses presented in Table S1.

Characteristic	Persistently low	Decreasing	Persistently moderate	Increasing	Persistently high
BMI	17.1 (331)	28.4 (550)	11.8 (229)	25.0 (484)	17.7 (343)
Waist circumference	17.0 (330)	28.4 (550)	11.9 (230)	25.0 (484)	17.7 (343)
Skinfolds	17.4 (113)	31.3 (204)	11.5 (75)	21.5 (140)	18.3 (119)
Fat-free mass	17.4 (113)	31.3 (204)	11.5 (75)	21.5 (140)	18.3 (119)
Cardiorespiratory fitness	17.7 (108)	31.3 (191)	11.8 (72)	21.1 (129)	18.2 (111)
Physical activity	17.6 (238)	27.5 (373)	12.2 (165)	24.1 (326)	18.7 (253)
Dietary guideline index	17.9 (200)	26.0 (290)	13.2 (147)	23.9 (266)	19.0 (212)
Fruit intake	17.9 (200)	26.0 (290)	13.2 (147)	23.9 (266)	19.0 (212)
Vegetable intake	17.9 (200)	26.0 (290)	13.2 (147)	23.9 (266)	19.0 (212)
Protein intake	17.9 (200)	26.0 (290)	13.2 (147)	23.9 (266)	19.0 (212)
Education-based SES	16.7 (304)	28.6 (522)	12.1 (220)	24.7 (450)	17.9 (327)

Abbreviations: BMI, body mass index; SES, socioeconomic status.

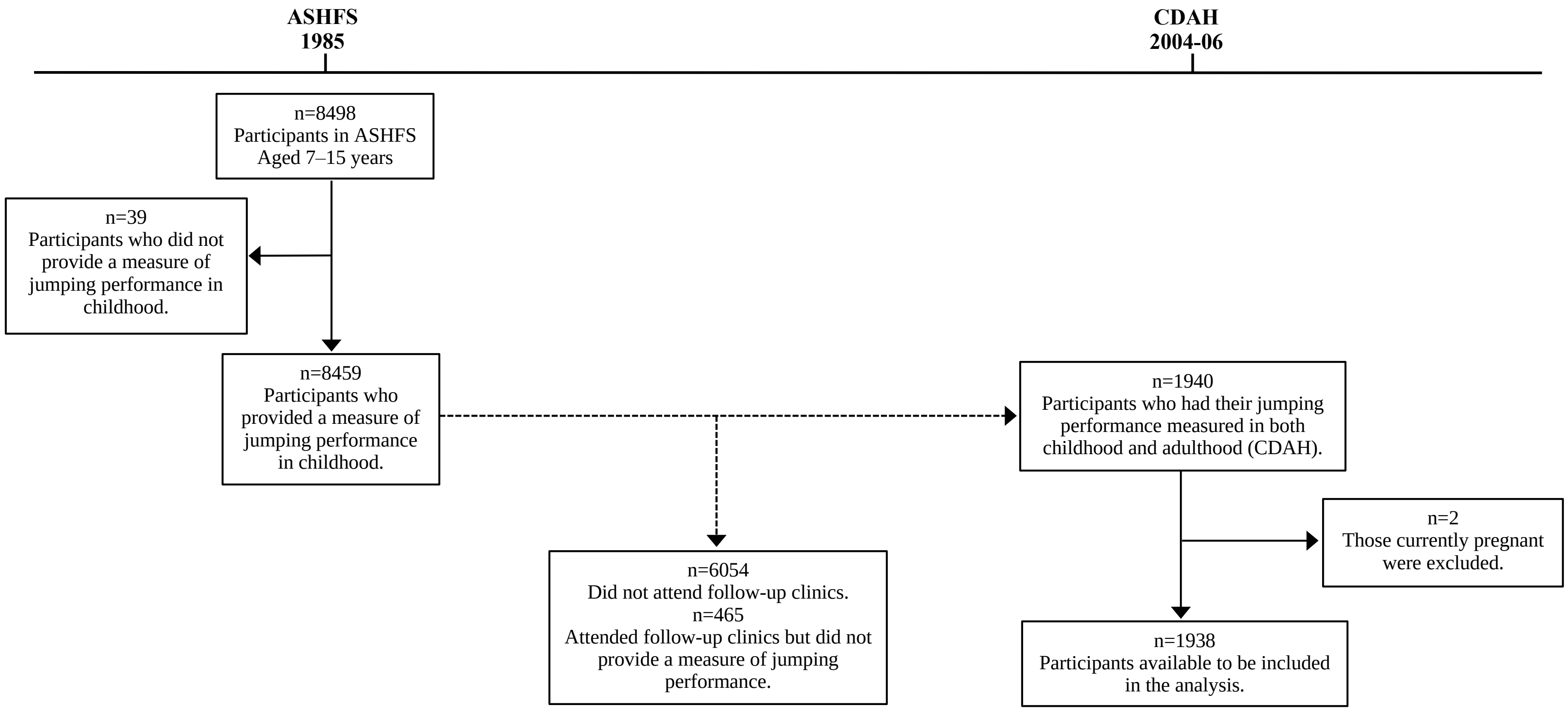

Figure S1
Flow chart of participation. Abbreviations: ASHFS, Australian Schools Health and Fitness Survey; CDAH, Childhood Determinants of Adult Health Study.

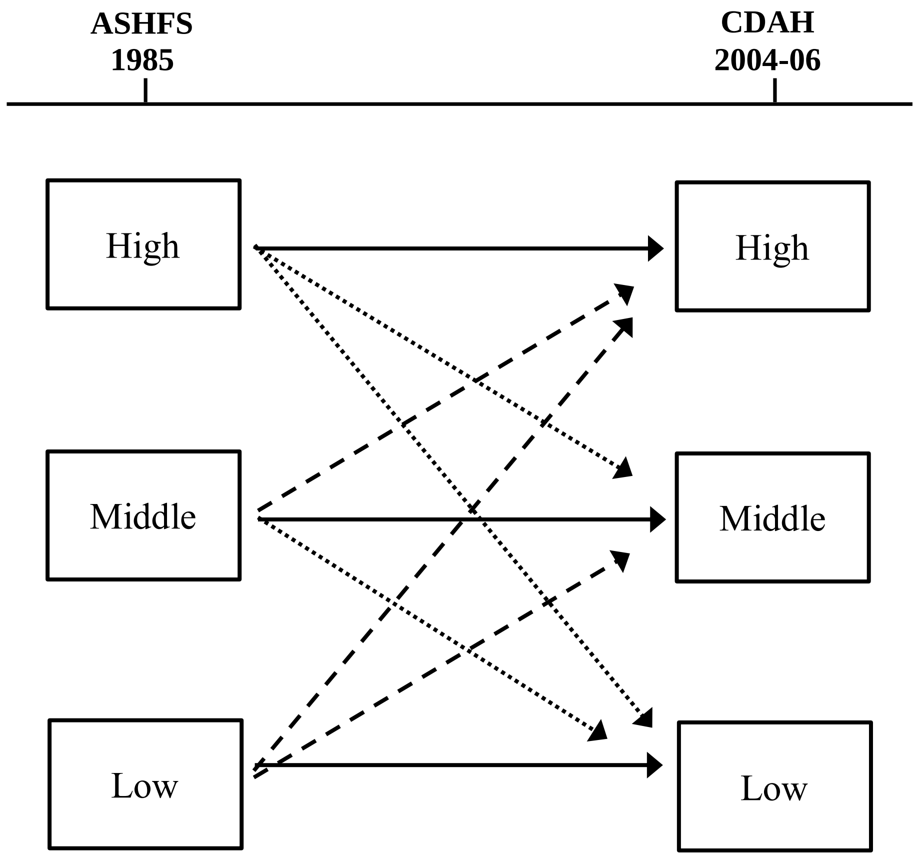

Figure S2
Diagram of muscular power groups based on age- and sex-specific thirds between childhood and adulthood. Solid line represents the persistently high, persistently middle and persistently low muscular power groups. Small dash line represents the decreasing muscular power group and large dash line represents the increasing muscular power group.
Abbreviations: ASHFS, Australian Schools Health and Fitness Survey; CDAH, Childhood Determinants of Adult Health.