The great leap backward: Changes in the jumping performance of Australian children aged 11−12-years between 1985 and 2015

Short Running Title: 30-year secular changes in jumping performance of Australian children

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Abstract

Previous data have indicated relative stability over time of paediatric jumping performance, but few data exist since the early 2000s. This study quantified the 30-year secular changes in jumping performance of Australian children aged 11−12-years using data from the Australian Schools Health and Fitness Survey (1985, n=1967) and Growing Up in Australia's Child Health CheckPoint (2015, n=1765). Both cohorts measured jumping performance (standing long jump distance), anthropometric and demographic data. Secular changes in jumping performance means and quantiles were examined using multivariable linear and quantile regression. Between 1985 and 2015, jumping performance declined by 16.4 cm or by 11.2% (standardised change 0.66 SD, 95%CI 0.60 to 0.73), independent of age and sex. Adjustment for body mass reduced the effect by 32%, although the decline remained (absolute change –11.1 cm, 95%CI −12.5 to −9.7; percent change 7.7%, 95%CI 6.7 to 8.6; standardised change 0.51 SD, 95%CI 0.44 to 0.57). This decline was evident across all quantiles. The jumping performance of Australian children aged 11−12-years has declined between 1985 and 2015, with body mass changes accounting for only part of the decline. Efforts should continue to promote paediatric muscular fitness, reduce adiposity, and aim to reverse this decline in jumping performance.

Keywords: physical fitness, temporal trends, children, cross-sectional studies, muscular fitness

Introduction

Muscular fitness is a term used to represent muscular strength, endurance and power. Generally defined, muscular strength is the muscle’s ability to generate maximal force on a single occasion, endurance is the muscle’s ability to continue to perform successive exertions, and power (or explosive strength) refers to the rate at which muscles perform work (American College of Sports Medicine, 2013). The importance of muscular fitness is becoming increasingly recognised in both paediatric and adult settings. In adulthood, low muscular fitness is a strong correlate of mortality (Katzmarzyk and Craig, 2002; Leong et al., 2015). In children and adolescents, associations have been reported linking muscular fitness to lower adiposity and cardiovascular risk factors, and better self-esteem and bone health (Ortega, Ruiz, Castillo, & Sjostrom, 2008b; Smith et al., 2014). Low childhood and adolescent muscular fitness has also been associated with cardiometabolic disease outcomes (Fraser et al., 2018; Fraser et al., 2016; Grontved et al., 2013) and all-cause mortality in later life (Ortega, Silventoinen, Tynelius, & Rasmussen, 2012). In paediatric populations, resistance training interventions have improved muscular fitness levels (Behringer, Vom Heede, Yue, & Mester, 2010; Lesinski, Prieske, & Granacher, 2016; Schranz, Tomkinson, & Olds, 2013). Collectively, these data highlight resistance training as a potential strategy to help benefit future health. Although efforts continue to promote the importance of muscular fitness, what effect a changing backdrop of physical, social and behavioural factors has had on paediatric muscular fitness is of interest.

Secular trends in paediatric muscular fitness have been the focus of previous meta-analyses. Globally, muscular fitness levels, defined as jumping performance, appear to have been relatively stable for the past half a century (Tomkinson, 2007). In a systematic analysis of 20.8 million children and adolescents aged 6–19 years from 23 countries, Tomkinson (2007) indicated very small improvements in mean jumping performance of 0.3% per decade between 1958 and 2003, though, a uniform pattern of change was not present across the 45-year period. Improvements in jumping performance were present from the late 1950s to the mid 1980s and declines were present thereafter. It is plausible that jumping performance has continued to decline in recent years, although additional research extending trends to include contemporary cohorts is required to confirm this. Secular changes in paediatric jumping performance have been examined in part since 2003, although research is limited and results vary. Independent of changes in body size, the jumping performance of Spanish adolescents decreased between 2001–02 and 2006–07 (Moliner-Urdiales et al., 2010), a similar trend observed for Lithuanian boys between 2002 and 2012 (Venckunas, Emeljanovas, Mieziene, & Volbekiene, 2017). However, the jumping performance of English children improved between 1998 and 2008 (Cohen et al., 2011). Given these inconsistencies, there is a need to better understand how the jumping performance of children and adolescents has evolved over time using contemporary data.

Using data from two population-based samples of Australian children aged 11−12-years, we aimed to determine the 30-year secular changes in jumping performance and assess whether these secular changes remained independent of changes in body mass. We hypothesised that jumping performance had declined between 1985 and 2015 and changes in body mass would explain only part of the decline.

Materials and Methods

Participants

This study used cross-sectional data from two national Australian cohorts, the Australian Schools Health and Fitness Survey (ASHFS) and the Child Health CheckPoint (CheckPoint) nested within the Longitudinal Study of Australian Children (LSAC).

The ASHFS, conducted in 1985, collected data on a nationally representative sample of 8498 Australian school children aged 7 to 15 years from 109 schools. Additional details on the two-stage probability sampling strategy have been published elsewhere (Dwyer and Gibbons, 1994). Participants provided information on their health and fitness, with muscular fitness and anthropometric measures recorded. Consent was obtained from parent and assent from the child prior to inclusion in the ASHFS, with the State Directors-General of Education approving the study.

The second data source was CheckPoint (Wake et al., 2014). In 2004 as part of LSAC, 5107 infants aged 0–1 year were recruited as a nationally representative birth cohort. These children were followed up biennially, providing general health, fitness and anthropometric data. In 2014, 3764 LSAC participants were available at age 10–11 years for data collection. At this point, contactable families of LSAC birth cohort participants were invited to consent to be contacted the following year regarding possible participation in CheckPoint (n=3513), a cross-sectional wave of comprehensive biophysical data. In 2015, 1874 Australian families participated in CheckPoint and provided informed consent for use of their data. CheckPoint was approved by The Royal Children’s Hospital Melbourne Human Research Ethics Committee (33225D) and The Australian Institute of Family Studies Ethics Committee (14-

26). A parent/guardian provided written informed consent for their child's participation and children provided assent.

To obtain comparable samples, participants aged 11 or 12 years who performed a standing long jump test were included within this study (1985: n=1967; 2015: n=1765).

Muscular fitness

The standing long jump test was used as a measure of muscular fitness in both 1985 and 2015. In children and adolescents, the standing long jump demonstrates very strong-to-nearly perfect test-retest reliability (r=0.83 to 0.99; Docherty, 1996). Negligible test-retest differences in mean jumping performance have been previously reported (Fernandez-Santos, Ruiz, Cohen, Gonzalez-Montesinos, & Castro-Pinero, 2015; Ortega et al., 2008a). In childhood, the standing long jump demonstrates moderate-to-strong construct validity with established measures of lower-body strength (e.g. 1RM leg press/body mass: r=0.39, Milliken, Faigenbaum, Loud, & Westcott, 2008), upper body strength (e.g. 1RM chest press: r=0.35, Milliken, et al., 2008; push-ups: r=0.66, Castro-Pinero et al., 2010b) and overall muscular strength (r=0.77, Castro-Pinero, et al., 2010b). The standing long jump also correlates strongly (r=0.70-0.91) with other lower- and upper-body field-based explosive strength tests (e.g. vertical jump, countermovement vertical jump, explosive basketball throw) in 6−17-year-olds, controlling for age, sex, body mass, or body mass index (Castro-Pinero, et al., 2010b; Milliken, et al., 2008). In this study, the standing long jump test was administered by physical education graduates in 1985 and by research assistants in 2015. All personnel were trained to administer the test and instructed to verbally encourage participants. Participants used a double-leg take off to jump horizontally for the greatest possible distance, swinging their arms and bending their knees preparatory to take off.

Standing long jump was recorded as the better of two trials to the nearest 0.1 cm in 1985 and as the best of three trials to the nearest 0.1 cm in 2015. To replicate the same standing long jump measure across the two cohorts, the maximum distance of the first two trials was used. To create a jumping performance measure not attributable to body mass, body mass was regressed on standing long jump distance and the residuals were used (Quan et al., 2014).

Anthropometric measures

In 1985, a constant-tension tape was used to measure waist circumference at the level of the umbilicus, to the nearest 0.1 cm. Using regularly calibrated weighing scales, body mass was measured to the nearest 0.5 kg, whilst a KaWe height tape (KaWe Kirchner & Wilhelm, Asperg, Germany) was used to measure height to the nearest 0.1 cm. BMI was calculated as mass in kilograms divided by height in metres squared. BMI values were used to categorise participants as normal weight, overweight or obese according to Cole cut-points (Cole, Bellizzi, Flegal, & Dietz, 2000). Fat-free mass was calculated using mass and estimates of percentage body fat derived from the sum of skinfolds. Triceps, biceps, subscapular, and suprailiac skinfolds were measured to the nearest 1 mm using Holtain calipers (Holtain, Crymych, UK). Body density was calculated from the log of the sum of four skinfolds using age-specific regression estimates (Durnin and Rahaman, 1967; Durnin and Womersley, 1974), and fat percentage was estimated (Siri, 1956). Fat mass was calculated by percentage body fat multiplied by body mass and fat-free mass was then calculated by subtracting fat mass from total body mass. In 2015, anthropometric data were measured in light clothing without shoes or socks. Using an InBody230 (InBody230, Biospace, Seoul, Korea) bioelectrical impedance analysis scale, body mass was measured to the nearest 0.1 kg and fat mass and fat-free mass were derived from body composition equations. Height was measured using a portable rigid stadiometer (Invicta IP0955, Leicester, UK) with BMI subsequently derived. A steel anthropometric measuring tape (Lufkin Executive Diameter W606PM, Maryland, USA) was used to measure waist circumference at the narrowest point between the 10th rib and the iliac crest, or at the midpoint between these landmarks if no narrowing was present.

Socioeconomic status

In 1985, area-level socioeconomic status (SES) was derived from residential postcode, using the Australian Bureau of Statistics Socio-economic Index for Areas (SEIFA) index of relative SES disadvantage and 1981 census data. A similar approach was used in 2015, whereby area-level SES was derived from residential postcode using the SEIFA Disadvantage Index and 2011 census data. Participants were categorised as least disadvantaged, 2nd least disadvantaged, middle, 2nd most disadvantaged or most disadvantaged. As area-level SES was scaled differently in the two studies, the ASHFS measure (range 1–4) was rescaled to have the same range as the CheckPoint measure (range 1–5).

Statistical analyses

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

Demographics

Characteristics of participants in 1985 and 2015 were stratified by sex and presented as mean and standard deviation (SD) for continuous variables or number of participants (percentage) for categorical variables.

Secular changes in jumping performance

Multivariable linear regression was used to examine changes in mean jumping performance and multivariable quantile regression (at 1st, 5th, 10th, 20th percentile, 25th, 50th, 75th, 80th, 90th, 95th and 99th percentiles) was used to examine percentile shifts in jumping performance between 1985 and 2015. For both the linear and quantile regressions, two multivariable models with successive adjustment were considered. Model one adjusted for age and sex, and model two adjusted for age, sex and body mass. Wald's test of the coefficient of the binary term for cohort provided a test of the statistical difference in mean or specific quantile values between the two time points. To assess whether changes in jumping performance over time were more marked for males or females, we presented these data both sex-combined and sex-stratified. Percent change was determined by the percentage difference in mean jumping performance. Standardised change was calculated as Cohen's *d* (categorised as small [~0.2], moderate [~0.5] and large [~0.8]) (Cohen, 1988).

Results

Demographics

Characteristics of the 3732 participants are presented in Table 1. All participants had a mean (standard deviation, SD) age of 11.5 (0.5). Participants in 2015 were generally taller and heavier than participants in 1985. At both time points, the distribution of area-level SES was skewed with those most disadvantaged under-represented.

Secular changes in jumping performance

The secular changes in mean jumping performance of Australian children aged 11−12-years between 1985 and 2015 are presented in Table 2. Participants in 1985 could jump on average 16.4 cm further than participants in 2015 (percent change 11.2%, 95% CI 10.2 to 12.2; standardised change 0.66 SD, 95% CI 0.60 to 0.73), independent of age and sex. Upon additional adjustment for body mass, the mean difference between 1985 and 2015 was 11.1 cm (percent change 7.7%, 95% CI 6.7 to 8.6; standardised change 0.51 SD, 95% CI 0.44 to 0.57), representing a moderate decline in jumping performance. The secular decline in jumping performance, independent of body mass, was somewhat more marked in males than in females (males: absolute change −12.0 cm, 95% CI −14.0 to −10.0; percent change 8.0%, 95% CI 6.7 to 9.3; standardised change 0.55 SD, 95% CI 0.45 to 0.64; females: absolute change −10.4, 95% CI −12.4 to −8.4; percent change 7.4%, 95% CI 6.0 to 8.8; standardised change 0.48 SD, 95% CI 0.39 to 0.57). Although, a consistent trend was present; in 1985 participants could jump further than those in 2015.

Results from quantile regression models highlighting the secular changes in jumping performance distributional characteristics between 1985 and 2015 are shown in Table S1. A secular decline in jumping performance was evident at all examined percentiles, although the decline in jumping performance for females at the 1st and 99th percentile was not statistically significant ($p>0.05$). The distribution of standing long jump percentile values for participants in each cohort, adjusted for age, sex and body mass, are presented in Table S2 and visually shown in Figure 1.

Sensitivity analyses

In a series of sensitivity analyses, we additionally considered the influence of height, BMI, waist circumference, fat-free mass and fat mass on changes in mean jumping performance by replacing body mass with each of these body measures in turn in model 2 (Table S3). Secular declines remained after adjustment for these variables, with effect estimates reducing by 12−21%. Furthermore, when area-level SES was included in model 2, the magnitude of the observed secular decline became 3.6% greater.

Discussion

This study quantified the 30-year secular changes in the jumping performance of Australian children aged 11−12-years, with estimates suggesting that jumping performance has declined moderately between 1985 and 2015. Australian children aged 11−12-years in 1985 could jump approximately 11 cm further than their peers could in 2015, independent of age, sex and body mass. The observed decline was a moderate shift equivalent to 7.7% or to approximately half a standard deviation. This secular decline was also independent of area-level SES. Our results contribute to the field by not only identifying the secular changes in mean jumping performance, but also examining the secular changes in jumping performance distributional characteristics. The secular decline in jumping performance was relatively uniform throughout the distribution, suggesting children aged 11−12-years irrespective of their performance level, should be targeted with strategies aimed at reversing this decline.

The most comprehensive analysis of secular trends in jumping performance available suggests there has been little change internationally (improvements of ~0.3% per decade) in over 20 million children and adolescents from 23 (mostly high income) countries between 1958 and 2003 (Tomkinson, 2007). A similar trend was presented in a meta-analysis of muscular fitness of 105,360 Australian children and adolescents aged 6–17 years (improvements of ~0.5% per decade in jumping performance) between 1960 and 2002 (Tomkinson, Hamlin, & Olds, 2006). Although the results of these two large studies indicate that jumping performance has remained relatively stable throughout the last half of the 20th century, the international pattern of change presented by Tomkinson (2007) was not uniform over the entire 45-year period. There was evidence of improvements from the late 1950s to the mid-1980s (improvements of 0.4% per annum in the 1960s and 0.3% per annum in the 1970s) and declines thereafter (declines of 0.04% per annum in the 1980s and 0.2% per annum in the 1990s) (Tomkinson, 2007). Unfortunately, we were unable to determine the true time-related pattern of change between 1985 and 2015 because we were limited to a linear analysis between two time points. However, it is possible that our findings reflect the declines in jumping performance presented by Tomkinson (2007) to have continued past the early 2000s. Though, additional studies extending current trends to include contemporary cohorts are required to help confirm this.

Recent studies have examined secular changes in jumping performance after controlling for changes in body size using contemporary data, although results vary. Annual decreases in jumping performance have been observed between 2001–02 and 2006–07 (1.04% for males; 1.68% for females) for Spanish adolescents (n=791, aged 12–17 years) (Moliner-Urdiales, et al., 2010) and between 1985 and 2015 (0.29% for males; 0.24% for females) in the current study of Australian children aged 11−12-years. These findings conflict with annual increases in jumping performance of 0.57% (sexes combined) observed between 1998 and 2008 for 10-year-old English children (n=624) by Cohen et al. (2011). However, Cohen et al. found other examined measures of muscular fitness (grip strength, sit-up performance) declined over the same time period. Although Cohen et al. suggested the observed increase in jumping performance could be an anomaly, this difference could potentially reflect varying secular changes for different phenotypes of muscular fitness. Although declines in jumping performance after the year 2000 seem plausible, additional research and more recent data is required to confirm these findings.

The secular decline in jumping performance of Australian children aged 11−12-years could partly be due to the concurrent secular increase in paediatric overweight and obesity (Ho, Olds, Schranz, & Maher, 2017). Increases in obesity are commonly operationalised as increases in BMI, although greater BMI may indicate both increased fat mass and fat-free mass (Tomkinson, et al., 2006). An increase in fat-free mass has the potential to positively influence jumping performance by increasing the body's ability to perform the jumping action, whereas an increase in fat mass is likely to have a negative impact by adding weight that does not confer any functional advantage. The observed decline in jumping performance could partly be explained by the detrimental effect of increased fat mass overriding the benefit of increased fat-free mass. The decline was only partly attenuated following adjustment for body mass and fat-free mass. Obesity rates in Australian children have plateaued since the late 1990s (Olds, Tomkinson, Ferrar, & Maher, 2010); however, it is possible that the stabilisation in BMI masks a decrease in fat-free mass and a concomitant increase in fat mass. The potential impact this has on jumping performance requires additional research. The secular decline in jumping performance could alternatively reflect a general decline in Australian adolescents' overall physical activity levels. Although data on secular trends in paediatric physical activity are limited, consistent declines in active transport have been reported (Booth, Rowlands, & Dollman, 2015). Variations in the administration of the standing long jump test could also potentially explain the change in jumping performance. Differences in the background of administrative staff, the training received, and the level of encouragement provided to participants could have influenced jumping performance. Furthermore, Tomkinson et al. (Tomkinson, Lang, & Tremblay, 2017; Tomkinson and Olds, 2007) previously argued that a network of environmental, social, behavioural, physical, psychosocial and physiological factors that probably underlie international declines in paediatric cardiorespiratory fitness. The declines observed in this study are also likely to be explained by a similar causal network of factors.

The importance of paediatric muscular fitness has recently been advocated in physical activity guidelines, both in Australia and internationally (Australian Government Department of Health, 2014; World Health Organization, 2010), which suggest muscle strengthening exercises should be performed in addition to endurance exercise on at least 3 days a week in childhood. Despite these recent guideline changes, the results of this study suggest paediatric muscular fitness requires continued encouragement.

This study captured two time points, making it possible to determine absolute linear change rather than exact pattern and timing of the secular change. Strengths of this approach included secular changes being examined: i) using similar standing long jump protocols collected by trained measurement teams; ii) in two samples controlled for age, sex, body size and area-level SES related differences in standing long jump; and iii) across two random national samples that were broadly representative of their source population at each time point. Therefore, irrespective of the pattern of change, our analysis provides a good approximate of the overall magnitude of change between 1985 and 2015.

Study limitations include concurrent secular trends in biological maturation, which today is reached earlier (Bellis, Downing, & Ashton, 2006; Herman-Giddens, 2006). Therefore, children aged 11−12-years in 2015 were possibly more biologically advanced than children aged 11−12-years in 1985, which theoretically would favour children of the same chronological age in 2015. As standing long jump performance increases with age, an age-related *improvement* in jumping performance is expected based on earlier biological maturation alone. However, our results show a *decline* in jumping performance between 1985 and 2015, with this decline potentially underestimating the true effect. A conservative pubertal advancement of three months per decade would equate to a nine-month advancement over 30 years. Based on previously defined normative data for Australian adolescents (Catley and Tomkinson, 2011), the magnitude of this underestimation could be estimated as approximately 5 cm for males and 4 cm for females.

Additional limitations include the inability to examine what effect changes in ethnic distribution and motor competence/ability had on jumping performance, as these data were not available at both time points, and our conclusions being based on results from only one measure of muscular fitness. However, the standing long jump test is commonly used in field settings and is a good surrogate measure of overall muscular fitness, demonstrating very good test-retest reliability (Fernandez-Santos, et al., 2015; Ortega, et al., 2008a) and good construct validity (Castro-Pinero et al., 2010a; Milliken, et al., 2008). Moreover, under-representation of the most disadvantaged could have potentially introduced bias and limited generalisability. Further, different sampling approaches were used to recruit participants in 1985 and 2015. This could partly explain the observed secular decline in jumping performance; however, when analyses were repeated considering sampling weights, weighting did not appreciably change the effect estimates shown.

In conclusion, there has been a moderate decline in the jumping performance of Australian children aged 11−12-years between 1985 and 2015. Notwithstanding the limitations outlined, this study provides the most up-to-date analysis of secular changes in the jumping performance of Australian children aged 11−12-years over a 30-year period from 1985 to 2015, extending the end of the previous temporal picture from 2002 to 2015. Growing recognition of the benefits of muscular fitness in children and adolescents highlights the importance of efforts to promote it and to reverse this decline.

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Declaration of interest statement

The authors declare no conflict of interest.

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Figure Legends

Figure 1. Distribution of standing long jump (cm) percentile values for Australian children aged 11–12-years in 1985 and 2015, adjusted for age, sex and body mass.

Tables

Table 1. Characteristics of participants.

	ASHFS 1985			CheckPoint 2015		
		Male	Female		Male	Female
Characteristic	n	Statistic*	Statistic*	n	Statistic*	Statistic*
Age, years	1967	11.5 (0.5)	11.5 (0.5)	1765	11.5 (0.5)	11.5 (0.5)
Standing long jump, cm	1967	151.3 (21.2)	142.9 (20.8)	1765	137.7 (23.4)	131.2 (22.2)
Standing long jump not attributable to body mass, cm	1966	151.5 (23.9)	141.9 (22.0)	1764	133.5 (28.4)	127.0 (24.6)
Height, cm	1966	148.7 (8.0)	150.2 (7.9)	1764	153.3 (8.2)	154.3 (7.8)
Body mass, kg	1966	40.9 (8.9)	42.0 (8.7)	1764	44.9 (10.6)	46.3 (10.2)
BMI, kg/m^2	1965	18.4 (2.8)	18.5 (2.7)	1764	19.0 (3.4)	19.3 (3.4)
BMI categories						
Normal	1731	862 (87.1)	869 (89.1)	1363	701 (78.3)	662 (76.2)
Overweight	192	102 (10.3)	90 (9.2)	321	152 (17.0)	169 (19.5)

Obese	42	26 (2.6)	16 (1.6)	80	42 (4.7)	38 (4.4)
Waist circumference, cm	1966	65.9 (8.2)	64.0 (7.5)	1763	66.8 (8.6)	65.2 (8.0)
Fat-free mass, kg	974	34.4 (5.5)	32.9 (4.9)	1435	34.9 (6.2)	34.8 (5.6)
Fat mass, kg	974	8.4 (4.6)	11.4 (4.2)	1754	9.7 (6.6)	11.3 (6.2)
ASHFS socioeconomic status coding, %	1876					
High		223 (23.9)	236 (25.1)			
Medium-high		275 (29.4)	264 (28.1)			
Medium-low		356 (38.1)	351 (37.3)			
Low		81 (8.7)	90 (9.6)			
CheckPoint socioeconomic status coding, %				1761		
Least disadvantaged					324 (36.3)	295 (34.0)
2nd Least disadvantaged					201 (22.5)	211 (24.3)
Middle					159 (17.8)	171 (19.7)
2nd Most disadvantaged					132 (14.8)	127 (14.6)
Most disadvantaged					77 (8.6)	64 (7.4)

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*Mean and standard deviation for continuous variables and n (%) for categorical variables.

Abbreviations: ASHFS, Australian Schools Health and Fitness Survey; BMI, body mass index; CheckPoint, Child Health CheckPoint study.

Table 2. Secular changes in jumping performance between 1985 and 2015*.

		Model 1†			Model 2‡		
Sex	n	β (95% CI)	SE	*p*	β (95% CI)	SE	*p*
Combined							
	3730	−16.4 (−18.0, −14.8)	0.8	*<0.001*	−11.1 (−12.5, −9.7)	0.7	*<0.001*
Males							
	1886	−18.0 (−20.4, −15.6)	1.2	*<0.001*	−12.0 (−14.0, −10.0)	1.0	*<0.001*
Females							
	1844	−14.8 (−17.0, −13.0)	1.1	*<0.001*	−10.4 (−12.4, −8.4)	1.0	*<0.001*

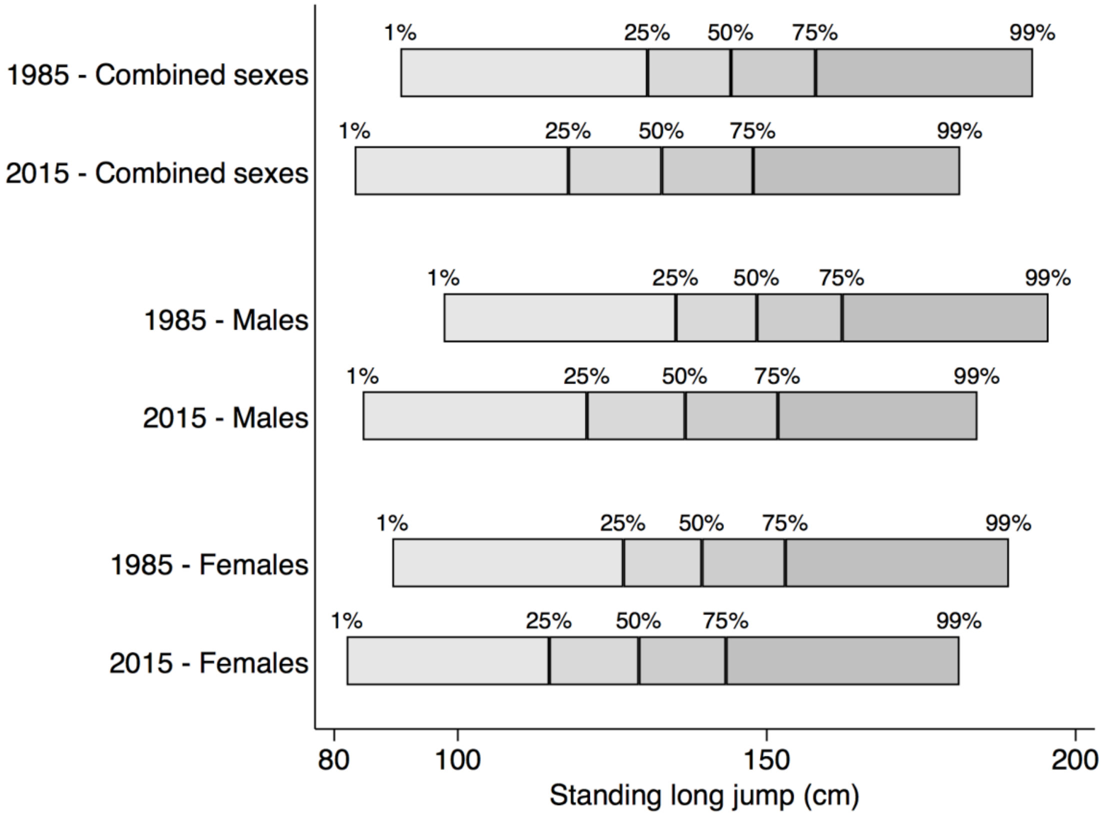
* Beta coefficients, 95% CI and standard errors are expressed in cm.

† Model 1 adjusted for age and sex (sex combined) or adjusted for age (sex stratified).

‡ Model 2 adjusted for Model 1 covariates and body mass.

Abbreviations: β, Beta coefficient; CI, confidence intervals; SE, standard error.

Figures


1985 - Combined sexes
2015 - Combined sexes
1985 - Males
2015 - Males
1985 - Females
2015 - Females
1%
25%
50%
75%
99%
80
100
150
200
Standing long jump (cm)

Online-only supplement

Table S1. Secular changes in jumping performance distributional characteristics between 1985 and 2015*.

	Combined (n=3730)						Males (n=1886)						Females (n=1844)					
	Model 1†			Model 2‡			Model 1†			Model 2‡			Model 1†			Model 2‡		
Percentile	β (95% CI)	SE	*p*	β (95% CI)	SE	*p*	β (95% CI)	SE	*p*	β (95% CI)	SE	*p*	β (95% CI)	SE	*p*	β (95% CI)	SE	*p*
P_1	−27.0 (−34.7, −19.4)	3.9	*<0.001*	−7.4 (−14.5, −0.3)	3.6	*0.04*	−27.5 (−45.4, −9.6)	9.1	*0.003*	−13.1 (−21.8, −4.5)	4.4	*0.003*	−26.1 (−33.8, −18.4)	3.9	*<0.001*	−7.4 (−16.0, 1.2)	4.4	*0.09*
P_5	−21.4 (−26.0, −16.8)	2.3	*<0.001*	−12.4 (−15.7, −9.2)	1.7	*<0.001*	−26.0 (−34.4, −17.7)	4.3	*<0.001*	−13.4 (−18.2, −8.6)	2.5	*<0.001*	−19.4 (−24.4, −14.3)	2.6	*<0.001*	−11.0 (−15.0, −7.0)	2.0	*<0.001*
P_{10}	−20.5 (−23.7, −17.3)	1.6	*<0.001*	−12.5 (−14.8, −10.1)	1.2	*<0.001*	−22.0 (−27.3, −16.8)	2.7	*<0.001*	−12.6 (−16.4, −8.9)	1.9	*<0.001*	−18.6 (−23.1, −14.1)	2.3	*<0.001*	−12.8 (−16.0, −9.6)	1.6	*<0.001*

P_{20}	−19.6 (−22.2, −16.9)	1.3	*<0.001*	−13.2 (−15.2, −11.2)	1.0	*<0.001*	−20.9 (−24.9, −16.8)	2.0	*<0.001*	−15.1 (−17.7, −12.5)	1.3	*<0.001*	−17.9 (−21.1, −14.6)	1.7	*<0.001*	−11.6 (−15.0, −8.1)	1.8	*<0.001*
P_{25}	−19.8 (−22.3, −17.4)	1.3	*<0.001*	−12.9 (−14.8, −10.9)	1.0	*<0.001*	−21.8 (−25.7, −18.0)	2.0	*<0.001*	−14.4 (−17.1, −11.7)	1.4	*<0.001*	−18.6 (−21.7, −15.5)	1.6	*<0.001*	−12.0 (−15.0, −8.9)	1.6	*<0.001*
P_{50}	−16.2 (−17.9, −14.4)	0.9	*<0.001*	−11.2 (−13.0, −9.4)	0.9	*<0.001*	−18.1 (−20.8, −15.5)	1.3	*<0.001*	−11.5 (−14.2, −8.9)	1.3	*<0.001*	−14.1 (−16.5, −11.7)	1.2	*<0.001*	−10.2 (−12.8, −7.6)	1.3	*<0.001*
P_{75}	−13.8 (−16.0, −11.7)	1.1	*<0.001*	−10.1 (−11.9, −8.3)	0.9	*<0.001*	−14.6 (−17.8, −11.6)	1.5	*<0.001*	−10.3 (−12.7, −7.9)	1.2	*<0.001*	−12.4 (−15.3, −9.6)	1.5	*<0.001*	−9.6 (−12.2, −7.0)	1.3	*<0.001*
P_{80}	−13.1 (−15.1, −11.2)	1.0	*<0.001*	−9.6 (−11.6, −7.6)	1.0	*<0.001*	−14.1 (−16.9, −11.3)	1.4	*<0.001*	−11.0 (−14.0, −8.1)	1.5	*<0.001*	−12.2 (−14.8, −9.5)	1.4	*<0.001*	−9.5 (−12.6, −6.4)	1.6	*<0.001*
P_{90}	−12.1 (−14.5, −9.8)	1.2	*<0.001*	−9.2 (−11.7, −6.8)	1.3	*<0.001*	−13.2 (−16.7, −9.7)	1.8	*<0.001*	−7.7 (−10.9, −4.6)	1.6	*<0.001*	−12.0 (−15.9, −8.0)	2.0	*<0.001*	−8.6 (−12.3, −5.0)	1.9	*<0.001*

P_{95}	−10.8 (−13.6, −8.0)	1.4	*<0.001*	−7.6 (−11.0, −4.3)	1.7	*<0.001*	−11.4 (−15.2, −7.6)	1.9	*<0.001*	−8.0 (−12.4, −3.6)	2.2	*<0.001*	−9.6 (−14.0, −5.2)	2.2	*<0.001*	−9.6 (−14.7, −4.5)	2.6	*<0.001*
P_{99}	−13.0 (−18.6, −7.4)	2.9	*<0.001*	−11.8 (−17.0, −6.6)	2.6	*<0.001*	−10.2 (−17.6, −2.7)	3.8	*0.007*	−11.6 (−18.0, −5.1)	3.3	*<0.001*	−14.2 (−23.9, −4.4)	5.0	*0.004*	−7.9 (−15.9, 0.0)	4.1	*0.05*

* Beta coefficients, 95% CI and standard errors are expressed in cm.

† Model 1 adjusted for age and sex (sex combined) or adjusted for age (sex stratified).

‡ Model 2 adjusted for Model 1 covariates and body mass.

Abbreviations: β, Beta coefficient; CI, confidence intervals; SE, standard error.

Table S2. Standing long jump (cm) percentile values by sex for Australian adolescents in 1985 and 2015, adjusted for age, sex and body mass.

Sex	P_1	P_5	P_{10}	P_{20}	P_{25}	P_{50}	P_{75}	P_{80}	P_{90}	P_{95}	P_{99}
Combined											
1985	90.7	109.3	117.3	127.4	130.7	144.2	157.9	161.1	170.7	177.8	193.1
2015	83.3	96.8	104.9	114.2	117.9	133.0	147.8	151.5	161.5	170.1	181.3
Difference	−7.4	−12.5	−12.4	−13.2	−12.8	−11.2	−10.1	−9.6	−9.2	−7.7	−11.8
Males											
1985	97.7	114.0	122.2	132.1	135.3	148.4	162.2	166.0	174.4	181.0	195.6
2015	84.6	100.0	109.6	117.0	120.9	136.8	151.8	154.9	166.6	173.0	184.1
Difference	−13.1	−14.0	−12.6	−15.1	−14.4	−11.6	−10.4	−11.1	−7.8	−8.0	−11.5
Females											
1985	89.4	105.1	113.6	122.5	126.8	139.5	153.0	156.6	166.1	174.5	189.2
2015	82.0	94.1	100.8	110.9	114.8	129.3	143.4	147.1	157.5	164.8	181.2
Difference	−7.4*	−11.0	−12.8	−11.6	−12.0	−10.2	−9.6	−9.5	−8.6	−9.7	−8.0*

* Difference in standing long jump distance was not statistically significant ($p>0.05$)

Table S3. Secular changes in jumping performance between 1985 and 2015, adjusted for changes in different body composition measures*.

		Model 1†			Model 2 (additionally adjusted for height)		
Sex	n	β (95% CI)	SE	*p*	β (95% CI)	SE	*p*
Combined	3729	−16.4 (−18.0, −14.8)	0.8	<*0.001*	−13.3 (−14.6, −11.9)	0.8	<*0.001*
Males	1885	−18.0 (−20.4, −15.6)	1.2	<*0.001*	−15.0 (−16.9, −13.1)	1.2	<*0.001*
Females	1844	−14.8 (−17.0, −12.7)	1.1	<*0.001*	−11.7 (−13.6, −9.8)	1.1	<*0.001*
		Model 1†			Model 2 (additionally adjusted for body mass index)		
	n	β (95% CI)	SE	*p*	β (95% CI)	SE	*p*
Combined	3729	−16.4 (−18.0, −14.8)	0.8	<*0.001*	−14.5 (−16.2, −12.9)	0.7	<*0.001*
Males	1885	−18.0 (−20.4, −15.6)	1.2	<*0.001*	−15.2 (−17.6, −12.7)	0.9	<*0.001*
Females	1844	−14.8 (−17.0, −12.7)	1.1	<*0.001*	−13.8 (−16.1, −11.6)	1.0	<*0.001*
		Model 1†			Model 2 (additionally adjusted for waist circumference)		
	n	β (95% CI)	SE	*p*	β (95% CI)	SE	*p*
Combined	3728	−16.5 (−18.1, −14.9)	0.8	<*0.001*	−14.6 (−15.9, −13.3)	0.7	<*0.001*

Males	1885	−18.1 (−20.4, −15.7)	1.2	*<0.001*	−16.2 (−18.1, −14.4)	0.9	*<0.001*
Females	1843	−14.9 (−17.0, −12.7)	1.1	*<0.001*	−13.0 (−14.9, −11.2)	1.0	*<0.001*

		Model 1†			Model 2 (additionally adjusted for fat-free mass)		
	n	β (95% CI)	SE	*p*	β (95% CI)	SE	*p*
Combined	2409	−17.9 (−20.4, −15.5)	1.3	*<0.001*	−14.9 (−17.3, −12.4)	1.3	*<0.001*
Males	1204	−19.2 (−22.9, −15.5)	1.9	*<0.001*	−16.5 (−20.1, −12.9)	1.8	*<0.001*
Females	1205	−16.6 (−19.9, −13.3)	1.7	*<0.001*	−13.6 (−16.9, −10.2)	1.7	*<0.001*

		Model 1†			Model 2 (additionally adjusted for fat mass)		
	n	β (95% CI)	SE	*p*	β (95% CI)	SE	*p*
Combined	2728	−18.1 (−20.4, −15.8)	1.2	*<0.001*	−15.6 (−17.4, −13.8)	0.9	*<0.001*
Males	1376	−18.9 (−22.3, −15.4)	1.8	*<0.001*	−15.0 (−17.5, −12.5)	1.3	*<0.001*
Females	1352	−17.4 (−20.5, −14.3)	1.6	*<0.001*	−16.0 (−18.5, −13.5)	1.3	*<0.001*

* Beta coefficients, 95% CI and standard errors are expressed in cm.

† Model 1 adjusted for age and sex (sex combined) or adjusted for age (sex stratified).

Abbreviations: β, Beta coefficient; CI, confidence intervals; SE, standard error.