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Temporal Trends In The Standing Broad Jump Test Performance Of United States Children And Adolescents

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TEMPORAL TRENDS IN THE STANDING BROAD JUMP TEST PERFORMANCE OF UNITED STATES CHILDREN AND ADOLESCENTS

by

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07/25/2019

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Muscular fitness is a very important indicator of health. Using a systematic review strategy, the aim of this study was to estimate the temporal trends in broad jump performance of United States youth. Broad jump data on apparently healthy United States youth (aged 10–17 years) were located through a systematic electronic database search and by pearling reference lists, topical systematic reviews and personal libraries. Sample-weighted temporal trends (expressed as percent and standardized trends) were estimated for separate age-sex groups using best-fitting regression models relating the year of testing to mean jump performance. Mean trends standardized to the year 1985 were calculated using a post-stratified population-weighting procedure. Data from 12 studies comprising 16 unique datasets were used to estimate trends for 65,527 United States youth between 1911 and 1990. Collectively, there was a small improvement in broad jump performance of 7.9% (95%CI: 7.1 to 8.6) or 1.0% per decade (95%CI: 0.9 to 1.1). Improvements were observed for all sex and age groups, with improvements substantially larger for girls than for boys, and similar for children (10–12 years) and adolescents (13–17 years). Improvements in broad jump performance were not always uniform across time, with steady improvements observed for boys, a diminishing in the rate of improvement observed for girls and adolescents, and an increasing rate of improvement observed for children. Given that muscular fitness is a good marker of health, and that the broad jump is a practical, feasible, and scalable marker of muscular fitness, then the

broad jump should be routinely assessed to screen and monitor the health and muscular fitness of United States youth.

INTRODUCTION

Physical fitness is an important marker of general health (Ortega et al 2008; Ross et al 2016; Ross et al 2017). Although cardiorespiratory fitness has long been considered a powerful marker of health, the importance of muscular fitness (MF) to health has only recently emerged, with the majority of the literature available for adults. In adults, MF is significantly associated with risk of all-cause, cardiovascular and non-cardiovascular mortality (Leong et al 2015), stroke (Aberg 2015), diabetes (Mainous et al 2015), disability (Phillips and Haskell 1995), falls risk (Chan et al 2006), cognition (Alfaro-Acha et al 2006), and functional capability (McGrath et al 2018). Although less is known, MF appears to be linked to both current and future health in youth. In a meta-analysis, Smith et al (2014) reported that higher levels of MF in childhood and adolescence were associated with higher self-esteem, improved bone health, lower levels of body fat, and reduced cardiometabolic risk. High levels of youth MF are also significantly associated with reduced adiposity, reduced cardiometabolic risk, and improved bone health in later life (Garcia-Hermoso et al 2019). In a cohort of over one million males with a median follow-up of 24 years, Ortega et al (2012) found higher MF in adolescence were associated with a 20–35% risk reduction in cardiovascular, suicide and all-cause mortality, with adolescents falling below the tenth percentile for MF being at the greatest risk for all-cause mortality.

MF has multiple components (strength, power/explosive strength and endurance) and its assessment is a task-specific evaluation of the motor system (neural and muscle function). Generally defined, muscular strength is the ability to generate maximal force on a single occasion; muscular power is the rate at which work is performed; and muscular endurance is the ability to repeatedly generate force (ACSM 2018). Muscular fitness has been evaluated in a variety of ways and the National Academy of Medicine (formerly known as the Institute of Medicine), as well as European experts (Ruiz et al 2011), has recommended the handgrip strength and broad jump for school-based fitness testing because of their health-related predictive utility (Institute of Medicine 2012). Jumping performance has been commonly employed to assess youth power/explosive strength, has been meaningfully linked to health, and is consistently related to vigorous physical activity levels (Smith et al 2019). The consistent relationship between jumping performance and physical activity is likely due to correspondence: jumping, leaping and running are natural movements commonly performed during children's leisure time activity and physical education. In addition, jumping tests are highly reliable (Docherty 1996), moderately to highly valid (Castro-Pinero et al 2010; Milliken et al 2008), and scalable for school-based fitness testing. Thus, jumping performance seems a good fit for tracking temporal trends in youth MF and for determining the efficacy of public health efforts to improve youth MF.

Temporal trends in the MF of United States youth have largely focused on handgrip strength, with trends spanning 110 years over the period 1899–2009 (Espenchade and Meleney 1961; Hunsicker and Reiff 1977; Malina 1978; Montpetit et al 1967; Reiff et al 1986; Silverman 2011; Silverman 2015). While much less is known about trends in broad jump performance of United States youth, the most comprehensive analysis to date suggests that broad jump performance improved over the last part of the 20th century (Tomkinson 2007). In a systematic analysis of 20.8 million youth (aged 6–19 years) from 23 countries, Tomkinson (2007) indicated that broad jump performance improved at 2.6% per decade between 1970 and 1989 in 39,937 North American (Canadian and United States) youth. This study provides a 12-year update of the comprehensive review by Tomkinson (2007), restricted to United States youth. Using a systematic review approach, the aim of this study is to estimate the temporal trends in the broad jump performance of United States youth. It was hypothesized that broad jump performance had improved over time.

METHODS

Protocol and Registration

The protocol for the systematic review was registered with the International Prospective Register of Systematic Reviews (PROSPERO; registration number: CRD42019125072). The Preferred Reporting Items for Systematic review and Meta-Analysis Protocols 2015 (PRISMA-P 2015) was followed for this systematic review (Moher et al 2015).

Eligibility Criteria

Studies reporting descriptive statistics (sample sizes, means, and/or standard deviations) for apparently healthy (no known disease, signs/symptoms of disease, or injury) United States youth (aged 10–17 years) tested on the broad jump tests were included. Descriptive statistics must have been reported at the age-sex-year level (e.g., 10-year-old boys tested in 1975). Broad jump performance was operationalized as a standing horizontal double-legged jump for the greatest possible distance.

Information Sources

An electronic database search was performed on the 27th of November 2018, using SPORTDiscus, CINAHL, and MEDLINE without date or language restrictions. The search strategy was developed in consultation with an academic librarian experienced in systematic review searching. Additional studies were located by pearling the reference lists of the included studies, topical systematic reviews, and the personal library of one of my advisors.

Search Strategy

The electronic database search was restricted to keywords, abstract, and title. The Boolean OR was used to combine terms within a group, and the Boolean AND was used to combine search groups. Proximity operators were used to search for root words. Three search groups were used: the first described the fitness measure ("musc* fitness" OR "musc* strength" OR "musc* power" OR "jump*"); the second described the population ("child*" OR "adolescen*" OR "boy*" OR "girl*" OR "youth"); and the third described the geographical location ("America*" OR "U.S.*"). The full search strategies for each database are shown in Appendix 1.

Study Selection

Database records were imported into RefWorks (v2.0; ProQuest LLC, Ann Arbor, MI, USA) and de-duplicated. At the first level, two researchers independently screened the titles and abstracts against inclusion criteria, with consensus required for further screening. At the second level, full text copies were obtained and independently screened by two researchers against inclusion criteria, with consensus required for final inclusion. A third researcher resolved discrepancies if consensus was not reached.

Data Collection Process

Descriptive data were extracted into Excel (Microsoft Corp., Redmond, WA, USA) using a pre-determined template (Tomkinson et al 2019) and reviewed by a second researcher for accuracy. Email contact was made with corresponding authors if additional information was required (e.g., to clarify published results).

Data Items

The following study-specific descriptive data were extracted: author, sampling frame (national, state/regional, or other [city/district/school]), sampling method (probability or non-probability), year of testing, sex, age (calendar age), broad jump test protocol, sample size, mean, standard deviation, and/or median. All mean, standard deviation and median data were converted to the common metric of centimeters. Testing year was recorded as the midpoint year of testing (e.g., 1975.5 was recorded as the measurement year for a study that reported testing children in 1975), with two years prior to the publication year assumed for studies when missing, as this was the median difference for those studies in which the testing year was known.

Missing means were estimated from the reported medians using the equation: $mean=0.978\times median+3.209$, where $r=0.997$ and $SEE=1.7$. This equation was generated by first locating all studies reporting both medians and means at the sex-age-year level and second, by determining the best-fitting and most parsimonious linear or curvilinear (second-order and third-order polynomials) regression models between median (predictor variable) and mean (response variable) values. Missing standard deviations were estimated from sample-weighted mean coefficient of variation of 15.2% (Tomkinson et al 2018). This sample-weighted mean coefficient of variation was estimated by first locating all studies reporting both means and standard deviations at the sex-age-year level; second, by calculating the corresponding sex-age-year coefficients of variation; and third, by calculating the sample-weighted mean coefficient of variation.

Summary Measures and Synthesis of Results

Temporal trends were analyzed at the sex-age level using best-fitting sample-weighted linear or polynomial (quadratic or cubic) regression models relating the year of testing to mean broad jump performance (Lamoureux et al 2019; Tomkinson et al 2019). Trends in mean broad jump performance were expressed as percent changes (i.e., change in means expressed as a percentage of the overall mean) and as standardized effect sizes (ES) (i.e., change in means divided by the pooled standard deviation). ES of 0.2, 0.5, and 0.8 were used as thresholds for small, moderate, and large, respectively, with ES<0.2 considered to be negligible and ES≥0.2 considered to be meaningful. Positive trends indicated increases in mean broad jump performance and negative trends indicated declines in mean broad jump performance.

National temporal trends (for boys, girls, children [10–12 year-olds], adolescents [13–17 year-olds] and all [10–17 year-old boys and girls]) were calculated using a post-stratified population-weighting procedure that has been described in detail elsewhere (Lamoureux et al 2019; Tomkinson et al 2019). Population estimates were standardized to the year 1985—a common testing year to all sex-age groups—using United Nations (2019) data. The post-stratification population-weighting procedure helped to correct the national trends for systematic bias associated with over- and under-sampling and to standardize the trends to underlying country-sex-age-specific demographics. National trends were also examined for non-uniformity by: (a) using the D_{max} method (Cheng et al 1992) to locate a breakpoint; (b) fitting linear regression models to data points before and after the breakpoint; and (c) comparing the resultant linear trends.

RESULTS

Study Selection

A total of 828 unique records were obtained from the electronic database search, with 23 retained after the first level of screening (title and abstract review) and 1 retained after the second level of screening (full-text review) (Figure 1). An additional 11 studies were identified the pearling of reference lists, topical systematic reviews, and personal libraries, resulting in a total of 12 studies which represented 16 unique datasets.

Study Characteristics

Broad jump data were available on 62,527 United States youth (34,569 boys and 27,957 girls) aged 10–17 years between 1911 and 1990 (Table 1). Data were available for 180 sex-age-year groups, with an average sample size of 347 per group.

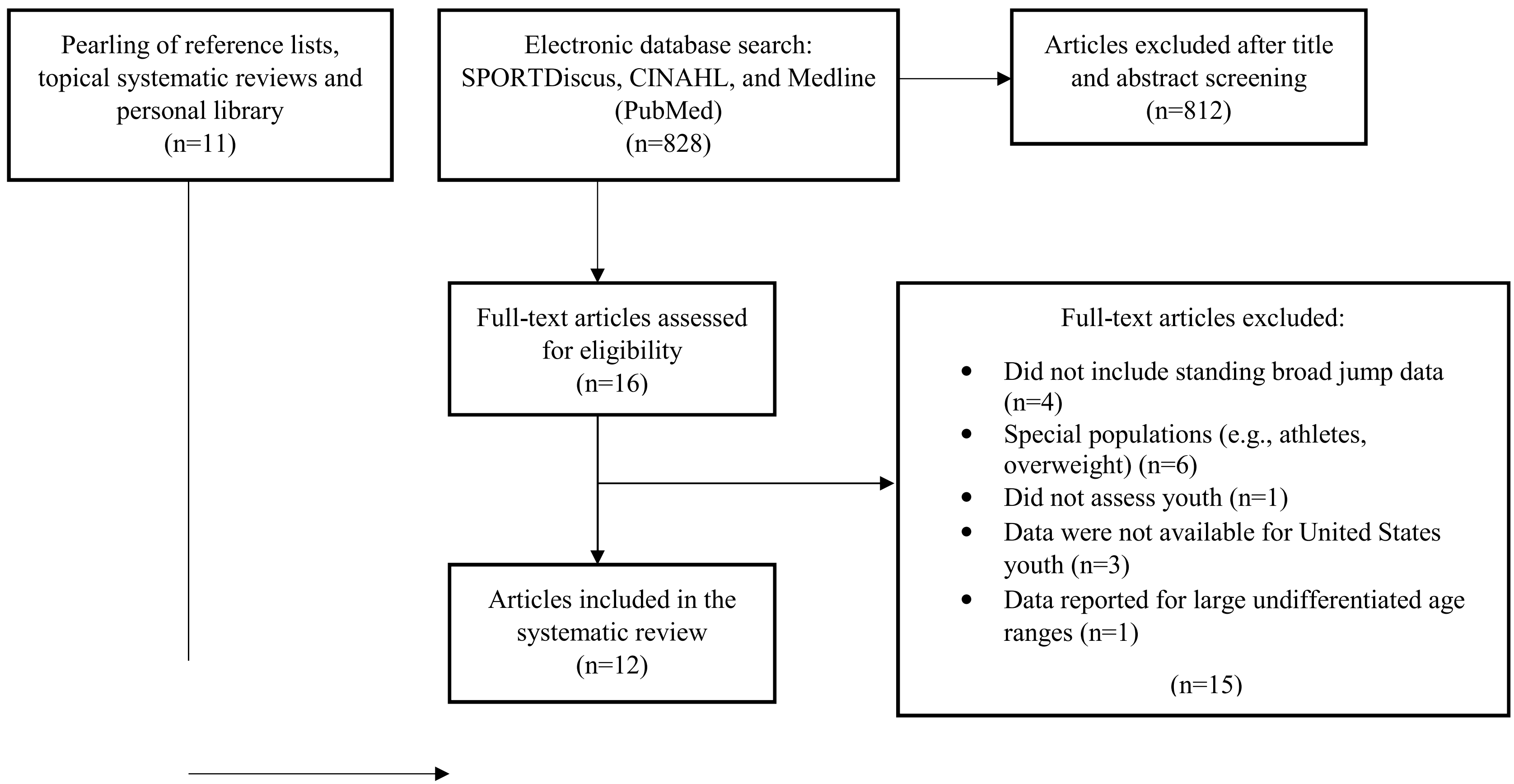

Figure 1. PRISMA flow chart outlining the flow of studies through the review.

Table 1. Description of the studies included in the systematic review.

Study	Sampling strategy	Sample base	Year of testing	Sex	Age (years)	Sample size
Chase (cited in Bos, 1961)	NP	O	1911	F (30%) M (70%)	10–15	188
Richards (cited in Bos, 1961)	NP	O	1914	M	10–16	308
Bovard (cited in Bos, 1961)	NP	O	1916	F (50%) M (50%)	10–16	7,924
Dunbar (cited in Bos, 1961)	NP	O	1925	M	10–15	960
Espenchade (1960)	NP	O	1934, 1937	F (49%) M (51%)	13	159
Espenchade (cited in Bos, 1961)	NP	O	1937	F (50%) M (50%)	13–16	664
Hunsicker & Reiff (1977)	P	N	1958	F (47%) M (53%)	10–17	8,254
Espenchade (1960)	NP	O	1958, 1959	F (54%) M (46%)	13	262
Fleishman (1964)	NP	N	1961	F (38%) M (62%)	13–17	13,334
Ikeda (1961)	NP	S	1961	F (50%) M (50%)	10–12	266
Hunsicker & Reiff (1977)	P	N	1965	F (49%) M (51%)	10–17	9,503
Weber (1969)	P	S	1965	F (42%) M (58%)	12–14	2,809
Katzmarzyk (1997)	NP	O	1966	F (49%) M (51%)	10–12	370
Corroll (1967)	NP	O	1967	M	11	100
Brogdon (1972)	P	S	1971	M	10, 11	300
Hunsicker & Reiff (1977)	P	N	1975	F (49%) M (51%)	10–17	7,262
Robbins (1984)	NP	S	1983	F (49%) M (51%)	10–17	1,288
Reiff et. al (1986)	P	N	1985	F (49%) M (51%)	10–17	8,412
Koebel (1992)	NP	O	1990	F (34%) M (66%)	10–15	164

Note: P= Probability sampling; NP= Non-probability sampling; N=National sample; S=State/regional sample; O=Other sample (e.g., city, district, or school level); M=Male; F=Female.

Synthesis of results

Overall trend

Collectively, there was a small improvement in mean broad jump performance between 1911 and 1990 (change in means [95% CI]: 7.9% [7.1 to 8.7]; ES 0.49 [0.46 to 0.53]) (Figure 2). Figure 2 (bottom panel) suggests that the national rate of improvement slowed in the latter decades. This was confirmed by D_{max} analysis which located a breakpoint at 1965, with rates of improvement pre-1965 (change in means [95% CI]: 1.1% per decade [1.0 to 1.2]) nearly double those post-1965 (change in means [95% CI]: 0.6% per decade [0.5 to 0.7]).

Trends in Children and Adolescents

There was a negligible difference in the trends between children and adolescents, with a moderate improvement in children (change in means [95% CI]: 8.2% [7.4 to 9.0]; ES 0.52 [0.44 to 0.59]) and a small improvement in adolescents (change in means [95% CI]: 7.8% [7.1 to 8.6]; ES 0.49 [0.41 to 0.57]) (Figure 2). Despite similar magnitudes of improvement, Figure 2 (middle panels) suggests an increasing rate of improvement in children and a decreasing rate of improvement in adolescents. D_{max} analysis located breakpoints at 1950 and 1959 for children and adolescents respectively, with rates of improvement increasing 2-fold after 1950 in children (change in means [95% CI]: pre-1950, 0.7% per decade [0.5 to 0.9]; post-1950, 1.4% per decade [1.3 to 1.5]) and decreasing 4-fold after 1959 in adolescents (change in means [95% CI]: pre-1959, 1.3% per decade [1.2 to 1.4]; post-1959, 0.3% per decade [0.1 to 0.5]).

Trends in Boys and Girls

There was a small difference in the trends between boys and girls, with a moderate improvement in girls (change in means [95% CI]: 11.4% [10.7 to 12.2]; ES 0.72 [0.64 to 0.79]) and a small improvement in boys (change in means [95% CI]: 4.6% [3.8 to 5.4]; ES 0.29 [0.21 to 0.37]) (Figure 2). Despite a 2.5-fold difference in the magnitudes of improvement, Figure 2 (top panels) suggests a steady improvement over time in boys and a slowing of the rate of improvement in girls. D_{max} analysis located breakpoints at 1968 and 1963 for boys and girls respectively, with no significant difference in rates of improvement pre- and post-1968 in boys (change in means [95% CI]: pre-1968, 0.6% per decade [0.5 to 0.7]; post-1968, 0.4% per decade [0.2 to 0.6]), yet a 2-fold decrease after 1963 in girls (change in means [95% CI]: pre-1963, 1.6% per decade [1.5 to 1.7]; post-1963, 0.8% per decade [0.6 to 1.0]).

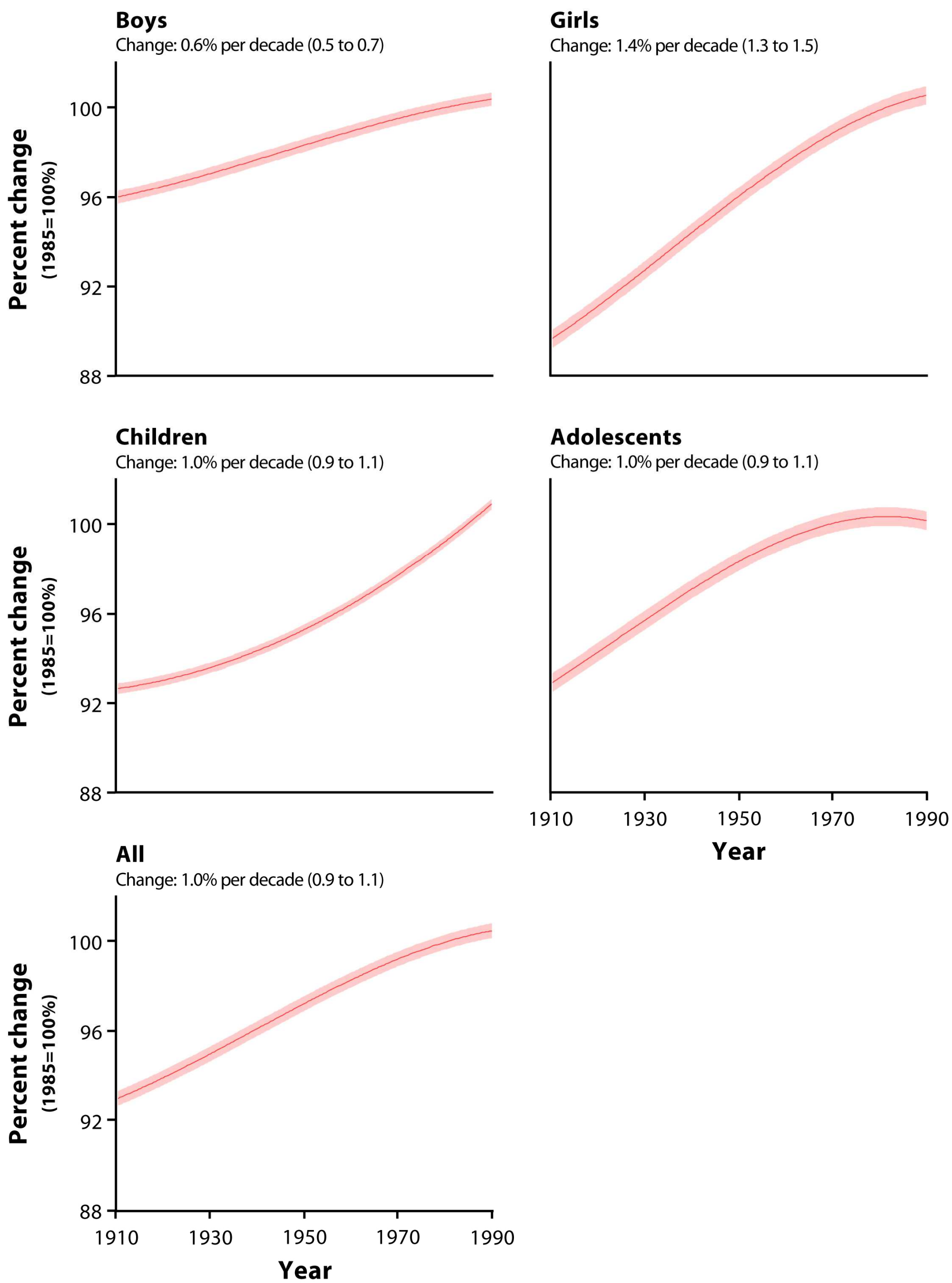

Figure 2. Trends in mean broad jump performance of United States youth (1911–1990).

Note: data were standardized to the year 1985=100%, with higher values (>100%) indicating better broad jump performance and negative values (<100%) indicating poorer broad jump performance; the solid lines represent the national trends and the shaded areas represent the 95% CIs; upward sloping line indicated improvements and downward sloping lines indicate declines; mean (95%CI) percent changes (per decade) are shown at the top of each panel.

DISCUSSION

This systematic analysis examined temporal trends in the broad jump performance of United States youth over the 79-year period from 1911 to 1990 and found: (a) a small national improvement in broad jump performance; (b) similar improvements in children and adolescents; (c) a 2.5-fold larger improvement in girls than in boys; and (d) generally non-uniform improvements over time. The absence of broad jump data after 1990, combined with its health-related predictive utility, underscore the need for national surveys to reintroduce the broad jump test to assess current trends in United States youth. These data could be used to inform policy-making and public health planning.

Muscular Fitness Trends

While numerous studies have recently reported on temporal trends in youth broad jump performance (Australia [Fraser et al 2018]; Greece [Smpokos et al 2012]; Lithuania [Venckunas et al 2017]; New Zealand [Albon et al 2010]; Poland [Ignasiak et al 2016]; Spain [Moliner-Urdiales et al 2010]; UK [Sandercock and Cohen 2019]) the most comprehensive study to date was a large systematic analysis of over 20 million youth from 23 countries (Tomkinson 2007). Tomkinson's systematic analysis indicated a very small international improvement of 0.3% per decade between 1958 and 2003, although the trend was not uniform over time, with performances improving from the late 1950s to the mid 1980s and declining thereafter. The trend for North American youth was considerably larger than the international trend — 2.6% vs. 0.3% improvement per decade, respectively. By way of comparison, between 1958 and 1990, the present study observed a collective improvement of 0.7% per decade. The temporal difference between the present study and that of the North American youth in Tomkinson (2007) could be because: (a) the North American trend in Tomkinson (2007) was generated using data on both Canadian and United States youth aged 6–17 years whereas this study used only data on United States youth aged 10–17 years; and (b) because Tomkinson (2007) included only studies that explicitly reported on temporal trends in broad jump performance whereas this study included studies that reported on broad jump performance even if measured on a single occasion.

Maturation

Advances in maturation likely contributed to the increased MF observed in this study. Changes in body size, shape and composition occur throughout maturation (Rogol et al 2000) and modify performance on MF assessments. It appears the timing of this process, which is influenced by genetic, endocrine and environmental factors (Ozen and Darcan 2011) has shifted to an earlier chronological age. Data suggest that maturation is advancing at a rate of about 2 and 4 months per decade for boys (the age boys' voices break) and girls (age of menarche), respectively (Cole, 2000). Thus, a 13-year-old boy in 1911 would be maturationally similar to a 12-year-old in 1990 and a 13-year-old girl would be maturationally similar to a 10.5-year-old in 1990. Since calendar age was used to establish temporal trends in this study, the divergence of chronological and biological age likely contributed to the overall trend for increase MF, the increased magnitude of change for girls compared to boys and the temporal differences between children and adolescents.

Body size, which includes height and mass, has also been shown to increase over time (Karpati et al 2002). On average, height has increased approximately 1.5 and 2.5 centimeters per decade for children and adolescents respectively, between 1880 and 1980 in Europe and North America (Hauspie et al 1997). The long bones, which consist of the arms and the legs, are known to grow first during a pubertal growth spurt (Cole 2000). Although not population specific, evidence exists suggesting increased leg length as the primary contributor to observed height increases (Malina 2004). Given the nature of broad jump performance, increased height and associated leg length may afford an advantage by increasing takeoff and landing horizontal displacement, independent of displacement during the flight phase. This mechanical advantage may have contributed to the trends of increased MF over time.

Until the latter years, youth body mass, relative to height, appears to have remained fairly stable. Using the National Health and Nutrition Examination Survey among United States youth, (Ogden et al 2002) reported the prevalence of overweight to have increased by 7% in 6–11 year olds and by 6% in 12–19 year olds from the 1960s to 1988–94. However, the majority of the increase in the prevalence of overweight occurred after 1976–80 (Malina 2004; Ogden 2002). It is possible the additional adiposity associated with overweight status may have contributed to slowing the rate of improvement in this study. It appears compensatory gains in muscle mass, associated with increased weight status, offset the negative influence of added adiposity on jump performance, at least at the levels specific to the study period. A “tipping point” although, likely exists at the population level where increased BMI negatively influences jumping performance. The leveling off of adolescents' broad jump performance near 1980 in this study (Figure 2) may be evidence of such and is consistent with studies around the globe reporting recent increases in BMI and declines in jumping performance post-1980 (Albon et al 2010; Fraser et al 2018).

Social/Public Health Factors

Increasing youth MF is a critical public health concern due to its association with current and future health. In this study, female MF increased at a faster rate than boys' MF. This may be due to sex-related differences in trends in moderate to vigorous physical activity (MVPA) and vigorous physical activity (VPA) (Bassett et al 2015; Booth et al 2015; Canizares and Badley 2018; Eime et al 2016; Owens et al 2017). Given that Smith et al (2019) reported a significant positive association between broad jump performance and VPA and organized sport participation, it is possible that sex-related temporal differences in VPA help explain the sex-related temporal differences in broad jump performance.

Girls' participation in sport has increased over time. For example, in 1972 an Amendment was passed called Title IX — a Federal law that forbids discrimination based on sex in any federally funded education program or activity (The United States Department of Justice 2000). This led to a 600% increase in girls' sport participation between 1972 and 1978 (Kaestner 2010). The Title IX Amendment may have significantly influenced girls' participation in sport and physical activity, and in turn positively influenced broad jump performance.

Strengths and Limitations

This study used a systematic review approach and a strict set of inclusion/exclusion criteria to locate studies reporting on the broad jump performance of apparently healthy United States youth. It used a statistical approach previously adopted in other systematic review on trends in children's fitness (Tomkinson 2007; Tomkinson et al 2019), including weighted regression and post-stratification population weighting to adjust for sampling bias and underlying demographics. However, calculating trends using descriptive data meant that the influence of trends in body size and maturation could not be removed. An inclusive strategy was adopted where data collected on national, state/regional and community samples were included. This obviously raises the issue of representativeness. However, given the first national fitness survey was conducted in the late 1950s, the inclusion of state/regional and community level data allowed for a more complete temporal picture. It is also possible that assessment procedures (e.g., number of trials, level of encouragement, diurnal variation) varied over time.

CONCLUSION

There has been a small improvement in the broad jump performance of United States youth between 1911 and 1990. Unfortunately, the broad jump test is no longer used as part of routine fitness surveillance in the United States (e.g., The Presidential Youth Fitness Program; President's Council on Sports, Fitness & Nutrition 2018) despite the National Academy of Medicine's recommendation for its inclusion in school-based fitness testing. The inclusion of the broad jump in future national surveys in the United States may be useful to inform current and future public health policy relevant to the fitness and health of its youth.

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APPENDICES

Appendix 1. Search strategy for databases.

Search terms

(“musc* fitness” OR “musc* strength” OR “musc* power” OR “jump*”) AND (“child*” OR “adolescen*” OR “boy*” OR “girl*” OR “youth”) AND (“America*” OR “U.S.*”)

Databases

CINAHL (1991 to 27 November 2018): 152 studies identified.

MEDLINE (1974 to 27 November 2018): 268 studies identified.

SPORTDiscus (1956 to 27 November 2018): 408 studies identified.