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SHORT COMMUNICATION

Ten-year secular changes in muscular fitness in English children

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Low muscle strength is independently associated with a poorer metabolic profile during adolescence (1) and with disease and all-cause mortality in adulthood (2). Muscular fitness, which includes maximal isometric strength, explosive strength and muscular endurance is also positively associated with skeletal health (1). Tomkinson (3) reported steady increases in measures of explosive lower body strength (vertical and long jump performance) in developed countries until the mid 1980s, followed by steady declines. There were declines in muscle strength in Swedish adolescents between 1956 and 1981 and Russian adolescents between the 1960s and 1980s (4). Later reports show increases in some components of muscular fitness (5,6), but the most recent studies in Canadian and Spanish children show declines in either handgrip strength (HG) (7) or both HG strength and standing long jump (SLJ) (8).

Contemporary data showing trends in muscular fitness in English children are lacking. The aim of this study was to examine 10-year secular changes in measures of muscular fitness in English children.

In 1998, after gaining parental consent, 309 children (51% boys) aged 10–10.9 years were recruited from a random sample of six schools in Chelmsford, Essex, UK. In 2008, 315 children (48% boys) aged 10–10.9 years from five schools matched for size and socioeconomic status were recruited. The University of Essex ethics committee approved the study.

Abbreviations
BMI, body mass index; CRF, cardiorespiratory fitness; FFM, fat free mass; HG, handgrip strength; SLJ, standing long jump.

Duplicate measures of mass and stature were taken to the nearest 0.1 kg and 0.1 cm, respectively (Seca, Hamburg, Germany). Participants wore sports clothing (shorts and T-shirt) but no shoes. Unless specified, the following tests were performed according to standardized methods, with the protocols reported elsewhere (6,9,10). SLJ was used to measure lower body explosive strength (11). HG strength was taken as a measure of upper body maximal isometric strength (11). Two maximal isometric contractions of the dominant hand were performed using a portable dynamometer (Takei Corp Ltd., Tokyo, Japan), and the highest value achieved (kg) was recorded. Bent-arm hang was used to measure upper body strength endurance (11). A score of zero was recorded if the child could not hold the required position, using a pronated grip, for at least 1 sec. Otherwise, the time spent with their chin above the bar, was recorded in seconds. Trunk and hip-flexor muscular endurance was measured by the maximum number of sit-ups performed in 30 sec (11), with knees flexed to 90° and feet held. HG, SLJ and sit-ups were performed in random order, while the bent-arm hang was undertaken last.

Two-way (gender by year of testing) analysis of covariance (ANCOVA) was used to determine main effects and potential year-by-gender interactions while controlling for mass, stature and body mass index (BMI), using SPSS Version 16.0 for Windows (SPSS Inc.: an IBM company, Chicago, IL, USA). School was included as a random factor to correct for clustering. Bent-arm hang data were positively skewed, so a log transformation was performed on bent-arm (s) +1. The addition of 1 to each score was necessary as the bent-arm data included zero values. A chi-square test was used to compare the number of zero scores in the bent-arm hang between year of testing.

Table 1 Anthropometric measures and muscular fitness test performance in 10-year-old English children in 1998 and 2008

	1998 N = 309	2008 N = 315	Percentage difference	p-Value for
	Mean ± SD	Mean ± SD	(%)	difference
Age (years)	10.4 ± 0.3	10.4 ± 0.3	0.2	NS
Stature (cm)	142.2 ± 6.9	142.2 ± 7.0	−0.1	NS
Mass (kg)	36.8 ± 8.3	37.1 ± 7.9	0.8	NS
BMI (kg/m^2)	18.1 ± 3.4	18.3 ± 2.9	0.9	NS
Standing long jump (cm)	132.6 ± 24.2	139.9 ± 26.0	5.5	<0.001
Handgrip (kg)	17.5 ± 3.4	16.4 ± 3.2	−6.3	<0.001
Sit ups (counts/30 sec)	26.2 ± 7.3	19.1 ± 6.4	−27.1	<0.001
Log_{10} bent arm hang +1 (sec)	17.8 ± 17.1	13.2 ± 13.3	−25.9	<0.001

p Values after controlling for stature, mass, BMI.
NS, not significant; BMI, body mass index.

There was no significant difference between the 1998 and 2008 sample in stature, mass or BMI. There were no significant gender-by-year interactions; therefore, only main effects are shown in Table 1. Mean SLJ performance was significantly higher in 2008 compared with 1998 ($p < 0.001$). HG, sit-ups performance and bent-arm hang time were all significantly lower in the 2008 sample ($p < 0.001$). The number of children who could maintain the bent-arm hang position for >1 sec was also significantly lower in 2008.[1] Controlling for stature, mass and BMI did not alter the results for HG, SLJ sit-ups or bent-arm hang performance ($p < 0.001$).

The aim of this study was to examine secular trends in muscular fitness between 1998 and 2008 in 10-year-old English children. With the exception of an increase in SLJ, all measures of muscular fitness significantly decreased. These data are the first to report contemporary secular trends in muscular fitness in English children, and the secular changes in each component of muscular fitness are discussed in turn below.

The mean annual decline in HG is identical to that reported in Canadian 7–10 year olds (0.58% in boys; 0.64% in girls) between 1981 and 2007–2009 (7) and cannot explained by differences in stature, mass or BMI. Larger annual declines in HG (0.90% in boys; 0.92% in girls) were reported in Spanish adolescents between 2001 and 2002 and 2006 and 2007 in the AVENA and HELENA studies (8). We found significant annual increases in SLJ (0.43% in boys; 0.71% in girls), conflicting with significant decreases in SLJ reported in Spanish adolescents (1.88% in boys; 2.4% in girls) (8). The mean annual decline in sit-ups performance (2.68% in boys; 2.70% in girls) contrasts with a 1.8% mean annual increase in 10- to 14-year-old New Zealand children between 1991 and 2003 (5). However, a substantial change in the ethnic composition of this sample is likely to have influenced their findings. We found large and significant annual decreases in bent-arm hang performance (1.27% in boys and 2.27% in girls) that could not be accounted for by changes in body mass or BMI. In contrast, Spanish adolescents (8) showed a non significant decline in bent-arm hang performance despite a larger decrease in HG than found in the present study. Moliner-Urdiales et al. (8) also found a decrease in body mass, which is advantageous to performance in the bent-arm hang. This decrease may have compensated somewhat for the loss of upper body strength indicated by declines in HG.

Given the declines that we found in all the other muscular fitness tests, the increase in SLJ appears to be an anomaly, and is particularly puzzling when observed along side decreased HG. These two measures correlate, and are both good indexes of overall muscle strength in children (10,12). The present study is not however unique, in finding divergent trends in measures of upper versus lower body strength. Significant declines in sit-ups performance and bent-arm hang were observed between 1987 and 2001 in Swedish adolescents, while vertical jump performance was stable over this period (6). These data and the present findings might reflect divergent secular trends in strength, which may be attributed to participation in activities that differentially stimulate the development of upper and lower body strength.

Until the 1990s, secular increases in muscular fitness were generally reported, and attributed to increases in stature, mass and earlier maturation (4) with which measures of static strength such as HG are positively correlated (13). Recent secular declines in muscular fitness have been attributed largely to changes in physical activity (4,7). Our findings, which cannot be explained by differences in body mass, BMI or stature, are likely related to changes in patterns of physical activity or 'sedentariness'. Both physical activity and sedentariness are independently associated with muscular fitness (14).

We did not measure body composition and cannot exclude the possibility that the relative stability in body mass and BMI has concealed an increase in fat mass and a decline in fat free mass (FFM). Such trends were reported recently in Spanish adolescents (8), and there is indirect evidence suggesting declines in FFM in English children in recent decades (15). A secular decline in FFM would explain the present decline in strength.

We also did not evaluate sexual maturation, so our findings could be associated with differences in maturity between the 1998 and 2008 samples, but similarities in stature suggest that this was not the case. We evaluated two relatively small samples from an affluent area of England that included only 10 year olds, so these trends may not be generalizable to other age or socioeconomic groups. However, mean HG for boys and girls in the 2008 sample was similar to that previously reported in an English sample that included children with more varied socioeconomic status (9). Furthermore, our secular declines in HG are remarkably similar to those reported in a larger and more representative sample of 7- to 10-year-old Canadians (7).

[1]Number of children unable to hold body mass; in 1998: 8, in 2008: 16, $p < 0.001$.

We found secular declines in most but not all measures of muscular fitness in English children between 1998 and 2008. With respect to HG, these findings confirm contemporary declines reported in developed countries (7,8) and are of concern from a public health perspective. HG and SLJ are both associated with markers of health in children (1, Garcia-Artero, personal communication), and it is difficult therefore to assess the overall impact these divergent secular trends may have on health. Our findings nonetheless highlight the importance of monitoring components of muscular fitness in youth, and a need to emphasize the development of muscular as well as cardio-respiratory fitness.

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CONFLICT OF INTEREST

No competing interests.

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