

Title Page

Title: Changes in cardiorespiratory fitness in 9-10.9yr old children: SportsLinx 1998-2010

Running title: Changes in children's fitness, 1998-2010

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Abstract

Purpose: 1. Assess changes in cardiorespiratory fitness (CRF) from 1998-2010, controlling for decimal age and body mass index (BMI). 2. Repeat the analysis in cohorts from 2005-2010, controlling for maturation, deprivation and BMI.

Methods: 27,942 (n = 14,247 boys) 9-10.9yr old participants from one UK city were included in this serial cross-sectional study from 1998-1999 to 2009-2010. A deprivation score (IMD) was assigned to each participant on the basis of home postcode. Stature, sitting stature and body mass were estimated. BMI and somatic maturity were calculated. Performance on the 20m multi-stage shuttle runs test (20mSRT) was used to estimate of CRF (total shuttles). One-way ANCOVAs were completed to assess temporal trends in CRF, separately by sex. Model one assessed changes from 1998-2010 and included decimal age and body mass index as covariates. Model two assessed changes from 2005-2010 and included maturity, IMD and BMI as covariates.

Results: Results indicate that 20mSRT performance has declined in UK schoolchildren. An annual decline of 1.34% and 2.29% was observed in boys and girls respectively. Model 1: For boys, the baseline cohort performed better than all other groups with the exception of the 1999-2000 group. For girls, declines in 20mSRT performance were observed from 2003 onwards. Model 2: For boys, the 2007-2008 and 2008-2009 cohorts completed fewer 20mSRT shuttles than all other groups. For girls, the 2008-2009 cohorts performed worse than all other years, with the exception of 2007-2008.

Conclusion: The decline in CRF suggests children in the more recent SportsLinx cohorts may be at an increased risk of cardiometabolic illness in comparison to earlier cohorts. The promotion of vigorous physical activity is urged to promote CRF in children.

Keywords: cardiorespiratory fitness; children; cardiometabolic risk; maturation; SportsLinx

Introduction

PARAGRAPH NUMBER 1.

Cardiorespiratory fitness (CRF) is cardioprotective, with a substantial body of evidence suggesting low fitness is associated with elevated clustered cardiometabolic risk in children and adolescents (2, 10, 11). The Chief Medical Officer in England, recently highlighted the importance of fitness as a health determinant in children, and advocated monitoring the fitness levels of children on a large-scale (9). Evidence from the UK and internationally suggests levels of CRF have declined in children in recent years (22, 24, 26), despite evidence suggesting that the prevalence of obesity and overweight has reached a plateau (4). Population level studies assessing fitness in children are relatively rare in the UK, particularly studies that account for confounders within analyses. Studies that have controlled for body size and indices of multiple deprivation describe declines in CRF independent of these confounders (4, 24); suggesting decrements are not entirely due to the widely documented increased prevalence of childhood obesity and overweight.

PARAGRAPH NUMBER 2

Accurately assessing CRF in the field is problematic. One commonly used method is the 20m multi-stage shuttle runs test (20mSRT), also known as the Pacer, or bleep test. The appropriateness and reliability of the 20mSRT has been questioned in the past, motivation, perceived worth and competency being cited as variables that influence performance (19). However, a recent systematic review discussed the utility of the 20mSRT and concluded the test is reliable and valid for use in paediatric studies (7). Furthermore, in large-scale, field-based studies the 20mSRT offers a cost effective and low resource alternative to the gold-standard laboratory based assessments of peak oxygen uptake that are impractical on a large-scale.

PARAGRAPH NUMBER 3

Many fitness testing programmes operate within schools, with children grouped into school years on the basis of date of birth. A year cohort (1st September and 31st August), of children can differ in chronological age by nearly 12 months. This will have implications for performance and the interpretation of fitness test scores. Furthermore, within a large cohort there will inevitably be some variation in physical maturation between participants independent of chronological age. In addition to maturation, deprivation is an established confounding variable when assessing fitness (15) and body composition (23) in children. For example, evidence from the AVENA study describes a positive association between socioeconomic status and muscular strength in boys, and cardiorespiratory fitness, muscular strength and agility in girls (15). When attempting to monitor population-level changes in CRF, it is important to take age, and/or physical maturation, and socioeconomic status into account as well as other more routine confounders such as body mass index. To date, no population studies have assessed temporal trends in fitness over a long period of time, controlling for other relevant confounders, such as maturation. The Liverpool SportsLinx project (25) annually assesses components of fitness in 9-10.9yr old (school Year 5) schoolchildren across the city. The project typically includes ~80% of 9-10.9yr old children within Liverpool Local Education Authority, and the methods have remained consistent from 1998 to present. In 2004, SportsLinx began collecting home postcode data, allowing an estimate of deprivation to be calculated for each participant. In 2005, sitting stature was introduced into the battery of field-based tests to allow an estimate of somatic maturity to be calculated, using regression equations (18). Because of the lack of population level studies investigating changes in CRF, and in particular the absence of any studies that account for maturation within analyses the purpose of this serial-cross sectional study was to:

1. Assess changes in CRF from 1998-2010 using SportsLinx data, controlling for decimal age and body mass index.
2. Repeat the analysis in cohorts from 2005-2010, controlling for maturation, indices of deprivation and body mass index.

Methods

PARAGRAPH NUMBER 4

After gaining Local Research Ethics Committee approvals, written informed parental consent, participant assent and medical screening 27,942 participants (n = 14,247 boys) were included in this serial cross-sectional study. All primary schools across Liverpool Local Education Authority were invited to take part in the SportsLinx programme each academic year from 1998-2010. The SportsLinx field-based fitness testing procedures have been described previously (24, 25), and the measures included in this study have acceptable test/re-test reliability (5). Briefly, children attend a local authority sports hall with their school class to complete a battery of fitness tests adapted from the Eurofit battery (1). Two senior fitness officers lead the testing sessions throughout the 1998-2010 periods, assisted by undergraduate students.

PARAGRAPH NUMBER 5 Measures:

An indices of multiple deprivation (IMD) score was assigned to each participant on the basis of home postcode using the National Statistics Postcode Directory database (8) and the GeoConvert application (17). IMD scores provide an estimate of area deprivation and comprise of seven domains of deprivation. IMD scores and are a commonly used method of estimating deprivation in similar studies within the UK (12). Stature and sitting stature were

estimated to the nearest 0.1cm (Seca, Bodycare, Birmingham, UK) and body mass was estimated to the nearest 0.1kg (Seca, Bodycare, Birmingham, UK) by two trained Fitness Officers using standard techniques (16). Body mass index (BMI) was calculated (body mass [kg] \div stature² [m²]). Leg length was calculated by subtracting sitting stature from whole body stature. Somatic maturity was estimated using decimal age, stature, sitting stature, leg length and body mass using regression equations. This method has been used in similar aged children in the past (13), and demonstrates acceptable agreement with skeletal age (18). Somatic maturity was expressed as time to peak height velocity (TPHV). The number of completed shuttles on the 20mSRT (the Queen's University of Belfast protocol (6)) was used as an estimate of CRF.

PARAGRAPH NUMBER 6 Statistical analyses:

CRF data were not normally distributed and were log-transformed. CRF data were back transformed for presentation purposes. One way analyses of co-variance, with Bonferroni post hoc analyses were completed to assess differences in CRF between the year cohorts. Analyses were completed using two models, one including all cohorts from 1998-2010, and the second including cohorts from 2005-2010. For the first model decimal age (in the absence of TPHV data) and BMI were included as covariates. For the second model, TPHV, BMI and IMD were included as covariates. Decimal age was removed as a covariate in model two to avoid collinearity, as decimal age is included in the calculation for TPHV. Annual decline in number of completed shuttles was estimated by plotting the adjusted 20mSRT values from 1998-2010 and recording the slope of the regression line. Percentage decline in performance was calculated by fitting a regression of time vs. 20mSRT (log transformed), the slope was then antilogged and subtracted from 1 to give the % annual decline. All statistical tests were completed separately by sex, and an alpha value of $p \leq 0.05$ was used to detect statistical significance. Analyses were conducted using SPSS v 17.0 (SPSS Inc. Chicago, IL).

Results

PARAGRAPH NUMBER 7 Table 1 displays the unadjusted baseline characteristics (plus SD) from 1998-2010. .

TABLE 1 ABOUT HERE***

PARAGRAPH NUMBER 8

After adjusting for decimal age and BMI, analysis of covariance found a number of significant differences between cohorts. Table 2 displays adjusted mean 20mSRT performance, percentage change from baseline (calculated from log-transformed data), number of participants within each cohort, plus the equivalent distance in metres and end running speed (calculated from adjusted mean shuttles) from 1998-1999 to 2009-2010. A decline in 20mSRT performance over time was observed. The mean annual decline in performance was 1.34% or 0.58 shuttles (11.6m) and 2.29% or 0.71 shuttles (14.2m) for boys and girls respectively.

TABLE 2 ABOUT HERE*****

PARAGRAPH NUMBER 9

For boys, the baseline cohort performed better than all other groups with the exception of the 1999/2000 to 2002/3 groups ($p < 0.001$). Apart from the baseline group, the 1999-2000 cohort outperformed all the other cohorts (2000-2001, $p = 0.001$, 2001-2002, $p = 0.031$, 2003-2005, $p = 0.043$, all other cohorts; $p \leq 0.001$). The 2003-2004 cohort performed worse than all groups with the exception of the 2006/7-2008/9 cohorts (2004-2005, $p = 0.006$, 2005-2006, $p = 0.023$, 2009-2010, $p = 0.01$, all other cohorts; $p \leq 0.001$). The 2007-2008 group performed

worse than all other cohorts with the exception of the 2008-2009 groups (all $p < 0.001$). The 2008-2009 group performed worse than all groups with the exception of the 2007/8-2008/9 cohorts (2009-2010, $p = 0.002$, all other cohorts; $p < 0.001$). The most recent cohort performed better than the 2003-2004 ($p = 0.01$), 2007-2008 ($p < 0.001$), and 2008-2009 ($p = 0.002$) groups, but poorer than the 1998-1999 ($p < 0.001$) and 1999-2000 ($p < 0.001$) cohorts.

PARAGRAPH NUMBER 10

For girls, significant differences in 20mSRT performance from baseline were observed from 2003 onwards (all $p < 0.001$). In addition, all cohorts from 2003-2004 onwards, performed worse than all 1998-2003 cohorts (2008-2009, $p = 0.009$, all other groups; $p \leq 0.001$). The 2007-2008 cohort performed worse than all other cohorts with the exception of 2006-2007 and 2008-2009 (2005-2006, $p = 0.02$, all other groups; $p < 0.001$). The 2008-2009 cohort performed significantly worse (2003-2004, $p = 0.009$, 2005-2006, $p = 0.004$, all other groups; $p \leq 0.001$) than all years with the exception of 2007-2008. The most recent cohort performed better than the 2007/8 and 2008/9 groups.

PARAGRAPH NUMBER 11

After controlling for TPHV, IMD and BMI, analyses of covariance detected additional statistically significant differences between the 2005-2010 groups. Table 3 displays the adjusted means, percentage change from baseline, number of participants within each cohort, distance and end running speeds, and differences between cohorts. For boys, the 2007-2008 and 2008-2009 cohorts completed significantly fewer 20mSRT shuttles than all other groups (all $p < 0.001$). For girls, the 2007-2008 and 2008-2009 cohorts performed worse than all other years (all $p < 0.001$).

Discussion

PARAGRAPH NUMBER 12

There are a lack of population-level studies that assess serial-cross sectional changes in cardiorespiratory fitness (CRF) in children within the UK. Furthermore, no population-level studies have controlled for maturation within analyses. Consequently, the purpose of this study was to assess changes in CRF from 1998-2010 using SportsLinx data, controlling for decimal age and body mass index, and to repeat the analysis in cohorts from 2005-2010, controlling for maturation, indices of deprivation and body mass index. Findings from the 1998-2010 analysis describe a significant decline in CRF over time, with all boys' cohorts from 2000-2010 and girls' cohorts from 2003-2010 performing significantly worse than baseline. For boys, the largest decrement in performance was observed in 2003-2004 and 2007-2008, with a 5.6% difference (calculated from log-transformed data) between these cohorts and baseline, which equated to ~3 shuttles, or 60m. For girls the poorest performance was observed in 2008-2009, a mean decline of 8.1% from baseline, which equated to a ~3 shuttles or 60m reduction. The adjusted baseline mean value for boys (47.1 shuttles) equates to the 63rd percentile for the 2009-2010 cohort, and vice versa the 2009-2010 adjusted mean (42.1 shuttles) equates to the 42nd percentile in 1998-1999. For girls the baseline adjusted mean value (34.1 shuttles) equates to the 72nd percentile for the 2009-2010 cohort, alternatively the most recent cohort's adjusted mean value (29.1 shuttles) equates to the 36th percentile at baseline. The overall declines reported are likely to be clinically meaningful, with previous research highlighting a linear relationship between fitness and cardiometabolic risk, and increases in risk across each declining quartile of fitness (3, 11). The mean declines in fitness of 1.34% for boys and 2.29% for girls observed in the study are greater than those reported internationally (26), a finding that mirrors previous research in the UK (22). In the absence of longitudinal studies it is difficult to explain this finding. As the analyses

accounted for BMI, the declines are not likely to be due to changes in body fatness, but may be due to insufficient vigorous physical activity. Furthermore, the declines were calculated using number of completed shuttles rather than end running speed. Our findings suggest that end running speed did not change substantially over time with the exception of a decline of 0.5km/h between 1998-1999 (11.0km/h) and all other years (10.5km/h) for boys and a 0.5km/h decline from 10.0km/h to 9.5km/h from 2003-2004 onwards in girls. Therefore, children from the latter cohorts attained similar running speeds as the earlier groups, but could not complete as many laps at the given speeds. Further, longitudinal research is required to assess changes in fitness and offer plausible explanations for the observed declines.

PARAGRAPH NUMBER 13

For the second analysis, differences were detected between the 2005-2010 cohorts that were not apparent in the initial analyses. The 2007-2008 and 2008-2009 cohorts performed significantly worse than all other years. Findings suggest that the 2009-2010 groups showed an improvement in CRF in comparison to the 2007-2009 cohorts. It remains to be seen whether the improvement in performance in the most recent cohort is a sign of a plateau or even an improvement in CRF, and more years' data are required to investigate trends. To our knowledge this is the first serial-cross-sectional population level study to assess changes in CRF in a large sample of schoolchildren after controlling for somatic maturity as well as other confounders.

PARAGRAPH NUMBER 14

There are a number of limitations within this study. Primarily, the 20mSRT was used to estimate CRF. The utility of the 20mSRT as a reliable and valid method of assessing CRF has been questioned in the past. However, recent studies and systematic reviews have concluded

that the 20mSRT is valid and reliable for use with children (5, 7, 22), particularly on a large-scale where laboratory assessments of peak oxygen uptake are impractical. A second limitation of the study is the testing environment; variables such as time of day were not controlled and may have affected 20mSRT performance. Another limitation is the unequal distribution of participants across the cohort years. The varied numbers reflect resource limitations, lack of school uptake for the testing programme due to school inspections and facility constraints, there is also a lack of information on those children and schools that declined the invitation to participate, therefore sampling bias cannot be estimated. Despite the low sample size within some of the cohorts, ($n \sim 490$ for the smallest cohorts), the 'small' cohorts compare favourably with other studies reporting secular trends in CRF (22). Furthermore, the total sample size is substantial, and represents a population-level study involving $\sim 80\%$ of 9-10.9yr old children for the majority of the cohorts. An additional limitation is that all participants were from the Liverpool Local Education Authority catchment area, which is made up of several areas of high deprivation and lacks any significant areas of affluence or rural communities. Therefore results may only be applicable to similar urban populations. Finally, time to peak height velocity (TPHV) was used to estimate maturation from 2005-2010. The inclusion of maturation within model two resulted in the ANCOVA detecting additional statistically significant differences between groups, but the overall results were not practically different from model one. The age-group of participants included in this study was predominantly pre-pubertal, and therefore the influence of maturation may be less substantial than if the participants were older. Furthermore, the assessment of somatic maturation represents a proxy measure that is less invasive and resource intensive than other methods such as the Tanner scale, but also potentially less accurate. Despite being a proxy for maturation this approach demonstrates

acceptable agreement with skeletal age (18), and has been used in studies with similar aged children in the past (13, 14).

PARAGRAPH NUMBER 15

Cardiorespiratory fitness is a key determinant of health, and low CRF is independently associated with increased clustered cardiometabolic risk in children (2, 21). This is the first study to highlight changes in fitness at the population level after controlling for relevant confounders. The substantial declines in CRF observed in this study suggest that children from more recent cohorts may be at an increased risk of cardiovascular disease in comparison to the earliest cohorts that participated in the SportsLinx programme. The upturn in performance observed in 2009-2010 is a promising finding, and may reflect the numerous physical activity and health promotion interventions being delivered locally and nationally. Further years' data are required to detect any changes in fitness at a population level. Investment in physical activity interventions that target improvements in CRF as well as improving energy expenditure are encouraged. As CRF is a product of vigorous physical activity (20), improvements in CRF may be achieved by placing more emphasis on the intensity of physical activity within existing and planned physical activity policies and programmes.

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