
Helen Peters,1 Peter H Whincup,2 Derek G Cook,2 Catherine Law,1 Leah Li1

ABSTRACT

Objective Little is known about whether levels of physical fitness, which is related to adiposity and physical activity (PA), have changed in children, particularly the progressive increase in childhood obesity levels. We aimed to examine the time trends in resting pulse rate (a marker of physical fitness) among UK children, in order to better understand the trends in levels of physical fitness in recent decades.

Design and setting We used a cross-sectional study design and included data on over 22 000 children aged 9–11 years (mean 10.3 years) from five population-based studies conducted in the UK between 1980 and 2008.

Main outcome measures Resting pulse rate (bpm).

Results Observed mean resting pulse rate was higher for girls than boys (82.2 bpm vs 78.7 bpm). During the study period mean pulse rate increased by 0.07 bpm/year (95% CI 0.04 to 0.09) among boys and to a lesser extent among girls, by 0.04 bpm/year (0.01 to 0.06) (p<0.05 for gender interaction). For boys, there was an indication that the trend was steeper after the mid-1990s, compared to that prior to 1994 (annual increase 0.14 vs 0.04 bpm). The trends for Body Mass Index (BMI) accounted for only 13.8% (11.3% to 16.3%) of increase in pulse rate for boys and 17.2% (9.4% to 24.9%) for girls.

Conclusions Increases in mean resting pulse rate have occurred during the period 1980–2008 in girls and especially in boys. The increase was not explained by increased BMI. The observed trends in children, though modest, could have important public health implications for future cardiovascular risk.

INTRODUCTION

Resting pulse rate is a marker of cardiovascular health, indicating relative stress placed on the cardiopulmonary system.1 In adults, increased resting pulse rate has been associated with hypertension, atherosclerosis and cardiovascular risk.2–4 In children, it is positively associated with blood pressure (BP) and adiposity.2 5 6 Resting pulse rate is a marker of physical fitness, and the two are inversely correlated, at individual and population levels.7–9

During the last 30 years, there has been growing concern about the effect on children's health of increasing adiposity10 and declining physical activity (PA) levels.11 12 It is possible that levels of physical fitness, which are related to adiposity and PA levels, have also declined in children. This would be an important public health concern, because low physical fitness is associated with increased cardiovascular disease (CVD) risk factors in children7 13 and risks of CVD mortality and morbidity in adults.2 14

METHODS

We included five population-based studies in which resting pulse rate was recorded during BP measurement in British children aged 9–11 years.16–21 Among these studies, one (Health Survey for England (HSE)) included resting pulse rate measurements at three time points (1995–1998, 2002, 2006–2008).20 21 As resting pulse rate might differ by ethnicity,6 analyses were based on white European children.
Study samples

The 1970 British birth cohort included all births in 1 week in 1970 in Britain (n=17 000). At 10 years, pulse rate was measured once by nurses over 1 min at the start and the end of the examination with the child seated after 2 min rest.16 Height (to 0.1 cm or ¼ inch) and weight (0.1 kg or ¼ ounce) were measured. We included 12 164 children aged 10 years in 1980.

The Brompton cohort included 1895 full-term births in Farnborough Hospital, Kent, between April 1975 and May 1977, followed to May 1985.17 We used data collected at 10 years or at 9 years when the follow-up ended. Pulse rate was measured twice by nurses with the child seated after 5 min rest. Height (cm) and weight (kg) were measured. We included 774 children aged 9–10 years in 1984–1985.

The Two-Towns Study included a sample of 9–11-year children in two English towns, Carlisle and Guildford.18 Three pulse rate measurements were taken by nurses with the Dinamap1846 BP recorder with the child seated after 5 min rest. Height (mm) and weight (0.1 kg) were measured. We included 1293 children aged 9–11 years in 1991.

The Ten-Towns Study included ten towns in England and Wales, five each with the highest and lowest rates of adult heart disease.19,22 In 1994, a survey was carried out in 9–11-year children. Two pulse rate measurements were made by nurses with the Dinamap1846 BP recorder with the child seated after 5 min rest. Height (mm) and weight (0.1 kg) were measured. We included 3363 children aged 9–11 years in 1994.

HSE is an annual health survey and has included a sample of children since 1995. We considered children aged 9–11 years in 1995–1998 and 2002 surveys (with boost child samples) and 2006–2008 surveys.21 Three pulse rate measurements were taken by nurses with the Dinamap 8100 device between 1995 and 2002 with the child seated after 5 min rest20 and with the Omron 907 BP recorder from 2003. Height (mm) and weight (0.1 kg) were measured. We included 5249 children aged 9–11 years between 1995 and 2008.

Statistical analysis

BMI (weight (kg)/height (m)2) was calculated for all children. Overweight and obesity were defined using age-specific and gender-specific International Obesity Taskforce (IOTF) standards.21

Measurements were not taken at the same age for all individuals (table 1). It is known that pulse rate decreases with age,6 whereas adiposity increases with age. We centred measures of pulse rate, height and BMI to 10.3 years (mean age of all participants) using predictions from regression models assuming a linear age trend in all studies.

All studies (except the 1970 cohort) had ≥2 readings at one occasion. Pulse rate tends to increase across readings which are made close together.24 We used the first reading as the resting pulse rate for these studies. For the 1970 cohort, we used the one reading at the end of the examination, which was lower than the reading at the start (mean 79.5 vs 79.9 bpm for boys; 82.0 vs 82.8 bpm for girls).

To assess whether resting pulse rate changed over time, we applied linear regression models with exact year of study as a covariate. The models were then adjusted for BMI and height to assess whether the pulse rate trends were explained by changes in BMI and height over time. The percentage of trends explained by changes in BMI and its 95% CI were estimated using bootstrap sampling. The interaction between study year and BMI was tested to establish whether the pulse rate trends differed across BMI levels.

Figure 1A indicates a nonlinear time trend for pulse rate in boys. We first applied fractional polynomial models to identify the shape of the trend. The best fitting model based on deviance (for models of the same degree), Bayesian Information Criterion and Akaike Information Criterion (models of a different degree) had only a cubic term (a+b×year3), suggesting two distinct trends. We applied a linear spline model with one knot in 1994 (determined using the likelihood profile)25 to assess the trends in pulse rate during 1980–1994 and 1994–2008. As shown in figure 1B, there was no significant nonlinear trend for girls.

We performed sensitivity analysis by restricting to (1) nationally representative studies (1970 cohort and HSE); (2) studies using automated devices (Two-Towns, Ten-Towns studies and HSE) and (3) girls aged 9–10 years to limit effects of earlier pubertal development in recent studies.

RESULTS

Our analyses were based on 22 843 children of white European origin in the UK, from five studies at seven time points (94% of all aged 9–11 years). Overall, mean pulse rate was higher in girls (82.2 bpm) than in boys (78.7 bpm) (p<0.001 for gender difference) (table 1).

Trends in pulse rate

Table 1 shows a slight increase in mean pulse rates (1980–2008) in both sexes, which was confirmed by regression analyses (table 2).

Table 1 Mean (SD) pulse rate (bpm), Body Mass Index (BMI) (kg/m2) and height (cm)*

<table>
<thead>
<tr>
<th>Study year</th>
<th>N</th>
<th>Age (y)</th>
<th>Mean</th>
<th>Range</th>
<th>Pulse rate†</th>
<th>Boys</th>
<th>BMI</th>
<th>Overweight/obese (%)</th>
<th>Height</th>
<th>Pulse rate†</th>
<th>Girls</th>
<th>BMI</th>
<th>Overweight/obese (%)</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>12 164</td>
<td>10.3</td>
<td>9.8–10.7</td>
<td>78.4 (10.5)</td>
<td>16.9 (1.9)</td>
<td>5.7</td>
<td>139.0 (6.3)</td>
<td>81.9 (11.0)</td>
<td>17.1 (2.2)</td>
<td>9.7</td>
<td>138.6 (6.5)</td>
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<td>1984–1985</td>
<td>774</td>
<td>9.7</td>
<td>9.0–10.7</td>
<td>79.2 (10.1)</td>
<td>17.2 (2.2)</td>
<td>6.9</td>
<td>141.0 (5.7)</td>
<td>82.1 (10.4)</td>
<td>16.9 (1.9)</td>
<td>8.3</td>
<td>140.5 (6.3)</td>
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<td>1991</td>
<td>1293</td>
<td>10.3</td>
<td>9.0–11.7</td>
<td>78.2 (12.6)</td>
<td>17.5 (2.4)</td>
<td>10.0</td>
<td>140.3 (6.0)</td>
<td>82.4 (13.8)</td>
<td>17.7 (2.7)</td>
<td>18.1</td>
<td>140.0 (6.5)</td>
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<td>1994</td>
<td>3363</td>
<td>10.5</td>
<td>9.0–11.8</td>
<td>79.3 (12.2)</td>
<td>17.5 (2.7)</td>
<td>13.0</td>
<td>141.0 (5.7)</td>
<td>82.8 (12.1)</td>
<td>17.8 (2.6)</td>
<td>16.5</td>
<td>140.2 (5.9)</td>
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<td></td>
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<tr>
<td>1995–1998</td>
<td>3083</td>
<td>10.5</td>
<td>9.0–11.9</td>
<td>78.6 (11.3)</td>
<td>18.3 (3.3)</td>
<td>16.0</td>
<td>140.2 (6.2)</td>
<td>82.2 (12.0)</td>
<td>18.3 (3.1)</td>
<td>21.6</td>
<td>140.5 (6.4)</td>
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<td>2002</td>
<td>1181</td>
<td>10.5</td>
<td>9.0–11.9</td>
<td>80.9 (11.8)</td>
<td>18.8 (3.3)</td>
<td>21.9</td>
<td>140.1 (6.4)</td>
<td>84.0 (11.6)</td>
<td>19.2 (3.7)</td>
<td>30.4</td>
<td>140.8 (6.7)</td>
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<tr>
<td>2006–2008</td>
<td>985</td>
<td>10.5</td>
<td>9.0–11.9</td>
<td>80.6 (11.6)</td>
<td>18.3 (3.3)</td>
<td>21.1</td>
<td>140.1 (6.8)</td>
<td>82.0 (12.4)</td>
<td>18.8 (3.6)</td>
<td>24.2</td>
<td>141.1 (7.3)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total</td>
<td>22 843</td>
<td>10.3</td>
<td>9.0–11.9</td>
<td>78.8 (11.1)</td>
<td>17.3 (2.5)</td>
<td>12.0</td>
<td>139.8 (6.2)</td>
<td>82.2 (11.6)</td>
<td>17.7 (2.9)</td>
<td>16.7</td>
<td>139.6 (6.7)</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*All height, BMI and pulse rate measures were centred at mean age (10.3 years) using pooled estimate for all studies (estimated annual age trend for pulse rate was −2.34 bpm for boys and −1.48 bpm for girls).
†Study sample (9–11-year white European children with pulse rate measures).
‡First pulse rate reading for all studies; for 1970 cohort, the reading taken at end of exam was used.
The estimated annual increases in mean resting pulse rates were 0.07 bpm (95% CI 0.04 to 0.09) among boys and 0.04 bpm (0.01 to 0.06) among girls (p<0.05 for gender interaction).

Impact of changes in BMI and height
Mean BMI increased during the period, from 16.9 kg/m² (boys) and 17.1 kg/m² (girls) in 1980 to 18.8 kg/m² and 19.2 kg/m², respectively, in 2002, and remained high until 2008. The prevalence of overweight/obesity increased from 5.7% (boys) and 9.7% (girls) to 21.9% and 30.4%, respectively, in 2002, remaining high thereafter. While not all studies included were national samples (ie, were drawn from certain UK areas), the prevalences of overweight/obesity in the Brompton study in 1985 (7.6%) and Ten-towns study in 1994 (18%) were comparable to those in the National Study of Health and Growth (NSHG) in 1984 (8.8%) and 1994 (16.9%). Mean height between 1980 and 1985, but changed little thereafter (table 1). Resting pulse rate was positively associated with BMI and inversely associated with height among all children: mean pulse rate increased by 0.24 bpm for every kg/m² increase in BMI and decreased by 0.10 bpm (0.07 to 0.14) and 0.09 bpm (0.05 to 0.12), respectively, for every centimetre increase in height. Trends in pulse rate were only slightly reduced by adjustment for BMI and/or height, by 13.8% (11.3% to 16.3%) for boys and 17.2% (9.4% to 24.9%) for girls (table 2).

Trend in pulse rate were only slightly reduced by adjustment for BMI and/or height, by 13.8% (11.3% to 16.3%) for boys and 17.2% (9.4% to 24.9%) for girls (table 2). Adding polynomial terms of BMI to the model indicates a nonlinear association between BMI and resting pulse rate, such that the association strengthened with increasing BMI (data not presented). Specifically, there was no association for children with BMI<18 kg/m², whereas for every kg/m² increase in mean BMI mean pulse rate increased by 0.39 bpm (0.29 to 0.49) in boys and 0.21 bpm (0.11 to 0.30) in girls with BMI ≥18 kg/m² (24.8% children) (IOTF cut-offs for overweight/obesity at 10 years were 19.8 kg/m² (boys) and 19.9 kg/m² (girls)23). However, there was no significant interaction between study year and BMI, suggesting that pulse rate trends did not differ across BMI levels.

Findings from additional analysis
In boys, linear spline models suggest that mean pulse rate rose faster between 1994 and 2008 (annual increase of 0.14 bpm (0.09 to 0.19)) than between 1980 and 1994 (0.04 bpm (0.002 to 0.07)). The trend persisted after adjusting for BMI and height 0.13 bpm (0.07 to 0.19) (figure 2). For girls, the trend

![Figure 1](A) Observed mean resting pulse rate and estimated time trends† for boys 1980–2008. †Models for estimating adjusted trends included individual BMI and height. (B) Observed mean resting pulse rate and estimated time trends† for girls 1980–2008. †Models for estimating adjusted trends included individual BMI and height.

![Figure 2](Observed mean resting pulse rate and estimated nonlinear time trends† for boys 1980–2008. †Models for estimating adjusted trends included individual BMI and height.

### Table 2

<table>
<thead>
<tr>
<th>Boys</th>
<th>Model 1†</th>
<th>Model 2†</th>
<th>Model 3†</th>
<th>Model 4†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>0.07 (0.04 to 0.09)</td>
<td>0.06 (0.03 to 0.08)</td>
<td>0.07 (0.05 to 0.09)</td>
<td>0.06 (0.04 to 0.08)</td>
</tr>
<tr>
<td>BMI</td>
<td>0.18 (0.09 to 0.27)</td>
<td>0.24 (0.14 to 0.33)</td>
<td>0.08 (−0.11 to −0.05)</td>
<td>0.10 (−0.14 to −0.07)</td>
</tr>
<tr>
<td>Height</td>
<td>0.04 (0.01 to 0.06)</td>
<td>0.03 (0.01 to 0.06)</td>
<td>0.04 (0.02 to 0.07)</td>
<td>0.04 (0.01 to 0.06)</td>
</tr>
<tr>
<td>Girls</td>
<td>0.11 (0.03 to 0.20)</td>
<td>0.16 (0.07 to 0.24)</td>
<td>−0.07 (−0.11 to −0.04)</td>
<td>−0.09 (−0.12 to −0.05)</td>
</tr>
</tbody>
</table>

†First pulse rate for all studies, for 1970 cohort the reading taken at end of exam was used.
‡Model for estimating adjusted trends included individual BMI and height.
Mill pulse rate, BMI, and height measures were centred at mean age (10.3 years).
was consistent throughout the period with the annual increase of 0.04 bpm (0.02 to 0.07).

Sensitivity analysis restricting to national samples gave a similar annual trend for boys of 0.07 bpm (0.04 to 0.09) and a slightly weaker trend of 0.03 bpm (0.01 to 0.06) for girls. Analysis of studies using an automated device gave a similar trend for boys of 0.06 bpm (0.00 to 0.12) and a slightly stronger trend for girls of 0.08 bpm (0.05 to 0.10). Repeating analysis using 9–10-year girls made little difference to the findings with annual trends of 0.04 bpm (0.01 to 0.07), indicating that the trends were little affected by earlier maturation in recent studies (see online supplementary appendix, table A).

**DISCUSSION**

In our study based on over 22,000 UK children, resting pulse rate increased by approximately 2 bpm among boys and 1 bpm among girls between 1980 and 2008. The trends for pulse rate were not explained by changes of BMI and height during the period and did not differ across levels of BMI. For boys, there was an indication that the trends were steeper after the mid-1990s, compared to the trends prior to 1994 (annual increase of 0.14 vs 0.04 bpm, respectively).

**Methodological considerations**

This is the first investigation in the UK or elsewhere to examine the trends in resting pulse rate in children. Resting pulse rate is a proxy measure of fitness. There are no comparable measurements for physical fitness over time. We used data from several cross-sectional studies because data from standardised pulse rate surveys over extended time periods were limited. As methodological aspects of these studies differed, we have focused on white European children aged 9–11 years and centred their pulse rate to mean age of all children. Although not all studies included were national samples, the prevalence of overweight/obesity in British children increased from 15% in 1995 to 21% in 2008.34 This may also indicate gender differences in regulation and impact of pulse rate.33 If an increase of 2 bpm in mean resting pulse rate in boys persists to the adult population, this could result in a 4% increase in coronary heart disease mortality among healthy men34 and a 2% increase in risk of developing diabetes among over 65 years.35

A school-based PA intervention shows significant improvement in cardiorespiratory fitness and cardiovascular risks in children without much change in BMI.31–33 While health benefits of PA are well accepted, children have become less active in many countries.11 Data from the HSE suggest that daily PAs in children may have declined, particularly in boys. For example, the prevalence of engaging in PA for >30 min/day in boys of same ages declined from 66.7% (63.3% to 70.0%) in 1997 to 59.2% (53.8% to 64.4%) in 2007, while there was an increase in girls from 46.4% (43.2% to 50.3%) to 55.2% (49.6% to 61.0%). The marked decline in PA in boys would be consistent with the greater increase in mean pulse rate observed. There is little research on trends in physical fitness in the UK.

**Implications**

Observed trends in children could have important public health implications for future CVD risk. The association between pulse rate and risk of CVD mortality is found to be stronger in boys than girls. This may also indicate gender differences in regulation and impact of pulse rate.33 If an increase of 2 bpm in mean resting pulse rate in boys persists to the adult population, this could result in a 4% increase in coronary heart disease mortality among healthy men34 and a 2% increase in risk of developing diabetes among over 65 years.35

In summary, mean resting pulse rate has increased by up to 2 bpm among 9–11-year UK children over nearly 30 years. Although modest, it is important to monitor these trends, especially in boys as they appear to have increased at a faster rate in recent years. Increases in PA in children would have a beneficial effect on their physical fitness and cardiovascular health while reducing resting pulse rate.

**Acknowledgements**

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**Contributors**

LL, PWH and DGC conceptualised and designed the study. PWH and DGC provided data for the Two-Towns and Ten-Towns studies. CL provided data for the Brompton study. HP carried out the analyses and prepared the Methods and Results sections of the text. LL drafted the initial manuscript. All authors critically reviewed and revised the manuscript and approved the final version as submitted. LL will act as a guarantor for the paper.
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Competing interests None.

Provenance and peer review Not commissioned; externally peer reviewed.

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