One-year surveillance of body mass index and cardiorespiratory fitness in UK primary school children in North West England and the impact of school deprivation level

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ABSTRACT

Objectives Cardiorespiratory fitness (CRF) is independently associated with health and academic attainment in childhood and adolescence. Yet overweight/obesity remains the focus in public health policy. Surveillance of body mass index (BMI) and CRF considering school deprivation levels is limited. Therefore, we examined this in English primary schools.

Methods Participants (n=409) were students (9–10 years) from 13 schools. BMI and CRF (20m shuttle run) were measured at three time points across the academic year and a fourth after summer recess.

Results BMI z-scores significantly decreased (p=0.015) from autumn (z=0.336 (95% CI 0.212 to 0.460)) to spring (z=0.252 (95% CI 0.132 to 0.371)), and then significantly increased (p=0.010) to summer (z=0.327 (95% CI 0.207 to 0.447)). CRF significantly increased (p<0.001) from autumn (z=0.091 (95% CI −0.014 to 0.196)) to spring (z=0.492 (95% CI 0.367 to 0.616)), no change (p=0.308) into summer (z=0.411 (95% CI 0.294 to 0.528)) and a significant decrease (p=0.001) into the following autumn term (z=0.125 (95% CI 0.021 to 0.230)). BMI was unaffected by deprivation; however, pupils from the most deprived areas saw significantly greater reductions in CRF compared with pupils from affluent areas. No time, or deprivation level, by sex interactions were found.

Conclusion Significant reductions in children's CRF occurred over the summer recess and were greater among children from schools in the most deprived areas. This may help inform future research into interventions targeting physical activity of schoolchildren, particularly over the summer recess.

INTRODUCTION

Cardiorespiratory fitness (CRF) is modifiable by physical activity (PA) and independently associated with health,1 and higher academic attainment2 3; in children and adolescents. Evidence supports tracking CRF from childhood to adulthood,4 and that childhood CRF predicts adult cardiovascular disease and metabolic syndrome risk,4 highlighting the importance of maintaining and improving children’s CRF.5 6 Lang et al4 proposed these factors considered together indicate that population status of CRF in children may help predict future non-communicable disease burden.

Cross-sectional data and meta-analyses have demonstrated rapid secular decline in CRF globally of around 0.36% per annum increasing in magnitude since 1970.8 While public health agencies encourage novel interventions to increase childhood PA, widespread lack of routine health data hampers evaluation of their impact.9 Indeed, the UK Chief Medical Officer has stated, ‘The introduction of a standardised school based fitness assessment in England may have multiple benefits that extend beyond the benefits for the individual.’10

Currently, the only mandated measure of children’s health status in England is the National Child Measurement Programme (NCMP).11 The NCMP is an annual programme that measures height and weight of children in reception (aged 4–5 years) and year 6 (aged 10–11 years). Ease of implementation is a key consideration for school-based
measurement with height and weight easily measured to determine body mass index (BMI). Tracking of CRF levels should also follow a feasible and scalable approach.

The 20 m shuttle run test (20mSRT) is the most commonly employed field-based measurement of CRF in children, is low cost, simple and can test large groups simultaneously.12 13 There is strong evidence the 20mSRT has criterion validity in children12 and as a surveillance instrument could help identify populations with either low or high CRF (based on international normative values for children12) and provide indicators that inform policy or intervention practice.7

Physical fitness, including muscular power and CRF, increases from school year to school year.14 Both BMI and CRF vary seasonally in children15 16 with increases seen throughout the school year.16 17 However, improvements in CRF do not continue and are often lost over the summer recess.16 17 Despite sedentary time and PA both potentially affecting BMI and CRF,16 21 the loss of CRF over the summer is particularly surprising as PA levels often increase during the summer periods.21

Socioeconomic status also influences BMI with children from more deprived areas having greater obesogenic growth trajectories than more affluent peers.22–24 Yet, PA levels and CRF may explain the impact of deprivation levels on BMI.23 24 Children from more deprived areas often have greater barriers to PA in general potentially influencing their BMI and CRF.25 However, it is unknown whether seasonal variation seen in CRF, including the typical loss over summer holiday periods, is also influenced by deprivation levels. It may be that children from more deprived areas have greater barriers to summer PA opportunities25 and thus, though in general children’s PA levels increase through the summer,25 this may not be the case for those in more deprived areas.

Though there are currently programmes examining anthropometric measures in children in the UK, there is a lack of CRF testing in primary schools. Considering the importance of CRF, recent scoping work highlighted that it can be measured in schools in a simple scalable way using the 20mSRT.9 In light of this and the seasonal variation seen in CRF, in addition to the current lack of research examining the impact of deprivation on CRF, the current study had the following aims:

1. To investigate the BMI and CRF in primary school pupils in North West England over a 1-year period.
2. Examine the impact of school deprivation levels on CRF and BMI.

METHODS

Participants

Participants were (n=409) children aged 9–10 (mean±SD; height 132±6 cm, weight 30.75±7.15 kg; 222 males and 187 females) from 13 schools in North West England. Uptake to the testing at the individual level was 100% from children in the age groups tested across the schools involved. Participants were recruited through schools’ involvement with the investigation, and schools were themselves recruited via National Teaching Schools in the local area and existing links with Premier Sport. All schools approached agreed to participate in the investigation.

Ethics and informed consent

As the result of guidance from our institutional ethics panel, the protocol of the present investigation deviated from existing procedures for governance of child measurement. The norm is for schools to opt in to an investigation and provide consent on behalf of pupils with parents provided the opportunity to opt their children out of the investigation. In the present investigation, schools and parents/guardians were required to provide consent and opt in to the investigation.

Consent was obtained from schools and subsequently parents/guardians of all potential participants. Children were provided the opportunity to not participate in testing sessions if they did not wish to. This model has been developed through consultation with Public Health England and the Office for Standards in Education, Children’s Services and Skills (Ofsted).

Confidentiality

All data were anonymised immediately following collection and stored on secure systems approved by Ofsted. Opt-out forms and paper files were stored in locked cabinets within schools, and electronic files stored on password-protected computers, in both cases in accordance with the Ofsted information governance team. All files were destroyed on completion of the investigation. Data were anonymised when transferred to the research team, and stored on password-protected computers.

Measures

All testing was completed by in situ service staff delivering curricular physical education lessons and other extracurricular PAs in schools. All staff were employees of Premier Sport. This organisation was identified as being well placed to deliver the fitness testing described above on the scale necessary as they were already situated in the schools included in the study and delivering the 20mSRT as part of their core business. Measurements were taken at four time points throughout a single calendar year: autumn term (October 2014), spring term (March 2015), summer term (June 2015) and the following autumn term (October 2015). All protocols and procedures were overseen by a member of the research team at the first time point, and thereafter random visits made to ensure standard protocols were followed. Further, delivery staff were provided with standard electronic forms to record all data.

Body mass index

Height was measured to the nearest centimetre and weight measured to the nearest 0.1 kg. BMI was calculated from height and weight scores (kg/m²). BMI z-scores specific to age and sex were calculated using UK 1990 growth reference data.26 International Obesity Task Force (IOTF) classifications were then established.27

Fitness

The 20mSRT was conducted involving 20 m shuttles starting at an initial speed of 8.5 km/hour increasing by 0.5 km/hour/min. An audible signal indicated when a participant should initiate each shuttle. The final shuttle was recorded once a participant failed to maintain the audible controlled pace or stopped due to volitional exhaustion. End speed (km/hour) was determined by the final stage of the 20mSRT based on the number of completed shuttles. The speed for the final completed stage was used as the end speed.28 Age and sex-specific z-scores were calculated using age global reference values for children.29

Area-level deprivation

The area-level deprivation of each school was classified using the English Index Deprivation (EID) 201529 obtained from the school postcode (zip code). The EID is a multidimensional measure of relative deprivation for small areas in England. The UK Government ranks areas based on decile of EID score (from...
decile 1 representing areas with the highest level of deprivation to decile 10—the lowest). Areas falling in EID deciles 1 and 2 are considered deprived with area-level deciles 9 and 10 considered non-deprived (affluent). Participants were grouped from ‘Most Deprived’ (deciles 1–2; n=153), ‘Mid-Deprived’ (deciles 3–8; n=124), to ‘Least Deprived’ (deciles 9–10; n=132).

Data treatment
Missing data resulted at some time points due to child sickness, injury or absence from school on the day of testing. The last observation carried forward (LOCF) method was used to provide a full data set. LOCF was used if a participant had two or more data entries producing a total sample of 409 for analysis. LOCF can provide biased estimates where it is expected that dependent variables might change over time (producing conservative or liberal estimates dependent on whether it is expected that improvement or reduction respectively will occur). However, as standardised z-scores were used based on age appropriate normative data as the dependent variables for analysis, thus providing a stable variable over time, it was considered that LOCF was appropriate. The total number of missing points, interpolated points and comparison between the groups before and after data treatment are presented in the online supplementary material. Independent samples t-test indicated no statistical difference between the original data and LOCF data, therefore the 409 participants with full data were used in subsequent analysis.

Statistical analysis
Data were analysed using IBM SPSS Statistics V.24 for Windows (IBM). Significance was accepted at an α level of p≤0.05. Assumptions of sphericity were examined using Mauchly’s Test of Sphericity. A two-way ‘time’ × ‘group’ analysis of variance (ANOVA) was used to compare the main effects for ‘time’ (Autumn 2014, Spring 2015, Summer 2015, Autumn 2015), ‘group’ (Most Deprived, Mid-Deprived, Least Deprived) and ‘time’ × ‘group’ interaction effects. Effects by ‘sex’ were also examined in addition to ‘time’ × ‘sex’ and ‘group’ × ‘sex’ interactions. Where sphericity was violated a Greenhouse-Geisser correction was used. Post hoc pairwise comparisons examined in addition to ‘time’ × ‘sex’ and ‘group’ × ‘sex’ interactions. Where sphericity was violated a Greenhouse-Geisser correction was used. Post hoc pairwise comparisons at any time point. BMI significantly decreased (p=0.015) from autumn (z=0.336 (95% CI 0.212 to 0.460)) to spring (z=0.252 (95% CI 0.132 to 0.371)), and then significantly increased (p=0.010) to summer (z=0.327 (95% CI 0.207 to 0.447)). Thus, there were no significant differences between the first and following autumn terms (p>0.999). Figure 1 shows mean z-scores over time for BMI and figure 2 shows BMI z-scores by deprivation group. There was no significant between-group effect by ‘sex’ for BMI (F(4,403)=0.008, p=0.930) and there were no ‘group’ × ‘sex’ (F(2,403)=0.139, p=0.870) or ‘time’ × ‘sex’ (F(2,397,963.074)=0.536, p=0.617) interactions.

Cardiorespiratory fitness
For CRF, ANOVA revealed a significant effect by ‘time’ (F(2,395,1644.256)=41.043, p<0.001), a significant effect by ‘group’ (F(2,406)=4.351, p=0.013) and a significant ‘time’ × ‘group’ interaction effect (F(5,715,1644.256)=5.987, p<0.001). CRF significantly increased (p<0.001) from autumn (z=0.091 (95% CI −0.014 to 0.196)) to spring (z=0.492 (95% CI 0.367 to 0.616)), no change (p=0.308) into summer (z=0.411 (95% CI 0.294 to 0.528)) and a significant decrease (p<0.001) into the following autumn term (z=0.123 (95% CI 0.021 to 0.230)). Thus, there were no significant differences between the first and following autumn terms (p>0.999). Figure 3 shows z-scores over time for CRF. Post hoc pairwise comparisons revealed pupils in the Most Deprived group had significantly lower CRF compared with the Least Deprived group in the autumn (p<0.001). In the spring and summer there were no differences between groups. However, in the following autumn pupils in the Most Deprived group had significantly lower CRF compared with the Least Deprived group (p<0.001) and the Mid-Deprived group (p=0.003). Figure 4 shows CRF scores by deprivation group. There was a significant between-group effect by ‘sex’ for CRF (F(1,403)=23.394, p<0.001). However, there was no

RESULTS
Body mass index
IOTF classifications are reported in table 1. The majority of participants were classified as normal weight. For BMI, ANOVA revealed a significant effect by ‘time’ (F(2,395,971.538)=6.469, p=0.001), though no significant effect by ‘group’ (F(2,406)=1.171, p=0.311). There was a significant ‘time’ × ‘group’ interaction effect (F(4,786,971.538)=3.916, p=0.002), though no significant post hoc pairwise comparisons at any time point. BMI significantly decreased (p=0.015) from autumn (z=0.336 (95% CI 0.212 to 0.460)) to spring (z=0.252 (95% CI 0.132 to 0.371)), and then significantly increased (p=0.010) to summer (z=0.327 (95% CI 0.207 to 0.447)). Thus, there were no significant differences between the first and following autumn terms (p>0.999).

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Table 1 Number of participants in each IOTF grade at each of the four measurement points

| Grade                  | Autumn 2014 |            | Spring 2015 |            | Summer 2015 |            | Autumn 2015 |            |
|------------------------|-------------|------------|-------------|------------|-------------|------------|-------------|------------|
|                        | %  | n  | %  | n  | %  | n  | %  | n  |
| Underweight (BMI <18.5 kg/m²) | 8.1 | 33 | 41 | 9.0 | 35 | 8.6 | 35 | 8.6 |
| Normal weight (BMI 18.5 to <25 kg/m²) | 68.9 | 282 | 285 | 69.7 | 286 | 69.9 | 276 | 67.5 |
| Overweight (BMI 25 to <30 kg/m²) | 14.9 | 61 | 60 | 14.7 | 64 | 15.6 | 70 | 17.1 |
| Obesity (BMI ≥30 kg/m²) | 8.1 | 33 | 23 | 5.6 | 24 | 5.9 | 28 | 6.8 |

BMI, body mass index; IOTF, International Obesity Task Force.
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DISCUSSION

Main findings: BMI, CRF and deprivation levels

The primary purpose of this investigation was to examine the BMI and CRF of children over a 1-year period including academic year and summer recess, and the influence of school deprivation levels on this. CRF increased (+3.8% end speed for 20mSRT) from autumn to spring and was maintained throughout the school year. However, CRF levels decreased (−2.3% end speed for 20mSRT) over the summer holidays to a level similar to the previous autumn. Maturation may impact CRF, however normative data indicate an annual increase in boys and girls 9–10 years of age13 so was unlikely to have caused the variation seen. Further, climate correlates with 20mSRT performance with higher CRF in colder countries though was also unlikely to have caused the variation as meteorological data of the nearest UK station suggest mean temperature remained <20°C over the summer.30 CRF changes were compounded by school area deprivation level increasing towards spring and decreasing over summer in all deprivation groups, yet with schools in the poorest areas diverging from others after summer recess. The Most Deprived group had initially lower CRF suggesting there may be the greatest potential for improvement in these children, yet similarly the greatest potential for CRF loss over the summer. BMI followed a similar pattern with initial decreases followed by increases over the year such that BMI was similar at both the beginning and end of the academic year and summer recess. BMI, however, was relatively unaffected by deprivation level. Further, though CRF was affected by sex, there were no interactions for BMI or CRF by sex with either time of year or deprivation level.

These findings may have implications for policymakers and those responsible for the health and well-being of children. First, from a positive perspective, school-based PA delivery programmes may be positively impacting on CRF of children during the academic year. Indeed, children from schools in all deprivation levels increased CRF. Such increases are not dissimilar from specific training to increase CRF in children (~4%–5%31). Other work has reported CRF increases over the school year in Greek schoolchildren16 and Carrel et al found a school-based PA intervention in US children improved CRF over the school academic year. However, some studies show CRF plateaus over summer recess,31 and Carrel et al reported follow-up analysis that improvements from their intervention were eradicated during this period. Recent work on seasonal variation in PA levels suggests children are least active during the autumn and winter seasons,13 and PA levels increase consistently during the summer season.21 It seems counterintuitive that children in the present study lost CRF over this period.

It appears moderate to vigorous PA rather than light PA is more strongly associated with sustained health, fitness and well-being in children.1 3 34 35 Indeed, a recent study reported reallocation of sedentary time to light or moderate PA was not associated with improved CRF whereas vigorous PA was.20 Though PA tends to increase over the summer this is mainly due to increased moderate PA, whereas vigorous PA tends to vary far less.21 Thus, building CRF during youth through vigorous PA should be a focus of school-based and summer PA programmes. Summer day camps may provide opportunities to increase vigorous PA by 15%–18%36 and as such could represent a potentially valuable intervention.

Although PA levels were not measured, a notable limitation, anecdotally parents of children in this study suggested accessible opportunities to keep children active are limited during school holidays, and often unaffordable or difficult to manage around working hours. This may be a barrier that is amplified for those from deprived areas15 and involved in the greater loss of CRF in the most deprived children. As such, future work should...
examine whether interventions addressing barriers such as accessibility and cost can facilitate uptake in the most deprived.

Limitations
Although all students consented to participate, we did not have complete data for all time points (see online supplementary material). This was primarily due to sickness, injury and school absence, though it is possible some children may have been absent because of awareness of the forthcoming testing and thus there may be some bias to estimates produced from LOCQ data. PA levels were not measured in this study and so it is also not clear whether changes in CRF were a result of PA levels. Further, deprivation was considered on the basis of school area. Individual participant-level data were not available for deprivation levels. Some participants may have been based in areas outside of the schools that represented differing EID levels. Future work should consider this and also other factors indicative of deprivation level such as eligibility for free school meals. Lastly, this research was conducted in the North West of England. Thus, the generalisability to other schools across England is not clear. Future work should similarly examine seasonal change in CRF in other areas of the UK and worldwide.

CONCLUSION
Our data highlight that, although CRF increases throughout the academic year, reductions in children’s CRF levels occur over the summer holiday period—an effect which is significantly more apparent among children from the most deprived schools and unaffected by children’s sex. As such, these results highlight a need for interventions aimed at increasing children’s PA levels, particularly vigorous PA, targeted towards the summer holidays to maintain the improvements produced during the school year.

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Competing interests None declared.

Patient consent Not required.

Ethics approval Institution ethics was granted for this study by the ethics committee at Aberystwyth University.

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