

The Influence of Relative Age Effects on the Cardiorespiratory Fitness Levels of Children Age 9 to 10 and 11 to 12 Years of Age

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The aims of this study were firstly to examine whether there was an observed relative age effect in the cardiorespiratory fitness scores of 9–10 and 11–12 year old children, and secondly whether any observed effect was maintained after controlling for somatic maturity. Cardiorespiratory fitness data from 11,404 children aged 9–10 years and 3,911 children aged 11–12 years were obtained from a large cross-sectional field-based fitness testing program. A one-way ANOVA revealed a statistically significant relative age effect ($p < .01$) existed in the 20mSRT scores across all the age groups. Furthermore, ANCOVA analyses identified a statistically significant relative age effect was maintained after controlling for somatic maturation ($p < .05$). From a public health perspective these results confirm the existence of relative age effects for the first time and consequently may hold implications for relatively younger children in the accurate assessment of their cardiorespiratory fitness scores.

There are concerns surrounding declining levels of childhood cardiorespiratory fitness levels (CRF; 8, 38), which are inversely associated with cardiovascular disease (17) and clustered cardiometabolic risk in children (3,18,34). Furthermore, the observed attenuation of children's CRF levels is independent of increases in childhood obesity (8,38). The high prevalence of childhood obesity has prompted substantial investment in physical activity interventions which are predominantly designed to increase moderate-to-vigorous physical activity to promote energy expenditure rather than to promote CRF. In body composition studies, data are equated to age-and-sex-specific norm values (e.g., the IOTF BMI cutpoints (14)), to account for differences in chronological age and physical development. In studies assessing changes in children's CRF, scores are often adjusted for school year group, socioeconomic status (SES), and sex to account

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for the confounding effects of these variables. Data however are rarely adjusted for the decimal age of the participants (i.e., age at measurement) or maturation status.

The most commonly used field test of CRF is the 20m multistage shuttle run test (20mSRT). A recent systematic review of CRF studies concluded that the 20mSRT is valid and reliable among pediatric populations (32). Furthermore, large scale CRF studies have used the 20mSRT as a preparatory step in diagnosing poor physical fitness levels (4,32,38). A recent United Kingdom (UK) physical education-based study demonstrated that when the 20mSRT was used to record CRF scores, those children born in the first quarter of the school year (i.e., September—November) significantly outperformed those children born in the final quarter of the academic year (i.e., June—August; 35, in press). The recorded differences in CRF performance were attributed to variations in chronological and biological age between individuals grouped within the same annual age band. The common procedure of annually age grouping children in education and sport, likely done under the assumption that similarly aged children share comparable learner characteristics and physical attributes, has received criticism for favoring those older children born closer to the ‘cut off’ date for entry and selection (36).

In the UK the educational age-grouping policy currently runs from September 1st to August 31st. Therefore a child born on September 1st 2000 would be 10 years of age on September 1st 2010. However, a child born on August 31st 2000 would also be 10 years of age in 2011, but eligible to attend school in the same age group despite being 364 days younger. The variation in chronological age among individuals grouped in the same annual age band is commonly referred to as the ‘relative age’ and its implications for advantaging those individuals born closer to the ‘cut off’ date are known as ‘relative age effects’ (RAEs; 11, 30). The prevalence of RAEs in competitive sport has received a great deal of attention since it was first observed in Canadian ice-hockey and volleyball (22). A recent meta-analytical review of 38 relative age effect studies found evidence of significant uneven birth date distributions between quartiles (i.e., per 3 months; Q1= 31.2% & Q4 = 20.6%) and half-yearly (i.e., per 6 months) comparisons (52.2% born in the first 6 months of an age-band v 42.7% born in the second 6 months of an age-band; 13). Evidence of RAEs in competitive sport has also been observed in baseball (39), ice hockey (9), soccer (24), both codes of rugby (1), swimming (5), tennis (16) and handball (36).

Despite these ubiquitous findings the primary causes of RAEs are still unclear. Pathological suppositions which have received attention in educational research include the gestational hypothesis (28), where evidence suggests there is an increased risk of fetal infections from pneumonia and influenza during the winter months (20). In addition, reduced availability of ultra-violet light necessary for the production of vitamin D during fetal development has also been cited as a possible cause for central nervous system malformations (31). Unfortunately, there is little available evidence to support the gestational hypothesis in sport. Therefore, based on available evidence in this under-researched area, the most commonly cited explanations for the existence of RAEs are the interindividual growth and maturational differences which exist between individuals within the same age band (12,27). This supposition is supported by those studies which have attributed the existence of RAEs to those sporting activities where physicality is important (i.e., soccer and ice-hockey; 30, 37). Moreover, a recent study which examined a

nonphysical sporting discipline (i.e., shooting sports) did not report the existence of RAEs among its female population, however a moderately biased distribution was observed in a number of the male age groups (15).

RAEs are rarely examined in children's CRF studies, in particular large serial cross-sectional cohort epidemiological studies, in which subtle differences in age between cohorts may have a substantial impact upon fitness results. This in turn may have substantial implications for public health policy, resource allocation and the requirement for CRF intervention studies. To further our knowledge of the causes of RAEs in sport, it has been argued that future research extends beyond the identification (or not) of RAEs in a previously unexamined sporting context (43). To date, however, there are no studies that have examined the possibility of RAEs in the measurement of children's CRF. Despite evidence of previous studies controlling for biological maturity in the identification of talent (37) team sport selection (40) and assessment of children's physical activity levels (19) it is uncommon for children's health and fitness studies to adhere to this methodology. Therefore, the aims of the current study were (1) to examine whether RAEs existed on CRF scores in 9–10 and 11–12 year old children? and (2) to investigate whether any observed RAEs persist after controlling for somatic maturation?

Materials and Methods

Participants

The SportsLinx program has Local Research Ethics Committee approvals, and the methods for the serial-cross sectional study have been described elsewhere (38,42). Briefly, all primary schools and a subsample of secondary schools within the Liverpool Local Education Authority are annually invited to take part in the program. Within each participating primary school, all Year 5 pupils (age 9–10.9 yrs) and within each secondary all Year 7 pupils (age 11–12.9 yrs) school were invited to take part. SportsLinx consists of one field-based fitness testing session (Fitness Fun Day), where participants complete a battery of tests adapted from Eurofit (2). The SportsLinx field-based fitness testing sessions have described acceptable test/retest reliability (7). After receiving informed parental consent, participant assent and medical screening 11,404 Year 5 participants ($n = 5,754$ boys) and 3,911 Year 7 participants ($n = 1,509$ boys), from cohorts 2006–2007–2009–2010, were included in the analyses for the current study.

Measures

Children wore light athletic clothing throughout the fitness testing session. Stature, sitting stature (Seca, Bodycare, Birmingham, UK) to the nearest 0.1cm, and body mass to the nearest 0.1kg (Seca, Bodycare, Birmingham, UK) were measured by one experienced Senior Fitness Officer using standard techniques (26). Body mass index (BMI) was calculated as body weight in kilograms divided by the square of height in meters. Leg length was calculated by subtracting sitting stature from stature. Total number of completed shuttles on the 20mSRT was used as a marker of cardiorespiratory fitness. Decimal age was calculated for each participant using date of birth and date of testing. Somatic maturity (years from peak height velocity

[YPHV] was estimated using the Mirwald method (29). This method has been used previously in studies with similar aged participants (19), and has acceptable agreement with skeletal age (29).

Statistical Analysis

Data were separated by sex and school year group. Participants were then assigned to one of four groups on the basis of date of birth and the UK academic age-grouping policy which runs from September 1st to August 31st each year. Relative age (RA) group 1 included children born 1st September–30th November, group 2 = 1st December—28(9)th February, group 3 = 1st March—31st May, group 4 = 1st June—31st August, within each cohort year. Data were investigated for normality, and 20mSRT scores were log transformed. These values were back-transformed for presentation purposes. Differences in descriptive characteristics across the RAE groups by sex and year group were examined using one-way analysis of variance. Analyses of covariance were completed to assess differences in log transformed 20mSRT scores between the four RA groups by sex and year group. Body mass index and year of testing were included in all models as covariates. In addition to BMI and year of testing, somatic maturity (YPHV) was included as a covariate in the second analysis model. Year of data collection was included as a covariate in all models to account for changes in CRF previously reported elsewhere (8). An alpha value of 0.05 was used to determine statistical significance. All analyses were conducted using SPSS V.17 (SPSS Inc., Chicago, IL).

Results

Tables 1 and 2 display the mean plus standard deviation descriptive characteristics of the four RA groups separately by sex and year group. Figures 1 and 2 display adjusted mean (BMI, year, YPHV) plus *SE* 20mSRT performance by RA group for Y5 and Y7 participants respectively.

Analysis of covariance revealed a number of significant differences between RA groups after controlling for school year and BMI. For all sex and year groups RA group 1 performed significantly better on the 20mSRT than RA group 4 (all $p \leq .01$). Unadjusted mean differences: Y5 boys RAE group 1 vs 4 = 10.0% (41.3 shuttles vs 37.6 shuttles), Y5 girls group 1 vs 4 = 6.6% (28.5 shuttles vs 26.6 shuttles), Y7 boys group 1 vs 4 = 11.4% (49.4 shuttles vs 43.8 shuttles), Y7 girls group 1 vs 4 = 8.3% (33.7 shuttles vs 30.9 shuttles). With the exception of Y7 boys the 20mSRT performances of all RA group 1 were better than group 3 ($p \leq .01$). Mean differences Y5 boys group 1 vs 3 = 5.5% (41.3 shuttles vs 39.1 shuttles), Y5 girls group 1 vs 3 = 6.5% (28.5 shuttles vs 26.6 shuttles), Y7 girls group 1 vs 3 = 9.8% (33.7 shuttles vs 30.4 shuttles). For Y5 girls group 1 also outperformed group 2 ($p \leq .01$) mean difference = 3.6%, 28.45 shuttles vs 27.44 shuttles. With the exception of Y7 girls, group 2 completed more shuttles than group 4 (Y5 and Y5 boys: $p \leq .01$, Y5 girls: $p \leq .05$). Mean differences; Y5 boys group 2 vs 4 = 6.6% (40.2 shuttles vs 37.6 shuttles), Y5 girls group 2 vs 4 = 3.1% (27.4 shuttles vs 26.6 shuttles), Y7 boys group 2 vs 4 = 7.9% (47.5 shuttles vs 43.8 shuttles). In addition for both boys year groups RA group 3 outperformed group 4 ($p \leq .05$). Mean differences; Y5 boys 3 vs 4 = 3.9% (39.1 shuttles vs 37.6 shuttles), Y7 boys 3 vs 4 = 9% (48.1 shuttles

Table 1 20mSRTDescriptive Characteristics by RA Group for 9–10-Year-Old Participants

	Boys				Girls				Group Difference
	Group 1 (n = 1477)	Group 2 (n = 1412)	Group 3 (n = 1437)	Group 4 (n = 1428)	Group 1 (n = 1461)	Group 2 (n = 1377)	Group 3 (n = 1425)	Group 4 (n = 1387)	
Age (years)	10.16 ± 0.21	9.92 ± 0.21	9.66 ± 0.21	9.4 ± 0.21	10.17 ± 0.21	9.92 ± 0.21	9.65 ± 0.21	9.42 ± 0.21	All p < 0.01
YPHV (years)	-3.34 ± 0.44	-3.47 ± 0.43	-3.64 ± 0.43	-3.78 ± 0.39	-1.69 ± 0.56	-1.89 ± 0.53	-2.1 ± 0.47	-2.27 ± 0.49	All p < 0.01
Stature (cm)	140.0 ± 6.5	139.1 ± 6.5	137.7 ± 6.5	136.3 ± 6.2	140.0 ± 7.1	138.5 ± 6.9	137.1 ± 6.4	135.9 ± 6.4	All p < 0.01
Body mass (kg)	36.3 ± 8.8	35.5 ± 8.5	34.7 ± 8.5	33.6 ± 7.7	37.2 ± 9.5	36.1 ± 9.4	35.1 ± 8.5	34.1 ± 8.2	All p < 0.01
BMI (kg/m ²)	18.40 ± 3.48	18.22 ± 3.34	18.16 ± 3.48	17.94 ± 3.07	18.81 ± 3.63	18.65 ± 3.61	18.51 ± 3.48	18.29 ± 3.35	G1 > G4, p < 0.01, G2 > G4, p < 0.05

Table 2 20mSRT Descriptive Characteristics by RA Group for 11–12-Year-Old Participants

	Y7 Boys				Y7 Girls				Group Difference
	Group 1 (n = 363)	Group 2 (n = 397)	Group 3 (n = 369)	Group 4 (n = 380)	Group 1 (n = 612)	Group 2 (n = 567)	Group 3 (n = 563)	Group 4 (n = 660)	
Age (years)	12.01 ± 0.16	11.77 ± 0.16	11.51 ± 0.15	11.25 ± 0.16	12.04 ± 0.18	11.78 ± 0.17	11.52 ± 0.18	11.27 ± 0.18	All p < 0.01
YPHV (years)	-2.14 ± 0.56	-2.3 ± 0.55	-2.49 ± 0.49	-2.67 ± 0.51	-0.05 ± 0.63	-0.31 ± 0.54	-0.56 ± 0.58	-0.80 ± 0.56	All p < 0.01
Stature (cm)	150.7 ± 7.7	149.2 ± 7.4	147.5 ± 7.0	146.0 ± 6.8	152.3 ± 7.5	150.3 ± 7.5	148.6 ± 7.3	146.8 ± 8.4	All p < 0.01
Body mass (kg)	45.0 ± 11.3	43.8 ± 10.2	42.2 ± 10.2	41.6 ± 11.0	47.1 ± 10.8	45.3 ± 10.9	43.6 ± 10.5	42.2 ± 10.1	All p < 0.01 except G3 > G4, p < 0.05
BMI (kg/m ²)	19.6 ± 3.86	19.55 ± 3.52	19.24 ± 3.64	19.31 ± 3.83	20.18 ± 3.79	19.92 ± 3.82	19.60 ± 3.8	19.42 ± 3.61	G1 > G3 & G4, p < 0.05, G2 > G4, p < 0.05

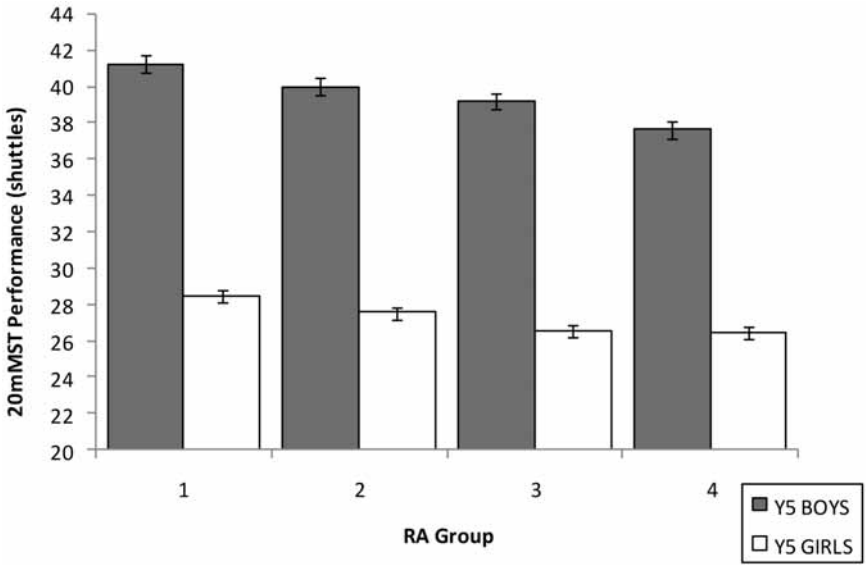


Figure 1 — Adjusted mean (plus standard error) 20mSRT performance by RA Group for 9–10yr old participants

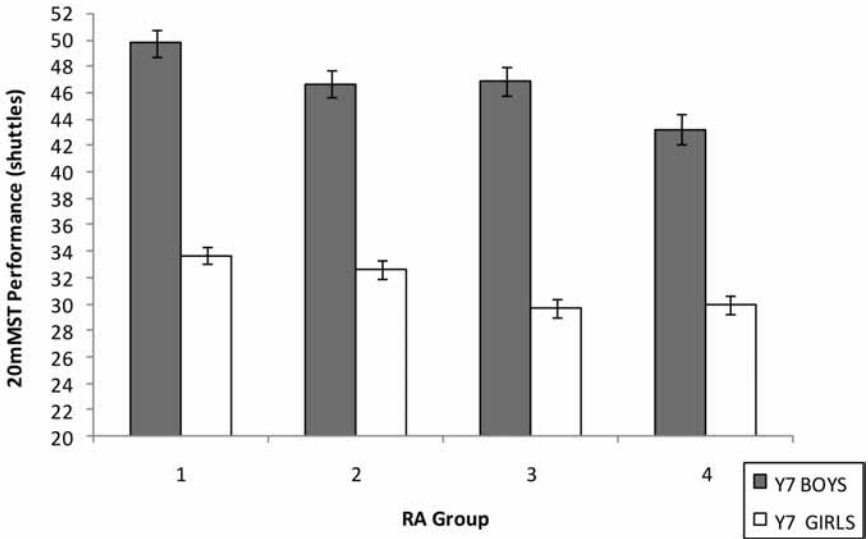


Figure 2 — Adjusted mean (plus standard error) 20mSRT performance by RA group for 11–12yr old participants

vs 43.8 shuttles). Finally, for Y7 girls, group 2 performed better than group 3 ($p \leq .05$), mean difference = 6.7% (32.6 vs 30.4 shuttles).

After controlling for maturation a number of significant differences between groups remained. For boys and girls within both year groups, those in RA group 1 outperformed those in RA group 4 (all $p \leq .01$). In addition, Year 5 boys within RA group 2 completed more shuttles than RA group 4 ($p \leq .05$). Y5 girls in RA group 1 performed better on the 20mSRT than group 3 ($p \leq .01$). For the older age group, Y7 boys within group 3 ($p \leq .05$) completed a greater number of shuttles than group 4, and for Y7 girls those in group 2 performed better than groups 3 and 4.

Discussion

The results of the current study indicate that a statistically significant relative age effect existed in the 20mSRT scores of 9–10 and 11–12 year old children. Furthermore, a statistically significant relative age effect was maintained after controlling for somatic maturation. Specifically, there was a statistically biased distribution of children born in quarter one (Q1), recording higher 20mSRT scores than those children born in quarter three (Q3) and quarter four (Q4). The RAEs were observed in both boys and girls and were present across all the age categories. Previous studies which have investigated the existence of RAEs and their implications in competitive sports, have attributed their prevalence to insensitive selection procedures biased toward those individuals who are born closer to a designated ‘cut-off’ point and who demonstrate advanced levels of physical maturity and maturation (43). This supposition was partially supported in a youth ice-hockey study, where relatively younger children with increased physical stature, were selected ahead of smaller, older children (37). However, to our knowledge, there are no studies which have examined RAEs and CRF among children directly, therefore comparisons with similar studies is problematic.

Although it is acknowledged that CRF is determined by a number of factors including body fatness, sex, health status, age and genetics (25) it is unclear why those children born in (Q1) significantly outperformed those children born in (Q3) and (Q4) on the 20mSRT, especially when the final analyses incorporated measures to offset the effects of somatic maturity as well as sex, and body size. Therefore, the current findings are at odds with current relative age effect theory, which suggests the primary causes of RAEs are maturational differences among individuals within the same chronological age band (33). As there are reported positive associations between CRF and objectively measured levels of physical activity (23) one possible hypothesis is that those children born in (Q3) and (Q4) are less active than children born in (Q1), however, this assumption is speculative and requires additional support. Alternatively, it is plausible that the relatively older children in (Q1) might have been exposed to greater practice or play opportunities than relatively younger peers, and over time, these increases may have impacted positively on levels of CRF. This may be similar to what is known in education as, the ‘length of schooling’ effect, which has been cited has a possible cause for the existence of RAEs in education (6).

Strengths of this study were the large, representative sample and the innovative nature of the analysis. Limitations include the following: the CRF testing

was conducted in a field-based setting, and although data were collected from professionals trained in CRF data collection procedures, there remains the potential for systematic bias, based on the inconsistent quality of the fitness data. Moreover, although participation rates for SportsLinX are high (typically 70–80% of Year 5 children, and approximately 40% of Year 7 children), data do not exist for children who declined to participate; therefore recruitment bias cannot be determined. Furthermore, although the 20mSRT test is acknowledged to be a reliable indicator of children's CRF (32) there are reports that children's performance during the 20mSRT can be adversely affected by motivation (21). Finally, somatic maturation was estimated using a regression approach, rather than direct measurement (for example by assessing skeletal age), which may have introduced error. The estimation of maturation also did not take into account cognitive development, which may be an important contributor to RAE in youth. To date, no studies have examined RAEs and cognitive development specifically, and this is one avenue of future research that is required to elucidate the determinants of RAEs.

From a public health perspective the findings suggest that children born earlier in the school year are fitter, and therefore potentially at a lower risk of health complications, than children born in the latter half of the school year. However the younger children may be of more similar fitness, and risk, if assessed at the same decimal age. Age-and-sex-specific cut points are required to accurately assess children's fitness levels. The use of such cut points would allow health professionals to identify those of genuinely low fitness and consequently at increased risk of cardiometabolic illness. Conversely, age-and-sex-specific fitness cut points may help teachers and practitioners identify children with high fitness levels that could be referred to talent identification and development programs. In the absence of age and sex specific cut points, future studies should control for decimal age as well as maturation in analyses.

Conclusion

To our knowledge this is the first study to investigate the existence of RAEs in CRF from a large cross-sectional cohort epidemiological study. Significant RAEs were observed across all the age group categories as well as across gender. Furthermore, the prevalence of RAEs remained after controlling for the effects of physical maturity. These results suggest, in CRF studies at least, the existence of RAEs for the first time. From a public health perspective this may contain implications for relatively younger children and the accurate assessment of their CRF. Current research suggests RAEs are caused primarily by maturational and biological differences between individuals within the same chronological age band. Although, we do not dispute this particular argument, our results are contrary to this particular theory, and to develop this argument further, we propose that future relative age effect studies attempt to develop this discussion. Unfortunately, we can only speculate as to why the RAEs remained after the physical maturity analyses were conducted. However, this is an interesting and new insight into the relative age effect phenomena and one that warrants further scientific attention.

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