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Quantification of the relative age effect in three indices of physical performance.

Running Head: Relative age and performance.

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Abstract.

The relative age effect (RAE) describes the relationship between an individual's birth month and their level of attainment in sports. There is a clustering of birth dates just after the cut-off used for selection in age-grouped sports and it is hypothesised that such relatively older sportspeople may enjoy maturational and physical advantages over their younger peers. There is, however, little empirical evidence of any such advantage. This study investigated whether schoolchildren's physical performance differed according to which quarter of the school year they were born in.

Mass, stature, BMI, cardiorespiratory fitness, strength and power were measured in n=8550 10-16 year olds (53% male). We expressed test performance as age- and sex-specific z-scores based on reference data with age rounded-down to the nearest whole year and also as units normalised for body mass. We then compared these values between yearly birth quarters

There were no significant main effects for differences in anthropometric measures in either sex. Girls born in the first quarter of the school year were significantly stronger than those born at other times when handgrip was expressed as a z-score. As z-scores, all measures were significantly higher in boys born in either the first or second yearly quarters. Relative to body mass, cardiorespiratory fitness was higher in boys born in the first quarter and power higher in those born in the second quarter.

The relative age effect does not appear to significantly affect girls' performance test scores when they are expressed as z-score or relative to body mass. Boys born in the first and second quarters of the year had a significant physical advantage over their relatively younger peers. These findings have practical bearing if coaches use fitness tests for talent identification and team selection. Categorising test performance based on rounded-down values of whole-year age may disadvantage children born later in the selection year. These relatively younger children may be less to gain selection for teams or training programmes.

INTRODUCTION.

The rapid anthropometric and physiological development seen during childhood and adolescence, has great inter-individual variation due to heterogeneity in the onset of puberty and achievement of peak height velocity (29). Paediatric studies of strength and conditioning often account for the 'whole-year' age of participants; usually by rounding actual age down to the nearest whole year. This means, however, that children differing in age by up to 364 days may be compared with one another.

The relative age effect (RAE) refers to the relationship observed between an individual's month of birth relative to their peers and their achievement in sports (31). The RAE is evident in many sports, observable by the overrepresentation of elite athletes' birth dates in the early part of the selection year (4). For example, the cut-off date for age grouping in Ice Hockey is 1st January and significantly more Hockey players are born from January to March than between September and December. In the United Kingdom the cut-off date for soccer is 1st September. More elite-level soccer players are born from September to December than between June and August (27). The clustering of birth dates reported in these retrospective studies is often explained using the following reasoning. During age-group sport (which precedes nearly all elite-level representation) children born early in the selection year are relatively older than those born at the year's end, but compete against one another for selection (31). The relatively older children may enjoy maturational and physical advantages over their peers within the same age-group (33). Relatively older children receive more attention from coaches (7) which provides them with more playing time (28) increasing the overall likelihood of being selected for sports teams (26).

Few studies have empirically assessed physical differences according to relative age within age-grouped sports participants. Hirose *et al.*(9) found no differences in maturation or skeletal age in 10-15 year old Japanese soccer players divided according to relative age (birth quarters). Carling *et al.*(3) found no differences in measures of body size, strength, power or cardiorespiratory fitness in elite soccer academy players. One problem in such studies which compare across quartiles within academies or representative teams is that the players (in all quarters) are already a selective population. The smallest, least mature players are likely to have already been 'de-selected', which may explains why, for instance, Hirose *et al.*(9) found significantly more academy players were born in the first quarter of the selection year. This pre-selection also means that any relatively younger players (those born in the third or fourth quarters of the year) may not be truly representative of other children their age. They may, for instance over-represent those who mature earlier or who are larger than the population average.

Talent identification is the process of recognizing individuals within a population possessing the potential to excel in a given sport (32) and the popularity of such programmes' has increased in recent decades. Cross-sectional talent identification programmes may, however, discriminate against late-maturing and/or relatively younger individuals via the RAE. While there appears to be little evidence of an RAE in pre-selected groups of soccer players (3, 9) only one study (21) has assessed differences in physical fitness according to relative age in a non-selective sample.

Roberts et al. (21) reported small but statistically significant differences in absolute measures of cardiorespiratory fitness (shuttles completed during the 20-m shuttle-run test). Performance on the 20 m shuttle-run test is strongly influenced by age and sex (23) and it is normal to express performance according to age- and sex-specific normative data (22) or criterion-referenced standards (16).

Age- and sex-normalised standards, and reference data which they use are essential tools in the assessment in talent identification (16). The maturational changes observed during childhood and adolescence demand the use of age-specific reference values to create z-scores or percentiles to facilitate fair and appropriate evaluation of body dimensions(6) and physical performance (6) across age groups. It is somewhat surprising that, to date, no study of the RAE has utilised test scores expressed in this way.

If large-scale, cross-sectional assessments of youth are to be used in talent identification, they must be able to account for differences in relative age and maturational status between children within similar age groups. The aim of this study was, therefore, to assess whether there were differences in three measures of physical performance (cardiorespiratory fitness, strength and power) within youth placed in age-groups according to school year. We also aimed to assess whether such differences can be minimised or eliminated by the use of units normalized for body mass or age (z-scores).

METHODS.

Experimental approach to the problem.

To test the hypothesis that physical differences may explain the relative age effect we measured three elements of physical fitness recognised as being predictive of athletic success: cardiorespiratory fitness, strength and power. These dependent variables are important potential outcome measures in talent identification and conditioning programmes(10). To contrast between-group differences in a manner comparable with retrospective RAE studies, participants' yearly quarter of birth (starting at the school year cut-off date of 1st September) was chosen as the independent variable as this is known to be associated with the likelihood of selection in numerous sports(4). The year was divided into quarters (labelled: Q1, Q2, Q3 &Q4) with Q1 corresponding to the period of 1st September-31st November. The study was approved by the University of Essex Ethics Committee; informed parental consent was obtained as was the full assent of each participant at point of contact. All measurements were made during scheduled physical education (PE) classes (between 9 am and 3 pm) in either May-July or in September in the years 2007-2010. As participants were tested in one of these two discrete periods, we used month of testing as a covariate.

Participants.

We sampled n=8550 10-16 year olds from 24 schools as part of The East of England Healthy Hearts Study. The sample was representative of the region in terms of ethnic mix, rural/urban dwelling and socioeconomic status measured using the English Indices of Multiple Deprivations obtained via the UK Office of National Statistics(19).

Procedures.

Date of birth, sex and ethnicity were self-reported. Ethnicity was collapsed into White, Black, Asian, Mixed and Other. Birth date was subtracted from date of testing to provide decimal age (to the nearest day). Decimal age of the sample is given in table 1 and by birth-quarter in table 2. Table 2 also contains each individual's 'age-group' age. This represents the rounded-down value used for comparison with reference data. As it is the most-common practice reported, we rounded decimal age down to the nearest whole year (i.e. those age 12.0 to 12.99 were all compared with reference data for 12 year olds).

Stature (±1 mm) and mass (±0.1 kg) were measured with participants dressed in physical education clothing without shoes. Body Mass Index (BMI) was calculated ($kg \cdot m^{-2}$) and converted to z-scores based on UK reference data (6). Cardiorespiratory fitness was assessed using the 20 m shuttle-run test (20mSRT) performed as the FITENSSGRAM PACER™ Test (15) which has a test-retest ICC of R=0.81.(2) Cardiorespiratory fitness was expressed as estimated Vo_{2peak} ($ml \cdot kg^{-1} \cdot min^{-1}$) derived from the equation of Leger et al. (12) from maximal running speed achieved (relative cardiorespiratory fitness) and also as z-scores (age-normalised cardiorespiratory fitness) based on UK reference data. (22)

Isometric handgrip strength was measured as instantaneous, maximal isometric force production using a portable dynamometer (Takei Corp Ltd., Tokyo, Japan). After verbal instruction and adjustment of the dynamometer for hand size, participants performed two maximal isometric contractions using their dominant hand, in the standing position wthout Valsalva's manoeuvre. The highest value was recorded and converted to relative strength by dividing the highest score achieved by body mass and termed relative strength ($W \cdot kg^{-1}$). Handgrip was also expressed as a z-score based on our own reference data and referred to as age-normalised strength (5). Handgrip dynamometry typically produces test-retest high reliability coefficients (20)with ICC values R>0.80 in children (18).

Vertical jump height was measured using an electronic timing mat (NewTest Ltd. Oulu, Finland). Participants performed a countermovement jump with the use of arms which is a reliable technique producing ICC values R>0.90 in children(1). The jump began from a standing position, with plantigrade foot and the leg vertically aligned. On instruction, the countermovement was performed and the individual flexed their knees flexed to approximately 90^0 before rapid extension and take-off. Landing (initial contact with the jump mat) was with toes initially and the knee angle close to full extension. If these criteria were not met, the jump was performed again. Two trials were given and the highest value recorded and expressed as a z-score (age-normalised jump height) based on UK reference data (30). Peak power was calculated from body mass and flight time (25), defined as the power exerted during the take-off phase of the jump. This value was expressed as relative to body mass ($W \cdot kg^{-1}$) as relative peak leg power. Table 1 shows the descriptive characteristics of the sample and mean (±SD) values for all variables measured.

Statistical Analyses

We used ANCOVA (controlling for age in whole years, month of testing, deprivation and including school as a random factor) to identify differences in anthropometric measures between quarters. For physical performance variables, we additionally controlled for stature (z-score) as a proxy for maturation. We performed *post hoc* tests (Bonferroni) to identify individual differences in the estimated marginal means between the yearly quarters. A value of p<0.05 was assumed to show statistical significance. All analyses were performed using PASW 18.0 (SPSS Inc. An IBM Company Chicago, Il. USA.)

RESULTS.

As expected, there were differences in the actual (decimal) age of participants when divided into yearly birth quarters; the earlier in the school year participants were born, the older they were. The z-scores for anthropometric measures were all positive as expected due to well-documented increases in body stature and particularly body mass since the release of the reference data sample during the 1990s(6). The z-scores for a physical performance tests were closer to zero, also as expected due the sample's similarity with the development populations for the reference data.

TABLE 1. Here

There were no significant main effects for ANCOVA in any anthropometric measures in boys or girls. In girls there was a *post hoc* difference indicating greater stature in Q1 vs. Q4. The only main effect observed for physical performance measures in girls was a difference in age-normalised handgrip strength. *Post hoc* analysis showed girls born in Q1 were significantly stronger than those born in Q2-4, but only when handgrip was expressed as a z-score.

TABLE 2. Here

Boys born in Q1 had higher cardiorespiratory fitness than those born in all other quarters, whether expressed in relative (Vo_{2peak}, $ml \cdot kg^{-1} \cdot min^{-1}$) or age-normalised units. Age-normalised handgrip and jump were higher in Q1 boys but there was no difference in relative strength across remaining quarters. While there was a significant main effect for relative power, *post hoc* analysis showed that Q2 boys had a mean value significantly greater than that in all other groups.

DISCUSSION.

This is the first study to examine whether differences in physical differences can explain the relative age effect (RAE) according to school year by examining multiple indices of body dimensions and physical performance in a non-selective population of schoolchildren. Our data provide little evidence of any anthropometric differences between birth quarters (greater stature or body mass) in either sex. The data do suggest, however, that boys born in the first quarter of the school year have higher relative and age-normalised cardiorespiratory fitness, greater age-normalised handgrip strength and greater relative and age-normalised leg power compared with their relatively younger peers. This effect was evident despite the majority of our attempts to normalise scores for body mass and age.

Retrospective analyses of the birth dates of elite players' in many sports shows they tend to be more likely to be born early in the sport's selection year (4).While there is some evidence of maturational or anthropometric differences between those born in different quarters of the selection year (3, 9) any evidence of differences in physical performance is relatively sparse. Carling *et al.* (3) found no significant differences in cardiorespiratory fitness, strength or power between youth academy soccer players of different relative ages despite a large sample size (n=160) and performance of multiple (n=12) uncorrected statistical tests. The problem with such studies is that the population is already highly selective (by being at a youth soccer academy) which may explain the lack of differences between birth-quarters. Roberts *et al.*(21) reported small but statistically significant differences in cardiorespiratory fitness test results (laps run on 20 m shuttle-run test) between birth quarters; with the largest difference (~5 shuttles) reported in the oldest (11 year old) boys. This difference is of a very similar magnitude of that observed in boys in Q1 (54±7) *vs.* Q4 (39±6) in the present study (laps data not shown).

We chose not to report raw test scores (laps) as these are rarely useful in children. To further improve on previous work we compared three different indices of performance expressed in units more commonly used and more appropriate for comparative assessment of children. We found little evidence of a relative age effect for anthropometric variables (expressed as z-scores) despite only rounding age down to the nearest whole year. In girls there was little evidence of a relative age effect for any performance index except handgrip (z-score); and scores on this measure did not follow the expected pattern for a true relative age effect (Q1>Q2>Q3>Q4) as the lowest value was found in Q3. The difference observed in Q1 is probably the product of a true relative age effect and the trend towards greater stature and mass in Q1 girls as handgrip is positively related to both measures(24). Further evidence against a relative age effect in girls was the fact that the highest values for Vo_{2peak} and Jump-z were both found in Q4; the youngest group. To our knowledge this is the first attempt to quantify physical performance RAE in females. Roberts et al.(21) found that Grade 7 girls in Q2 completed more shuttles than those in Q3 or Q4. While we found no significant between-group differences it is of interest to note that the highest shuttle-run z-score was also found in Q2. While the present results are difficult to compare to those of Roberts, et al.(21) due to differences in the age-groups studied and the units of measure used, a feature common to both studies is the much greater evidence of RAE in boys than girls.

In boys, however, there were clear differences in cardiorespiratory fitness between quarters regardless of units of expression. Vo_{2peak} in boys born near the beginning of the school year (September-November) was 2 $ml \cdot kg^{-1} \cdot min^{-1}$ higher than their peers born June-August but there were no other significant differences between Q2, Q3 or Q4. This pattern was the same when CRF was expressed as a z-scores with differences between Q1 and Q3 equal to 5 percentile points (40th *vs.* 35th percentile). Differences in z-scores for handgrip (Q1, 55th percentile) *vs.* (Q2, 45th percentile) and jump height (Q1, 51st percentile) *vs.* (Q3, C44th percentile) were even larger suggesting that the use of z-scores based on age rounded down to whole-years unfairly compare strength and power in boys. No relative age effect was evident, however, when strength was expressed per unit body mass. Differences in peak power expressed relative to body mass were small and did not show an advantage for Q1 as the relative age effect would predict. Together these results suggest that expression of strength and power indices per unit body mass may provide fairer comparison within boys and girls of this age-range. The relative age effect predicts a gradient in performance between birth quarters as observed previously (21). Presently, we only found significant differences in performance between Q1 and all other birth quarters; there were no differences between Q2, Q3 or Q4. The present data may suggest an additional physical advantage to being born in Autumn in particular. This is not an unprecedented suggestion as northern hemisphere, autumn-born individuals are known to have greater adult body (11) size and even increased longevity (8) when compared with summer-born individuals.

The more pronounced relative-age effect in boys may be a product of the population's age. At 13 years (mean and median age), the majority of the girls measured would be pubertal whereas there is likely to have been more variation in boys' developmental stage. As well as beginning later, boys' physical development is slower than girls and they take significantly longer to achieve their adult stature and mass (13). Such differences in timing and rate of pubertal growth may explain why the relative age effect is less observable in female sportspeople than in males (4).

The strengths of the present data lie in the large and inclusive sample and the use of population-specific age- and sex-normalised population scores to express fitness test results. The present study lacks a true estimate of maturity status which is likely to differ significantly between yearly quarters (21). The data are also limited by the use of the school-year cut-off date. This approach, combined with the use of age- and sex-normalised or scaled values was the only viable method by which to assess the RAE across the age-ranges in our whole sample. Future research, may wish to quantify differences in key fitness test scores within sex and age categories. While such information may be more directly valuable to coaches and those involved in talent identification, quantification requires that large samples, such as those of Roberts et al., are necessary.

Practical Applications.

There is no simple answer to this problem. Replacing the convenience and simplicity of comparing individuals according to their whole year age group with a system that is likely to be more complex to administer and understand will likely be unpopular, not least because it may mean selecting sports performers that don't maximise the short term success of the team or squad. Where there is a clear objective measurement of talent however, optimizing talent identification requires coaches to take some account of the relative age of young athletes.

In sports that are judged on objective performance criteria, such as time or score to complete a task, it may be possible, through analysis of historical data, to create an age-correction factor for whole year age group performances according to month of birth. This approach would, of course, be advantageous to early maturing individuals born late in the year, but, would eliminate the systemic bias created by the whole year age group comparison of individual performances.

In sports where individual performances are judged subjectively, such as team sports selection, an individual's contribution to the team performance is usually assessed in comparison to his/her peers in the team by the team coach. Those individuals born later in the year may be outperformed by relatively older, and thus stronger and fitter, players. In order to assess the long-term potential of players it may be necessary to compare individuals born in the first quarter or half of the whole year age group, where physical advantages in our study were apparent, with those in the year group above, in order to eliminate the relative age effect on talent selection.

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References.

Table Legends.

Table 1.

Title: Descriptive characteristics for 8550 10-16 year old schoolchildren.

Legend:

SD – standard deviation, z = z-score based reference data; BMI - body mass index: CRF – Cardiorespiratory fitness measured as final running speed on the 20 m shuttle run test; Jump – maximum vertical jump height achieved in countermovement jump.

Reference data for BMI : Colet *et al.* (6). Reference data for 20 m shuttle run: Sandercock *et al.* (23). Reference data for handgrip: Cohen *et al*. (5). Reference data for vertical jump: Taylor *et al*. (30)

Table 2

Title: Differences in cardiorespiratory fitness, strength and power expressed relative to body mass and as age- and sex-specific z-scores.

Legend:

ANCOVA – Analysis of covariance controlling for age (whole years), month of testing, deprivation and stature (z-score) for performance variables; school entered as random factor in all analyses
SD – standard deviation. z = z-score based on population reference data; HG - hand grip, Jump – Vertical Jump, BW – body mass, W –Watts; W/kgBW – Watts expressed per kilogram of body mass.
Reference data for BMI : Colet *et al.* (6). Reference data for 20 m shuttle run: Sandercock *et al.* (23) Reference data for handgrip: Cohen *et al*. (5). Reference data for vertical jump: Taylor *et al*. (30)
*****indicates highest quartile mean value. Values in **bold** indicate significant difference in group mean compared with highest value.
[a] Corrected for age, date of testing and deprivation (school entered as a random factor)
[b] Corrected for stature (z-score) age, date of testing and deprivation (school entered as a random factor).

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Table 1.

Title: Descriptive characteristics for 8550 10-16 year old schoolchildren.

	All (n=8550)		**Males (n=4514)**		**Females (n=4036)**	
	Mean	SD	Mean	SD	Mean	SD
Age (yrs)	12.9	1.50	13.00	1.54	12.8	1.45
Stature (z)	0.22	1.05	0.23	1.07	0.20	1.03
Weight (z)	0.51	1.16	0.56	1.11	0.46	1.10
BMI (z)	0.52	1.20	0.59	1.18	0.45	1.13
CRF ($km \cdot h^{-1}$)	10.3	0.12	10.7	1.27	9.79	0.92
CRF (z)	-0.35	1.15	-.331	1.25	-0.36	1.03
Handgrip (kg)	23.8	1.00	25.8	9.19	21.7	5.70
Age-normalised Handgrip (z)	0.00	7.20	-0.01	1.01	0.00	0.99
Jump Height (cm)	27.9	7.20	29.9	7.72	25.6	5.74
Age-normalised (z)	-0.07	1.11	-0.07	1.10	-0.07	1.12

Legend:

SD – standard deviation, z = z-score based reference data; BMI - body mass index: CRF – Cardiorespiratory fitness measured as final running speed on the 20 m shuttle run test; Jump – maximum vertical jump height achieved in countermovement jump.

Reference data for BMI : Colet *et al.* (6). Reference data for 20 m shuttle run: Sandercock *et al.* (22). Reference data for handgrip: Cohen *et al*. (5). Reference data for vertical jump: Taylor *et al*. (30)

Table 2.

Title: Differences in cardiorespiratory fitness, strength and power expressed relative to body mass and as age- and sex-specific z-scores.

	Males Sept-Nov	Males Dec-Feb	Males Mar-May	Males June-Aug	ANCOVA	Females Sept-Nov	Females Dec-Feb	Females Mar-May	Females June-Aug	ANCOVA
Age (rounded down)	12.57 *±1.52*	12.64 *±1.51*	12.65 *±1.50*	12.47 *±1.51*	-	12.42 *±1.41*	12.31 *±1.42*	12.40 *±1.43*	12.30 *±1.41*	-
Actual age (Decimal)	13.25 *±1.51*	13.15 *±1.55*	12.98 *±1.52*	12.66 *±1.53*	-	13.09 *±1.48*	12.84 *±1.47*	12.72 *±1.49*	12.42 *±1.45*	-
[a]Stature (z)	*.245 *±1.08*	.205 *±1.06*	.206 *±1.09*	.294 *±1.04*	F=1.20 *p=0.340*	*.247 *±1.03*	.183 *±1.05*	.203 *±1.02*	**.182** ***±1.02***	F=1.87 *p=0.133*
[a]Weight (z)	*.567 *±1.12*	.535 *±1.09*	.566 *±1.11*	.588 *±1.11*	F=1.38 *p=.244*	.*496 *±1.11*	.469 *±1.11*	.452 *±1.08*	.425 *±1 .10*	F=.354 *p=.786*
[a]BMI (z)	*.588 *±1.19*	.574 *±1.15*	.620 *±1.20*	.585 *±1.19*	F=.328 *p=.805*	*.482 *±1.10*	.473 *±1.16*	.440 *±1.12*	.424 *±1 .15*	F=.611 *p=.608*
[b]Age-normalised CRF (z)	*-.233 *±.997*	**-.345** ***±.924***	**-.371** ***±.973***	**-.343** ***±.941***	**F=4.10** ***p=.006***	-.371 *±.883*	*-.352 *±.928*	-.421 *±.880*	-.441 *±.860*	F=1.78 *p=.148*
[b]Relative Cardiorespiratory Fitness (ml.kg^{-1}.min^{-1})	*46.3 *±6.5*	**45.5** ***±6.3***	**45.3** ***±6.0***	**45.6** ***±6.3***	**F=4.47** ***p=0.004***	41.2 *±5.1*	41.5 *±5.4*	41.1 *±5.0*	*41.6 *±4.8*	F=1.88 *p=.132*
[b]Age-normalised handgrip strength (z)	*.118 *±1.06*	**-.086** ***±.968***	**-.104** ***±.976***	**.008** ***±1.03***	**F=11.6** ***p<.001***	*.129 *±1.00*	**.033** ***±1.01***	**-.079** ***±0.96***	**-.046** ***±1.00***	**F=8.13** ***p<.001***
[b]Relative handgrip strengtg (kg/kgBW)	*.518 *±.128*	.516 *±.122*	.511 *±.126*	.514 *±.124*	F=1.86 *p=.134*	.449 *±.098*	*.450 *±.112*	.446 *±.099*	. 446 *±.099*	F=.348 *p.791*
[b]Age-normalised jump height (z)	*.034 *±1.12*	**-.111** ***±1.11***	**-.140** ***±1.11***	**-.069** ***±1.08***	**F=3.49** ***p=0.015***	-.047 *±1.13*	-.126 *±1.11*	-.092 *±1.16*	*-.032 *±1.09*	F=.902 *P=.439*
[b]Relative peak leg power W/kgBW	**38.7** ***±9.91***	37.9* *±10.0*	**37.3** ***±9.54***	**37.4** ***±9.99***	**F=6.02** ***p<0.001***	*33.5 *±7.13*	32.5 *±8.03*	32.7 *±8.45*	32.5 *±8.20*	F=1.55 *P=.200*

Legend:

ANCOVA – Analysis of covariance controlling for age (whole years), month of testing, deprivation and stature (z-score) for performance variables; school entered as random factor in all analyses
SD – standard deviation. z = z-score based on population reference data; HG - hand grip, Jump – Vertical Jump, BW – body weight, W –Watts; W/kgBW – Watts expressed per kilogram of body weight.
Reference data for BMI : Colet *et al.* (6). Reference data for 20 m shuttle run: Sandercock *et al.* (22). Reference data for handgrip: Cohen *et al*. (5). Reference data for vertical jump: Taylor *et al*. (30)
*indicates highest quartile mean value. Values in **bold** indicate significant difference in group mean compared with highest value.
[a] Corrected for age, date of testing and deprivation (school entered as a random factor)
[b] Corrected for stature (z-score) age, date of testing and deprivation (school entered as a random factor).