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Original citation & hyperlink:
Nevill, AM, Duncan, M & Sandercock, G 2020, 'The dose-response association between V̇O2peak and self-reported physical activity in children', Journal of Sports Sciences, vol. 38, no. 16, pp. 1829-1835.
https://dx.doi.org/10.1080/02640414.2020.1756682

DOI 10.1080/02640414.2020.1756682
ISSN 0264-0414
ESSN 1466-447X

Publisher: Taylor and Francis

This is an Accepted Manuscript of an article published by Taylor & Francis in Journal of Sports Sciences on 13/05/2021, available online: http://www.tandfonline.com/10.1080/02640414.2020.1756682

The dose-response association between $\dot{V}O_{2peak}$ and self-reported physical activity in children

Running head: The dose-response association between $\dot{V}O_{2peak}$ and physical activity

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Abstract

***Background*:** Previous research into the association between aerobic fitness and physical activity in children is equivocal. However, previous research has always assumed that such an association was linear. This study sought to characterize the dose-response association between physical activity and aerobic fitness and to assess whether this association is linear or curvilinear and varies by sex, age and weight status.

***Methods*:** Physical activity (assess using the Physical Activity Questionnaire), aerobic fitness (20 m shuttle-run), BMI, screen-time and socio-demographic data were collected at ages 12, 14 and 16-years in (n=1422) volunteers from 9 English schools. Multilevel-regression modelling was used to analyse the longitudinal data.

***Results*:** The analysis identified a significant inverted ‘u-shaped’ association between VO_2max and PAQ. This relationship remained havingcontrolling for the influences ofsex, age and weight status. Daily screen time >4 hours and deprivation was also associated with being less fit (P<0.01).

***Conclusions*:** This longitudinal study suggests that the dose-response relationship between PA and aerobic fitness in children is curvilinear. The health benefits of PA are greater in less active children and that sedentary and less active children should be encouraged to engage in PA rather than more active children to increase existing levels of PA.

Introduction

Cross-sectional studies in adults show physical activity (PA) and aerobic fitness share a positive, dose-responserelationship (1,2).When adjusted for anthropometric and sociodemographic factors, PA explainsas much as 20% of the variance in aerobic fitness (3).Studies in youthare less consistent (4)showing only low-to-moderate associations (r=.10-.45) between PA and fitness (5)Weight status explains a significant proportion of the variance in fitness (1,6); moderating and mediating its association with PA (4,7,8).Onecross-sectional study by Nevill et al (9)has recently reported the association between children's PA and aerobic fitness. Nevill et al (9)found the association of PA with fitness to be curvilinear(inverted u-shaped) withgreater/steeperincrements in fitnessper unit difference in activity at lowerPA levels with the authors suggesting a dose-response relationship.

However, it could be argued that a true dose-response relationship can only be determined using a longitudinal approachwith repeated assessments. Studies of this nature are rare although,in the Amsterdam Growth and Health Study a 30% increase in PA over a 15-year period was associated with a 2-5% increase in $\dot{V}O_{2peak}$ (10). The authors of the Amsterdam Growth and Health Study concluded, 'no clear relation can be proved between PA and $\dot{V}O_{2peak}$ in free living males and females' (10). Likewise, in a longitudinal study of over 200 children Armstrong et al. (11)used multilevel modelling to examine change in PA, from the ages of 11–13 years. When adjusted for age, gender and maturitythere was no evidence for an association with fitness (11). Other research using multilevel modelling of longitudinal pooled data (12) confirmed the findings of cross-sectional studies showing effects of body size and body composition on $\dot{V}O_{2peak}$ but found no association withPA (12). However, the lack of evidence that a dose-response association exists between aerobic fitness and PA in previous studies (10,11,12) may well be due to the authors not allowing for the strong possibility that the association between aerobic fitness and PA is curvilinear rather than linear (see 9).The extant literature in regard to dose-response relationships between PA and aerobic fitness in children remains equivocal but it is important to also note that fewstudies examining the association between PA and aerobic fitness consider other important confounders; in particular deprivation and correlates of low PA in childhood such as screen-time (13). Deprivation in particular is a key confounder as more deprived children in the UK are likely to have lower levels of aerobic fitness (14) and PA (15,16).

This study sought to address this gap in the literature by exploring the dose-response rate (i.e., associations) between fitness and PA to be curvilinear rather than linear using a longitudinal study design and accounting for known confounders (age, sex, and weight status) as well as other possible influences such as deprivation and screen time.

Methods

Participants

We drew data from the East of England Healthy Hearts (EoEHHS) study, a large (n=8800) school-based health and fitness survey of 11-16 year-olds (overall consent: 96%). The longitudinal arm of the EoEHHS comprised a subsample of students from n=9 public schools all of whom were in grade 7 at baseline (summer months of 2007; *n*=1503, 46% female). Parents gave written informed consent prior to data collection. Trained researchers conducted all measurements during regularly scheduled physical education classes. We replicated two season-matched follow up assessments in grade 9 and grade 11. The present longitudinal analysis includes n=1422 participants who had complete data for cardio-respiratory fitness, self-reported physical activity and screen time at all time points after wave 1.

Table 1 here

Measures of Weight Status

Body mass and stature were measured (to the nearest 0.1 kg and 0.1 cm, respectively) with light clothing (T-shirts and shorts) and without shoes. Body mass index (BMI) of each participant was calculated in kilograms per square metre. BMI was categorized as underweight, normal weight, overweight and obese according to the International Obesity Task Force (IOTF) criteria (17).

Measures of Physical Activity

Each participant completed the Physical Activity Questionnaire (PAQ)(18)a self-administered seven day recall instrument comprising 9-items scored on a 5 point Likert scale (1–5. A sample item: ‘In the last 7 days, what did you do most of the time at break?’ the full scale is freely available as is the scoring method (18). PAQ were anglicized (e.g., recess became break; soccer became football) as described previously (19).

Measures of Deprivation

An area-level measure of deprivation was employed for each participant using their individual home postcode. The English Index of Multiple Deprivation 2007 is measured based on the small-area geographical units known as lower super output areas (LSOAs); each LSOA containing 1,000-3,000 inhabitants (20). There are 32,482 LSOAs in England and these are ranked from 1, the most deprived to 32,482, the least deprived based on multicomponent score ranging from 0.4 (least deprived) to 85.5 (most deprived). A lower score indicates low area-level deprivation, with a high score indicating higher deprivation. Within the present data, this resulted in 32,394 IMD units/ranks ranging from low (very deprived) to high (less deprived).

Screen time

Self-reported daily screen-time was assessedby asking: ‘How much time do you spend on average each day watching television, watching DVDs or videos, using a computer or games console’. Participants chose one of six responses: none, 0–30 min, 30–60 min, 1–2 hours, 2–4 hours and >4 hours. Responses were then collapsed to create groups based on international recommendations(21) which represented low (<2 hours), high (2-4 hours), and very high (>4 hours), screen-time.

Estimation of Aerobic Fitness

Fitness was assessed using the 20m shuttle-run test (20mSRT), an incremental running test to maximal exertion (22). Testing was carried out by researchers accompanied by school physical education staff. Testing was conducted in groups of up to 30 with a ratio of five participants to one researcher. All participants had undertaken the 20mSRT before as part of their school physical education. Recorded instructions on the informed participants to “run for as long as possible” and a researcher at the beginning of each test reiterated this. Researchers acted as “spotters” during the test and recorded the participants’ final shuttle count at either the point of volitional exhaustion, or when they failed to maintain the given pace for the second time. Running speedat final completed level wasused to predict$\dot{V}O_{2peak}$(ml·kg^{-1}·min^{-1}) using the equation of Leger et al (22).

Statistical Methods

Descriptive statistics including the number of children (N) plus mean and standard deviations (SD) of age, height, weight cardiorespiratory fitness (mlkg^{-1}.min^{-1}) and PAQ scores by sex, visit occasions (wave) and year group are given in Table 1.To determine whether analyses required adjustment for possible school-level clustering, an unconditional multilevel model with school as a Level-3 predictor was fitted. As Level 3 (between-school) variances for latent intercept and slope were non-significant subsequent models were not adjusted by school.An appropriate way of analysing longitudinal (repeated-measures) data can be multilevel modelling approach, using the program Multilevel Models Project MLwiN (23). Multilevel modelling is an extension of ordinary multiple regression where the data have a hierarchical or clustered structure. A hierarchy consist of units or measurements grouped at different levels. One example is repeated measure data where individuals are measured on more than one occasion. Here, the children, assumed to be a random sample, represent the Level 2 units andtheir repeated measurements recorded at each visit occasions were consideredLevel 1 units.

In the present study, multilevel regression analyses were performed using the MLwiN software to identify those factors associated with the development of $\dot{V}O_{2peak}$, having adjusting for differences in physical activity and age. The two levels of hierarchical or nested observational units were the visit occasions at level 1 (within-individuals), and the sample of children (between-individuals) at level 2. The model adopted is shown in Equation 1.

$$\dot{V}O_{2peak}\ (ml\cdot kg^{-1}\cdot min^{-1}) = a_i + b \cdot PAQ + c \cdot PAQ^2 + d \cdot age + \varepsilon_{ij} \qquad \text{(Eq. 1)}$$

All parameters were fixed with the exception of the ‘constant’ parameter ‘a_i’ that was allowed to vary randomly from child to child (level 2), and ε_{ij}, that was assumed to have a constant error variance between visit occasions (level 1). The subscripts i and j are used to indicate random variation at levels 2 and 1 respectively.

Potentialpredictors (sex, weight status and screen time)were incorporated into the analysis by introducing them as indicator variables. Sex was introduced as a (boys=0, girls=1) indicator variable, since, by doing so, the boys’ constant term would be incorporated within a baseline parameter a_i, from which the girls’ constant term would deviate. Similarly, the weight statusgroup of “obese”was used as the baseline parameter (the constant ‘a_i’) from which other weight status groups (underweight, normal and overweight) were compared, i.e. allowed to deviate from the constant baseline ‘a_i’. To allow the rate (slope) of fitness to vary with PA(either PAQ, PAQ^2), age-by-groups(sex and weight status), the product between age, PAQ and PAQ^{2}and the group indicator variable was included in the analysis as interaction terms.

Model 1 (Eq. 1) is the simplest model fitted that introduced sex as the sole categorical predictor together with sex-by-PAQ and sex-by-age interactions. Model 2 incorporated weight status and screen time as a further categorical variablesplus the Index of Multiple Deprivation (recorded as ranks) as a further continuous covariate.

In order to provide a measure of goodness-of-fit "deviance" (-2 Log Likelihood) or more specifically the change in deviancewas employed. The deviance statistic is a generalization of the sum of squares of residualsused in ordinary least squaresbut where model-fitting is achieved by maximum likelihood. It plays an important role in assessing the quality of fit in generalized linear models especially multilevel analyses. The difference between the deviances for competing models follows an approximate χ^2 distribution with k-degrees of freedom (24)

Results

The multilevel-regression analysis of aerobic fitness ($\dot{V}O_{2peak}$in ml·kg^{-1}·min^{-1})) incorporating terms fromthe simplest Model 1(Eq. 1) revealed estimated parameters given in Table 2a. Theanalysis identified a significant quadratic polynomial association betweenfitness andPA whereby the linear PAQ term was steeper for boys (b=3.83) than girls (= 3.83-1.01=2.82) but the quadratic PAQ^2 term (c) was found to be common for both sexes, see Table 2a (Model 1). The PAQ values at which $\dot{V}O_{2peak}$peaks can be estimated using differential calculus, estimated for boys as 5.8 and for girls as 4.3. Figures 1 illustrates the nature of the curvilinear associations between $\dot{V}O_{2peak}$and PAQ for boys and girls.

The regression analysisalso revealed significant declines in fitness with age in both boys (d=-0.20) and girls, but with the age decline in girls being significantly steeper (d=-0.20-0.61=-0.81) (see Model 1).

Table 2 Here

*** Figure 1. Here ***

The multilevel-regression analysis of $\dot{V}O_{2peak}$($ml \cdot kg^{-1} \cdot min^{-1}$) incorporating terms in model 2 revealed the estimated parameters as reported in Table 2b. LikeModel 1, the more complexModel 2 alsorevealed a quadratic polynomial association between aerobicfitness and PA (both linear PAQ and PAQ^2 terms, $P<0.001$). The slope of the decline in fitness with age, which varied for boys and girls, also remained as in model 1.

Model 2 identified differences in fitnessby weight status. Comparedwith obese participants, those who were underweight,normal weight and overweightwere all fitter:3.0, 2.9and 1.3 $ml \cdot kg^{-1} \cdot min^{-1}$respectively.

Model 2 also indicates that youth reporting >4 hours daily screen time were less fit (-1.17$ml \cdot kg^{-1} \cdot min^{-1}$)than children who <2 hours per day. Note that children who spent between 2-4 hours screen time were marginally fitter than the baseline group who spent less than 2 hours on screen time per day.

Finally, deprivation was also found to be significantly associated with VO_2max having controlled for differences in PA, sex and age. The rate of increase in VO_2maxfitnesswaspredicted to be 0.8 ($ml \cdot kg^{-1} \cdot min^{-1}$) per 10,000 IMD ranks($P<0.001$) (rank 1 being most *deprived* area and rank 32,844 being the least *deprived* area).

From Model 1 to 2, i.e., with increasing model complexity, the change in deviance (-2 Log Likelihood) went from 25445.4 (df=7) to 24717.7 (df=13). This change in deviance was 727.6 with df=6 (P<0.001).

Discussion

This is the first longitudinal study in English schoolchildren to identify the dose-response relationshipbetweenaerobic fitness and PA to be curvilinear rather than linear whilst at the same time, allowingfor potential confounding effects of weight status, deprivation andscreen-time. No prior longitudinal study has allowed for the possibility that the dose-response relationship is curvilinear, potentially explaining the lack of association in some of the earlier studies examining this topic (10,11). The current study therefore presents new knowledgeon the nature of the dose-response between aerobic fitness and PA in youth.

Only two cross-sectional studies and two longitudinal studies, reviewed by Rauner et al (4). assessed the interactions among physical activity, fitness and weight status (25,26). Like the present study both used the 20mSRT to provide estimates of aerobic fitness and both used BMI to categorize weight status. The authors of these studies chose weight status as the outcome measure in their analyses with fitness and PAused as predictorsof change in BMI or weight status at follow-up.

The findings of the present studyalign withrecent cross-sectionalfindings in British children (27). However, the approach employed in the current study, which is based on longitudinal data, provides a more robust assessment as compared to studies using cross sectional designs (25,26,27). Longitudinally assessment of children across three different occasions (repeated measures) showed thatincreases in PA resulted in a positive dose-response associationwith aerobic fitness.In agreement with recent cross-sectional findings (9)the association of PA with fitness in the current studywas curvilinear rather than linearin both boys and girls, see Table 2 (Model 1) and Figure 1.The nature of these curves suggest that initially (for low levels of PA) these dose-response rates or slopes were steeper for boys(β=3.8)*compared with girls (β=2.8) and that the curves peaked at PAQ score means of 5.8 for boys and 4.3 for girls when no further benefit in $\dot{V}O_{2peak}$with increasing PAis anticipated/predicted.(*ml·kg^{-1}·min^{-1}per unit of PAQ)

The fact that the boys' slope parameter (β) is steeper than the girls' (for the same level of PA),can be explained simply by the fact that boys report more games activities (football, rugby etc.) thought to be more "vigorous" PA when completing their PAQ questionnaire. In contrast, girls report more activities such as walking and horse riding (thought to be more moderate PA), but when the total PAQ score is summed, these activities are given equal weights.

Fitness declined with age at an annual rate β=0.20 ml·kg^{-1}·min^{-1}in boys and β=-0.81 (-.20-0.61=-0.81)in girls. Incorporating additional factors such as introducing weight status as a categorical variable(Model 2) revealed better fitness in underweight,(+3.0 ml·kg^{-1}·min),normal-weight (+2.9 ml·kg^{-1}·min) and overweight (+1.3 ml·kg^{-1}·min) groups compared withthe reference group ofobese children (all P<0.001). However, the effects (and their estimated parameters) associated with sex, age and PA remained almost unchanged in the revised Model 2.

Even after adjusting for sex, age, weight status and PA, children reporting>4 hours daily screen time were -1.17(95CI; -0.71 to -1.63 ml·kg^{-1}·min^{-1})lower thanthose reporting<2 hours per day. Screen time is a known correlate of children's health generally and PA (7,24). Systematic review evidence shows significant, but weak, inverse associations between children's daily screen time and aerobic fitness (14).The screen-time findings presented here agree with cross-sectional research in English youth which found that ownership and access to electronic devices to benegatively associated with aerobic fitness (27).

Deprivationwas a predictor of aerobic fitnessindependent of sex, age, PA and weight status. The rate of increase in VO_{2peak}per 10,000 ranks of IMD was estimated as 0.8 (ml·kg^{-1}·min^{-1}). England comprised 32,000 lower super output areas (28);10,000 ranks represents approximatelya third of the variance for deprivation. Consequently, Model 2predicts that fitness of youth from the most deprived areas of England was 2.4 ml·kg^{-1}·min^{-1}lower than thoseliving in the least deprived areas. Such a finding is not unexpected as low aerobic fitness is more prevalent in youth from moredeprived areas (14,29); who tend to be less physically active (30). Deprived children are also less likely at access facilities and sports clubs for PA, a recognized barrier to physical activity for deprived youthand a predictor of low fitness (14).

The Muscatine (31) and Amsterdam (10)longitudinal studies and pooled data from the UK (6, 12) have previously reported associations between indices of aerobic fitness and PA. However, the longitudinal design, repeated measurement points in a sample of this size (n=1422) is astrength of the present study. To our knowledgeonly He et al (26). have reportedlongitudinaldata of a comparable sample size (n=1795).Similarly, few studies previously conducted that have examined the relationships between PA and aerobic fitness variables have also considered key confounders of weight status, deprivation and screen time, as is the case in the current study. The current study is also the first to present a true examination of the dose-response between PA and aerobic fitness in children by virtue of tracking data at three time points.

There are some limitations of the present study. The 20m shuttle-run test is widely used estimate of aerobic fitness in pediatric populations. However, test familiarization and day-to-day performance variation may influence results particularly when repeated measurements are made. The use of the Leger prediction (22) is also a limitation. Leger's equation is valid it may underestimate$\dot{V}O_{2peak}$, and while this is a criticism leveled at other similar prediction equations (32) this should be considered by researchers in future studies. Likewise, age is a component within the Leger equation and was also considered in the multilevel models used in the current study it is possible this could increase collinearity in the data. In addition, during the 20m shuttle-run test motivation to perform and understating of instruction might also differ because of age and maturity level, meaning aerobic fitness may be underestimated (33).

PA wasself-reported and while the PAQ has acceptable convergent validity recall error and biasareboth likely (18). The PAQ, is one of the most reliable and valid tools used to assess PA in youth, however, the same review (4,34)also noted that children's self-report of activity does not provide the fidelity of PA measurement that objective methods, such as accelerometry, may provide (34). The limitations are however consistent with other large-scale epidemiological studies which necessitate such approaches. Direct measurement of VO_2max was not possible in the current study due to the time and labour intensive nature of such assessment techniques in large numbers of participants. This is also the case for using objective measures such as accelerometry to capture PA

In summary, the results of thislongitudinal study suggest the dose response between aerobic fitness and PA in children aged 10-15 years is curvilinear rather than linear. The nature of the dose response curve depends on a number of factors including sex and activity level.In the current study the association betweenaerobic fitnessand PAis greater/steeper in magnitude when children are less active demonstrating that the benefit of increasing PA on aerobic fitness is greater in low active children, compared to high active children. The steeper dose-response rate or slope found with boys compared with girls can be explained by the fact that boys report more vigorous PA such as games. Girls, on the other hand, report more moderate PA such as walking and horse riding, but allsuch activities are given equal weight when summed in the final PAQ score.

Competing interests: The authors declare that they have no competing interests.

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Figure Captions

Figure 1. The curvilinear association between VO_2max and PAQ for boys and girls

Table Captions

Table 1. Number of children (N) plus mean ± standard deviation (SD) of age, height, weight cardiorespiratory fitness ($ml.kg^{-1}.min^{-1}$) and PAQ scores by sex, visit occasions (wave) and year group.

Tables 2a and 2b. The estimated parameters (means ± SE) from the multilevel regression analyses of predicted VO_2max ($ml\cdot kg^{-1}\cdot min^{-1}$) using Models 1 and 2.

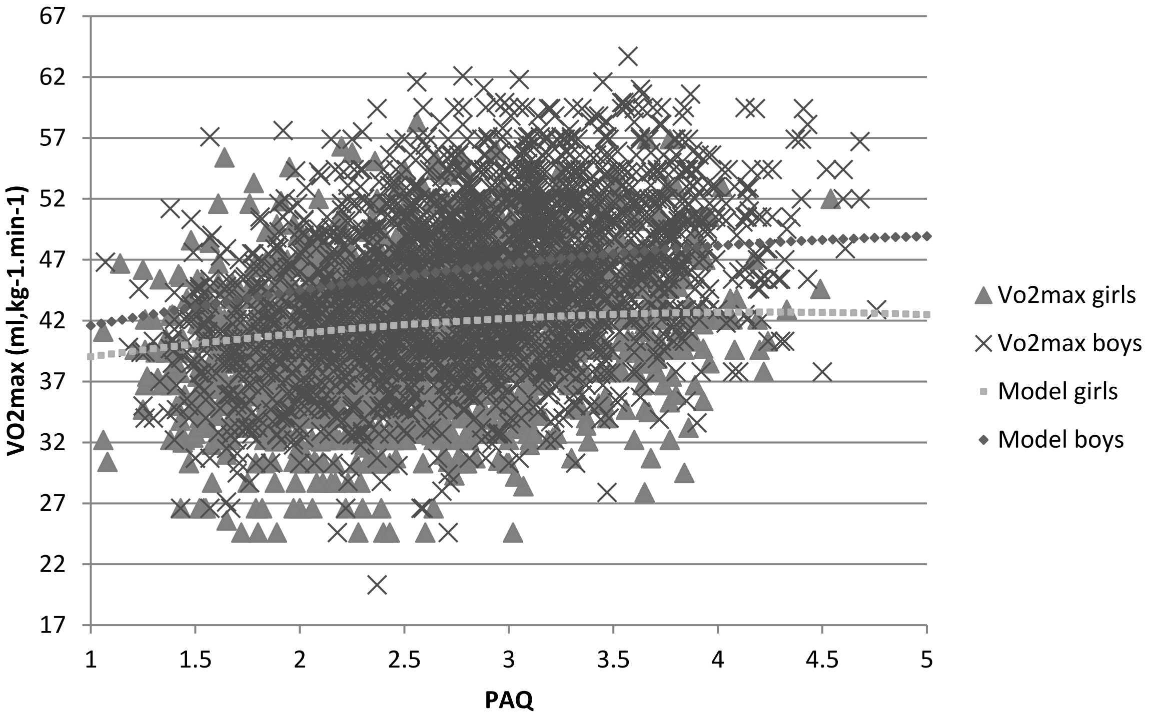

Figure 1. The curvilinear association between VO_2max and PAQ for boys and girls

Table 1. Number of children (N) plus mean ± standard deviation (SD) of age, height, weight cardiorespiratory fitness (ml.kg-1.min-1) and PAQ scores by sex, visit occasions (wave) and year group.

		Male									Female								
Variables	Year	Wave 1			Wave 2			Wave 3			Wave 1			Wave 2			Wave 3		
		N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
Age (yrs)	11.00	419	11.6	.3							334	11.6	.3						
	12.00	352	12.4	.3							315	12.4	.2						
	13.00				419	13.6	.3	1	13.4		2	13.4	.2	339	13.7	.3			
	14.00				352	14.4	.2	4	14.7	.4				310	14.3	.2	4	14.6	.3
	15.00							459	15.6	.2				2	15.3	.2	351	15.6	.2
	16.00							307	16.3	.2							296	16.3	.2
Height (cm)	11.00	419	148.7	7.8							334	150.6	7.9						
	12.00	352	152.0	8.0							315	152.8	7.1						
	13.00				419	162.0	9.1	1	165.2		2	163.3	9.5	339	161.2	7.3			
	14.00				352	164.8	8.6	4	163.3	6.3				310	162.4	6.7	4	174.7	7.2
	15.00							459	172.2	7.7				2	175.2	4.0	351	169.1	8.0
	16.00							307	172.8	7.9							296	170.4	7.7
Weight (kg)	11.00	419	42.6	10.1							334	44.4	10.3						
	12.00	352	45.3	10.4							315	46.7	10.0						
	13.00				419	54.3	11.6	1	73.9		2	64.0	5.6	339	53.8	10.5			
	14.00				352	56.2	11.6	4	51.6	6.9				310	55.7	9.9	4	62.0	11.7
	15.00							459	62.6	11.6				2	74.1	16.2	351	59.9	10.5
	16.00							307	62.6	11.0							296	61.3	10.4
Fitness (ml.kg-1.min-1)	11.00	419	46.2	5.5							334	43.3	3.9						
	12.00	352	44.8	5.7							315	41.2	4.7						
	13.00				419	45.7	6.2	1	38.9		2	41.1	3.7	339	41.3	4.5			
	14.00				352	44.5	6.6	4	49.6	6.1				310	39.6	5.0	4	39.9	7.5

	15.00							459	44.2	7.1				2	42.5	1.9	351	38.5	5.7
	16.00							307	43.9	7.2							296	38.8	6.4
PAQ (scale 1 to 5)	11.00	419	3.0	.6							334	2.7	.6						
	12.00	352	3.0	.7							315	2.8	.5						
	13.00										2	2.6	.4	339	2.4	.5			
	14.00				352	2.8	.6	4	2.9	.5				310	2.5	.6	4	2.1	.7
	15.00				771	2.8	.6	459	2.6	.6				2	3.1	1.4	351	2.4	.6
	16.00							307	2.7	.6							296	2.5	.6

Tables 2a and 2b. The estimated parameters (means ± SE) from the multilevel regression analyses of predicted VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) using Models 1 and 2.

Fixed effects	Fixed factors	2a Model 1		95%CI		2b Model 2		95%CI	
	Parameter	Estimate	SE	Lower	Upper	Estimate	SE	Lower	Upper
	Constant (a)	36.91	1.19	34.58	39.24	32.69	1.28	30.18	35.20
Sex	Girls (Δa)	-1.38	0.76	-2.87	0.11	-1.59	0.76	-3.08	-0.10
PAQ	PAQ (b)	3.83	0.80	2.26	5.39	3.95	0.81	2.37	5.52
	Girls*PAQ (Δb)	-1.01	0.27	-0.60	-0.06	-0.97	0.27	-0.62	-0.08
	PAQ^2 (c)	-0.33	0.14	-1.54	-0.48	-0.35	0.14	-1.50	-0.44
Age	Age-13.96 years (d)	-0.20	0.05	-0.30	-0.11	-0.16	0.05	-0.27	-0.06
	Girls*(Age-13.96) (Δd)	-0.61	0.07	-0.75	-0.47	-0.60	0.07	-0.75	-0.46
Weight status	Underweight (Δa)					2.97	0.47	2.06	3.88
	Normal (Δa)					2.92	0.31	2.31	3.52
	Overweight (Δa)					1.33	0.32	0.71	1.94
Screen Time	2-4h (Δa)					0.26	0.16	-0.05	0.57
	>4h (Δa)					-1.17	0.23	-1.63	-0.72
Deprivation	IMD rank					0.00008	0.00002	0.00004	0.00012

Deviance	**- 2 Log Likelihood**	**25445.4**	**(df=7)**	**24717.7**	**(df=13)**
Random variation	Variances				
Level 2	(between participant)	18.39	0.86	15.41	0.76
Level 1	(within participant)	13.17	0.35	13.27	0.36

Values are means ± standard errors of estimate (SE) plus 95% Confidence Intervals (CI). VO_2max was expressed in $ml.kg^{-1}.min^{-1}$. The reference or baseline group were boys (‘a’ in Model1), and obese boys who spend less than 2 hours per day on screen time (‘a’ in Model 2) and other groups compared with it, indicated by (Δa). Age was centred about the mean age=13.96 years. IMD rank was incorporated into model 2 with rank 1 being most *deprived* area and rank 32,844 being the least *deprived* area.