Four-Year Longitudinal Associations Between Effort in Physical Education Classes and Fitness Outcomes in UK Adolescents

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Four-Year Longitudinal Associations Between Effort in Physical Education Classes and Fitness Outcomes in UK Adolescents

Sally Waterworth,[1] Chris McManus,[1] Henry Chung,[1] Ben Jones,[1] Osama Aljuhani,[2] and Patrick Schoenmakers[1]

[1]School of Sport, Rehabilitation, and Exercise Sciences, University of Essex, Colchester, United Kingdom;
[2]Department of Physical Education, King Saud University, Riyadh, Saudi Arabia

Background: Student engagement and effort in physical education (PE) can influence long-term physical fitness development. This study examined whether self-reported effort in PE (ePE) predicts changes in physical fitness among English secondary school students. ***Methods:*** A 4-year longitudinal study involved 1422 adolescents from 9 public schools in the East of England. Assessments took place at years 7, 9, and 11 (year 7 = 12 [0.5] y), measuring aerobic fitness, muscular strength, and muscular power. ePE was self-reported using the Physical Activity Questionnaire for Adolescents. Latent growth curve models examined changes in fitness over time, and whether these associations were modified by sex, body mass index (BMI), or socioeconomic status (via Index of Multiple Deprivation). ***Results:*** Girls had lower baseline fitness and smaller gains over the 4-year period than boys across aerobic fitness, muscular power, and muscular strength. Higher baseline BMI and living in a disadvantaged area were associated with lower initial fitness, and changes in BMI influenced longitudinal changes in fitness. Baseline ePE positively predicted all baseline fitness measures, with aerobic fitness showing the strongest association. Change in ePE over time was the strongest predictor of improvements across all fitness components. ***Conclusion:*** Effort in PE classes supports long-term fitness development. Interventions that encourage students to be active and engaged in PE may benefit all adolescents, especially girls and those with higher BMI or from disadvantaged areas. These findings highlight the value of promoting effortful participation in PE to enhance adolescent health and physical fitness.

Keywords: physical fitness, aerobic fitness, strength, muscular power

Physical education (PE) plays a key role in increasing students' physical activity levels, with evidence indicating students are more active on days they have PE classes compared with non-PE days.[1–3] PE provides opportunities for students to engage in moderate-to-vigorous physical activity (MVPA), which typically accounts for 35% to 55% of PE lessons time.[4] Lesson characteristics (eg, activity type and location), and individual factors (eg, enjoyment, task value) influence MVPA levels.[5] Students with lower habitual activity levels, higher body mass, or low aerobic fitness tend to be less active during PE.[1,3,6,7] School-based interventions, through modified PE content or increased lesson duration, have been shown to improve health-related fitness,[8–11] however, less is known about how regular PE provision contributes to students' overall physical fitness.

The benefits of physical activity in school-aged children are well-documented including improvements in physical health, psychological well-being, social competence, cognitive function, behavior, and academic performance.[12,13] Physical activity in this age group is essential for developing and maintaining health-related components of physical fitness, including body composition, cardiorespiratory fitness, and muscular fitness.[14,15] Higher levels of physical activity and fitness in youth are associated with superior cardiovascular health, metabolic function, bone health, psychological well-being, and overall long-term health outcomes (for a detailed review, see Ortega et al[16]). Despite these findings, research directly linking PE participation to physical fitness outcomes remains relatively limited. Coledam and Ferraiol[17] reported that 10- to 17-year-old Brazilian students were more likely to meet health-related benchmarks for aerobic fitness and muscular strength when they regularly attended PE classes particularly when not engaged in extracurricular sport.[17] Similarly, studies showed that motivational factors such as health beliefs, fear of failure, and success orientation were linked to aerobic fitness, with distinct differences between high-school boys and girls.[18] Supportive teaching environments that promote enjoyment, encouragement, and positive learning experiences have further been shown to enhance students' engagement and fitness outcomes.[19,20] Collectively, these findings emphasize that PE can promote physical activity and fitness, with supportive, high-quality lessons being crucial for maximizing student engagement.

While cross-sectional evidence highlights associations between PE and fitness, longitudinal data confirming these effects remain scarce. A 12-month daily PE program produced modest fitness improvements among normal weight, and overweight adolescent girls but not in those with obesity.[21] Erfle and Gamble[20] reported improvements in aerobic and muscular fitness after the addition of 30-minute daily PE lessons in middle schools, with greater benefits in girls and students at risk due to weight status.[20] Additionally, the proportion of lesson time spent in vigorous activity during PE was positively associated with aerobic fitness improvements in boys, independent of organized sports participation and habitual MVPA.[7]

In English secondary schools, PE is a core subject for all year 7 to year 11 students. Among adolescents, national data recently indicated declines in aerobic and muscular fitness,[22–24] which coincided with a 16% nationwide reduction in secondary school PE provision between 2010 and 2019.[25] Students' effort and active engagement during PE lessons may play a key role in the

Schoenmakers (ppscho@essex.ac.uk) is corresponding author.

development of their fitness. These associations may also vary according to individual characteristics including sex, body mass index (BMI), and socioeconomic status.[26,27] Understanding how these factors relate to changes in physical fitness is critical for informing educational practice. Using latent growth modeling, which allows for the assessment of individual trajectories over time, the aim of this study was to determine the prospective associations between students' engagement and effort in PE (ePE) and their fitness development.

Methods and Materials

East of England Healthy Hearts Study

This study used longitudinal data collected as part of the East of England Healthy Hearts Study, a large school-based cohort examining physical activity, fitness, and cardiometabolic health in adolescents.[28] The East of England Healthy Hearts Study was conducted between 2006 and 2011 across 9 public secondary schools, which were recruited through stratified convenience sampling to ensure representation of urban and rural areas. The longitudinal arm included students who were in year 7 at baseline (n = 1422; 46% female; mean age = 12 [0.5] y). All assessments were conducted by trained researchers, typically during morning PE classes following a light breakfast (nonfasted state). Parents provided written informed consent prior to participation, and students gave assent before data collection. For the present longitudinal analysis, data were drawn from 2 season-matched follow-up assessments conducted after 2 (year 9) and 4 years (year 11). One school did not participate in the 4-year follow-up assessment. Ethical approval was granted by the researchers' institutional review board and conformed to the Declaration of Helsinki (2013 revision).

Physical Activity and Self-Reported Effort

Participants completed the Physical Activity Questionnaire for Adolescents (PAQ-A), a self-administered 7-day recall instrument comprising 9 items scored on a 5-point Likert scale. The PAQ-A has demonstrated good internal consistency, and test–retest reliability, and acceptable validity in adolescent populations.[29,30] The North-American version of PAQ-A was anglicized (eg, recess became break; soccer became football) as described in detail previously.[31] Item 2 of the PAQ-A was used as a proxy for self-reported ePE. This item assessed ePE by asking: *In the past 7 d, how often were you very active during PE (getting sweaty, breathing hard, and/or getting tired legs)?* Responses range from 1: "Never, I don't do PE" to 5: "Always."

Anthropometry

Body mass was measured to the nearest 0.1 kg using a digital flat scale (Seca 875) and stature was measured to the nearest 0.1 cm using a portable stadiometer (Seca 213). All school children were dressed in regular gym clothing and were instructed to remove shoes for these measurements. BMI for each participant was calculated in kilograms per square meter from mass and stature at years 7, 9, and 11.

Physical Fitness

Aerobic fitness was assessed using the FitnessGram PACER Test.[32] This progressive running test, commonly administered during PE lessons in England, requires participants to run back and forth across a 20-m distance at a given pace, which increases every minute, until volitional exhaustion or when the required pace could not be maintained. The test was carried out outside on a hard-court surface, with the 20-m distance marked by cones. Researchers provided standardized instructions, acted as spotters, recorded the final shuttle completed, and served as pacers for younger participants (year 7). Performance was recorded as the total number of shuttles completed. The PACER Test demonstrated good validity as an estimate of maximal aerobic fitness (VO_2max) in adolescents, with moderate correlations between PACER-predicted VO_2max and directly measured VO_2max, independent of BMI.[33]

Muscular power was assessed using a vertical jump test on a NewTest timing mat (Newtest Oy). This approach has demonstrated good reliability and criterion validity in adolescents and is considered a suitable field-based substitute for laboratory measures of lower-limb power.[34,35] Participants performed 2 countermovement jumps using their arms, starting from an upright standing position. The jump involved flexing the knees to approximately 90° before rapid extension and take-off. Landing (initial contact with the jump mat) was with the toes and knees extended to approximately 180°. If these criteria were not met, jumps were repeated until 2 correctly performed jumps were completed. Flight time (in seconds) of the best jump was recorded and converted to jump height using the equation:

$$\text{Jump height} = 0.5g\ (t/2)^2,$$

where g is gravity (9.81 m/s^2) and t is flight time (in seconds).

Muscular strength was assessed using isometric handgrip dynamometry (Takei TKK 5001GRIP, Takei Scientific Instruments Co Ltd), a commonly used, reliable and valid field-based measure of overall upper-body muscular strength in adolescents.[36] The dynamometer was periodically calibrated against known weights, with no evidence of drift. The dynamometer was adjusted for differences in hand sizes, with the second metacarpals placed correctly on top of the "bar." The test was conducted in the standing position with the arm at the side, wrist in the neutral position, and the elbow extended. Participants were given verbal encouragement to "squeeze as hard as possible" for at least 2 seconds. Researchers monitored each attempt to prevent participants from pushing their hand or dynamometer against the outer thigh. Two trials were performed using the dominant hand (the hand used for writing), with the highest score recorded as peak grip strength (in kilograms). In cases of measurement error or poor agreement between measures, a third trial was performed.

Geographic Entities

Participants' Indices of Multiple Deprivation (IMD) were based on their residential Lower Layer Super Output Areas.[37,38] Each of the 32,482 Lower Layer Super Output Areas in England is assigned a multicomponent deprivation score ranging from 0.4 (least deprived) to 85.5 (most deprived), with participants' home postcodes used to attribute an IMD score to each individual.

Statistical Analysis

Latent growth curve modeling (LGM) was used to examine changes in aerobic fitness, muscular power, and strength across years 7, 9, and 11. LGM simultaneously models initial values and individual trajectories over time, enabling analysis of both between- and within-person variation.[39] LGM further accounts for the means and covariances of repeated measures, allowing simultaneous estimation of variable means and their interrelations.[40] Missing data were handled using Maximum Likelihood estimation with the FIML algorithm, which provides robust model fit under the assumption of data missing at random and normally distributed endogenous variables.[41] Data are presented as mean (SD), with analyses conducted in JASP (version 0.19.0) and significance set at $P < .05$. Standardized regression coefficients (Stdβ) are reported for interpretability, with 95% confidence intervals (95% CIs) calculated for the unstandardized coefficients and presented alongside the Stdβ values.

Supplementary Material 1 (available online) provides full details on the modeling procedures including initial goodness of fit statistics for each unrestrained latent growth curve and the unstandardized estimates for all models. Unconditional linear growth models were fitted separately for each fitness parameter (aerobic fitness, muscular power, and muscular strength). The intercept and slope were specified as latent variables, representing the initial fitness level and the rate of change over time, respectively. Linearity of change was assessed by comparing goodness-of-fit statistics for the covarying linear model for each measure. Figure 1 illustrates how the 3 endogenous variables (muscular strength at year 7, year 9, and year 11) were predictors of both the 2 latent variables, which were allowed to covary in the model.

Goodness-of-fit for the initial model was evaluated using the Comparative Fit Index, the Tucker–Lewis Index, the root mean square error of approximation, and the standardized root mean square residual (see Supplementary Material 1 [available online]). Values indicating good fit are Comparative Fit Index and Tucker–Lewis Index ≥.95, root mean square error of approximation <.06, and standardized root mean square residual <.08.[42] Once satisfactory fit was confirmed for each unconditional model, baseline values (Y0; year 7) for ePE, BMI, and deprivation (IMD) were introduced as predictors of the intercept and slope of aerobic fitness, muscular strength, and muscular power.

To examine how changes in the above predictor variables influenced physical fitness over the 4-year period, delta (Δ) values were calculated for ePE and BMI. For each predictor, Δ values were computed by subtracting baseline year 7 (Y0) values from year 11 (Y4) values. These Δ values were included in regression analyses as predictors of the slope latent variables, allowing assessment of their influence on changes in aerobic fitness, strength, and power over time. The resulting regression coefficients represent the effect of a 1-year change in each predictor on fitness development.

Results

Descriptive characteristics of participants, physical fitness parameters, and ePE at baseline are presented in Tables 1 and 2. In year 7, 54% participants (n = 772) were boys and 46% (n = 650) were girls. At baseline, boys and girls showed no meaningful differences in height, weight, BMI, and IMD.

The longitudinal analysis included 1340 students with complete baseline data, as 82 students had incomplete PAQ-A questionnaires in year 7. Complete data for all variables at all 3 measurement points were available for 46% of participants (n = 613). Overall, there were 509 missing values for ePE in year 11, equivalent to 38% of all values potentially available across these 2 measurement points. Little's MCAR test was not significant ($\chi^2 = 4.421$, $df = 9$, $P = .081$), indicating that values were missing completely at random. Importantly, there were no meaningful differences in measures of fitness, ePE, or BMI (all $d < 0.2$), confirming that missingness could not be accounted for by the values of variables themselves nor explained by the values of other variables included in the analysis. The frequency and patterns of missing data points for all independent and dependent variables across the 3 measurement points are provided in Supplementary Material 2 (available online).

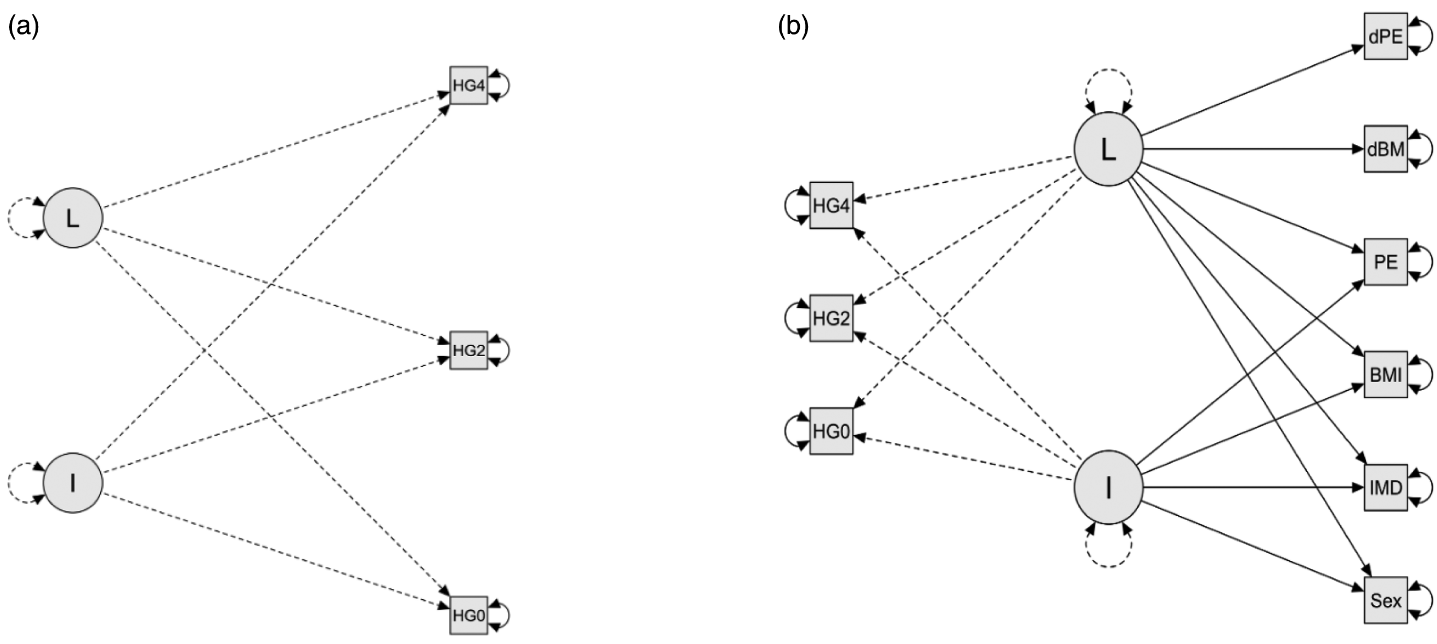

Figure 1 — Path diagrams for latent growth curve models. BMI indicates body mass index; dBM = change in BMI over 4 years; dPE, change in PE effort over 4 years; HG, handgrip strength; HG0, year 7; HG2, year 9; HG4, year 11; IMD, Index of Multiple Deprivation; PE, effort in physical education; Sex, biological sex.

Table 1 Descriptive Characteristics of Participants at Baseline (Year 7)

	Boys (n = 772)		Girls (n = 650)		Total (N = 1422)	
	Mean	SD	Mean	SD	Mean	SD
Age, y	11.97	0.46	11.99	0.44	11.98	0.45
Deprivation (Index of Multiple Deprivation)	11.9	7.6	11.5	6.89	11.7	7.3
Height, cm	150.1	8.2	151.6	7.55	150.8	7.9
Weight, kg	44.0	10.8	45.3	10.1	44.6	10.5
Body mass index, kg/m^2	19.37	3.60	19.59	3.40	19.47	3.51
Shuttles, n	45.5	21.2	32.4	14.6	39.0	19.5
Handgrip, kg	20.2	4.09	19.4	3.72	19.83	3.95
Vertical jump, cm	28.6	5.47	26.5	5.32	27.65	5.50

Table 2 Self-Reported Effort in PE

	Boys (n = 721)		Girls (n = 619)		Total (N = 1340)	
	n	% cohort	n	% cohort	n	% cohort
Effort in PE						
1 (Never)	7	1.0%	7	1.1%	14	1.0%
2 (Rarely)	17	2.4%	18	2.9%	35	2.6%
3 (Sometime)	183	25.4%	129	20.8%	312	23.3%
4 (Often)	283	39.3%	305	49.3%	588	43.9%
5 (Always)	231	32.0%	160	25.8%	391	29.2%

Abbreviation: PE, physical education.

Latent Growth Estimates and Covariances

Unstandardized mean estimates and variance in intercept and slope for aerobic fitness, muscular strength, and muscular power are shown in Table 3. Example plots for the effects of baseline and changes in ePE on aerobic fitness are shown in Figure 2. Latent covariances between intercept and slope showed nonsignificant negative associations of baseline with change for aerobic fitness ($\beta = -3.434$; 95% CI, −17.4 to 10.6, $P = .631$) and muscular power ($\beta = -0.337$; 95% CI, −1.8 to 1.1, $P = .653$), with positive nonsignificant associations for muscular strength ($\beta = 0.674$; 95% CI, −0.2 to 1.6, $P = .145$).

Determinants of Longitudinal Fitness Change

Unstandardized (β) and standardized regression coefficients (Stdβ) for associations between baseline measure and changes across the 4-year period on fitness trajectories are shown in Tables 4–6.

Aerobic Fitness

Female sex, BMI, and deprivation were all negatively associated with the intercept. Girls had lower levels of aerobic fitness at baseline (Std$\beta = -0.33$; 95% CI, −14.50 to −9.90; $P < .001$), and exhibited smaller increases in aerobic fitness over the 4-year period compared with boys (Std$\beta = -0.98$; 95% CI, −4.87 to −3.51; $P < .001$). Year 7 BMI was negatively associated with baseline aerobic fitness (Std$\beta = -0.36$; 95% CI, −2.56 to −1.81; $P < .001$), but was not a significant predictor of change over time (Std$\beta = -0.004$; 95% CI, −0.14 to 0.10; $P = .764$). However, ΔBMI significantly predicted 4-year changes in aerobic fitness from year 7 to year 11 (Std$\beta = -0.07$; 95% CI, −0.47 to −0.13; $P < .001$).

Year 7 ePE was the strongest predictor of baseline aerobic fitness (Std$\beta = 0.17$; 95% CI, 2.10 to 5.05; $P < .001$), and changes in ePE were the strongest predictor of greater aerobic fitness over the 4-year period (Std$\beta = 0.20$; 95% CI, 0.51 to 1.23; $P < .001$). Deprivation was negatively associated with baseline aerobic fitness (Std$\beta = -0.08$; 95% CI, −0.37 to −0.03; $P < .05$), but did not predict 4-year changes in aerobic fitness (Std$\beta = -0.003$; 95% CI, −0.06 to 0.04; $P = .627$).

Muscular Power

Girls had lower vertical jump height at baseline (Std$\beta = -0.18$; 95% CI, −2.49 to −1.06; $P < .001$) and exhibited smaller increases in vertical jump height over the 4-year period compared with boys (Std$\beta = -1.23$; 95% CI, −2.43 to −1.92; $P < .001$). BMI was negatively associated with both baseline muscular power (Std$\beta = -0.24$; 95% CI, −0.50 to −0.27; $P < .001$) and changes over time (Std$\beta = -0.035$; 95% CI, −0.11 to −0.01; $P < .05$). Changes in BMI over the 4-year period were also significantly associated with changes in muscular power (Std$\beta = -0.05$; 95% CI, −0.15 to −0.02; $P < .05$).

ePE was positively associated with baseline muscular power (Std$\beta = 0.14$; 95% CI, 0.37 to 1.20; $P < .001$) but did not predict longitudinal changes in muscular power (Std$\beta = 0.09$; 95% CI, −0.03 to 0.34; $P = .110$). However, ΔePE was positively associated with the slope of change in muscular power over the 4-year period (Std$\beta = 0.13$; 95% CI, 0.10 to 0.35; $P < .001$). IMD did not influence baseline muscular power (Std$\beta = -0.017$; 95% CI, −0.570 to 0.569; $P = .969$), nor did it predict change (Std$\beta = -0.019$; 95% CI, −1.957 to 0.050; $P = .05$).

Muscular Strength

Girls had lower levels of muscular strength in year 7 (Std$\beta = -0.09$; 95% CI, −1.17 to −0.16; $P < .05$) and a smaller increase in handgrip strength over the 4-year period than boys (Std$\beta = -1.44$; 95% CI, −2.51 to −2.14; $P < .001$). BMI was the strongest predictor of initial handgrip strength (Std$\beta = 0.40$; 95% CI, 0.38 to 0.54; $P < .001$), but did not predict 4-year change in strength (Std$\beta = 0.01$; 95% CI, −0.02 to 0.05; $P = .336$). ΔBMI was a significant positive predictor of increases in strength (Std$\beta = 0.05$; 95% CI, 0.03 to 0.13; $P < .01$).

Baseline ePE was positively associated with year 7 handgrip strength (Std$\beta = 0.07$; 95% CI, 0.01 to 0.58; $P < .05$), which was not influenced by IMD (Std$\beta = -0.05$; 95% CI, −0.06 to 0.01; $P = .192$). Neither baseline ePE (Std$\beta = 0.05$; 95% CI, −0.06 to 0.22; $P = .274$) nor IMD (Std$\beta = -0.007$; 95% CI, −0.03 to 0.002; $P = .100$) predicted 4-year change in strength. ΔePE was the strongest predictor of increases in strength (Std$\beta = 0.10$; 95% CI, 0.07 to 0.27; $P < .001$).

Table 3 Unstandardized Mean Estimates and Variance in Intercept and Slope

	Intercept (level)			Change over time (slope)		
	Estimate	SE	*P*	Estimate	SE	*P*
Aerobic fitness (mean)	39.649	0.534	<.001	3.304	0.179	<.001
Aerobic fitness (variance)	358.33	23.14	<.001	19.19	2.971	<.001
Muscular strength (mean)	19.848	0.105	<.001	3.526	0.053	<.001
Muscular strength (variance)	11.116	1.213	<.001	1.726	0.219	<.001
Muscular power (mean)	27.629	0.152	<.001	1.421	0.066	<.001
Muscular power (variance)	23.541	2.029	<.001	2.715	0.338	<.001

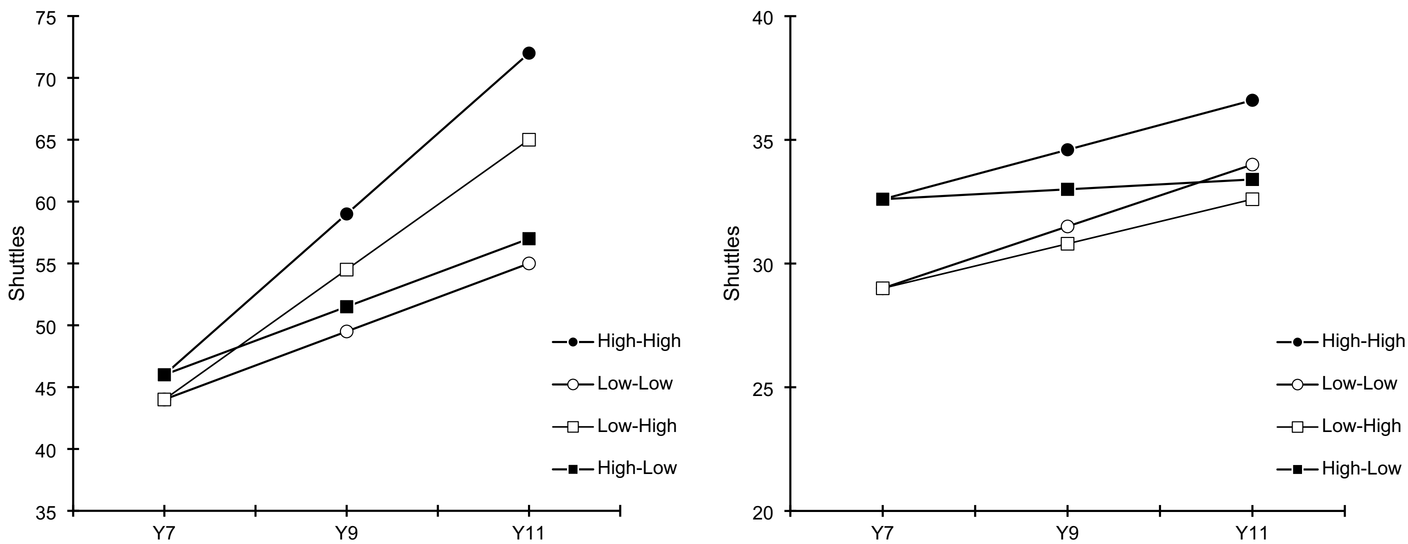

Figure 2 — Estimated effects of difference in baseline and change in effort in physical education on aerobic fitness (shuttles) in boys and girls.

Discussion

This study examined longitudinal trajectories of aerobic fitness, muscular strength, and muscular power across adolescence using LGM. Girls demonstrated lower baseline fitness and smaller improvements compared with boys, highlighting persistent sex differences in adolescent fitness trajectories. Year 7 ePE was the strongest positive predictor across all fitness domains, while higher BMI predicted lower aerobic fitness and muscular power but higher muscular strength. Socioeconomic deprivation was associated with lower baseline aerobic fitness, although its influence did not extend to muscular power or strength. Beyond baseline fitness, positive changes in ePE and BMI emerged as key determinants of fitness development over time, whereas deprivation showed limited influence. These findings underscore the importance of promoting sustained engagement in PE and supporting healthy BMI trajectories during adolescence to optimize fitness development.

Aerobic Fitness

Previous research has linked aerobic fitness to positive attitudes toward PE, skill acquisition, and perceived teacher support.[18,43] Consistent with these findings, our study found that baseline ePE was positively associated with initial aerobic fitness. Peralta et al[7] reported higher PE class intensities predicted greater aerobic fitness gains among boys, and our results extend this by showing that both baseline ePE and increases in effort over time in PE classes (ΔePE) were associated with improvements in aerobic fitness, even after accounting for deprivation, sex, BMI, and ΔBMI. In contrast, increases in BMI were linked to smaller gains in aerobic fitness, supporting evidence that lower or reduced BMI helps maintain or enhance cardiorespiratory fitness.[21,44] Girls demonstrated lower baseline aerobic fitness and smaller improvements across the 4-year period, reflecting established sex differences in cardiorespiratory fitness.[45] These differences may partly reflect broader patterns of physical activity, as boys are more likely to participate in organized sport and generally demonstrate higher ePE.[46] These findings also align with earlier work of Camhi et al,[21] who observed that greater PE participation, improved aerobic fitness among girls of similar age to those in the current study.

Muscular Power

Girls demonstrated lower baseline vertical jump heights and smaller improvements over the 4-year period compared to boys, consistent with previous research.[47] These differences may reflect current trends in body composition, as girls have been shown to gain fat mass faster than boys,[48,49] which may limit muscle performance alongside lower participation in organized sport and reduced ePE. Next to year 7 ePE, BMI emerged as a strong determinant of both baseline muscular

Table 4 Regression Coefficients as Predictors of Intercept and Slope of for the Development of Aerobic Fitness (Pacer Test) in High School Students Over 4 Years (Years 7–11)

	Initial (intercept)				4-y change (slope)			
Regression coefficients	*B*	SE	*P*	Std*β*	*β*	SE	*P*	Std*β*
Sex (female)	–12.17	1.17	<.001	–0.33	–4.19	0.35	<.001	–0.98
Deprivation	–0.20	0.09	.020	–0.08	–0.01	0.03	.627	–0.003
Effort in PE	3.58	0.75	<.001	0.17	0.54	0.26	.036	0.126
BMI	–2.18	0.19	<.001	–0.36	–0.02	0.06	.764	–0.004
ΔEffort in PE					0.87	0.19	<.001	0.204
ΔBMI					–0.30	0.09	<.001	–0.070

Abbreviations: BMI, body mass index; PE, physical education.

Table 5 Regression Coefficients as Predictors of Intercept and Slope of for the Development of Muscular Power (Countermovement Jump) in High School Students over 4 Years (Years 7–11)

	Initial (intercept)				4-y change (slope)			
Regression coefficients	*B*	*SE*	*P*	Std*β*	*β*	*SE*	*P*	Std*β*
Sex (female)	–1.77	0.37	<.001	–0.181	–2.17	0.13	<.001	–1.23
Deprivation	–0.02	0.03	.569	–0.025	–0.02	0.01	.05	–0.01
Effort in PE	0.78	0.21	<.001	0.140	0.15	0.10	.110	0.09
BMI	–0.38	0.06	<.001	–0.242	–0.06	0.02	.010	–0.03
ΔEffort in PE					0.221	0.06	<.001	0.13
ΔBMI					–0.081	0.03	.013	–0.05

Abbreviations: BMI, body mass index; PE, physical education.

Table 6 Regression Coefficients as Predictors of Intercept and Slope of for the Development of Muscular Strength (Handgrip Strength) in High School Students Over 4 Years (Years 7–11)

	Initial (intercept)				4-ye change (slope)			
Regression coefficients	*B*	*SE*	*P*	Std*β*	*β*	*SE*	*P*	Std*β*
Sex (female)	–0.66	0.26	.011	–0.09	–2.32	0.10	<.001	–1.44
Deprivation	–0.02	0.02	.192	–0.05	–0.01	0.01	.100	–0.01
Effort in PE	0.30	0.14	.039	0.07	0.08	0.07	.274	0.05
BMI	0.46	0.04	<.001	0.40	0.02	0.02	.336	0.01
ΔEffort in PE					0.17	0.05	<.001	0.10
ΔBMI					0.08	0.03	.002	0.05

Abbreviations: BMI, body mass index; PE, physical education.

power and longitudinal changes, suggesting that higher body mass may constrain initial performance and limit subsequent improvements. ΔePE was most strongly associated with gains across adolescence, highlighting that increased ePE can enhance muscular power even among students with lower starting levels. These results align with a recent systematic review linking vigorous physical activity to muscular power in adolescents,[50] while discrepancies with studies reporting no association are likely explained by differences in age and vertical jump assessment methods.[51]

Muscular Strength

ePE in year 7 was positively associated with muscular strength, supporting previous cross-sectional research linking greater engagement in PE with muscular development.[17] Across the 4-year period, increases in ePE continued to predict improvements in muscular strength, independent of deprivation, sex, baseline effort, BMI, and ΔBMI. Our findings are among the first to track this relationship across a substantial developmental window, extending earlier short-term evidence showing positive associations among prepubertal girls over a 12-month period.[52] However, our findings contrast with studies reporting no association, which may reflect both individual differences in responsiveness to ePE and variation in strength assessment methods.[53,54] Girls demonstrated lower baseline handgrip strength and smaller gains than boys, again, consistent with typical sex differences in early adolescent development.[24] This pattern was supported by the positive associations between both baseline BMI and ΔBMI and handgrip strength,[44] suggesting that increases in body mass, particularly lean mass contribute meaningfully to strength gains during adolescence.

Impact of Socioeconomic Deprivation on Fitness Trajectories

Previous research indicated that English schoolchildren from deprived areas were less likely to shower after PE, coinciding with lower overall physical activity and reduced participation in team sports.[55] Similarly, Welsh adolescents aged 11–13 years from deprived catchment areas were more likely to be unfit, with fitness parameters particularly affected in girls.[56] The current study supports these findings, showing that living in a disadvantaged area negatively impacts baseline aerobic fitness, though it did not affect baseline muscular strength or power. This is partly explained by the interplay between aerobic fitness and BMI: higher adiposity increases the metabolic cost of aerobic work, likely resulting in lower PACER test scores.[57] Adolescents from deprived areas are also less likely to participate in organized sport, further contributing to lower aerobic fitness.[58] Among the fitness indicators, deprivation predicted only longitudinal changes in muscular power. This aligns with previous cross-sectional and longitudinal work.[59,60] Negative effects on muscular power may relate to diet quality, as limited access to healthy dietary options has been suggested to influence muscular power in adolescents[61]; however, further research is needed to confirm these mechanisms.

Strengths, Limitations, and Implications

The longitudinal design and application of latent growth modeling allowed us to examine individual development across multiple fitness parameters while accounting for missing data,[40] and the inclusion of covariates, such as deprivation, sex, baseline ePE, BMI, and ΔBMI enabled assessment of associations independent of key individual differences in a relatively large sample. All fitness parameters were assessed using well-established field-based tests with high reliability and validity, however, ePE was self-reported and may be influenced by over- or underestimation of physical activity.[62] Differences in cognitive development between year 7 and year 11 students may have further contributed to variability in ePE assessment and reporting.[63] Future studies should incorporate objective measures, such as accelerometers, to more accurately assess physical activity levels during PE classes. Additionally, BMI was used as a proxy for adiposity, but more precise indicators (eg, fat-free mass or waist circumference) would offer additional insight into associations with muscular fitness. Finally, the lack of adjustment for pubertal status limits interpretation of developmental influences on strength and power, and potential effect modification, such as whether associations differ by sex, BMI category or deprivation was not explicitly tested and may warrant consideration in future research.

Our findings highlight that baseline ePE and maintaining healthy BMI trajectories are key determinants of fitness development. Change in ePE predicted gains in aerobic fitness, muscular strength, and power, highlighting the importance of promoting or facilitating engagement during PE classes. Previous school-based interventions provide practical examples: strength exercises incorporated into PE twice weekly alongside motivational sessions improved body composition and physical activity,[64] while increasing PE frequency or intensity enhanced aerobic fitness.[20,21] Building on this evidence, interventions should integrate both strength and aerobic components within PE lessons to optimize fitness development. Behavioral or motivational strategies may elicit change in ePE particularly among students with higher BMI or from socioeconomically deprived background, however, it remains currently unclear how such strategies can be delivered effectively in this population.[65] Embedding these strategies within the school context, supported by extracurricular activities and whole-school health promotion, offers a feasible approach to improving adolescent fitness while reducing disparities.

Conclusions

Changes in effort during PE classes, rather than the initial levels of effort, most significantly influenced the development of aerobic fitness and muscular power and strength in English secondary school students between years 7 and 11. Therefore, fostering and maintaining students' motivation to consistently invest ePE classes is necessary for promoting improvements in aerobic fitness, strength, and power. Consequently, PE programs should prioritize strategies that sustain student engagement and effort over time, as consistent participation is key to long-term health and physical development.

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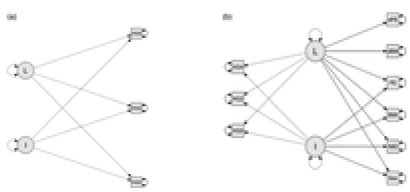
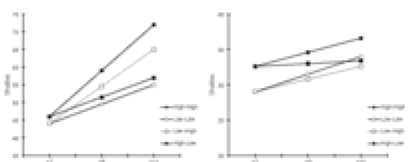
Figures with alt-text

(**Note:** *Alt-text descriptions for figures have been included in this proof to support accessibility review, please check and confirm if the accuracy of the inserted alt-text for Figure(s) is fine. This table is intended for the author/editor's review only and will not appear in the final published version.*

Figure Name	Graphic	Alt-text
Figure 1		Path diagrams for (a) a basic latent growth curve model and (b) an adjusted latent growth curve model. Circles represent latent variables; squares represent observed variables. Dashed arrows indicate factor loadings from latent variables to observed measures; solid arrows indicate regression paths. Two latent variables are derived from observed handgrip strength measures across 3 time points: I (Intercept), representing baseline muscular strength, and L (Slope), representing individual change over time. These labels are shown as "I" and "L" in the figure. In the adjusted model (b), baseline covariates (Sex, IMD, PE, BMI) influence both intercept and slope, while changes in PE effort (dPE) and BMI (dBM) influence only the slope. Dashed circles represent residual variances.
Figure 2		Example plots showing the estimated effect of differences in baseline and the effect of change in effort in PE (ePE) classes on aerobic fitness (shuttles) in (a) boys and (b) girls. These hypothetical scenarios show that children who had greater ePE in Year 7 and children who increased their ePE over the 4-year measurement period had higher aerobic fitness in Year 11 than children who maintained the mean ePE or who reduced their ePE over the 4-year measurement period.