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School-level variation in children's moderate to vigorous intensity physical activity before and after COVID-19: a multilevel model analysis

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Abstract

Background and objectives: Schools play a crucial role in facilitating physical activity among children, but the COVID-19 pandemic has affected both children's physical activity and the school environment. It is essential to understand between-school differences in children's physical activity post lockdown, to determine if and how the role of schools has changed.

Design and participants: Active-6 is a natural experiment comparing postlockdown accelerometer-estimated physical activity to a pre-COVID-19 comparator group. Accelerometer and individual data were collected on 1296 children aged 10–11 pre-COVID-19 (2017–8), with school characteristics collected from the 50 schools they attended. Post lockdown, we collected accelerometer, individual and school data from 393 children in 23 of the same schools and 436 children in 27 of the same schools in 2021 (Wave 1) and 2022 (Wave 2), respectively.

Methods: Sources of variation (between-school, between-pupil and within-pupil) in child weekday moderate to vigorous physical activity at each wave were modelled using linear mixed-effects models with school-level wave random coefficients. We extended the model to estimate the proportion of between-school variation explained by school policy, curriculum and physical environment factors and school-aggregated pupil characteristics. We also explored the extent to which postlockdown differences in moderate to vigorous physical activity were mediated by individual or school factors.

Results: Between-school variation comprised 13% of the total variation pre-COVID-19, 7% in Wave 1 and 13% in Wave 2. School factors associated with moderate to vigorous physical activity were the following: whether physical education was compromised due to space (often: 9 minutes lower moderate to vigorous physical activity; sometimes: 5.4 minutes lower); high after-school club attendance (7 minutes higher moderate to vigorous physical activity for each additional club attended on average in the school); cycle training policy (4 minutes higher moderate to vigorous physical activity); and higher prevalence of active travel (1 minute higher moderate to vigorous physical activity for each 10% point increase in prevalence). These factors explained 22% of the between-school variation pre-COVID-19, and 72% at Wave 2. The relative importance changed, with cycle training policy and active travel being the most important pre-COVID-19 and cycle training policy, active after-school clubs and compromised physical education space most important in Wave 2. No factors were found to mediate the postlockdown differences in moderate to vigorous physical activity, except compromised physical education space, which had a suppressor effect in Wave 2.

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Limitations: Only 27 of the initial 50 schools participated post lockdown, limiting our ability to make comparisons across waves. Sample sizes were additionally affected by missing data for some variables.
Conclusions and future work: While schools continue to play an important role in facilitating children's physical activity, the factors that contribute to this have changed post-COVID-19, with cycle training, active after-school clubs and ensuring physical education is prioritised even when space is limited now explaining nearly three-quarters of the between-school variation in children's moderate to vigorous physical activity. School-level interventions that focus on these areas, and policies that support them, may offer the potential to increase children's physical activity.
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Background

Physical activity is important for children's mental and physical health, including improved psychological well-being and a lower risk of cardiometabolic diseases.[1,2] The World Health Organization and UK Chief Medical Officers recommend that children should engage in an average of 60 minutes of moderate to vigorous physical activity (MVPA) per day,[3,4] and in the UK, government guidelines recommend that 30 minutes of this should take place during the school day.[4] Children spend a large portion of their time at school, and therefore schools play a crucial role in promoting and facilitating physical activity among children.

Children's physical activity levels vary between schools, with between-school variation, that is unmeasured school-level factors, accounting for 6–18% of the total variance in child daily accelerometer-measured MVPA.[5–8] These between-school differences remain even after adjustment for individual demographics such as age, gender, ethnicity and socioeconomic position, indicating that differences are due to features of the school environment rather than differing pupil demographics. Unmeasured school-level factors are estimated to be responsible for one and a half times more of the variation in children's MVPA than known individual correlates, such as demographics, active travel and active clubs.[7] Despite this, most studies focus on individual-level factors associated with physical activity,[9] resulting in limited evidence on the role of the school environment, such as school policies, curriculum and the physical environment. The existing literature suggests that physical activity is positively associated with policies that support active travel,[5,10] school crossing patrol[10] and cycle training for children.[11] Aspects of the curriculum can be both positive, such as time spent on physical education (PE), outdoor breaks[12] and the use of physical activity in non-PE subjects,[11] or negative, such as compromised PE due to lack of space and restriction on access to open space or facilities.[11] Evidence for associations with the physical environment (such as playground equipment and markings) and facilities is mixed,[13–15] with much of the research focused on specific contexts, such as active play during breaks, rather than across the full school day, despite current UK guidance, which advocates a 'whole-school' approach.[16,17]

Lockdowns due to the COVID-19 pandemic have affected both children's physical activity and the school environment, as schools closed, and children remained at home for large periods of the day. After lockdowns were lifted, children's physical activity was initially lower than before,[18,19] although recent work suggests that MVPA has now recovered to pre-pandemic levels after about a year.[20,21] We also found substantial variation in how the pandemic has affected the school environment, with initial prioritisation of physical activity in the curriculum when schools reopened giving way to pressure to catch up on academic learning, staffing pressures impacting on support for physical activity, and some social distancing policies retained for convenience.[22] These differences in adaptations, policies and provision in schools mean that it is essential to understand between-school variation in children's physical activity post lockdown, to determine if and how the role of schools has changed, and whether there are key recommendations that can help schools promote physical activity in future.

Aim and objectives

The aim of this report is to explore between-school variation (between-school differences) in children's physical activity before and after the COVID-19 lockdowns. We will investigate the following:

1. whether the proportion of between-school variation has changed post lockdown, which would indicate a potential change in the role that schools play
2. the extent to which school-level factors explain between-school variation in children's MVPA and whether this has changed post lockdown.

A secondary aim is to explore whether individual or school-level factors mediate the postlockdown reduction in children's MVPA.

Methods

The Active-6 study[18,20,23] compared postlockdown accelerometer-measured MVPA collected in two waves between May 2021 and July 2022 to a pre-COVID-19 comparator group, to investigate the effects of the COVID-19 lockdowns on the physical activity of children aged 10–11 years (in Year 6 of primary school). Pre-COVID-19 data came from the B-Proact1v study,[24] which collected data from 10- to 11-year-old children between March 2017 and May 2018 from 50 schools in and around Bristol, UK. Active-6 invited the same 50 schools to participate, with 23 schools taking part in Wave 1 (May–December 2021) and 27 schools in Wave 2 (January–July 2022); 22 schools participated in both waves. Wave 1 took place when schools had reopened, but some restrictions, such as size of gatherings remained, and there were still disruptions due to COVID-19 outbreaks. Wave 2 took place in 2022 when all restrictions were removed. At all measurement points, we collected child accelerometer and questionnaire data from both children and their parent/carer. Data on a total of 1296 children were collected pre-COVID-19, 393 children in Wave 1 and 436 children in Wave 2 (of whom 128 also participated in Wave 1). Full details of both studies are given elsewhere.[20,24] Both studies received ethical approval from the School of Policy Studies Ethics Committee at the University of Bristol, UK (Ref SPSREC/20-21/150) and parental consent was received for all participants.[25] The project was listed on the Research Registry (project 6646).[26]

Data

Outcome data

Children wore a waist-worn ActiGraph wGT3X-BT accelerometer (ActiGraph LLC; FL, USA) for 5 consecutive days in the pre-COVID-19 data, including weekends, and 7 consecutive days in Waves 1 and 2, increased to maximise the amount of valid data under difficult data collection conditions. Between 4 and 5 days of monitoring, including weekends, has been found to provide reliable estimates of usual physical activity in children.[27] Average accelerometer wear time and mean weekday minutes of MVPA, using Evenson population-specific cut-points for children,[28] were derived for all children who provided valid data (at least 500 minutes) on a minimum of 2 weekdays.[29]

Individual level data

Parents/carers reported child date of birth and gender and the highest education qualification in the household, which was recoded into two groups as 'Below University degree or equivalent' and 'University degree or equivalent or higher'. Parents reported the time their child typically spent engaging in screen-viewing on weekdays, with questions differing between pre- and post-COVID-19 studies.[30] In the pre-COVID-19 study, separate questions were asked about time spent screen-viewing from TVs, computers, phones/tablets and games consoles and time spent multiscreen-viewing (i.e. using multiple devices simultaneously), each coded from 'None' to '4 hours or more'. We summed the midpoints of each category over devices and subtracted the minutes of multiscreen viewing. In Active-6, parents/carers reported total leisure weekday screen-viewing in hourly categories from 'Less than 1 hour' up to '> 5 hours', and midpoints of each category were used to estimate the total leisure weekday screen-viewing. Children reported on which days (Monday to Friday) they attended an active after-school club based at their school, which was summed to give the number of days they attended a school-based active after-school club. Children also reported how they typically travelled to school. In the pre-COVID-19 data, children were asked about travel mode on each day of the week and we used the modal value to represent typical travel, as there was very little daily variation.[31] In the postlockdown data, children were asked directly for their typical travel mode. In both cases, we created a binary indicator of whether they typically used active (walk, bike or scooter) or inactive (car, bus or train) modes of travel to school. Quintiles of Index of Multiple Deprivation (IMD[32]) were derived from parent-reported postcode and categorised as most deprived area (lowest quintile) versus less deprived (above the lowest quintile).

School-level data

The number of pupils in Year 6 was reported by a school contact, the percentage of children in the school receiving free school meals[33] was retrieved from publicly available school data and school IMD quintile and population density of the local area[34] derived from school postcode. We also calculated aggregated pupil characteristics for each school: the percentage living in the most deprived IMD quintile, percentage using active travel to school, average number of after-school clubs attended and average minutes of weekday leisure screen-viewing.

A member of school staff was asked to provide information on the school policy environment and use of physical activity in the curriculum, using items

from the school physical activity policy assessment.[10,35] Trained fieldworkers completed a playground audit[11,36] during a normal school day to assess the presence of walking/cycling, sport and play provision, and design and aesthetics of the school grounds. The full policy, curriculum and playground audit measures collected are described in detail elsewhere.[11] In this report, we focus on policy and curriculum factors, which may have changed over the pandemic, and aspects of the school physical environment previously found to be associated with children's MVPA.[10,11] We included policies: cycle training, active travel and school crossing patrol and any restrictions on access to outdoor open space; curriculum: whether PE was often compromised due to space, whether physical activity was used in non-PE subjects and whether teachers provided activity breaks during lesson-time; and environment: provision of allotments, assault courses, pitches, drinking fountains and five or more pieces of playground equipment.

Statistical analysis

Individual and school characteristics and missing data were summarised by wave. Sources of variation and mediation were explored in relation to a base model, in a series of exploratory analyses as pre-specified in the Statistical Analysis Plan.[37] As this analysis was exploratory, we avoided formal hypothesis testing and focused on a combination of model fit [Akaike Information Criterion (AIC) and log likelihood] magnitude, precision of estimates and *p*-values. The base model, described in detail in the main Active-6 paper,[20] is a linear mixed-effects random intercepts model for child weekday MVPA, with repeated measurements within children within schools. Wave was included as a categorical explanatory variable, with pre-COVID-19 as the reference category, and the model was adjusted for accelerometer wear time, COVID-19 restrictions,[18] hours of daylight, seasonality via second-order harmonic sine/cosine functions,[38] and child age, gender and highest household education. This model partitions the total variation in child MVPA into different sources: between-school variation (attributable to unmeasured school-level factors), between-pupil variation (attributable to unmeasured individual characteristics) and within-pupil variation (due to repeated measures). The focus of this report is specifically in understanding between-school variation, so results in the main report present between-school variation only, however all sources of variation are reported in the Appendix tables. Models were run in MLwiN v3.06 [version 3.06 (program): Centre for Multilevel Modelling, University of Bristol, 2022] via the runmlwin[39] command in Stata v17 [Stata Statistical Software: Release 17 (program). College Station, TX: StataCorp LLC, 2021].

Between-school variation

To compare the proportion of between-school variation across the three waves, we extended the base model to include wave random coefficients at the school level, allowing the between-school variation to differ between waves (between- and within-pupil variation was assumed constant). We explored different covariance structures (unstructured and diagonal covariance matrix under different parameterisations) and used likelihood ratio tests and AIC to identify the best-fitting wave random coefficient model. We compared this to the base model via a likelihood ratio test to identify whether between-school variation differed between waves, and estimated the percentage of the total variation attributable to between school, between pupil and within pupil for each wave. We then used this model to estimate school-specific estimates of average weekday MVPA at each wave and plotted the change for each school, which included data at all three time points.

School characteristics that explain between-school variation

The between-school variation wave random coefficients model above estimates the percentage of the total variation due to unmeasured school factors. We explored how much of this between-school variation was explained by school characteristics, school-aggregated pupil characteristics, policy, curriculum and environmental school factors, by adding each variable to the wave random coefficients model separately. For school-aggregated pupil characteristic models we also included the corresponding individual variable, centred on school means, to allow school-level effects to be interpreted as contextual effects. Thus, for example, child weekday MVPA is assumed to relate to both the number of after-school clubs a child attends as well as the mean number of clubs attended by children in their year group. Factors that were separately associated with child MVPA were identified on the basis of magnitude and precision of estimates. These factors were then added to a combined model, assuming additive effects, and refined using a model selection process based on magnitude of estimates, *p*-values and model fit (AIC), to produce a final school characteristics model. We excluded any factors with substantial amounts of missing data at school level but added them to the final school characteristics model in a separate sensitivity analysis. For each model, we calculated the proportion of between-school variation explained by the variables included in the model for each wave.

Mediation by individual and school factors

We explored the extent to which differences in MVPA between pre- and post lockdown were mediated by

individual factors (active travel to school, screen-time and number of after-school clubs) and school factors (policy, curriculum and environment variables), which might feasibly have changed pre- and post-COVID-19. Formal mediation tests can be problematic in multilevel models and introduce confounding, as mediators may act at different levels,[40] and so we did not attempt to directly estimate a mediation effect. Instead, we identified potential mediators as those which were associated with MVPA, which varied between waves, and which made substantial changes to the estimates of differences in child weekday MVPA between waves. We restricted mediation analysis to those factors that were found to be associated with MVPA in the previous school characteristic models, with each potential mediator considered separately. To determine if potential individual mediators differed between waves, we fit an appropriate mixed-effects model (logistic model for active travel, Poisson model for screen-time[30] and number of after-school clubs) for differences between waves, with child and school random intercepts and adjusting for age, gender and household education. For potential school-level mediators, we compared proportions by wave descriptively, due to the lower number of schools. For both individual and school-level variables if the potential mediator differed sufficiently between waves, we fit the wave random coefficients model, adjusting for the potential mediator, and used a combination of magnitude and precision of estimates and *p*-values to assess the extent to which the potential mediator was responsible for all, part or none of the observed postlockdown differences in MVPA. Finally, if multiple mediators were identified, we included all of them simultaneously in the wave random coefficients model, to explore their combined additive effect.

Patient and public involvement

Patient and public involvement was integral throughout the Active-6 project, with children, parents, teachers and school staff involved in research design, data collection methods, development of study materials and dissemination plans. Parent representatives are active members of the study management and steering groups, children have participated in group sessions at schools to review materials, and early school-level results have been shared with schools and participating families.

Equality, diversity and inclusion

The 50 schools invited to take part in Active-6 were those that completed Phase 3 of the B-Proact1v study, which comprised a mix of urban and rural schools of different sizes across four local authorities in the Bristol area. Schools that took part in Active-6 were broadly representative of these schools. Participating children were roughly equally split by gender, and drawn from all IMD deciles, although with more participants from higher socioeconomic backgrounds, especially in the post-COVID-19 samples where the challenges of recruiting in a pandemic affected response rates especially among those who are typically less likely to engage in research. The sample had low ethnic diversity, with only 9% from non-white backgrounds, although this is typical of the ethnic diversity of the area as a whole.

Results

Individual and school characteristics are summarised by wave in *Tables 1* and *2*, respectively, with missing values presented in *Appendix 1*, *Table 5*. Although fewer schools took part in Waves 1 and 2, demographics were similar. As no schools reported more than five pieces of playground equipment post lockdown, this variable was excluded from subsequent analysis. In addition, we note that active travel policy, school crossing patrol and restrictions on access to open space had larger amounts of missing data (26–34%) and so should be treated with caution.

Between-school variation

A random coefficients model with school-level random-effect terms for each wave was used to compare the percentage of between-school variation across the three waves, which is the percentage of the total variation in child MVPA that can be attributed to school-level factors. A diagonal covariance matrix was found to be sufficient to capture the covariance structure, based on AIC and the log-likelihood ratio test (see *Appendix 1*, *Table 6*). A log-likelihood ratio test ($p < 0.001$) concluded that the school-level wave random coefficients model was a better fit to the data than the random intercepts model (see *Appendix 1*, *Table 6*), but that within-school random coefficients for waves were not needed. Total variation in child MVPA was similar between pre-COVID-19 and Wave 2, and slightly lower in Wave 1 (see *Appendix 1*, *Table 7*). The percentage of between-school variation (attributable to school-level factors) changed across waves, from 14% pre-COVID-19, dropping to 7% in Wave 1 and increasing again to 13% in Wave 2 (see *Figure 1*; *Appendix 1*, *Table 7*). *Figure 2* plots the difference in average MVPA for each school by wave, plotted for those schools with data at all three time points, although estimates of variation are based on data from all schools. Nearly all schools mirrored the overall pattern of an initial drop in average MVPA in Wave 1, followed by a recovery to pre-pandemic levels.

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TABLE 1 Individual child characteristics, and characteristics of the households in which they live

	Pre-COVID-19 2017–8	Post lockdown 2021–2	
		Wave 1	Wave 2
Female: *N* (%)	680 (52)	193 (49)	224 (51)
Household education degree or higher: *N* (%)	636 (53)	257 (66)	267 (62)
White British ethnicity: *N* (%)	944 (87)	310 (84)	323 (81)
Most deprived areas[a]: *N* (%)	142 (11)	31 (8)	31 (7)
Active travel to school: *N* (%)	747 (58)	227 (62)	238 (58)
Screen-viewing (minutes): mean (SD)	147 (92)	144 (77)	143 (75)
Number after school clubs attended: mean (SD)	0.7 (1.1)	0.7 (1.0)	0.7 (0.9)

a Percentage in most deprived Index of Deprivation quintile.

TABLE 2 School-level characteristics

	Pre-COVID-19 2017–8	Post lockdown	
	N = 50	Wave 1 (2021) *N* = 23	Wave 2 (2022) *N* = 27
Urban: *N* (%)	45 (90)	19 (83)	24 (89)
Schools in most deprived areas[a]: *N* (%)	7 (14)	2 (9)	3 (11)
Population density: mean (SD)	32.3 (26.5)	31.8 (32.2)	34.9 (30.2)
Size of year group: mean (SD)	41.1 (20.1)	44.5 (23.8)	46.7 (26.0)
% pupils receiving free school meals: mean (SD)	10.2 (8.5)	12.9 (7.7)	12.9 (8.4)
% pupils of White British ethnicity: mean (SD)	85 (13)	84 (12)	78 (16)
% pupils living in most deprived areas[a]: mean (SD)	14 (22)	9 (20)	10 (17)
% pupils using active travel: mean (SD)	56 (21)	56 (25)	54 (23)
Mean number of after-school clubs attended: mean (SD)	0.8 (0.5)	0.7 (0.5)	0.7 (0.4)
Cycle training policy: *N* (%)	14 (33)	6 (26)	6 (24)
Written active travel policy: *N* (%)	17 (52)	6 (33)	9 (45)
School crossing patrol: *N* (%)	18 (53)	9 (50)	11 (52)
Restrictions on open space: *N* (%)	19 (51)	9 (50)	11 (55)
PA used in other subjects: *N* (%)	32 (78)	17 (74)	17 (71)
PE compromised due to space: *N* (%)			
Rarely	11 (27)	20 (87)	23 (88)
Sometimes	12 (29)	2 (9)	2 (8)
Often	18 (44)	1 (4)	1 (4)
Activity breaks during lesson-time: *N* (%)	13 (36)	11 (48)	12 (46)
Presence of allotments: *N* (%)	22 (44)	15 (65)	20 (74)
Presence of assault courses: *N* (%)	40 (80)	20 (87)	22 (81)

TABLE 2 School-level characteristics (*continued*)

	Pre-COVID-19 2017–8	Post lockdown	
	N = 50	Wave 1 (2021) *N* = 23	Wave 2 (2022) *N* = 27
Presence of pitches: *N* (%)	27 (54)	15 (65)	20 (74)
Presence of drinking fountains: *N* (%)	11 (22)	6 (26)	4 (15)
Five+ playground equipment: *N* (%)	11 (22)	0 (0)	0 (0)

a Percentage in most deprived Index of Deprivation quintile.

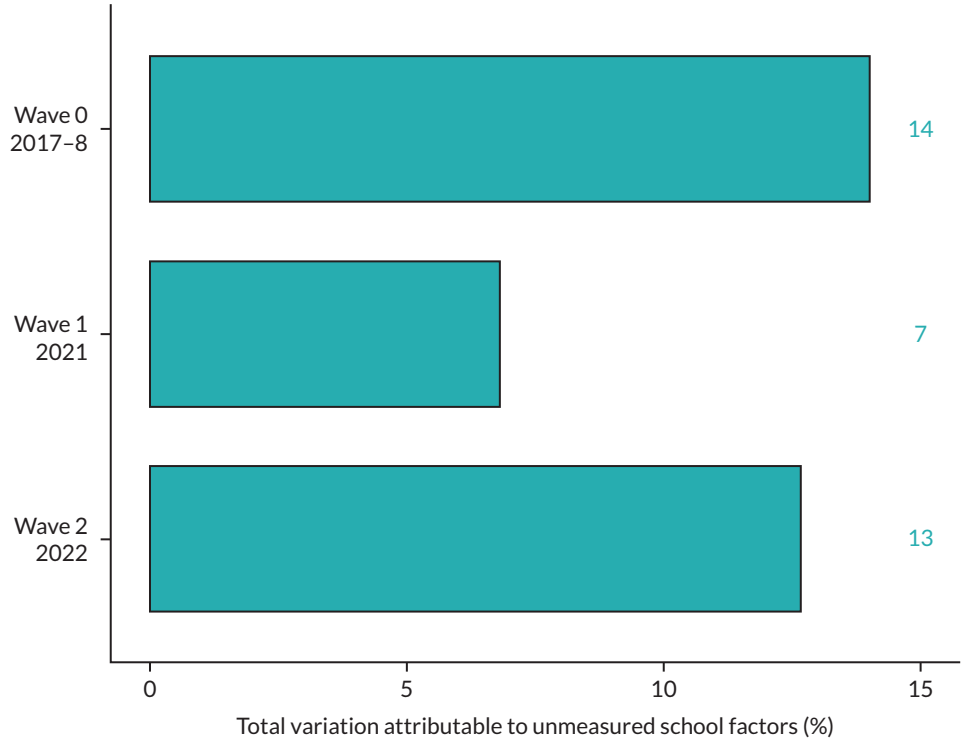

FIGURE 1 Percentage of unmeasured variation attributable to between-school variation by wave.

School characteristics that explain between-school variation

Table 3 shows the associations of school characteristics, school-aggregated pupil characteristics, policy, curriculum and environment school factors with child MVPA by adding each variable to the wave random coefficients model separately. The factors identified for the full school characteristics model were school IMD, cycle training policy, compromised PE space, allotments and pitches, plus individual and contextual effects for low IMD, active travel and number of active after-school clubs attended. The potentially relevant variables of an active travel policy and restrictions on access to open space were excluded from this stage due to high levels of missing schools (see *Appendix 1*, *Table 5*), but considered later in a sensitivity analysis.

The final school characteristics model (*Table 4*) included additive effects for the presence of a school cycle training policy, compromised PE space and individual and contextual effects for active travel and active after-school clubs. A cycle training policy in the school was associated with 4.0 minutes higher average daily MVPA (95% CI 0.4 to 7.5) for children in that school, compared to children in schools without cycle training. Children in schools where PE was sometimes compromised due to space engaged in an average of 5.4 minutes less MVPA (95% CI 0.5 to 10.2), rising to 9.3 minutes less (95% CI 4.4 to 14.1) when PE was often compromised. Individual-level effects were 6.0 minutes higher MVPA (95% CI 3.8 to 8.1) for a child using active travel, and 1.6 minutes higher MVPA (95% CI 0.5 to 2.6) for each active after-school club attended. Additional contextual effects were seen for attending

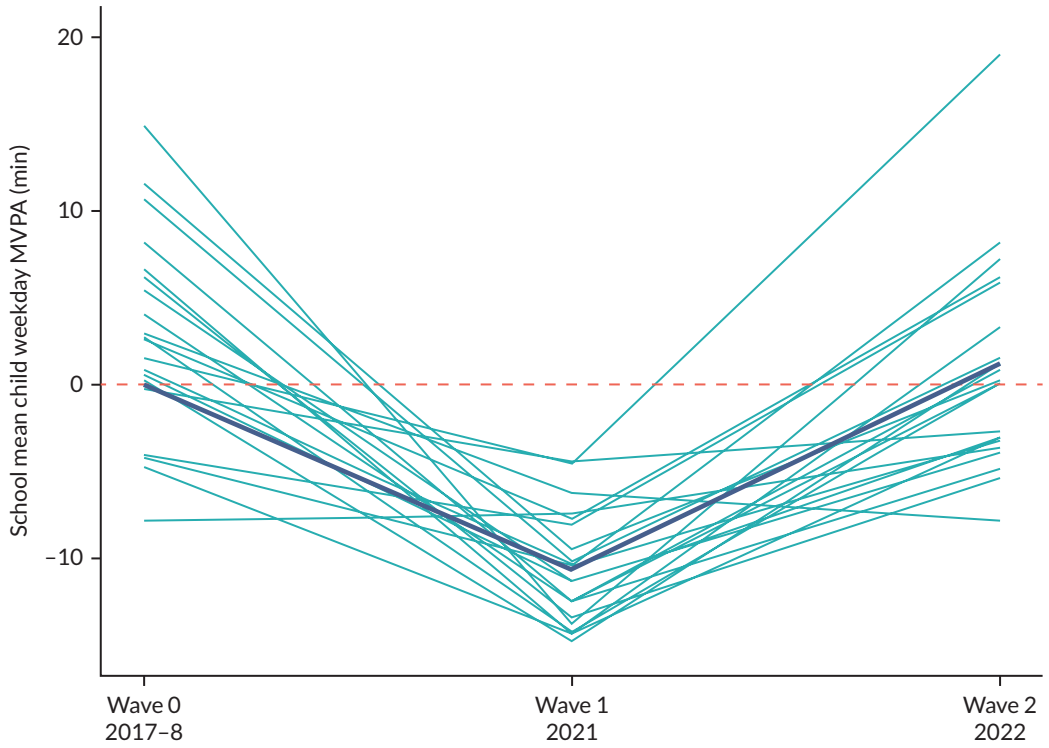

FIGURE 2 Between-school variation in MVPA by wave for wave random coefficients model. Note: Lighter lines plot the average MVPA by school (*N* = 21 schools with data at all three waves); the darker line indicates the overall average difference. Lines plotted in reference to overall pre-pandemic average (59.9 minutes; red dashed line).

a school with a higher percentage of pupils using active travel, of 1.0 minute higher MVPA (95% CI 0.3 to 1.7) for each 10% point increase in school active travel prevalence (e.g. from 10% to 20% or from 40% to 50%), and for attending a school where children attended more active after-school clubs, of 7.0 minutes higher MVPA (95% CI 3.5 to 10.5) for each additional club attended on average in the school. Together these factors explained 22% of the between-school variation in child MVPA (i.e. variation attributable to school-level factors) pre-COVID-19, with the proportion more than tripling to 82% at Wave 1 and 72% at Wave 2 (see *Figure 3*; *Appendix 1*, *Tables 8* and *9*). This represented 3%, 6% and 9%, respectively, of the total variation in child MVPA, that is variation attributable to the combination of both school and individual factors (see *Appendix 1*, *Table 9*). The relative importance of each school-level factor also changed, with cycle training policy and active travel most important pre-COVID-19, active after-school clubs, active travel and compromised PE space most important in Wave 1 and cycle training policy, active after-school clubs and compromised PE space most important in Wave 2. In a sensitivity analysis we added the variables for a written active travel policy and restrictions on access to open spaces to the model, both of which had a high number of schools missing data. Estimates for the previously included factors were similar (see *Appendix 1*, *Table 10*), although with larger confidence intervals and slightly larger estimates for compromised PE space. Restrictions on access to open spaces were additionally associated with 2.3 minutes lower MVPA (95% CI −2.3 to 7.0), compared to children in schools with no restrictions. There was no association with a school active travel policy.

Mediation by individual and school factors

The following factors were associated with child MVPA (see *Table 3*) and used in the mediation analysis: cycle training policy, compromised PE space, allotments, pitches, individual active travel to school and individual number of active after-school clubs. *Appendix 1*, *Table 11* gives modelled differences between waves for individual potential mediators, with the proportion in each wave for differences between waves for potential school mediators shown previously in *Table 2*. Potential mediators identified at this stage were cycle training policy, compromised PE space, allotments, pitches and individual number of active after-school clubs. All mediators were considered separately, and the postlockdown differences in MVPA for the mediated models are summarised in *Appendix 1*, *Table 12*. None of the variables were found to individually mediate the postlockdown differences in MVPA, with the exception of compromised PE space, which had a

TABLE 3 Associations between school characteristics, school-aggregated pupil characteristics, policy, curriculum and environment factors and child MVPA

		Estimate	95% CI	*N*
School characteristics				
Year 6 size (per 10 pupils)		0.8	0.0 to 1.5	1777
% in most deprived areas (per percentage point)		−4.0	−9.8 to 1.9	1777
% free meals (per percentage point)		< 0.1	−0.2 to 0.3	1777
Population density (per 10 people/hectare)		0.3	−3.0 to 9.5	1777
School policies				
Cycle training policy		5.1	1.2 to 9.1	1641
Written active travel policy		3.6	−0.6 to 7.7	1232
School crossing patrol policy		1.2	−2.9 to 5.2	1332
Restrictions on access to open space		−2.5	−6.7 to 1.8	1353
School curriculum				
PE compromised due to space[a]: often		−6.5	−12.1 to −0.9	1610
PE compromised due to space[a]: sometimes		−2.2	−7.8 to 3.3	1610
PA used in other subjects		3.0	−0.9 to 6.9	1574
Activity breaks during lesson-time		2.7	−1.3 to 6.7	1515
Playground environment				
Presence of allotments		4.5	0.9 to 8.1	1777
Presence of assault courses		−1.5	−6.0 to 3.1	1777
Presence of pitches		3.1	−0.5 to 6.8	1777
Presence of drinking fountains		3.0	−1.2 to 7.3	1777
Aggregated contextual effects				
Most deprived	Individual	1.313	−2.7 to 5.3	1742
	Contextual[b]	−1.162	−2.1 to −0.2	
Active travel	Individual	5.869	3.9 to 7.9	1735
	Contextual[b]	1.081	0.3 to 1.9	
Screen-viewing (per 10 minutes)	Individual	−0.081	−0.2 to 0.0	1647
	Contextual	−0.343	−1.03 to 0.4	
No. clubs attended	Individual	1.606	0.7 to 2.6	1744
	Contextual[c]	6.566	3.0 to 10.1	

a Compared to rarely compromised.
b Increase in MVPA for each 10% point increase in school prevalence, for example, from 10% to 20%.
c Increase in MVPA for each additional club attended on average in school.

suppressor effect in Wave 2. PE was compromised less often after the lockdowns, which explained some of the Wave 2 recovery in MVPA to pre-pandemic levels. As only a single mediator was identified, we did not explore potential additive effects of the different mediators.

Discussion

While average children's MVPA differed between schools and across waves, nearly all schools showed the same pattern of an initial drop in Wave 1 and recovery in Wave 2.

TABLE 4 Estimates from final school characteristics model (*N* = 1542)

		Estimate	95% CI
Cycle training policy		4.0	0.4 to 7.5
PE compromised due to space			
Sometimes		−5.4	−10.2 to −0.5
Often		−9.3	−14.1 to −4.4
Aggregated contextual effects			
Active travel	Individual	6.0	3.8 to 8.1
	Contextual[a]	1.0	0.3 to 1.7
No. clubs attended	Individual	1.6	0.5 to 2.6
	Contextual[b]	7.0	3.5 to 10.5
Wave estimates (compared to pre-COVID-19 2017–8)			
Wave 1 (2021)		−16.2	−24.8 to −7.6
Wave 2 (2022)		−2.4	−7.3 to 2.6

a Increase in MVPA for each 10% point increase in school prevalence, for example, from 10% to 20%.
b Increase in MVPA for each additional club attended on average in school.

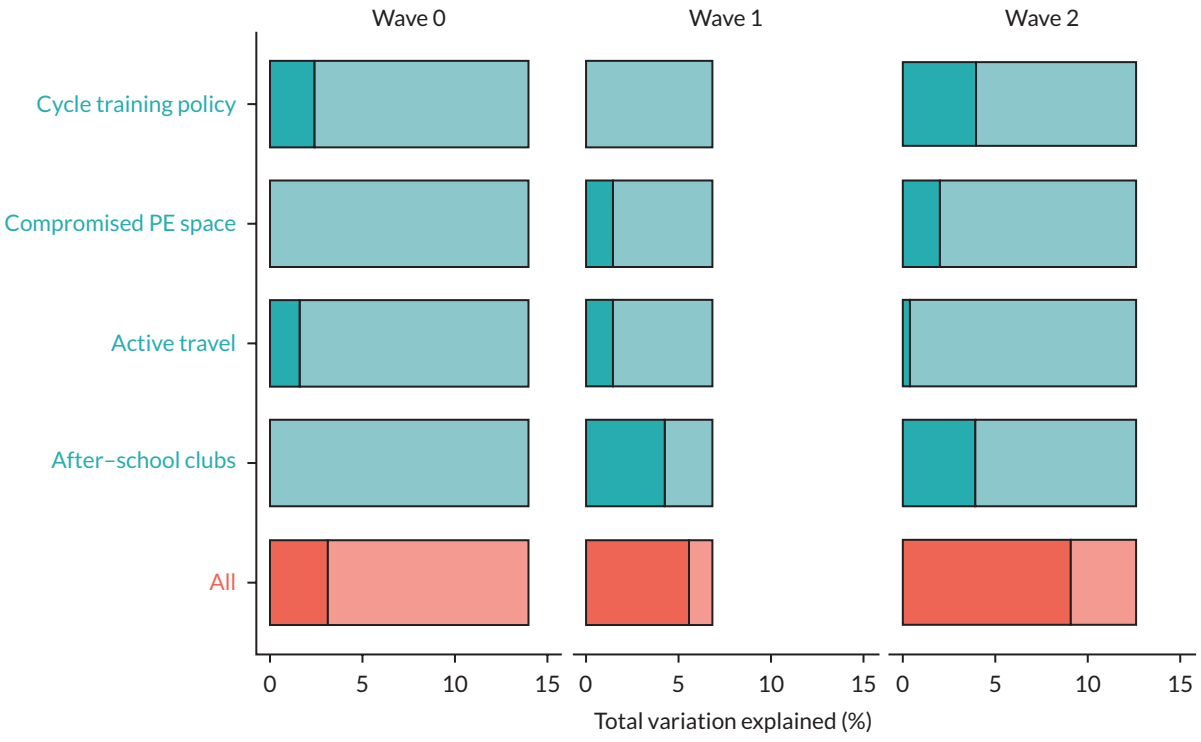

FIGURE 3 Between-school variation explained by school characteristics at each wave. Note: Box indicates total amount of between-school variation, while shaded area represents the proportion explained by the variables.

Moreover, there do not seem to be any systematic patterns to which schools experienced the largest drops in terms of school characteristics. There was no difference in the amount of within-school variation (between- and within-pupil), but between-school variation differed between waves, with the percentage of between-school variation in Wave 1 around half that pre-COVID-19 and in Wave 2 (7% compared to 14/13%). This suggests that in the initial months after restrictions were eased, it was individual factors that dictated a child's physical activity, with schools

only regaining their role as life became more settled by Wave 2. This is not surprising as during the initial period there were still disruptions due to COVID-19 outbreaks, such as school or class closures, and multiple children isolating. We also found no evidence that the initial drop was mediated by either individual- or school-level factors. Although we cannot entirely rule out the explanation that the drop is due to some other unknown factor changing over this time frame, these results support the conclusion that the COVID-19 pandemic and lockdowns led to reductions in children's physical activity in the shortterm, and that there was little schools could do to mitigate this.

The role of schools remains important after the COVID-19 lockdowns. School factors were responsible for 14% of the total variation in children's MVPA before COVID-19, consistent with pre-pandemic estimates seen elsewhere,[5–8] and returned to a similar level in 2022. Between-school differences in MVPA were explained by the following school factors: whether PE was compromised due to space (often: 9 minutes lower MVPA; sometimes: 5.4 minutes lower), high after-school club attendance (7 minutes higher MVPA for each additional club attended on average in the school), a cycle training policy (4 minutes higher MVPA), and higher prevalence of active travel (1 minute higher MVPA for each increase in 10% points). Individually, these associations of around 5–7 minutes difference in MVPA are moderate in size, representing around 20% of the 30 minutes MVPA recommended during the school day, but could cumulatively contribute to even greater increases, with associated health benefits. For example, replacing 10 minutes of sedentary time with 10 minutes of MVPA is associated with improved cardiometabolic indicators,[41] which in turn are associated with lower risk of cardiovascular disease in adulthood. However, there were postlockdown differences in both the overall and relative importance of these factors in describing difference between schools. In Wave 2, these factors explained nearly three-quarters (72%) of all between-school variation, compared to only a fifth (22%) pre-pandemic. This amounts to 9% of the total variation explained post lockdown, which aside from gender, equates to more than any of the individual factors considered (household education, individual club attendance, individual active travel), either separately or combined. There was also a change in which factors were most important in explaining variation between schools, where cycle training and active travel dominated pre-pandemic and cycle training, high active club attendance and compromised PE space most important in 2022. Thus, while the overall importance of the school has not changed, these factors are stronger contributors and have changed in relative importance, suggesting a change in the way in which schools influence children's physical activity post lockdown. These changes reflect other Active-6 findings, which suggest that although children's physical activity has recovered to pre-pandemic levels there are notable differences in who is being active and how.[20,42-44] This suggests that understanding the school-specific context is very important for future approaches to increase physical activity at school,[45] and that future research should explore the potential of a whole school approach.[17]

Pre-COVID-19, while active after-school clubs were important for individual child MVPA, they did not explain between-school differences. This has changed post lockdown, with differences in after-school clubs now accounting for nearly a third (30%) of the between-school variation. This is consistent with other Active-6 results, which found an increased reliance on structured activities, such as clubs post lockdown,[43] with a high demand for active school-based clubs that some schools were struggling to meet.[44] The findings in this report reinforce the importance of ensuring schools are able to meet that demand, as the benefits to children include both individual and contextual effects. This means that children benefit not just from attending an after-school club themselves, but from being in a school where children are encouraged or able to attend more active after-school clubs. A child who attends an additional club per week will have an MVPA 1.6 minutes higher on average across the week, but a child who attends a school where on average all the children attend an additional club will have an MVPA 7 minutes higher – even if they do not themselves attend a club. As mentioned above, there are potential health benefits associated with increases in MVPA of this magnitude. We are not aware of any other research that has looked at contextual effects on children's physical activity, where children benefit both directly from participating in an activity themselves, and indirectly by being in an environment where other children regularly take part, and so further exploration of contextual effects could be a fruitful area of future research.[45] Such factors could be due to a combination of school leadership, culture and/or expectations, as a school that provides lots of clubs that children are encouraged to attend are likely to encourage physical activity in other ways as well. It could also be through the influence of children themselves, with children who attend clubs more active at other times,[31] leading to their friends being more active as well,[7,46,47] and this in turn shapes the school culture with a higher demand for an active environment. Regardless, it is crucial to ensure that schools are supported in the provision of affordable, and accessible active clubs that are sufficient to meet demand, especially in an increasingly pressured environment.[22]

Other positive school factors identified were a cycle training policy and active travel. The importance of a school cycle training policy has nearly doubled, now explaining around a third of the total between-school variation. While previous evidence has shown an association between schools that offer cycle training and higher MVPA,[11] other research has found that cycle training did not increase cycling frequency or independent cycling,[48] and so it is not clear what is driving this association. Anecdotally, some parents reported that cycle training helped them feel more confident taking their children on bike rides, so cycle training may build confidence and skills and facilitate being more active generally. Cycling was one of the few activities possible during lockdowns, and less crowded roads may have encouraged children to put their training into practice. Cycling infrastructure, both in school (e.g. storage) and out of school (cycle routes), and safety have also been found to be related to active travel to school.[49] In this study, we found that the main benefit of active travel was at the individual level, presumably as it is highly dependent on location, traffic safety and environment as well as individual circumstances.[50,51] There was a small contextual effect of active travel, with 2 minutes higher MVPA for children attending a school with 60% active travel compared to 40%, which may be capturing differences between local neighbourhoods rather than between schools. However, there was no association with a school active travel policy, a reminder that it is the behaviour itself that is associated with MVPA, rather than just the existence of a policy, an important point to consider when recommending a school cycle training policy on the basis of these results.

A negative factor associated with postlockdown differences between schools was if PE lessons were sometimes or often compromised due to space, although this did not explain differences before the pandemic. We note that there was a large change in the number of schools reporting compromised PE sometimes or often before and after lockdowns, from 73% to 13%, respectively, so the role in between-school differences is potentially driven by the few schools where PE is still compromised, which have lower average MVPA. This factor was reported by a member of school staff, and it is possible that this result reflects changes in who answered the questionnaire pre- and post lockdown, although this would have needed to be a systematic change in nearly all the schools in our sample. Alternatively, it could be due to differences in interpretation of the question, with the experience of delivering virtual PE during lockdowns leading to a much wider definition of 'compromised', and PE lessons now being seen as less compromised by comparison. It may also be a genuine change, with schools placing more value on physical activity post lockdown[22] and thus more likely to prioritise it. Increased options for virtual PE during lockdowns may mean that even when space is an issue, there are now more classroom-based online activities available and so PE can be delivered more effectively in smaller spaces without compromise. The mediation analysis also suggests that the reduction in compromised PE in schools may be responsible for some of the recovery in children's MVPA to pre-pandemic levels. A related factor is restrictions on access to outdoor space, including the use of rota systems. Unfortunately, missing data makes it difficult to draw firm conclusions, but the study results suggest that such restrictions may be associated with a reduction in MVPA. This is concerning as some schools have reported the continuation of such systems introduced during the pandemic, often for convenience.[22] Access to open space is important for promoting physical activity and lack of sufficient space can impact both on facilitating PE lessons and in managing outdoor free play during play times.[52,53] However, these results show the need to prioritise physical activity even when space is an issue. Schools that use rota systems should ensure that these are in place for the benefit of pupils, rather than for the convenience of the school, and that they facilitate rather than limit physical activity. Those schools that still struggle to deliver PE due to space could explore wider options, such as classroom-based and/or online activities. It may be advantageous to work with schools that have overcome this problem, in order to identify examples of good practice that can be shared.

These findings suggest that post lockdown, the role of schools remains important, but the nature of this role has changed, with cycle training and active clubs being key school-level contributors to explaining difference between schools, along with ensuring that PE lessons are not compromised. It is possible that these are proxies for some other school-level factors that are responsible for differences in MVPA, although there were no strong associations between these factors and any of the extensive range of policies, curriculum and the built environment measures we investigated. They may also reflect a general positive school ethos around physical activity, rather than the presence of these features directly, although a review of the impact of the school physical activity climate on adolescents was inconclusive.[52] However, note that the reverse is also true: not allowing physical activity to be compromised and promoting cycle training, active clubs and active travel are themselves actions that can help build a positive culture around physical activity. The key message is that the focus should be on reducing differences between schools by increasing opportunities for physical activity through a number of

different strategies, depending on the school.[45] The study results suggest that a combination of the following could provide a good place to start:

- prioritising physical activity and PE lessons even when space is limited by sharing examples of good practice
- supporting pressured schools to meet the demand for active after-school clubs by offering a wide range of options and encouraging uptake to ensure these are accessible to as many as possible
- offering cycle training to pupils.

These factors are all associated with increases in MVPA of a magnitude that can be linked to improved cardiovascular health in both childhood and adulthood, which suggests that implementing these changes may have the potential to make a substantial public health impact, both in the short- and long-term.

Strengths, limitations and future research

This study has a number of strengths. It uses rich school-level data on the policies, curriculum and playground environment and combines this with accelerometer-measured MVPA and questionnaire from individual children. The use of the same schools before and after the COVID-19 lockdowns removes the between-school variability from measures of change across waves. In addition, the multilevel modelling includes all schools that provide data from at least one time point and allows us to jointly model both individual and school-level factors. In particular, the separation of individual and contextual effects gives a unique insight into which differences are attributable to differences in pupil behaviour versus differences in the schools themselves. However, only 27 of the initial 50 schools participated in the postlockdown study. Although these schools are broadly comparable to those included in terms of demographics and characteristics, they were slightly less likely to be from the most deprived areas, which limits our ability to make comparisons across waves, especially if the impact of lockdown has disproportionately affected schools in more deprived areas. Sample sizes were additionally affected by missing data for some variables, so, for example, we are unable to draw firm conclusions about the impact of rota systems and other restrictions on access to open space.

While schools play an important role, pre-COVID-19 research on school factors was limited. As these results suggest that context may have changed, with some factors playing a stronger role, it is therefore even more important to explore this further. School-level interventions, particularly those aimed at active clubs and cycle training, offer a promising avenue to increasing children's physical activity and the changes post lockdown mean that it may be worth revisiting approaches that were not found to be sufficiently effective pre-pandemic. In particular, it is important to understand and account for the school context when designing interventions.[45] In addition, future research should explore further the separation of individual and contextual effects of child behaviours, such as club attendance and active travel. Finally, more work is needed to explore further the possible impact of residual lockdown restrictions on open space, such as rota systems.

Conclusions

Nearly all schools experienced the same pattern of an initial short-term drop in MVPA followed by a recovery. While schools continue to play an important role in facilitating children's physical activity, the factors that contribute to this have changed post-COVID-19, with cycle training, active after-school clubs and ensuring PE is prioritised even when space is limited now explaining nearly three-quarters of the between-school differences in children's MVPA. School-level interventions that focus on these areas and policies that support them offer the potential to increase children's physical activity.

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William Hollingworth was a member of the HTA Clinical Evaluation and Trials Committee 1 July 2016–31 March 2021.

Data-sharing statement

All data requests should be submitted to the corresponding author for consideration. Access to anonymised data may be granted following review.

Ethics statement

Ethical approval was gained from the School of Policy Studies Ethics Committee at the University of Bristol, UK (Ref SPSREC/20-21/150) on 9 March 2021. The project was listed on the Research Registry.

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This article was published based on current knowledge at the time and date of publication. NIHR is committed to being inclusive and will continually monitor best practice and guidance in relation to terminology and language to ensure that we remain relevant to our stakeholders.

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List of abbreviations

AIC	Akaike Information Criterion
IMD	Index of Multiple Deprivation
MVPA	moderate to vigorous physical activity
PE	physical education

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Appendix 1

TABLE 5 Missing data

	Wave 0		Wave 1		Wave 2	
	N	%	*N*	%	*N*	%
Individual						
Active travel to school	17	1	24	6	27	6
Screen-viewing (minutes)	229	18	31	8	31	7
No. after-school clubs attended	2	< 1	24	6	28	6
Most deprived areas	45	3	4	1	4	1
School						
Size of year group	0	0	0	0	0	0
% free school meals	0	0	0	0	0	0
IMD	0	0	0	0	0	0
Population density	0	0	0	0	0	0
Cycle training policy	8	16	0	0	2	7
Written active travel policy	17	34	5	22	7	26
School crossing patrol	16	32	5	22	6	22
Restrictions on access to open space	13	26	5	22	7	26
PA used in other subjects	9	18	0	0	1	4
PE compromised due to space	9	18	0	0	3	11
Activity breaks during lesson-time	14	28	0	0	1	4
Presence of allotments	0	0	0	0	0	0
Presence of assault courses	0	0	0	0	0	0
Presence of pitches	0	0	0	0	0	0
Presence of drinking fountains	0	0	0	0	0	0
Five+ playground equipment	0	0	0	0	0	0

TABLE 6 Comparison of random intercept and random coefficient models

	AIC	Log-likelihood	Degrees of freedom	*p*-value
Random intercept	15612	−7787.8	18	
Random intercept and between-school wave coefficients				
Unstructured	15570	−7762.1	23	< 0.001[a]
Diagonal	15570	−7764.9	20	< 0.001[a]
Random intercept, between-school and between-pupil coefficients				
Diagonal	15611	−7784.6	21	1.000[b]

AIC, Akaike Information Criterion: lower value indicates better model fit.
a Compared to random intercept model.
b Compared to random intercept and between-school wave coefficients model.

Note
All *p*-values doubled due to testing variances on the boundary of the parameter space.

TABLE 7 Sources of variation at each level: wave random components model

	Wave 0	Wave 1	Wave 2
% between-school variation	14.0	6.8	12.6
% between-pupil variation	54.8	59.4	55.7
% within pupil variation	31.2	33.8	31.7
Total variation	414.3	382.3	407.9

TABLE 8 Percentage of variation explained by school factors

	Wave 0 (%)	Wave 1 (%)	Wave 2 (%)
Between-school variation	14	7	13
% of school variation explained by:			
Cycle training policy	17	0	31
No. active after school clubs attended	0	62	30
PE compromised due to space	0	21	16
Active travel to school	12	22	3
All	22	82	72
% of total variation explained at schoollevel	3	6	9

TABLE 9 Sources of variation at each level: final school characteristics model

	Wave 0	Wave 1	Wave 2
% variation explained (compared to wave random components model)			
% between-school variation	22	82	72
% between-pupil variation	0.4	0.5	0.5
% within pupil variation	0	0	0
% total variation	3	6	9
% variation unexplained			
% between-school variation	11.2	1.3	3.8
% between-pupil variation	56.3	62.6	61.0
% within pupil variation	32.4	36.1	35.1
Total variation	406.1	368.8	382.1

TABLE 10 Estimates from final school characteristics sensitivity model

		Estimate	95% CI
Cycle training policy		2.8	−1.8 to 7.4
Active travel policy		−0.3	−4.4 to 3.8
Restrictions on access to open space		−2.3	−7.0 to 2.3
PE compromised due to space			
Sometimes		−8.3	−14.0 to −2.7
Often		−12.5	−18.9 to −6.1
Aggregated contextual effects			
Active travel	Individual	5.2	2.5 to 7.8
	Contextual[a]	1.5	0.6 to 2.4
No. clubs attended	Individual	2.5	1.3 to 3.8
	Contextual	5.2	−0.0 to 10.4
Wave estimates (compared to Wave 0)			
Wave 1		−23.5	−34.0 to −13.0
Wave 2		−1.8	−8.3 to 4.7

a Per 10% points.

Note
Missing data in restrictions on access to open space means this model is based on reduced data: *N* = 1017, from 29 schools in Wave 0, 15 in Wave 1 and 16 in Wave 2.

TABLE 11 Potential individual mediators: differences between waves

	Difference in MVPA between Wave 0 and Wave 1		Difference in MVPA between Wave 0 and Wave 2		*p*-value
	Estimate	95% CI	Estimate	95% CI	
Individual					
Active travel to school (OR)	1.3	0.8 to 1.9	0.8	0.6 to 1.1	0.344
No. after-school clubs (RR)	0.7	0.5 to 0.9	0.9	0.5 to 0.9	0.004

OR, odds ratio; RR, relative rate ratio.

TABLE 12 Mediation models

	Difference in MVPA between Wave 0 and Wave 1		Difference in MVPA between Wave 0 and Wave 2		*N*
	Estimate	95% CI	Estimate	95% CI	
Base	−10.7	−19.3 to −2.0	1.2	−4.3 to 6.6	1777
Individual					
No. after-school clubs	−9.7	−18.1 to −1.4	0.7	−4.6 to 6.0	1744
School					
Cycle training policy	−10.3	−19.1 to −1.5	2.3	3.0 to 7.5	1641
PE compromised due to space	−10.1	−17.8 to −2.5	−7.6	−12.1 to −3.2	1610
Allotments	−11.4	−19.9 to −2.8	−0.1	−5.6 to 5.4	1777
Pitches	−11.5	−20.2 to −2.9	0.6	−3.9 to 6.1	1777