TITLE: Adiposity, fitness, health-related quality of life and the reallocation of time between children’s school day activity behaviours: a compositional data analysis

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Abstract

Sedentary time (ST), light (LPA), and moderate-to-vigorous physical activity (MVPA) constitute the range of school day activity behaviours. This study investigated whether the composition of school activity behaviours was associated with health indicators, and the predicted changes in health when time was reallocated between activity behaviours. Accelerometers were worn for 7-days between October and December 2010 by 318 UK children aged 10-11, to provide estimates of school day ST, LPA, and MVPA. BMI z-scores and percent waist-to-height ratio were calculated as indicators of adiposity. Cardiorespiratory fitness (CRF) was assessed using the 20-m Shuttle Run Test. The PedsQLTM questionnaire was completed to assess psychosocial and physical health-related quality of life (HRQL). Log-ratio multiple linear regression models predicted health indicators for the mean school day activity composition, and for new compositions where fixed durations of time were reallocated from one activity behaviour to another, while the remaining behaviours were unchanged. The school day activity composition significantly predicted adiposity and CRF (*p*=0.04-0.002), but not HRQL. Replacing MVPA with ST or LPA around the mean activity composition predicted higher adiposity and lower CRF. When ST or LPA were substituted with MVPA, the relationships with adiposity and CRF were asymmetrical with favourable, but smaller predicted changes in adiposity and CRF than when MVPA was replaced. Predicted changes in HRQL were negligible. The school day activity composition significantly predicted adiposity and CRF but not HRQL. Reallocating time from ST and LPA to MVPA is advocated through comprehensive school physical activity promotion approaches.

Trial registration: ISRCTN03863885

Key words: time-use epidemiology, physical activity, sedentary behaviour, accelerometer, schools, children, health, CoDA

[[1]](#footnote-1)

Introduction

Schools are key settings for initiatives to engineer moderate-to-vigorous physical activity (PA) (MVPA) into children’s daily routines, through expansion, extension, and enhancement of existing school day activity opportunities [1]. Children spend a significant proportion of waking hours in schools, which have the physical and curriculum infrastructures, and personnel to promote health and wellbeing. Further, schools can positively influence children’s PA irrespective of socio-demographic characteristics, which drive health inequalities [2]. However, while schools provide various opportunities for PA engagement, they are also environments where children are sedentary for long periods [3].

The increased attention given to the role of PA in positively influencing children’s academic performance [4-6] has led to PA beyond physical education classes being advocated as a regular element of the school day [7, 8]. For example, in the US and UK it is recommended that children accrue at least 30 minutes MVPA during the school day [7, 8]. Such advocacy reflects the increased awareness of the influence of PA on child health and wellbeing, which is demonstrated by the volume and range of school-based PA initiatives and interventions reported over the last decade [9-13]. Such interventions require using a finite amount of time in the school day for one activity behaviour at the expense of another, which makes the proportions of time spent in these activity behaviours perfectly collinear [14]. For example, the TAKE 10! Programme [15] involves swapping 10 minutes of classroom sedentary activity with MVPA. This means that every change in time spent sitting is intended to result in a corresponding opposite change in time spent in MVPA. Data on children’s activity behaviours at school are therefore constrained, or *compositional data* [16], made up of mutually exclusive parts of a whole [17]. The sample space of compositional data differs from real space associated with unconstrained vectors [17], and therefore the mathematical properties of compositional vectors should be accounted for when analysing time-use data [14]. Recently, studies have applied this *time-use epidemiology* concept [14] by treating activity behaviour data as compositional data [18-24] to properly understand the relationships between health and activity [14]. School day activity behaviours (i.e., sedentary time (ST), light PA (LPA), and MVPA) collectively constitute the range of activity behaviours that children engage in during this period. Associations between children’s ST [25], LPA [26], and MVPA [27] and various health outcomes have been reported, but rarely have these individual exposure variables been analysed relative to the other activity behaviours which help compose the full period of time under examination [14]. Furthermore, it is unclear what the potential health effects are of substituting one school day behaviour, such as ST, for another, such as MVPA. Considering the importance placed on schools promoting child health and wellbeing and the range of school-based interventions that are advocated, the aims of this study were to (1) examine whether the school day activity composition was associated with indicators of physical health and health-related quality of life, which is increasingly used as an indicator of general health and wellbeing in epidemiological studies [23], and (2) investigate predicted differences among these health indicators when a fixed duration of time was reallocated from one activity behaviour to another.

Methods

*Participants*

This cross-sectional study was a secondary analysis of baseline data from the Children’s Health, Activity, Nutrition: Get Educated! (CHANGE!) intervention (ISRCTN03863885). The methods have previously been reported [28], but are described briefly here. Four-hundred and twenty children aged 10-11 years from 12 UK primary schools were invited to participate. Schools were located in Wigan, northwest England, which is an area of high deprivation and health inequalities. Parental consent and child assent were obtained for 318 children (75.7% participation rate), approximately 95% of whom were of white British ethnicity which was representative of the local school age population [29].  Ethical approval was obtained from the Liverpool John Moores University Research Ethics Committee (10/ECL/039). Data were collected between October and December 2010.

*Anthropometric and fitness measures*

Stature to the nearest 0.1 cm (Seca Ltd. Birmingham, UK), body mass to the nearest 0.1 kg (Seca Ltd. Birmingham, UK), and waist circumference to the nearest 0.1 cm were measured using standard techniques [30]. BMI was calculated and BMI z-scores (zBMI) were assigned to each participant [31]. Percentage waist-to-height ratio (%WHtR) was used as an indicator of central obesity [32]. Children completed the 20-m shuttle run test (20-m SRT) to provide an estimate of cardiorespiratory fitness (CRF) [33, 34]. The running speed at the last completed lap was used to estimate peak oxygen uptake (VO2 peak; ml·kg·min−1) [34].

*Demographic measures*

Decimal age was calculated from dates of birth and dates of data collection. Neighbourhood-level socio-economic status (SES) was calculated from home postcodes to generate indices of multiple deprivation (IMD) scores, with higher scores representing higher degrees of deprivation [35].

*Psychosocial and physical health-related quality of life (HRQL).* Each child completed the Pediatric Quality of Life Inventory (PedsQLTM) generic core scales [36] supervised by the research team. The PedsQLTM consists of four scales measuring physical functioning (8 items), emotional functioning (5 items), social functioning (5 items), and school functioning (5 items) on 5-point likert scales. Item scores are reversed and transformed to a 0-100 scale, with higher scores representing better wellbeing. The psychosocial HRQL score was computed as the mean of the scores in the emotional, social, and school functioning scales. The physical HRQL score was represented by the physical functioning score.

*Activity behaviours: Physical activity and sedentary time.* Each child wore a waist-mounted ActiGraph GT1M accelerometer for 7 consecutive days. Children were asked to wear the monitor during waking hours only and to only remove it during water-based activities or contact sports where it might cause injury or get damaged. Monitors were set to record using 5 second epochs [37] and consecutive 20 minute periods of zero counts were considered non-wear time [38]. Data were analysed in agd format using ActiLife v.6.11.5 (ActiGraph, Pensacola, FL). Each school day commenced at 09:00 and ended at 15:30 (i.e., 390 minutes school day duration). Children were included in the data analysis if they wore the monitor for at least 70% of the school day on at least 3 days [39]. The cutpoints of Evenson et al. [40] were used to define ST, LPA, and MVPA, which were the exposure variables used to form the school day activity composition. These cutpoints have previously been shown to demonstrate strong classification accuracy across a range of intensities [41].

*Statistical analyses*

Exploratory and descriptive analyses were undertaken using IBM SPSS Statistics Version 24 (IBM Corp., Armonk, NY). To account for nested data (i.e., children within schools), intra-class correlations were calculated to determine the dependency of the child data on schools. A negligible school-level effect was observed (ICC = 0.02 to 0.04) and so subsequent analyses were not adjusted for clustering of children within schools. Compositional data analyses (CoDA) were performed in R ([http://cran.r-project.org](http://cran.r-project.org/)) using the compositions (version 1.40-1) [42], robCompositions (version 0.92-7) [43], and lmtest (version 0.9-35) packages. The school day composition (daily school time spent in ST, LPA, and MVPA) was described in terms of central tendency (the geometric mean of time spent in each part, linearly adjusted so that together all parts summed to the total school day for interpretation in min·day−1, or 100%, for interpretation in percentages of the school day). Multivariate dispersion of the school day composition was described by pairwise log-ratio variation [17, 19].

Multiple linear regression models were used to investigate the relationship between school day activity behaviour composition (explanatory variable) and each health indicator (dependent variable). Prior to inclusion in the regression model, the composition was expressed as a set of two isometric log ratios (*ilr*) co-ordinates. Sociodemographic covariates (sex, age, and IMD score) were also included as explanatory variables. The outcome variables were zBMI, %WHtR, VO2 peak, number of completed 20-m SRT laps, psychosocial HRQL, and physical HRQL. The *ilr* multiple linear regression models were checked for linearity, normality, homoscedasticity and outlying observations to ensure assumptions were not violated. The significance of the school day activity behaviour composition (i.e., the set of *ilr* coordinates) was examined with the car::Anova() function, which uses Wald Chi squared to calculate Type II tests according to the principle of marginality, testing each covariate after all others [44].

The above *ilr* multiplelinear regression models were used to predict differences in the outcome variables associated with the reallocation of a fixed duration of time (10 minutes) between two activity behaviours, keeping the third unchanged. This was done by systematically creating a range of new activity compositions to mimic the reallocation of 10 minutes between all activity behaviour pairs, using the mean composition of the sample as the baseline, or starting composition. The new compositions were all expressed as *ilr* coordinate sets, and each subtracted from the mean composition *ilr* coordinates, to generate *ilr* differences. These *ilr* differences (each representing a 10-minute reallocation between two behaviours) were used in the linear models to determine estimated differences (95% CI) in outcomes. Predictions were repeated for pairwise reallocations of up to 60 minutes, and corresponding estimates were plotted to aid interpretation (Supplementary Files 1-3).

The associations between the school day activity behaviour composition and health outcomes were further explored by using the same *ilr* linear multiple regression models to predict health outcomes for a large number (2000) of randomly generated school day compositions (expressed as *ilr* coordinates). The predictions were plotted in colour on a ternary diagram (with axes for ST, LPA, and MVPA) [45] and the area between the predictions was interpolated using the MATLAB function alchemist/ternplot [46] to produce a continuous response surface where increasing blue saturation represented a more favourable health outcome, and increasing red saturation less favourable association with the health outcome.

Results

The mean age of the children was 10.6 years and 54% were girls (Table 1). Mean IMD scores reflected that most children lived in areas of high relative deprivation (IMD quintile 4). On average the children achieved the accelerometer wear time criterion on 4.4 days from 5, and the mean accelerometer wear time was 359 min∙school day−1, which represents 92% of the school day. Application of the wear time inclusion criteria resulted in an analytical sample of 243 children (76.7% of consenting children) whose descriptive characteristics did not differ from those of the excluded children (*p* = 0.24 – 0.95).

Table 1. Participant characteristics. Study took place in the UK in 2010.

|  |  |
| --- | --- |
|  | All (n = 243) |
| Age (years) | 10.6 (0.3) |
| Sex (%) |  |
| Boys | 46.1 |
| Girls | 53.9 |
| Stature (cm) | 144.2 (7.4) |
| Mass (kg) | 37.6 (9.1) |
| BMI (kg·m2) | 18.0 (3.3) |
| zBMI | 0.14 (1.28) |
| Waist circumference (cm) | 61.8 (7.7) |
| %WHtR | 42.9 (4.8) |
| 20-m SRT laps | 29.3 (15.7) |
| VO2 peak (ml·kg·min-1) | 43.4 (4.3) |
| IMD score | 24.4 (15.0) |
| Accelerometer wear time (min·day-1) | 359.1 (22.9) |
| Psychosocial HRQL | 78.2 (16.0) |
| Physical HRQL | 85.4 (12.7) |

Data are presented as mean ± SD for continuous variables and as percentage for sex. *BMI* body mass index; *zBMI* body mass index z-score; *%WHtR* percentage waist circumference-to-height ratio; *20-m SRT* 20-metre shuttle run test; *VO*2 *peak* peak oxygen uptake; *IMD* indices of multiple deprivation

Compositional means for ST, LPA, and MVPA are presented in Table 2. Children spent 69% of the school day in ST, and approximately 25% of the day engaged in LPA. Analysis of variance of multiple linear regression model parameters indicated that the school day activity composition (expressed as *ilr* coordinates) was a statistically significant predictor of zBMI, %WHtR, VO2 peak, 20-m SRT laps, but not of psychosocial HRQL and physical HRQL (Table 3).

Table 2. Geometric means of school day activity behaviours. Study took place in the UK in 2010.

|  |  |
| --- | --- |
|  | n = 243 |
| ST (min·day-1) | 247.8 (69.0%) |
| LPA (min·day-1) | 88.7 (24.7%) |
| MVPA (min·day-1) | 23.0 (6.4%) |

Data are presented as geometric means (adjusted to sum the total school day (390 min)) and percentages of the school day. The spread of the compositions is described by variation matrices in Supplementary file 4.

Table 3. Multiple linear regression models for each health indicator: Analysis of Variance. Study took place in the UK in 2010.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Sum Sq | df | F value | p |
| zBMI |  |  |  |  |
| Isometric log-ratio co-ordinates | 19.97 | 2 | 6.56 | 0.002 |
| IMD score | 6.90 | 1 | 4.54 | 0.03 |
| Sex | 2.68 | 1 | 1.77 | 0.19 |
| Residuals | 363.77 | 239 |  |  |
|  |  |  |  |  |
| %WHtR |  |  |  |  |
| Isometric log-ratio co-ordinates | 277.8 | 2 | 6.59 | 0.002 |
| IMD score | 218.4 | 1 | 10.36 | 0.001 |
| Sex | 52.3 | 1 | 2.48 | 0.12 |
| Residuals | 5039.3 | 239 | 1.2 |  |
|  |  |  |  |  |
| VO2 peak |  |  |  |  |
| Isometric log-ratio co-ordinates | 166.8 | 2 | 5.28 | 0.006 |
| IMD score | 87.2 | 1 | 5.52 | 0.02 |
| Sex | 295.1 | 1 | 18.69 | <0.001 |
| Residuals | 3772.9 | 239 |  |  |
|  |  |  |  |  |
| 20-m SRT laps |  |  |  |  |
| Isometric log-ratio co-ordinates | 1230 | 2 | 3.30 | 0.04 |
| IMD score | 544 | 1 | 2.92 | 0.09 |
| Sex | 3222 | 1 | 17.30 | <0.001 |
| zBMI | 5109 | 1 | 27.43 | <0.001 |
| Residuals | 44330 | 238 | 0.0 | 0.99 |
|  |  |  |  |  |
| Psychosocial HRQL |  |  |  |  |
| Isometric log-ratio co-ordinates | 305 | 2 | 0.62 | 0.54 |
| IMD score | 2101 | 1 | 8.53 | 0.004 |
| Sex | 76 | 1 | 0.31 | 0.58 |
| zBMI | 818 | 1 | 3.32 | 0.07 |
| Residuals | 58625 | 238 |  |  |
|  |  |  |  |  |
| Physical HRQL |  |  |  |  |
| Isometric log-ratio co-ordinates | 469 | 2 | 1.55 | 0.21 |
| IMD score | 656 | 1 | 4.34 | 0.04 |
| Sex | 1 | 1 | 0.005 | 0.95 |
| zBMI | 992 | 1 | 6.57 | 0.01 |
| Residuals | 35947 | 238 |  |  |

The predicted differences in the health indicators when 10 minutes of the school day were reallocated between pairs of activity behaviours with the other activity behaviour remaining constant, are presented in Table 4. When 10 minutes were reallocated from MVPA to LPA, zBMI was predicted to be 0.37 units higher than the predicted mean zBMI (See Supplementary file 5 for predicted mean health indicator values at the mean activity composition). %WHtR was predicted to be 1.13 percentage units higher than the predicted mean when 10 minutes were reallocated from MVPA to LPA. Similar trends in %WHtR were observed when ST replaced MVPA, but these changes were not significant based on the 95% CIs. The predicted changes in 20-m SRT laps and VO2 peak were significantly lower than the predicted mean values when 10 minutes of MVPA were reallocated to ST or LPA. The opposite 10-minute reallocations (i.e., adding time to MVPA at the expense of ST or LPA) predicted lower zBMI, lower %WHtR, higher 20-m SRT laps, and higher VO2 peak values. However, these relationships were asymmetrical, as the greatest predicted changes in each outcome were observed when MVPA was replaced with ST or LPA. For example, predicted zBMI was reduced by a smaller amount with the addition of 10 minutes MVPA (−0.08 for ST; −0.32 for LPA) than the increase in zBMI predicted for 10 minutes less MVPA (+0.22 for ST; +0.37 for LPA). The predicted changes in psychosocial and physical HRQL as a result of time reallocation between activity behaviours were negligible.

Table 4. Predicted changes in health indicators following reallocation of 10 minutes between school day activity behaviours. Study took place in the UK in 2010.

|  |  |  |  |
| --- | --- | --- | --- |
| Add 10 minutes | Remove 10 minutes | zBMI predicted change (95% CI) | %WHtR predicted change (95% CI) |
| ST | LPA | **-0.24 (-0.37, -0.10)** | **-0.92 (-142, -0.42)** |
| ST | MVPA | 0.16 (-0.08, 0.39) | 0.28 (-0.58, 1.15) |
| LPA | ST | **0.22 (0.10, 0.35)** | **0.86 (0.39, 1.32)** |
| LPA | MVPA | **0.37 (0.10, 0.65)** | **1.13 (0.12, 2.14)** |
| MVPA | ST | -0.08 (-0.24, 0.07) | -0.11 (-0.69, 0.47) |
| MVPA | LPA | **-0.32 (-0.53, -0.12)** | **-1.03 (-1.81, -0.26)** |
| Add 10 minutes | Remove 10 minutes | 20-m SRT laps predicted change\* (95% CI) | VO2 peak predicted change (ml·kg·min-1) (95% CI) |
| ST | LPA | 1.06 (-0.47, 2.58) | **0.53 (0.10, 0.96)** |
| ST | MVPA | **-3.02 (-5.6, -0.45)** | **-0.91 (-166, -0.16)** |
| LPA | ST | **-0.97 (-2.39, 0.45)** | **-0.49 (-0.89, -0.08)** |
| LPA | MVPA | **-3.98 (-7.04, -0.93)** | **-1.40 (-2.27, -0.52)** |
| MVPA | ST | **1.95 (0.22, 3.68)** | **0.57 (0.07, 1.07)** |
| MVPA | LPA | **3.01 (0.66, 5.35)** | **1.10 (0.43, 1.77)** |
| Add 10 minutes | Remove 10 minutes | Psychosocial HRQL\*  (95% CI) | Physical HRQL\*  (95% CI) |
| ST | LPA | 0.11 (-1.65, 1.86) | 1.19 (-0.18, 2.56) |
| ST | MVPA | 1.63 (-1.33, 4.60) | 0.27 (-2.05, 2.59) |
| LPA | ST | -0.11 (-1.74, 1.52) | -1.11 (-2.39, 0.16) |
| LPA | MVPA | 1.53 (-1.99, 5.04) | -0.83 (-3.58, 1.92) |
| MVPA | ST | -1.11 (-3.10, 0.88) | -0.29 (-1.85, 1.27) |
| MVPA | LPA | -1.00 (-3.7, 1.69) | 0.91 (-1.20, 3.02) |

Bold type indicates statistical significant change in health indicator. All analyses adjusted for sex and SES. Analyses additionally adjusted for zBMI indicated with\*

Figure 1a-f presents ternary response surface plots describing predicted changes in each health outcome for variations in the movement behaviour compositions. Panels a and b demonstrate that a gradient towards higher predicted zBMI and %WHtR respectively (red areas) were observed in the direction of higher relative LPA, and lower MVPA. The ternary response surface plots representing the time reallocations for the CRF outcomes (Panels c and d) show that higher relative MVPA and lower relative LPA predicted higher 20-m SRT laps and VO2 peak values, respectively (blue areas). Panel e describes the gradient towards lower perceived psychosocial HRQL (red area), which was observed in the direction of higher relative MVPA and lower relative ST. A gradient towards higher perceived physical HRQL (blue area) was observed in the direction of higher relative MVPA and lower relative LPA (Panel f).

FIGURE 1a-f HERE (THIS FIGURE SHOULD BE IN COLOUR)

Discussion

We examined whether the school day activity composition was associated with indicators of physical health and HRQL, and investigated the predicted differences among these indicators when time was reallocated between activity behaviours. The results demonstrate that the school day activity composition was significantly associated with adiposity and CRF, but not HRQL HRQL.

This is the first study to examine children’s activity compositions constrained to the school day. The results concur with those reported from CoDA of children’s free-living activity behaviours [18, 20]. A consistent finding was that when school time was reallocated from MVPA to LPA with ST held constant, significant positive changes in zBMI and %WHtR were predicted. Both adiposity indicators were predicted to increase when MVPA was swapped with ST, but these changes were not significant. Our previous work demonstrated meaningful predicted increases in zBMI and %WHtR when time was reallocated from free-living MVPA to ST and LPA [20], while greater changes in zBMI were reported in a large sample of Canadian youth when MVPA was replaced by ST, than by LPA [18]. Time reallocations from school day MVPA to LPA and ST were reflected by significant predicted decreases in CRF. This finding also mirrors free-living data from similarly aged children [20], whereby VO2 peak was predicted to reduce by 2.4 ml·kg·min-1 when 15 minutes were reallocated from MVPA to ST and LPA. More modest decreases in CRF were reported in Canadian youth who undertook a sub-maximal step test [18]. As expected, the predicted changes in adiposity and CRF were smaller than those reported in studies of free-living activity behaviours [18, 20]. Nonetheless, the predicted reductions in zBMI when MVPA replaced LPA were meaningful and were greater than those reported in childhood obesity interventions [28, 47-51]. Moreover, the predicted increases in VO2 peak would substantially contribute to shifting a child up into the next centile of international normative VO2 peak values [34]. Combined, these findings reinforce the importance of making regular school day MVPA opportunities available to all children, and support recommendations for daily engagement in 30 minutes school day MVPA [7, 8]. Within the mean activity composition the children accumulated 23 minutes MVPA. When we reallocated 7 minutes to MVPA from ST and LPA to bring the MVPA element of the activity composition to 30 minutes, the significant predicted differences in adiposity and CRF were still apparent, although as expected they were smaller (Supplementary File 6). Our data suggest that regularly achieving the school day 30 minute MVPA recommendation by reallocating time from ST or LPA is favourable for promoting healthy weight and CRF.

Reallocating LPA for MVPA resulted in more unfavourable differences in adiposity and CRF than when ST replaced MVPA. This may have been partially due to accelerometer cutpoint intensity misclassification, whereby some ST was misclassified as LPA. Although we used the widely adopted 100 cpm as the ST cutpoint, it has been suggested that the validity evidence for this threshold is quite limited [52, 53], and that a higher threshold may be more appropriate [54]. Moreover, 100 cpm is anchored to 1.5 METs [55], but it is recommended that children’s sedentary behaviour be defined by 2 METs [56]. Therefore, it is possible that the 100 cpm threshold underestimated ST and overestimated LPA. Misclassification may also explain the observed influence on adiposity and CRF when ST and LPA were reallocated, which reflects similar analysis of free-living activity compositions [20]. We observed favourable differences in adiposity and CRF when ST replaced LPA, and unfavourable differences when the reallocation was reversed. These findings are equivocal when compared with previous CoDA and isotemporal substitution studies that have reported unfavourable [18] or negligible effects [57-59] on adiposity and CRF when ST was replaced by LPA.

The relationships between reallocated school day ST, LPA, and MVPA around the average compositions for adiposity and CRF indicators were asymmetrical. As has previously been observed [18, 20, 24] the magnitudes of change in predicted zBMI, %WHtR, 20-m SRT laps, and VO2 peak were smaller when MVPA replaced ST or LPA. This has been attributed to the relative contributions of the different activity behaviours to the period of constrained time under consideration [45]. ST accounted for 69% of the school day, compared to 24.7% and 6.4% for LPA, and MVPA, respectively. Taking 10 minutes from MVPA is a more significant relative change than taking 10 minutes from ST or LPA[19]. Moreover, the children in our study were relatively active, accumulating ~54 minutes MVPA across the full day [28] and were at low risk of overweight [60]. Thus, it is possible that additional MVPA for these relatively active children would predict somewhat smaller improvements in adiposity and CRF, which is consistent with the dose-response relationship observed between youth PA and cardiometabolic risk [61-63]. Irrespective of the potential mechanisms of predicted change, our findings support previous work [7, 8, 24, 64-66] advocating that during school, optimal opportunities for MVPA are provided to avoid unfavourable effects on adiposity and CRF. Initiatives that target MVPA and that are becoming more embedded as part of the regular school day, such as The Daily Mile [67] and Marathon Kids [68] have potential to meaningfully influence children’s health if implemented at scale, although currently there is limited formal evidence of the effectiveness of these programmes [69].

Associations between the school day activity composition and HRQL scores were not significant. These scores were comparable with previously reported PedsQLTM psychosocial and physical HRQL scores in UK children [70] and straddle the ‘minor clinical risk/healthy’ classification threshold [71]. Thus, the children’s HRQL was perceived as being high and so the ceiling effect of these scores may have diminished the potential associations with the activity composition. Recent CoDA of HRQL and activity behaviours has highlighted equivocal associations between these exposure and outcome variables [72] [23]. Use of different HRQL methods, combined with the limited number of activity behaviour studies employing CoDA to investigate associations with HRQL, makes it challenging to generalise further about direction and strength of associations relative to our findings.

*Study strengths and limitations*

Study strengths include the objective measurement of activity behaviours, and the range of health and wellbeing indicators reported. Accelerometer wear compliance was very high, and the CoDA adjusted for all collinear and co-dependent activity behaviours occurring over the school day. Using CoDA with longitudinal data and appropriately presented visualisations of CoDA results could help shape health-promoting policies and targeted interventions, as part of a wider push towards implementing comprehensive school PA programmes [64]. The study also had a number of limitations. The data were collected in 2010 therefore may not reflect current movement behaviour compositions. Accelerometers would have been removed for swimming and possibly some physical education activities, which would have led to underestimations of movement behaviours. Though we used ActiGraph thresholds [40] that have demonstrated strong classification accuracy [41], activity estimates may have been subject to some intensity misclassification, and reintegration into 5-second epochs may have resulted in some overestimations of MVPA. Analyses were adjusted for sociodemographic variables, but there may have been some residual confounding from unmeasured factors. Children were sampled from an area of relatively high deprivation of northwest England, which limits generalisability. The data were cross-sectional and focused only on the school day, which precludes inferences being made about cause and effect, and the influence of out-of-school activity behaviours [19].

Conclusions

The school day activity composition significantly predicted zBMI, %WHtR, 20-m SRT laps, and VO2 peak but did not predict psychosocial or physical HRQL. Replacing MVPA with ST or LPA around the mean activity composition predicted higher adiposity and lower CRF. The reverse was true when ST or LPA were reallocated for MVPA but the magnitude of the predicted differences was smaller. These findings amplify the benefits of MVPA and provide further evidence for the regular integration of MVPA into the school day. Creating opportunities for reallocating school time from ST and LPA to MVPA is advocated through whole-school comprehensive PA promotion approaches.

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Availability of data and material

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Conflicts of interest

The authors declare no conflicts of interest.

Figure caption

Figure 1a-f. Predicted health outcome response surfaces for school day activity compositions. Study took place in the UK in 2010.

a. Predicted zBMI (adjusted for SES and sex)

b. Predicted %WHtR (adjusted for SES and sex)

c. Predicted 20-m SRT laps (adjusted for SES, sex, and zBMI)

d. Predicted VO2 peak (adjusted for SES and sex)

e. Predicted Psychosocial HRQL (adjusted for SES, sex, and zBMI)

f. Predicted Physical HRQL (adjusted for SES, sex, and zBMI)

Legend. The edges of the triangles are the “time” axes, each grid line represents 10% of the school day (390 min), i.e., 10 = 10% of 390 min, = 39 min. The white point represents the mean school-day composition (24.7% LPA; 69% SED, 6.4 % MVPA). The black point represents the composition where 10 minutes (i.e., 2.6% of the school day) have been reallocated from LPA to MVPA, and SED is unchanged. For zBMI the response surface under the white point is green, whereas under the black point it is blue, indicating that zBMI is predicted to decrease with this time reallocation. The colour legend accompanying each ternary surface plot enables interpretation of the white and black points for the other health indicators. Table 4 in the main text includes predicted differences for all 10-minute reallocations around the mean composition (i.e., the white point).

Supplementary files

Supplementary file 1. Adiposity line graphs (pdf)

Supplementary file 2. CRF line graphs (pdf)

Supplementary file 3. HRQL line graphs (pdf)

Supplementary file 4. Variation matrices (docx)

Supplementary file 5. Predicted health indicators at the mean activity composition (docx)

Supplementary file 6. Predicted changes in health indicators when 7 minutes reallocated to MVPA (docx)

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1. Non-standard abbreviations. CRF: cardiorespiratory fitness, HRQL: health-related quality of life, IMD: indices of multiple deprivation, SRT: shuttle run test [↑](#footnote-ref-1)