



## The Association of the Body Composition of Children with 24-Hour Activity Composition

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**Objectives** To evaluate how the reallocation of time between sleep, sedentary time, light, and moderate-vigorous activities is associated with children's body composition.

**Study design** Population-based cross-sectional Child Health CheckPoint within the Longitudinal Study of Australian Children (n = 938 11-12 year-olds, 50% boys). Twenty-four hour activity composition via accelerometry (minutes/day of sleep, sedentary time, light, and moderate-to-vigorous physical activity [MVPA]) and 3-part body composition (percentage truncal fat, percentage nontruncal fat, and percentage fat-free mass) via bioelectrical impedance analysis were measured. We estimated differences in 3-part body composition associated with the incremental reallocation of time between activities, using dual-compositional regression models adjusted for sex, age, puberty, and socioeconomic position.

**Results** Reallocation of time between MVPA and any other activity was strongly associated with differences in body composition. Adverse body composition differences were larger for a given MVPA decrease than were the beneficial differences for an equivalent MVPA increase. For example, 15 minutes less MVPA (relative to remaining activities) was associated with absolute percentage differences of +1.7% (95% CI 1.2; 2.4) for truncal fat, +0.8% (0.6; 1.2) for nontruncal fat, and -2.6% (-3.5; -1.9) for fat-free mass, and a 15-minute increase was associated with -0.7% (-0.9; -0.5) truncal fat, -0.4% (-0.5; -0.3) nontruncal fat, and +1.1% (0.9; 1.5) fat-free mass. Reallocations between sleep, sedentary time, and light physical activity were not associated with differences in body composition.

**Conclusions** Preventing declines in MVPA during inactive periods (eg, holidays) may be an important intervention goal. More MVPA, instead of other activities, may benefit body composition. (*J Pediatr* 2019;208:43-9).

Time spent in daily activity behaviors (sleep, sedentary time, and light and moderate-to-vigorous physical activity [MVPA]) is clearly linked to children's body composition.<sup>1-3</sup> Yet, it is unknown how reallocation of time between these activities is associated with differences in whole-of-body composition because the compositional nature of each of time use and body composition has not been taken into account.

Changing time spent in one daily activity requires compensatory changes in at least one other activity in any given 24-hour period.<sup>4</sup> For example, it is not possible to increase sleep without an equal reduction in some combination of sedentary time, light physical activity, and MVPA. How, then, do we know whether it is the increase in sleep or the reduction in other activities that brings about any observed consequence? Activity behavior research is now moving toward an integrated 24-hour time-use paradigm,<sup>5</sup> where reallocations of time between all daily activity behaviors are considered in relation to health outcomes.<sup>6</sup> Previously, the issue of multicollinearity prevented the inclusion of all activity behaviors in statistical models. Novel compositional isotemporal substitution methodology now overcomes this problem.<sup>7</sup>

Findings from compositional isotemporal substitution studies suggest that relatively more time in MVPA is associated with higher percent body fat, and that the estimated differences in adiposity are similar when either sleep, sedentary time, or light physical activity are replaced by MVPA.<sup>8-10</sup> Importantly, all these studies reported nonlinear and asymmetrical relationships with the amount of time displaced and the direction of displacement. These new insights suggest that preventing reallocations of even small increments of time away from MVPA may be a crucial intervention goal for improving body composition.

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ILR	Isometric log ratio
LSAC	Longitudinal Study of Australian Children
MVPA	Moderate-to-vigorous physical activity

We aimed to explore the relationship between reallocation of time among daily activity behaviors and children's body composition (percentage truncal fat, percentage nontruncal fat, and percentage fat-free mass).

## Methods

Participants (aged 11-12 years) were drawn from the cross-sectional Child Health CheckPoint study, nested between waves 6 and 7 of the Longitudinal Study of Australian Children (LSAC). LSAC commenced in 2004 with a nationally representative birth cohort of 5107 infants recruited through a 2-stage random sampling design. The initial recruitment rate was 57.2%. In 2014, during LSAC wave 6 ( $n = 3764$ , 73.7% retention), 3513 families consented to provide their contact details to the Child Health CheckPoint team. In 2015, these families were mailed an information pack, followed by a recruitment phone call. Data were collected from 1874 child participants between February 2015 and March 2016. Ethical approval was granted by The Royal Children's Hospital (Melbourne) Human Research Ethics Committee (HREC33225) and the Australian Institute of Family Studies Ethics Committee (AIFS14-26). A parent/guardian provided written informed consent.

Participants were invited to attend a mobile assessment center in one of Australia's 7 major cities or 8 regional cities. Demographics, pubertal status, and body composition were reported/measured during these visits. Participants unable to attend a center were offered a home visit, however, these participants did not undergo full body composition measures, as the equipment was too large to transport. Thus, these participants were excluded from the ensuing analyses (Figure 1).

At the end of the center visit, a research assistant fitted the participant with a GENEActiv accelerometer (Activinsights Ltd, Kimbolton, Cambridgeshire, United Kingdom) on their nondominant wrist. Participants were given an activity card (Figure 2; available at [www.jpeds.com](http://www.jpeds.com)) to log bed time, wake time, a free-text description of their day (eg, school, unwell), and time and reasons for device removal.

The daily activity behavior composition was derived from 24-hour, 8-day accelerometry.<sup>11</sup> Data were downloaded at 50 Hz (GENEActiv PC Software; Activinsights Ltd), and converted to 60-second epoch files. These files were analyzed in MATLAB (MathWorks, Natick, Massachusetts) to determine sleep and nonwear time (visual interpretation of trace, combined with activity card sleep/wake and device removal times). If the reason for device removal was "sport," the associated period of nonwear was replaced with MVPA. This occurred among 34% of participants, with replaced MVPA totaling 54% of their total daily MVPA.

The 60-second epochs were classified into energy expenditure bands using validated cut points.<sup>12</sup> These cut points were linearly adjusted to account for the 50 Hz sampling frequency, so that the cut points were 244, 878,

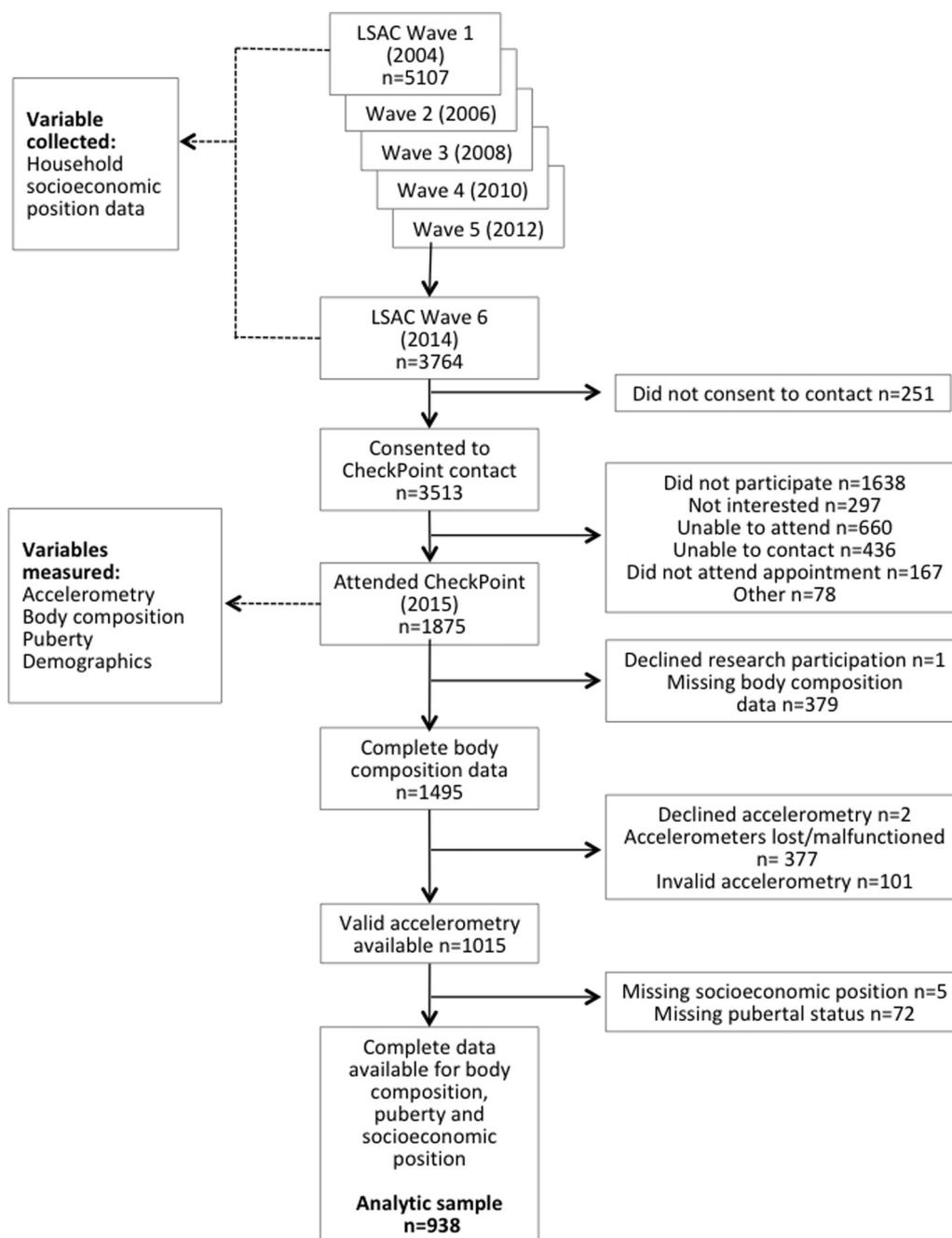
and 2175 gravity minutes (ie, acceleration because of gravity multiplied by minutes) for sedentary time, light physical activity, and MVPA, respectively. Accelerometer days were considered invalid if waking wear time was  $\leq 10$  hours, or if daily average sleep duration was  $\leq 200$  minutes or sedentary time  $\geq 1000$  minutes. Participants with  $< 4$  valid days were excluded. Average minutes spent in each intensity band were weighted at 5:2 for weekday and weekend days, and linearly adjusted to collectively sum to 24 hours. This created an "average" 4-part activity composition per participant (sleep, sedentary time, light physical activity, and MVPA). All these 4 activities cannot be included as independent variables in statistical models as they are perfectly multicollinear (together they must always sum to 24 hours). To enable the inclusion of all 4 activity components, they were expressed as a set of isometric log ratio (ILR) coordinates.<sup>13</sup> The ILRs contain all the relative information regarding the composition, but do not suffer from perfect multicollinearity.

Body composition was measured with bioelectrical impedance analysis using the InBody230 4-limb segmental body composition scale (Biospace, Seoul, Korea).<sup>14</sup> Bioelectric impedance analysis has been shown to be valid (correlation with underwater weighing,  $r = 0.69-0.79$ ) and reliable (coefficient of variation = 3%) for estimating body fat in school-aged children.<sup>15</sup> We distinguished between truncal fat, nontruncal fat, and fat-free mass, as these body compartments have been differentially associated with health outcomes.<sup>16,17</sup> Body composition (percentage of total mass in each body compartment) was expressed as a set of ILR coordinates.

Sex and age were obtained from LSAC. Children completed an iPad questionnaire to self-report pubertal signs using the Pubertal Development Scale.<sup>18</sup> They were categorized as either prepubertal, early pubertal, midpubertal, late pubertal, or postpubertal. A previously constructed composite z score was used for family-level socioeconomic position.<sup>19</sup> This score was derived from parent-reported occupation, household income, and highest parental education level, with higher scores indicating higher socioeconomic position.

Analyses were conducted in R (Vienna, Austria) using the *Compositions* package.<sup>20</sup> A multivariate multiple linear regression model was constructed with body composition ILRs as the dependent variables, and activity composition ILRs as the explanatory variables. The model was adjusted for sex, age, pubertal status, and socioeconomic position. Analyses were repeated among sex-stratified samples.

To estimate the differences in body composition associated with reallocation of time between activity behaviors, the above linear model was used as a predictive formula. First, body composition was predicted for the mean activity composition (sleep = 576 minutes; sedentary = 683 minutes; light physical activity = 158 minutes; MVPA = 23 minutes). Second, body composition was predicted for an activity composition in which time had been reallocated between activities. For example, the new activity composition



**Figure 1.** Child participant flow chart (Child Health CheckPoint, birth cohort).

representing the reallocation of 30 minutes from sleep to MVPA was sleep = 546 minutes; sedentary = 683 minutes; light physical activity = 158 minutes; MVPA = 53 minutes. The estimated difference in body composition for the reallocation of 30 minutes from sleep to MVPA was calculated by finding the difference between the 2 predicted body compositions. Absolute percentage differences between body compartments were calculated, rather than relative differences, to facilitate meaningful interpretation of estimated differences in body composition.

We explored 2 ways of theoretically reallocating time between activities, one-for-remaining and one-for-one. The

one-for-remaining reallocations simulated the increasing dominance of one behavior relative to the remaining behaviors. For example, one new predictive composition may simulate increasing MVPA by 15 minutes from the daily average, whilst simultaneously decreasing the sum of the remaining behaviors by 15 minutes. The one-for-remaining predictive compositions used in this study simulated reallocations of 0-60 minutes to/from the dominant behavior, in 15-minute increments. Each behavior was iteratively considered to be the dominant behavior, resulting in 4 sets of predictive one-for-remaining activity compositions (one set for each behavior). The differences (in absolute percentage

units) between body compositions predicted for the new activity compositions and the mean activity composition were calculated. The procedure was bootstrapped with 1000 replicates to obtain 95% CIs for the difference estimates.

Further activity compositions were created to estimate body compositions associated with one-for-one reallocations. This emulated substituting fixed durations (eg, 15 minutes) of one behavior for one other, keeping the remaining behaviors constant.<sup>7</sup> The absolute percentage differences in predicted body composition associated with these one-for-one reallocations were calculated, and 95% bootstrap CI obtained.

## Results

Participants were included if they had complete/valid body composition, accelerometry and covariate data (Figure 1). Sample characteristics are tabulated in Tables I-VI (available at [www.jpeds.com](http://www.jpeds.com)).

The activity composition ILRs were associated with body composition ILRs, following adjustment for sex, age, socioeconomic position, and pubertal status ( $F = 13.6$ ,  $P < .001$ ; Table VII; available at [www.jpeds.com](http://www.jpeds.com)).

The estimated differences in body components (in absolute percentage units) associated with the reallocation of time between one behavior and all other behaviors (one-for-remaining reallocations) and between MVPA and one other behavior only (one-for-one reallocations) are displayed in Figure 3. Estimated differences in body composition for all 15-minute reallocations are presented in Table VIII.

Reallocations involving MVPA as the dominant behavior (MVPA-for-remaining reallocations) were associated with greater estimated differences in body composition than reallocations between other activities. For example, a 15-minute reallocation away from MVPA (to remaining activities) was associated with absolute percentage differences of +1.7% (effect size [ES] = 0.5) for truncal fat, +0.8% (ES = 0.3) for nontruncal fat, and -2.6% (ES = 0.5) for fat-free mass. By comparison, a 15-minute reallocation away from sleep (to remaining behaviors) tended to be associated with just +0.1% truncal fat, +0.0% nontruncal fat, and -0.1% fat-free mass. The same 15-minute reallocation away from sedentary time and away from light physical activity tended to be associated with similar absolute differences, but in the opposite direction (Table VIII).

One-for-one reallocations involving MVPA were associated with greater estimated differences in body composition than one-for-one reallocations involving only sleep, sedentary time or light physical activity. Reallocations between MVPA and either sedentary time or light physical activity appeared to be associated with greater differences in body composition than reallocations between MVPA and sleep (Figure 3 and Table VIII).

Estimated body composition differences were smaller when time was reallocated to MVPA than when the same amount of time was reallocated away from MVPA

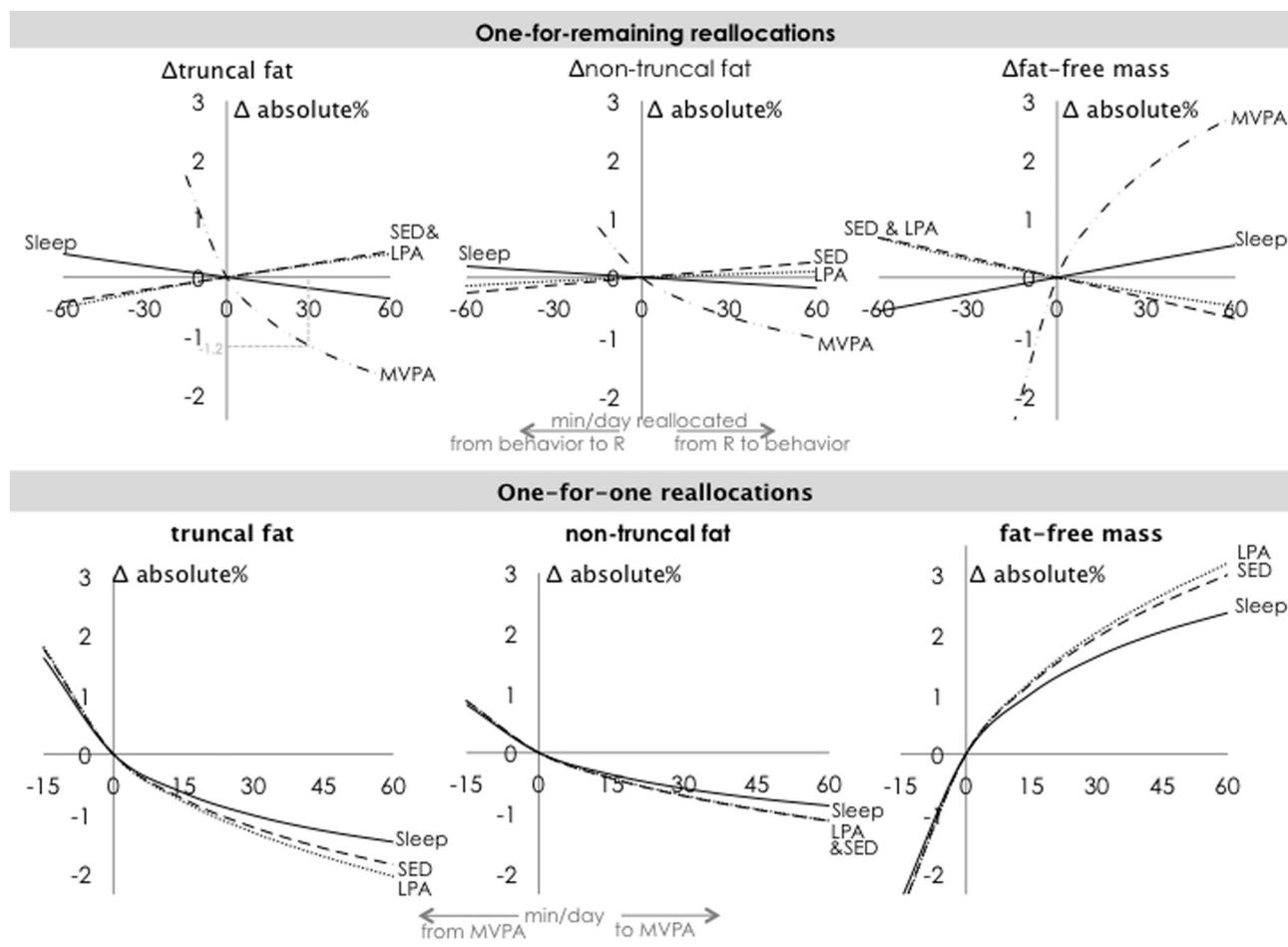
(Figure 3), (ie, they were not symmetrical). Increasing durations of time reallocated to MVPA were associated with diminishing differences, whereas increasing durations of time reallocated away from MVPA were associated with escalating differences in all body compartments (Figure 3).

Similar patterns of association between activity behavior reallocations and body composition were observed in sex-stratified analyses. Activity composition was significantly related to body composition in boys and girls, following adjustment for age, socioeconomic position, and pubertal status (boys:  $F = 10.30$ ,  $P < .001$ , and girls:  $F = 5.10$ ,  $P < .001$ ). The most unfavorable differences in body composition (higher percentage truncal and nontruncal fat, lower percentage fat-free mass) were observed for reallocations from MVPA to sedentary time among boys and from MVPA to light physical activity among girls (Figure 4 and Figure 5 [available at [www.jpeds.com](http://www.jpeds.com)] and Table IX and Table X [available at [www.jpeds.com](http://www.jpeds.com)]).

## Discussion

We found MVPA to be the most important activity behavior for body composition, with reallocation of time away from MVPA being associated with greater worsening of body composition than improvements for reallocating the same duration to MVPA. Our findings cannot be directly compared with those of previous noncompositional studies. However, the relationships between some body compartments and some activity behaviors concur with previous research. For example, an isothermal (non-compositional) substitution study among 1036 children aged 6-11 years estimated differences in body compartments (percentage android and gynoid fat) associated with the reallocation of 60 minutes between waking activity behaviors.<sup>21</sup> Separate models were used for each body compartment outcome. As the statistical models were linear, results can be rescaled to indicate the estimated differences for 15-minute reallocations. Based on their findings, the reallocation of 15 minutes of MVPA to sedentary time was associated with +1.65 percentage android (trunk and upper body) fat and +1.10 percentage gynoid (hips, thighs, and buttocks) fat percentage. Although not directly comparable, the above differences are similar to those observed for percentage truncal fat (+1.8) and percentage nontruncal fat (+0.9) in our study.

Our findings differ to previous traditional isothermal studies, in that estimated differences in body composition were not symmetrically opposite when a behavior was increased as opposed to decreased.<sup>22</sup> Furthermore, estimated differences were not linearly related to the duration of time reallocated. The asymmetry and nonlinearity of estimated differences associated with reallocations to and from MVPA found in the present study are consistent with findings from previous compositional data analyses.<sup>4,8-10,23</sup> This may be because activity components and body compartments are relative data, and relative change in a



**Figure 3.** Estimated absolute difference in body compartment percentages for systematically altered activity compositions: One-for-remaining and one-for-one (MVPA-for-one) reallocations of activity behaviors. For example, the difference in truncal fat % estimated for increasing MVPA by 30 minutes, at the expense of the remaining behaviors (MVPA-for-remaining), is determined by finding where a vertical line drawn at  $x = +30$  intersects with the MVPA response curve, and then extending a horizontal line to  $y$  axis (first plot on left, grey broken lines). The value of the  $y$ -axis at this horizontal line indicates the estimated difference in truncal fat% (in this instance,  $-1.2$  absolute percentage units). The difference in truncal fat% estimated for increasing MVPA by 30 minutes, at the expense of SED (MVPAfor-SED) can be determined from the first plot in the second row, by finding where a vertical line drawn at  $x = +30$  intersects with the dashed SED line (about  $-1.3$ ). R=remaining behaviors, SED=sedentary time, LPA=light physical activity, MVPA=moderate-to-vigorous physical activity. Analyses adjusted for sex, age, pubertal status and socioeconomic position.

component differs from absolute change.<sup>24</sup> For example, an absolute increase of 30 minutes from 30 to 60 minutes/day is a relative increase of 100%, whereas for the same 30-minute absolute change in the opposite direction (60 to 30 minutes/day), the relative decrease is 50%. In addition, the distribution of total daily activity counts follows a power law.<sup>25</sup> As time spent in any energy expenditure band is derived by applying cut points to such a distribution, shifting time from one band to another will be associated with asymmetrical responses. These phenomena are reflected empirically, in the nature of dose-response curves, which often predict diminishing benefits with marginal temporal increases in exposures (eg, Sattelmair et al<sup>26</sup>).

The data in our study were cross-sectional and relationships may be bidirectional. Therefore, the differences

modeled in the time-reallocation analyses do not necessarily represent the adiposity change that would ensue if an individual changed their behavior. Instead, they represent differences between estimates of adiposity for individuals with different activity compositions, which may not be causal in nature.

In this study, nonwear periods identified from child-reported activity cards as “sport” were replaced with MVPA. This is likely to overestimate MVPA time but was considered preferable to excluding these periods of nonwear from analysis. As a sensitivity analysis, we replaced “sport” nonwear periods with 50% MVPA, 30% light physical activity, and 20% sedentary time. This caused the relationship between body composition and activity composition to be somewhat strengthened ( $F = 14.0$ ,  $P < .001$ , vs

**Table VIII.** Estimated difference (95% CI) in body composition\* for 15-minute reallocations of time between activity behaviors

Reallocations	Δ%Truncal fat	Δ%Nontruncal fat	Δ%Fat-free mass
<b>One-for-remaining reallocations</b>			
Sleep to remaining <sup>†</sup>	0.1 (−0.0; 0.2)	0.0 (−0.0; 0.1)	−0.1 (−0.3; 0.0)
SED to remaining	−0.1 (−0.2; 0.0)	<b>−0.1 (−0.1; −0.0)</b>	<b>0.2 (0.0; 0.3)</b>
LPA to remaining	−0.1 (−0.3; 0.0)	0.0 (−0.1; 0.1)	0.1 (−0.1; 0.4)
MVPA to remaining	<b>1.7 (1.2; 2.4)</b>	<b>0.8 (0.6; 1.2)</b>	<b>−2.6 (−3.5; −1.9)</b>
Remaining to sleep <sup>‡</sup>	−0.1 (−0.2; 0.0)	0.0 (−0.1; 0.0)	0.1 (−0.0; 0.3)
Remaining to SED	0.1 (−0.0; 0.2)	<b>0.1 (0.0; 0.1)</b>	<b>−0.2 (−0.3; −0.0)</b>
Remaining to LPA	0.1 (−0.0; 0.2)	0.0 (−0.0; 0.1)	−0.1 (−0.3; 0.1)
Remaining to MVPA	<b>−0.7 (−0.9; −0.5)</b>	<b>−0.4 (−0.5; −0.3)</b>	<b>1.1 (0.9; 1.5)</b>
<b>One-for-one reallocations</b>			
Sleep to SED <sup>§</sup>	0.1 (−0.0; 0.3)	0.1 (−0.0; 0.1)	−0.2 (−0.4; 0.0)
Sleep to LPA	0.2 (−0.0; 0.3)	0.1 (−0.0; 0.1)	−0.2 (−0.5; 0.0)
Sleep to MVPA	<b>−0.6 (−0.9; −0.4)</b>	<b>−0.4 (−0.5; −0.2)</b>	<b>1.0 (0.7; 1.4)</b>
SED to sleep	−0.1 (−0.2; 0.0)	−0.1 (−0.1; 0.0)	0.2 (−0.0; 0.4)
SED to LPA	0.0 (−0.1; 0.2)	0.0 (−0.1; 0.1)	0.0 (−0.2; 0.1)
SED to MVPA	<b>−0.8 (−1.0; −0.6)</b>	<b>−0.4 (−0.6; −0.3)</b>	<b>1.2 (0.9; 1.5)</b>
LPA to sleep	−0.2 (−0.3; 0.0)	−0.1 (−0.2; 0.0)	0.2 (−0.0; 0.5)
LPA to SED	0.0 (−0.2; 0.1)	0.0 (−0.1; 0.1)	0.0 (−0.2; 0.2)
LPA to MVPA	<b>−0.8 (−1.1; −0.5)</b>	<b>−0.4 (−0.6; −0.3)</b>	<b>1.2 (0.8; 1.6)</b>
MVPA to sleep	<b>1.6 (1.1; 2.2)</b>	<b>0.8 (0.6; 1.1)</b>	<b>−2.4 (−3.3; −1.7)</b>
MVPA to SED	<b>1.8 (1.3; 2.4)</b>	<b>0.9 (0.6; 1.2)</b>	<b>−2.6 (−3.4; −1.9)</b>
MVPA to LPA	<b>1.8 (1.2; 2.5)</b>	<b>0.9 (0.6; 1.2)</b>	<b>−2.7 (−3.6; −1.9)</b>

LPA, light physical activity; SED, sedentary time; SEP, socioeconomic position.

Bold indicates estimated difference is significant at  $\alpha = 0.05$ . Analyses adjusted for sex, age, pubertal status, and SEP.

\*Estimated difference is in absolute percentage units.

†When time in sleep is decreased by 15 minutes and reallocated evenly across the remaining activities, %truncal fat is estimated to increase by 0.1 units, %nontruncal fat is estimated to remain unchanged, and %fat-free mass is estimated to decrease by 0.1 units.

‡Time in sleep is increased by 15 minutes, being drawn evenly from the remaining activities.

§15 minutes are reallocated from sleep to SED.

$F = 13.6$ ,  $P < .001$ ), and estimated differences in percentage fat for 15-minute reallocations involving MVPA to be slightly larger (up to 0.1% units). It should be considered that our estimates may be subject to residual confounding as we did not adjust for potential confounders such as cardiorespiratory fitness in these analyses. Many participants were excluded due to malfunctioning accelerometers (Figure 1). Included participants represented the general Australian population with regard to sex and geographical distribution by state, however, lived in slightly more advantaged areas than the general population (Socioeconomic Indexes For Areas Index of Relative Disadvantage sample mean 1026 [SD 63], vs national mean 1000 [SD 100]).

Our findings indicate that children's activity behaviors are important to the relative distribution of their body fat. They suggest that MVPA should be promoted, at the expense of the remaining behaviors. It appears that replacement of either sedentary time or light physical activity by MVPA may be marginally more beneficial to body composition than the replacement of sleep. We note that participants were, on average, achieving recommended sleep durations (arithmetic mean [SD] = 568 [44] minutes/day). Results might differ in sleep-deprived populations as insufficient sleep has been linked with lower physical activity, higher screen time and obesity.<sup>27</sup>

We found clinically insignificant differences in body composition for the replacement of sedentary time by light physical activity or sleep. This implies that obesity interventions should advocate the replacement of sedentary time by MVPA rather than by light physical activity or

sleep. Furthermore, interventions to increase light physical activity or sleep may be of little benefit to body composition.

The asymmetry of our findings implies that the maintenance of MVPA, even in the absence of increases in MVPA, may be an important intervention goal. The loss of MVPA to other activity behaviors appears to be particularly deleterious to body composition, suggesting that interventions should target contexts where MVPA is likely to decline. There is some evidence that the transition to adolescence,<sup>28</sup> extremes of weather,<sup>29</sup> and summer holidays<sup>30</sup> are periods at especial risk of declines in MVPA, but this is an under-researched area.

Our study contributes new insights on the relationship between the composition of daily activity behaviors and body composition, but the potential implications need to be confirmed by longitudinal studies and trials. ■

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# Activity Monitor Card\*

Name: \_\_\_\_\_

Monitor number: \_\_\_\_\_

<participant barcode>

- This accelerometer starts recording on: \_\_\_\_ / \_\_\_\_ / \_\_\_\_ at \_\_\_\_am/pm
- Please remove the accelerometer on: \_\_\_\_ / \_\_\_\_ / \_\_\_\_ at \_\_\_\_am/pm

**What kind of day was it today?** Please describe your day and let us know if it was unusual in any way. For example, you might write ‘school day’, ‘weekend’, ‘holidays’, ‘sick’ or ‘sports carnival’.

	Day of week	Wake up time	Bed time	Description of my day
<b>0</b>	[eg Mon 8 June]	[eg 7:30am]	[eg 9:00pm]	[eg Took part in the Child Health CheckPoint!]
<b>1</b>		am/pm	am/pm	
<b>2</b>		am/pm	am/pm	
<b>3</b>		am/pm	am/pm	
<b>4</b>		am/pm	am/pm	
<b>5</b>		am/pm	am/pm	
<b>6</b>		am/pm	am/pm	
<b>7</b>		am/pm	am/pm	
<b>8</b>		am/pm	am/pm	

**The accelerometer is waterproof!** You don't need to take it off for swimming or showering. But, if you do take it off at any time, please write down the time you took it off, the time you put it back on, and why you took it off.

Day	Date	Time off	Time on	Reason taken off
	__/__/__	am/pm	am/pm	
	__/__/__	am/pm	am/pm	
	__/__/__	am/pm	am/pm	
	__/__/__	am/pm	am/pm	

**\*NB Participant Activity Cards used in the Child Health CheckPoint Study were based on this Activity Monitor Card.**

Figure 2. Participant Activity Cards. (Continues)

## Wearing and returning the Accelerometer

- The accelerometer records your movement every 15-30 seconds, day and night
- Wear it on your *non-dominant* wrist (**not** the hand you write with), just like a watch
- **Wear it for eight days** – keep it on all the time
- Leave it on over night! It should not disturb your sleep
- The accelerometer is **waterproof!** You don't need to take it off for swimming or having a bath or shower
- Please press the button when you go to bed and when you wake up

**Important!** If you do need to take the accelerometer off:

- **Write down when and why** on the front of this card
- **Put it back on as soon as you can** (on your *non-dominant* wrist )

### When the eight days are up:

- Mail the accelerometer with this Card back to us using the Express Post envelope we gave you
- Please post the Express Post envelope in a yellow Australia Post mailbox **as soon as possible**

If this isn't possible, call us and we may be able to arrange a time to collect the monitor from you.

Do you have any comments about wearing the accelerometer?

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Thank you for taking part!

The *Growing Up in Australia's* Child Health CheckPoint team

### Any questions?

☎ 1800 784 748    🌐 [www.isac-childhealthcheckpoint.org.au](http://www.isac-childhealthcheckpoint.org.au)

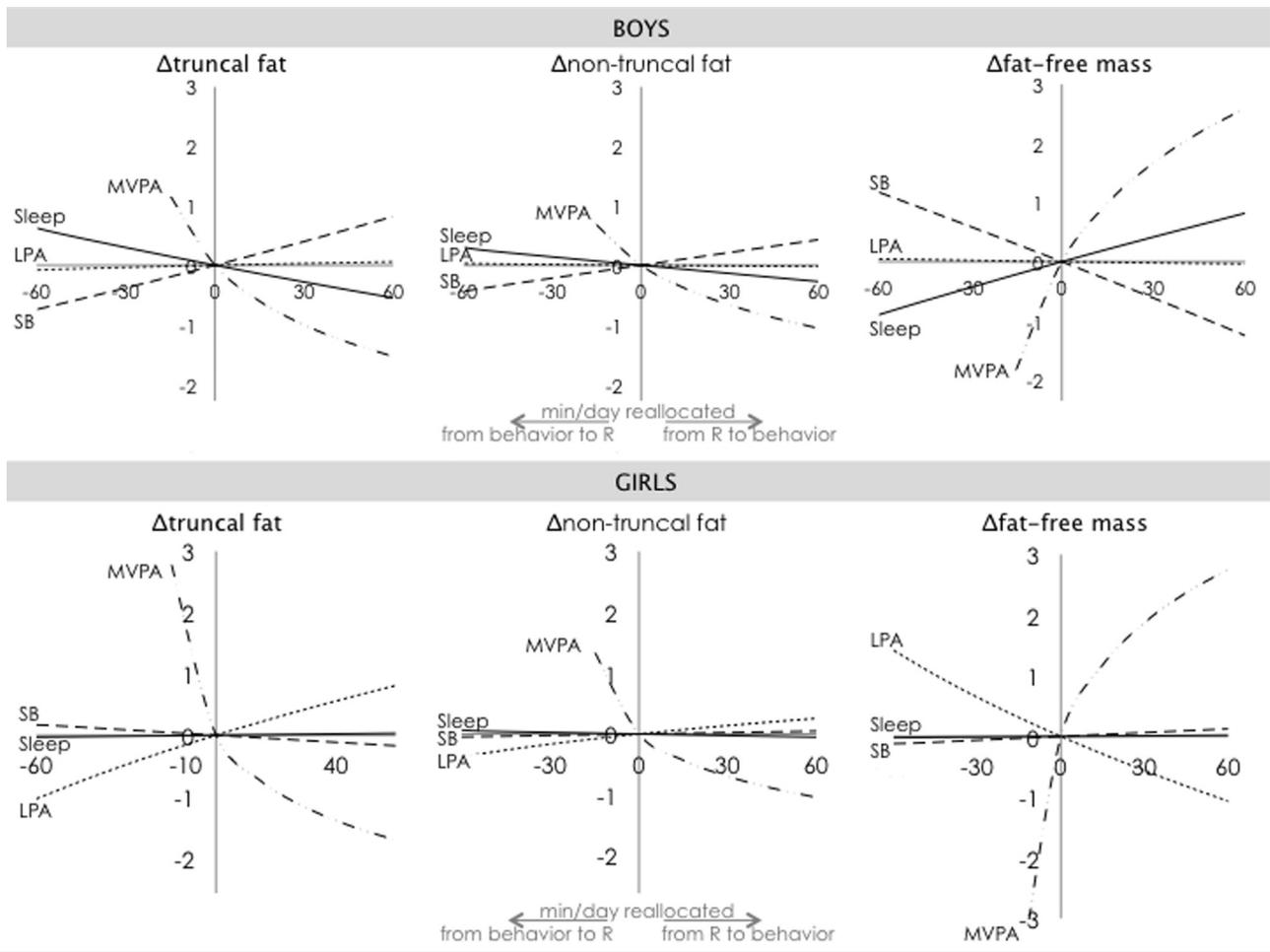
✉ [Isac.childhealthcheckpoint@mcri.edu.au](mailto:Isac.childhealthcheckpoint@mcri.edu.au)



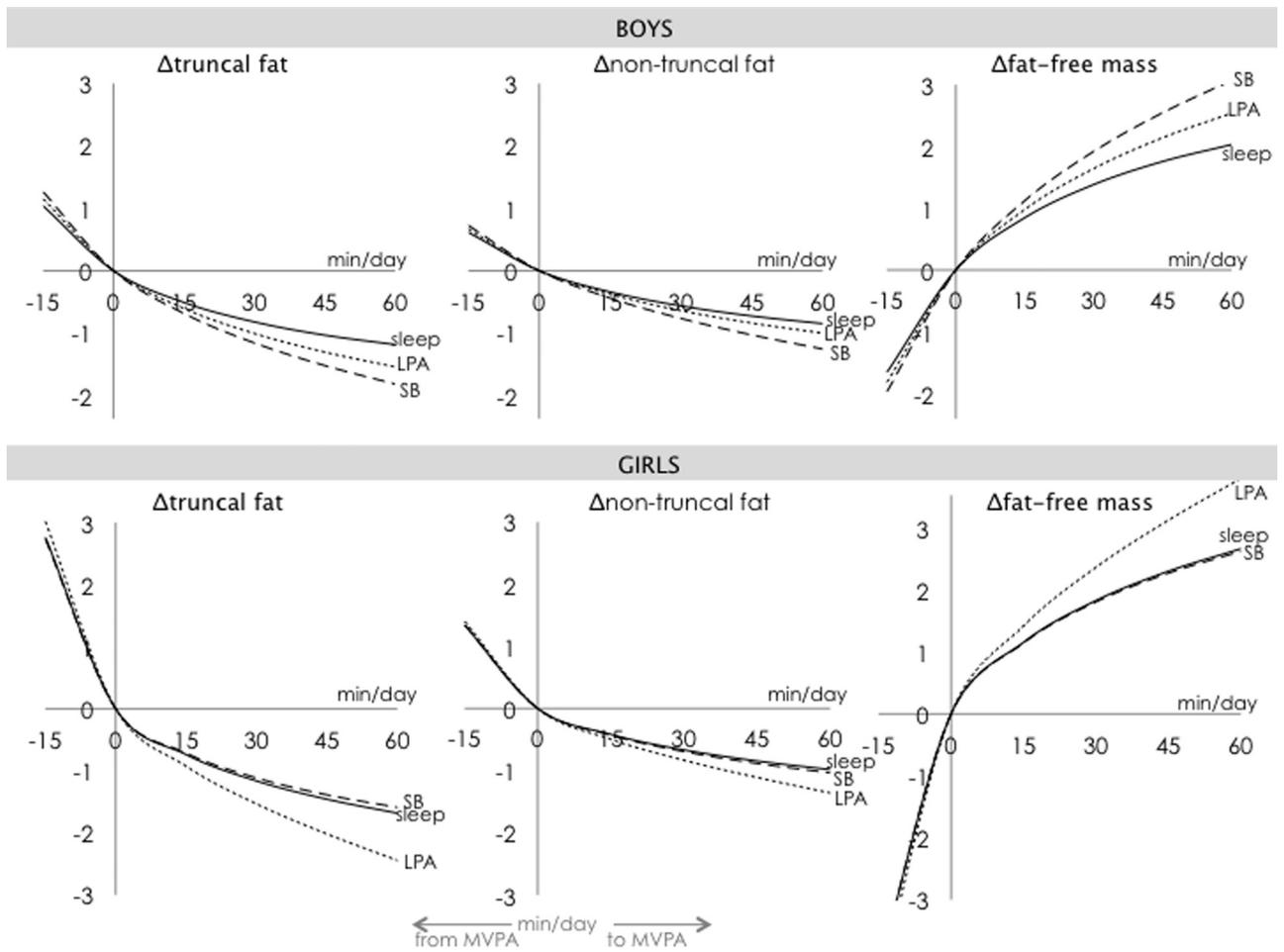
The longitudinal study of Australian children



**Figure 2.** (Continued).



**Figure 4.** Estimated absolute difference in body compartment percentages for systematically altered activity compositions: One-for-remaining reallocations of activity behaviors. *R*, remaining behaviors. Analyses adjusted for age, pubertal status, and SEP.



**Figure 5.** Estimated absolute difference in body compartment percentages for systematically altered activity compositions: One-for-one reallocations with MVPA. Analyses adjusted for age, pubertal status, and SEP.

**Table I. Included participant characteristics**

Characteristics	Included (n = 938)
Sex, male, n (%)	471 (50)
Age, y, mean (SD)	12.0 (0.4)
SEP, z score, mean (SD)	0.31 (0.98)
Pubertal status, n (%)	
Prepubertal	101 (11)
Early pubertal	241 (26)
Midpubertal	480 (51)
Late pubertal	113 (12)
Postpubertal	3 (0)
Activity composition, min/d, geometric means*	
Sleep	576
Sedentary	683
Light PA	158
MVPA	23
Activity behaviors, min/d, arithmetic means (SD)	
Sleep	568 (44)
Sedentary	676 (68)
Light PA	162 (46)
MVPA	34 (29)
Body composition, %, geometric means*	
Truncal fat	7.5
Nontruncal fat	12.5
Fat-free mass	80
Body compartments, kg; %, arithmetic means (SD)	
Truncal fat	4.5 (3.6) kg; 9.1 (5.3)%
Nontruncal fat	5.8 (2.7) kg; 12.5 (3.2)%
Fat-free mass	34.6 (5.7) kg; 78.4 (8.3)%

PA, physical activity; SEP, socioeconomic position.

Compositions are described by compositional means (geometric means of components, linearly adjusted to sum to 1440 minutes [activity] or 100% [body composition]).

\*The dispersion of compositional variables is described by a variation matrix (not SD), found in Tables II and III.

**Table III. Variation matrix for body composition**

Body compartment	Truncal fat	Nontruncal fat	Fat-free mass
Truncal fat	0	0.16	0.52
Nontruncal fat	0.16	0	0.09
Fat-free mass	0.52	0.09	0

**Table II. Variation matrices for activity composition**

Activity behavior	Sleep	SED	LPA	MVPA
Sleep	0	0.02	0.08	0.88
SED	0.02	0	0.12	0.98
LPA	0.08	0.12	0	0.79
MVPA	0.88	0.98	0.79	0

LPA, light physical activity; SED, sedentary time.

**Table IV. Participant characteristics by sex**

Characteristic	Boys n = 471	Girls n = 467
Age (y)	12.0 (0.4)	12.0 (0.4)
SEP z score	0.30 (0.99)	0.32 (0.98)
Pubertal status (n, %)		
Prepubertal	79 (17)	22 (5)
Early pubertal	201 (43)	40 (9)
Midpubertal	173 (37)	307 (66)
Late pubertal	18 (4)	95 (20)
Postpubertal	0 (0)	3 (0)
Activity behaviors min/d, arithmetic means (SD)		
Sleep	565 (44)	571 (43)
Sedentary	673 (72)	680 (64)
LPA	162 (46)	161 (47)
MVPA	42 (32)	27 (24)
Activity composition, min/d, geometric means*		
Sleep	572	579
Sedentary	679	687
LPA	159	157
MVPA	30	17
Body compartments, kg; %, arithmetic means (SD)		
Truncal fat	4.2 (3.7) kg; 8.4 (5.4)%	4.8 (3.4) kg; 9.8 (5.0)%
Nontruncal fat	5.6 (2.9) kg; 12.2 (3.4)%	6.0 (2.5) kg; 12.8 (2.9)%
Fat-free mass	34.6 (5.8) kg; 79.3 (8.6)%	34.6 (5.5) kg; 77.4 (7.8)%
Body composition, %, geometric means*		
Truncal fat	6.8	8.4
Nontruncal fat	12.1	12.8
Fat-free mass	81.1	78.8

Compositions are described by compositional means (geometric means of components, linearly adjusted to sum to 1440 minutes [activity] or 100% [body composition]).

\*The dispersion of compositional variables is described by a variation matrix (not SD), found in [Tables V](#) and [VI](#).

**Table V. Variation matrices of activity composition**

Activity behavior	Sleep	Sedentary	LPA	MVPA
<b>Boys</b>				
Sleep	0	0.02	0.08	0.77
Sedentary	0.02	0	0.1	0.83
LPA	0.08	0.1	0	0.71
MVPA	0.77	0.83	0.71	0
<b>Girls</b>				
Sleep	0	0.02	0.09	0.93
Sedentary	0.02	0	0.14	1.02
LPA	0.09	0.14	0	0.74
MVPA	0.93	1.02	0.74	0

**Table VI. Variation matrices of body composition**

Body compartment	Truncal fat%	Nontruncal fat%	Fat-free mass%
<b>Boys</b>			
Truncal fat%	0	0.23	0.56
Nontruncal fat%	0.23	0	0.1
Fat-free mass%	0.56	0.1	0
<b>Girls</b>			
Truncal fat%	0	0.12	0.43
Nontruncal fat%	0.12	0	0.09
Fat-free mass%	0.43	0.09	0

**Table VII. Fitted multiple linear regression models**

Explanatory variables	Estimate	SE	t value	P value
Response variable: Body composition ILR1				
(Intercept)	0.60	0.42	1.43	.154
Activity composition ILR				
ILR 1*	-0.20	0.13	-1.61	.108
ILR 2	-0.06	0.05	-1.18	.239
ILR 3	0.10	0.02	6.20	<.001
SEP	0.01	0.01	0.92	.356
Age	0.01	0.04	0.28	.778
Pubertal status (reference: prepubertal)				
Early pubertal	-0.12	0.05	-2.53	.012
Midpubertal	-0.19	0.05	-4.18	<.001
Late pubertal	-0.29	0.06	-4.96	<.001
Postpubertal	-0.30	0.23	-1.30	.195
Sex (reference: male)				
Female	0.00	0.03	0.03	.979
Response variable: Body composition ILR 2				
(Intercept)	1.06	0.48	2.21	.028
Activity composition ILR				
ILR 1*	-0.29	0.14	-2.04	.042
ILR 2	-0.04	0.06	-0.73	.468
ILR 3	0.15	0.02	7.72	.000
SEP	0.04	0.01	2.90	.004
Age	0.09	0.04	2.27	.023
Pubertal status (reference: prepubertal)				
Early pubertal	-0.08	0.05	-1.54	.124
Midpubertal	-0.10	0.05	-2.00	.045
Late pubertal	-0.16	0.07	-2.36	.018
Postpubertal	-0.22	0.26	-0.84	.402
Sex (reference: male)				
Female	-0.04	0.03	-1.04	.300

\*The ILR coordinates used in these analyses are not interpretable coordinates as used in Chastin et al.<sup>4</sup> Thus, they do not represent one behavior relative to remaining behaviors.

**Table IX. Estimated difference (95% CI) in body composition\* for 15-minute one-for-remaining reallocations between activity behaviors**

Reallocation	Δ%Truncal fat	Δ%Nontruncal fat	Δ%Fat-free
Boys			
Sleep to remaining <sup>†</sup>	0.2 (0.0; 0.3)	0.1 (-0.04; 0.2)	-0.2 (-0.5; 0.0)
SED to remaining	<b>-0.2 (-0.3; -0.1)</b>	<b>-0.1 (-0.19; -0.0)</b>	<b>0.3 (0.1; 0.5)</b>
LPA to remaining	-0.0 (-0.2; 0.2)	0.0 (-0.12; 0.1)	0.0 (-0.3; 0.3)
MVPA to remaining	<b>1.2 (0.7; 1.7)</b>	<b>0.7 (0.4; 1.0)</b>	<b>-1.8 (-2.6; -1.2)</b>
Remaining to sleep <sup>‡</sup>	-0.1 (-0.3; 0.0)	-0.1 (-0.2; 0.0)	0.2 (-0.0; 0.5)
Remaining to SED	<b>0.2 (0.1; 0.3)</b>	<b>0.1 (0.03; 0.2)</b>	<b>-0.3 (-0.5; -0.1)</b>
Remaining to LPA	0.0 (-0.2; 0.2)	-0.0 (-0.12; 0.1)	-0.0 (-0.3; 0.3)
Remaining to MVPA	<b>-0.6 (-0.8; -0.4)</b>	<b>-0.4 (-0.57; -0.2)</b>	<b>1.0 (0.6; 1.4)</b>
Girls			
Sleep to remaining <sup>†</sup>	-0.0 (-0.2; 0.2)	0.0 (-0.1; 0.1)	-0.0 (-0.3; 0.3)
SED to remaining	0.0 (-0.1; 0.2)	-0.0 (-0.1; 0.2)	-0.0 (-0.2; 0.2)
LPA to remaining	<b>-0.2 (-0.4; -0.1)</b>	-0.1 (-0.2; 0.0)	<b>0.3 (0.1; 0.6)</b>
MVPA to remaining	<b>2.8 (1.5; 5.4)</b>	<b>1.4 (0.8; 2.3)</b>	<b>-4.1 (-7.6; -2.4)</b>
Remaining to sleep <sup>‡</sup>	0.0 (-0.2; 0.2)	-0.0 (-0.1; 0.1)	0.0 (-0.3; 0.3)
Remaining to SED	-0.0 (-0.2; 0.1)	0.0 (-0.1; 0.1)	0.0 (-0.2; 0.2)
Remaining to LPA	<b>0.2 (0.1; 0.4)</b>	0.1 (-0.0; 0.2)	<b>-0.3 (-0.6; -0.0)</b>
Remaining to MVPA	<b>-0.8 (-1.1; -0.5)</b>	<b>-0.4 (-0.6; -0.3)</b>	<b>1.2 (0.8; 1.6)</b>

Bold indicates estimated difference is significant at  $\alpha = 0.05$ . Analyses adjusted for age, pubertal status, and SEP.

\*Estimated difference is in absolute percentage units.

<sup>†</sup>Time in sleep is decreased by 15 minutes and reallocated evenly across the remaining activities.

<sup>‡</sup>Time in sleep is increased by 15 minutes, being drawn evenly from the remaining activities.

**Table X.** Estimated difference (95% CI) in body composition\* for 15-minute one-for-one reallocations between activity behaviors

Reallocation	$\Delta\%$ Truncal fat	$\Delta\%$ Nontruncal fat	$\Delta\%$ Fat-free
<b>Boys</b>			
Sleep to SED <sup>†</sup>	<b>0.2 (0.0; 0.4)</b>	0.1 (−0.0; 0.2)	<b>−0.3 (−0.5; −0.0)</b>
Sleep to LPA	0.1 (−0.1; 0.3)	0.0 (−0.1; 0.2)	−0.1 (−0.5; 0.2)
Sleep to MVPA	<b>−0.5 (−0.7; −0.3)</b>	<b>−0.3 (−0.5; −0.2)</b>	<b>0.9 (0.5; 1.2)</b>
SED to sleep	<b>−0.2 (−0.3; −0.0)</b>	−0.1 (−0.2; 0.0)	<b>0.3 (0.0; 0.5)</b>
SED to LPA	−0.1 (−0.3; 0.1)	−0.1 (−0.2; 0.1)	0.2 (−0.1; 0.4)
SED to MVPA	<b>−0.7 (−0.9; −0.5)</b>	<b>−0.4 (−0.6; −0.3)</b>	<b>1.1 (0.8; 1.5)</b>
LPA to sleep	−0.1 (−0.3; 0.1)	−0.0 (−0.2; 0.1)	0.1 (−0.2; 0.5)
LPA to SED	0.1 (−0.1; 0.3)	0.1 (−0.1; 0.2)	−0.2 (−0.5; 0.1)
LPA to MVPA	<b>−0.6 (−0.9; −0.3)</b>	<b>−0.4 (−0.6; −0.2)</b>	<b>1.0 (0.5; 1.5)</b>
MVPA to sleep	<b>1.0 (0.6; 1.5)</b>	<b>0.6 (0.3; 0.9)</b>	<b>−1.7 (−2.4; −1.0)</b>
MVPA to SED	<b>1.3 (0.9; 1.8)</b>	<b>0.7 (0.4; 1.0)</b>	<b>−2.0 (−2.7; −1.3)</b>
MVPA to LPA	<b>1.2 (0.7; 1.7)</b>	<b>0.7 (0.3; 1.0)</b>	<b>−1.8 (−2.7; −1.0)</b>
<b>Girls</b>			
Sleep to SED <sup>†</sup>	−0.0 (−0.2; 0.2)	0.0 (−0.1; 0.1)	0.0 (−0.3; 0.3)
Sleep to LPA	0.2 (−0.0; 0.4)	0.1 (−0.1; 0.2)	−0.3 (−0.6; 0.1)
Sleep to MVPA	<b>−0.7 (−1.1; −0.4)</b>	<b>−0.4 (−0.6; −0.2)</b>	<b>1.2 (0.6; 1.7)</b>
SED to sleep	0.0 (−0.2; 0.2)	−0.0 (−0.1; 0.1)	−0.0 (−0.3; 0.3)
SED to LPA	<b>0.2 (0.0; 0.4)</b>	0.1 (−0.0; 0.1)	<b>−0.3 (−0.5; −0.0)</b>
SED to MVPA	<b>−0.7 (−1.0; −0.4)</b>	<b>−0.4 (−0.6; −0.3)</b>	<b>1.1 (0.7; 1.6)</b>
LPA to sleep	−0.2 (−0.4; 0.0)	−0.1 (−0.2; 0.1)	0.3 (−0.1; 0.6)
LPA to SED	<b>−0.2 (−0.4; −0.1)</b>	−0.1 (−0.2; 0.0)	<b>0.3 (0.0; 0.5)</b>
LPA to MVPA	<b>−0.9 (−1.3; −0.6)</b>	<b>−0.5 (−0.7; −0.3)</b>	<b>1.4 (0.9; 1.9)</b>
MVPA to sleep	<b>2.8 (1.3; 5.3)</b>	<b>1.3 (0.7; 2.3)</b>	<b>−4.1 (−7.5; −2.2)</b>
MVPA to SED	<b>2.7 (1.4; 5.2)</b>	<b>1.4 (0.8; 2.3)</b>	<b>−4.1 (−7.4; −2.3)</b>
MVPA to LPA	<b>3.0 (1.6; 5.6)</b>	<b>1.4 (0.8; 2.4)</b>	<b>−4.4 (−7.9; −2.4)</b>

Bold indicates estimated difference is significant at  $\alpha = 0.05$ . Analyses adjusted for age, pubertal status, and SEP.

\*Estimated difference is in absolute percentage units.

<sup>†</sup>15 minutes are reallocated from sleep to sedentary time.