JOURNAL OF SPORTS SCIENCES
2022, VOL. 40, NO. 18, 2085–2094
https://doi.org/10.1080/02640414.2022.2134969

PHYSICAL ACTIVITY, HEALTH AND EXERCISE

Association between childcare movement behaviour compositions with health and development among preschoolers: Finding the optimal combinations of physical activities and sedentary time

Matthew Bourke[a], Leigh M. Vanderloo[a,b], Jennifer D. Irwin[c], Shauna M. Burke[c,d], Andrew M. Johnson[c], Molly Driediger[e], Brian W. Timmons[d] and Patricia Tucker[a,f]

[a]School of Occupational Therapy, Faculty of Health Sciences, Western University, London, ON, Canada; [b]ParticipACTION, Toronto, ON M5S 1M2, Canada; [c]School of Health Studies, Faculty of Health Sciences, Western University, London, ON, Canada; [d]Children's Health Research Institute, London, Ontario, Canada; [e]School of Kinesiology, Faculty of Health Sciences, Western University, London, ON, Canada; [f]Child Health & Exercise Medicine Program, Department of Pediatrics, McMaster University, Hamilton, ON, Canada

ABSTRACT

Little is known about how wake-time movement behaviour compositions while in childcare relate to children's health and development. This study aimed to use compositional analysis to examine how childcare movement behaviour compositions were associated with standardised body mass index (*z*BMI) and physical and psychosocial functioning among children in the preschool setting. A total of 405 preschoolers wore accelerometers during childcare hours to measure their moderate-to-vigorous physical activity (MVPA), light intensity physical activity (LPA) and sedentary time. Compositional regression, isotemporal substitution models, and the "Goldilocks" approach was used to examine how wake-time childcare movement behaviour compositions related to each of the outcomes. Engaging in greater LPA relative to MVPA and sedentary time was associated with higher BMI *z*-scores, replacing sedentary time or time spent in MVPA with LPA was associated with greater physical functioning, and spending more time in sedentary behaviours relative to overall physical activity was related with greater psychosocial functioning. It is not clear what the optimal wake-time movement behaviour composition while in childcare is for health and development; however, LPA and sedentary time while in childcare may have some benefits. More research is needed to aid the development of childcare-specific guidelines for physical activity and sedentary behaviours.

ARTICLE HISTORY
Accepted 6 October 2022

KEYWORDS
Children; childcare; physical activity; sedentary behaviours; compositional analysis

1. Introduction

Higher levels of moderate-to-vigorous physical activity (MVPA) and light physical activity (LPA), and lower levels of sedentary time are associated with multiple health benefits in preschool-aged children (Tremblay et al., 2017). Additionally, levels of physical activity and sedentary behaviour track from early childhood to later periods of life, demonstrating how lifelong patterns of physical activity and sedentary behaviour begin to develop from a young age (Jones et al., 2013). Consequently, multiple countries, including Canada, Australia, and South Africa have adopted holistic movement behaviour guidelines. These guidelines recommend, in addition to getting adequate sleep, that preschoolers accumulate at least 180 minutes of physical activity each day, with 60 minutes being MVPA, and limit the amount of time spent sitting, with no more than 60 minutes of sedentary screen time each day (Australian Government Department of Health, 2017; Canadian Society for Exercise Physiology, 2016; Draper et al., 2020). Inauspiciously, less than 20% of preschool-aged children achieve both the physical activity and sedentary time recommendations in Canada (Chaput, Colley et al., 2017).

In high-income countries, most young children are enrolled in early childhood education. In the 38 member nations in the Organisation for Economic Co-operation and Development (OECD), for example, 87% of the young children aged 3–5 years are enrolled in early childhood education (OECD, 2021). Coupled with the fact that childcare environments have the infrastructure and resources to promote favourable wake-time movement behaviours, (Tassitano et al., 2020) these settings may be an ideal venue in which to promote physical activity and reduce sedentary time in young children. However, there is a lack of regulations or mandates related to physical activity in childcare settings, (Slining et al., 2014; Vanderloo & Tucker, 2018) and children spend the bulk of their time sedentary while in this type of care (O'Brien et al., 2018). Nevertheless, physical activity during childcare may contribute substantially to young children's total amount of daily physical activity and represents an important physical activity setting, especially for children who attend childcare full time (Berglind et al., 2017; Hesketh et al., 2015; Moller et al., 2017). Additionally, the majority of interventions targeting young children's physical activity and sedentary behaviour are delivered in childcare settings and target children's wake-time movement behaviours while in care (Downing et al., 2018; Hnatiuk et al., 2019). Therefore, it is important to understand how childcare physical activity and sedentary time relate to health and developmental indicators of young children.

CONTACT Matthew Bourke mbourke5@uwo.ca School of Occupational Therapy, Faculty of Health Sciences, Western University, London, ON, Canada

When examining the association between wake-time movement behaviours i.e., (MVPA, LPA, and sedentary time) with various health outcomes among children, it is important to recognise that these behaviours are mutually exclusive, whereby changes in one wake-time movement behaviour will naturally result in changes in another (Pedišić et al., 2017). For example, if a child increases their levels of MVPA by 5 minutes per waking-hour, they will consequently engage in 5 minutes per waking-hour less of all other movement behaviours combined. This means that the impacts on health of changing one wake-time movement behaviour will be, in part, due to changes in other movement behaviours and how wake-time movement behaviours are displaced may have important implications for health and development (Dumuid et al., 2020). For example, it is possible that reducing time spent sedentary and increasing engagement in MVPA during waking-hours may be more beneficial to health than replacing time spent sedentary with LPA. Traditional approaches to analysing physical activity and sedentary time do not account for the co-dependent nature of these behaviours meaning that they do not adequately adjust for other wake-time movement behaviours despite substantial shared variance (Pedišić, 2014). Therefore, estimated relationships might be unreliable due to poor adjustment for other behaviours (Pedišić, 2014). Simple linear models using raw measures of time spent in each behaviour are unable to accommodate the inclusion of all movement behaviours in a single model due to perfect multicollinearity (Dumuid et al., 2018). This is because compositional data are restricted to a total sum (i.e., 100% of the period of time under investigation), and therefore, represent a constrained D-part simplex – a dimensional subset of the unconstrained real space (Dumuid et al., 2018). Fortunately, expressing compositional data as log-ratios allows researchers to map compositional data into the real space, allowing for traditional statistical methods to be applied (Dumuid et al., 2018).

There is ample research examining the associations between physical activity (Carson, Lee et al., 2017) and sedentary time (Poitras et al., 2017) with health and development outcomes of young children. Several studies examining the association between movement behaviour compositions with adiposity outcomes in preschool-aged children have reported mixed and often inconclusive findings (Carson, Tremblay et al., 2017; Kuzik et al., 2020; Migueles et al., 2022; Taylor et al., 2018). There have also been mixed findings regarding the association between movement behaviour compositions and indicators of social-emotional (Brown et al., 2021; Kuzik et al., 2020) and physical development (e.g., fundamental movement skills; Kuzik et al., 2020; Martins de et al., 2021; Mota et al., 2020; Roscoe et al., 2021). This may be because the association between physical activity and sedentary time with health and development is context dependent (Aggio et al., 2016; Dempsey et al., 2018). For example, cognitively engaging and social physical activities and sedentary behaviours may be more beneficial for a child's development (Aggio et al., 2016; Best, 2010). Additionally, physical activity at school may be more beneficial for motor development in children than physical activity outside of school (Van Kann et al., 2019). Childcare is a unique setting which has a physical and social environment which may augment the association between wake-time movement behaviours and children's health and development (e.g., through co-participation with other children, having a wide array of physical features to stimulate their interest, instruction by early childhood educators). To the authors' knowledge, only one study has focused exclusively on wake-time childcare movement behaviours using compositional data analysis, (Martins de et al., 2021) and therefore, we do not have a good understanding of how replacing one wake-time movement behaviour with another while in childcare relates to health and developmental outcomes in preschoolers. This is despite childcare being an important activity setting where interventions are commonly targeted to decrease sedentary time and increase physical activity. Therefore, understanding how unique wake-time childcare movement behaviour compositions related to health and developmental outcomes is important to determine how childcare focused interventions should target movement behaviours holistically.

The overall aim of this study was to use compositional data analysis to determine the association between childcare wake-time movement behaviours with a range of health and developmental outcomes in preschoolers. A secondary aim was to determine if replacing certain childcare wake-time movement behaviours with others was associated with favourable health and developmental outcomes, and to identify the optimal wake-time movement behaviour compositions during childcare to promote each of the study outcomes.

2. Methods

This study is a secondary data analysis consisting of a cross-sectional examination of baseline data collected between 2015 and 2017 from the Supporting Physical Activity in the Childcare Environment (SPACE; Tucker et al., 2017) and SPACE Extension (Driediger et al., 2019) studies. The methods of these studies have been detailed previously. The original study was approved by the University of Western Ontario Human Research Ethics Committee (ID #105779) and was assigned an International Standard Randomised Controlled Trial Number (ISRCTN70604107).

2.1 Participants

Children aged 2.5–4 years enrolled in a preschool classroom at participating childcare centres where eligible to be included in this study. All English-speaking centre-based childcare facilities with at least one preschool classroom located in London, Ontario, Canada, were eligible to participate and randomly selected. Overall, 405 preschoolers met the inclusion criteria and had valid accelerometer wear time and complete data for at least one outcome (i.e., *z*BMI, physical and psychosocial functioning) and were included in this secondary analysis. Participants were recruited from 34 childcare facilities located in London, Ontario . Parents/guardians of all participants provided written informed consent for their child to participate in this study.

2.2 Measures

2.2.1 Physical activity and sedentary time

Preschoolers' physical activity and sedentary time during childcare hours were objectively assessed using Actical™

accelerometers (MiniMitter, Bend, Oregon), over 5 consecutive days (i.e., Monday to Friday, when in care). Accelerometers were secured on the participants' right hip (i.e., above the iliac crest) using an adjustable neoprene belt and were programmed to begin collecting activity data on the morning (i.e., 7 am) of the first day of data collection. Accelerometer training (i.e., how to place/remove the accelerometers) was provided to the childcare staff by research assistants prior to data collection. Data were collected in 15 second epochs. Minutes of sedentary time (≤24.75 counts/epoch), light physical activity (LPA; between 25 and 287.25 counts/epoch), and MVPA (≥287.5 counts/epoch) were identified using validated preschooler-specific cut-points (Adolph et al., 2012) and processed using KineSoft custom software (version 3.3.62; KineSoft, Loughborough, UK). To account for the varying times that participants spent in care, hourly rates of childcare movement behaviours were calculated. Valid accelerometer wear time was defined as at least 2 days with >5 hours of wear time (Byun et al., 2015). Non-wear time was defined as 20 minutes of consecutive zero counts (Esliger et al., 2005). Childcare centres reported on their daily nap times; however, not all children slept during this time (i.e., some children just sit or lay quietly) and individual participant sleep data were not available (as some children had their accelerometer removed during nap times), so reported nap times were removed from the analysis.

2.2.2 Preschoolers' anthropometric measurements

Children's height (using a Seca 214 "Road Rod" Portable Stadiometer; nearest 0.1 cm) and weight (using a Tanita 700-TBF300GS Body Fat Analyser w/Goal Setter scale; nearest 0.1 kg) were measured and used to calculate children's BMI. Before measurements were taken, children were asked to remove their shoes and any heavy items of clothing. Age- and sex-standardised *z*BMI were calculated according to World Health Organisation (WHO) growth standards (WHO Multicentre Growth Refecnce Study Group & de Onis, 2006).

2.2.3 Physical and psychosocial functioning

The Paediatric Quality of Life Inventory 4.0 (PedsQL; Varni et al., 1999) was used to measure children's physical and psychosocial functioning. The PedsQL uses parent-proxy report and has demonstrated reliability and validity in young children (Varni et al., 2007). Parents responded to the prompt "in the past month how much of a problem has your child had with ... " for a range of items for physical (e.g., walking, helping pick up his or her toys), and psychosocial functioning (e.g., feeling sad, playing with other children). Scores were reverse coded and converted to a value between 0 and 100, with higher scores indicating a better functioning.

2.2.4 Demographics

Children's parents completed a demographic questionnaire which captured the child's age, sex, and ethnicity, the annual family income, and the education level of the parent/guardian.

2.4 Data analysis

Analyses were conducted using R v. 4.1.3 (R Core Team, Vienna, Austria) in R studio v. 1.3 (RStudio Team, Boston, MA) using the compositions, (Van den Boogaart & Tolosana-Delgado, 2008) and ggplot2, (Wickham, 2016) and ClubSandwhich (Pustejovsky, 2022) packages, and SPSS v. 28 (IBM Corp, Armonk, NY). Data were inspected before analysis and each of the outcomes was roughly normally distributed (skewness <1.5; Tabachnick et al., 2007). Descriptive statistics were calculated for all demographic and outcome variables. Amount of time spent in each childcare movement behaviour was described as the geometric means linearly scaled to collectively sum to 60 minutes per hour. Dependencies between movement behaviours were calculated as a variation matrix, including variances of pairwise log-ratios between each combination of movement behaviours. Values closer to zero indicated higher proportionality between the amounts of time spent in two behaviours. All other variables were described as their arithmetic mean and standard deviation, or percentages.

Compositional data analysis (Dumuid et al., 2018) was used to examine the relationship between childcare activity behaviours and each of the outcomes in children with valid data. Rather than using raw movement behaviour data in a linear regression model, the composition of childcare movement behaviours was expressed as specific isometric log-ratio (*ilr*) coordinates called *pivot* coordinates. To account for differences in the amount of time that children attend childcare centres, the pivot coordinates were calculated based on the average minutes children engage in each movement behaviour per hour at childcare. The R-squared and overall significance were estimated for the linear regression models without covariates to determine if there was a significant association between wake-time childcare movement behaviour compositions and each of the outcomes. Additionally, separate compositional regression models were run with each movement behaviour as the dominant behaviour for each outcome. Regression models were estimated with cluster robust standard errors to account for the clustering of children within childcare centres with the small-sample methods suggested by (Pustejovsky & Tipton, 2018). Each model controlled for participant's age, sex, ethnicity, and if they were enrolled in extra-curricular sports, as well as household income, parents level of education, and if a child's childcare had nap times. Sex and age were not controlled for *z*BMI, where these variables were already accounted for during standardisation calculations. The coefficient of the first pivot coordinate was examined to determine if time spent in each childcare movement behaviour relative to the remaining movement behaviours was significantly associated with each outcome. Because the coefficients for pivot coordinates are not meaningfully interpretable, the results from the compositional regression were also reported as the effect of increasing the primary movement behaviour by 10% of its geometric mean while simultaneously decreasing all the remaining childcare movement behaviours by an equivalent amount of time.

Compositional isotemporal substitution models (Dumuid et al., 2017) were run to estimate if the changes associated with increasing time in one childcare movement behaviour on a health outcome was contingent on which other movement behaviour it replaced. The estimated changes with reallocations between childcare movement behaviours and their 95% confidence intervals were calculated using methods described in detail by Gába et al., (2020) previously. We estimated the effect of replacing one childcare movement behaviour with another movement behaviour in 1-min increments up to 5 minutes, except for when estimating the effect of replacing MVPA, which was only estimated up to 2 minutes given that its geometric mean was only 5 minutes per hour. The effect of replacing one movement behaviour with another movement behaviour was considered significant when the 95% confidence interval did not straddle zero.

Finally, we used the "Goldilocks" approach (Dumuid et al., 2022) to determine the optimal group level hourly time use compositions while in childcare to promote each of the studied outcomes which was significantly related to childcare movement behaviour compositions. The compositional models were used to estimate differences in each of the outcomes for every possible combination of childcare movement behaviours in 1-min intervals. The limits of estimated compositions were truncated as 99% confidence intervals for the sampling distribution of each movement behaviour, except where zero was included in the range, in which case movement behaviours were truncated to lower limit of 1 min per hour, resulting in a total of 393 unique childcare movement behaviour compositions. The limits in minutes per hour were 16.70–50.70 for sedentary time, 8.24–32.24 for LPA, and 1.06–14.06 for MVPA. The results for each outcome were sorted from most to least favourable, and the compositional mean for each childcare movement behaviour from the top 5% of results was measured to describe the time use composition for each outcome.

3. Results

Participant demographics and descriptive statistics for study outcomes are displayed in Table 1. The geometric means and variation matrix for the childcare movement behaviours are displayed in Table 2. On average, participants engaged in 34.70, 20.24 and 5.06 minutes per hour of sedentary time, LPA, and MVPA while in childcare, respectively.

3.1 Association between childcare movement behaviour compositions with zBMI and quality of life

Results from the compositional regression models are displayed in Table 3 and show that childcare movement behaviour compositions were significantly related to physical functioning (r^2 = .046, $p < .001$) and psychosocial functioning (r^2 = .050, $p < .001$); however, not *z*BMI (r^2 = .001, p = .181). Results indicate that spending a greater proportion of time sedentary relative to other childcare movement behaviours was associated with greater psychosocial functioning and lower physical functioning. Spending 10% more time sedentary compared to the geometric mean at the expense of other movement behaviours is associated with 1.94 units lower physical functioning, and 1.27 units greater psychosocial functioning. Spending a greater proportion of time in LPA relative to other childcare movement behaviours was associated with higher *z*BMI and greater physical functioning. Spending 10% more engaged in LPA compared to the geometric mean at the expense of other movement behaviours is associated with 0.07

Table 1. Descriptive statistics for participant demographics and outcome variables.

Variable	*N* (%)
Age – months, *M (SD)*	40.00 (7.45)
Sex	
Male	193 (47.65)
Female	199 (49.14)
Time spent in childcare per week	
Less than 10	13 (3.39)
10–19 hours	28 (7.31)
20–29 hours	51 (13.32)
30 hours	291 (75.98)
Household Income ($)	
0–39,999	74 (18.27)
40,000–79,999	58 (14.32)
80,000–119,999	65 (16.05)
120,000+	121 (29.88)
Parents highest level of education	
Did not complete secondary school	4 (1.00)
Secondary school	35 (8.64)
College	126 (31.11)
University	126 (31.11)
Graduate School	88 (21.73)
Prefer not to answer	4 (1.00)
Child Ethnicity	
Caucasian	284 (70.12)
African Canadian	7 (1.73)
Native/Aboriginal	10 (2.47)
Arab	9 (2.22)
Latin-American	13 (3.21)
Asian	15 (3.70)
Other	46 (11.36)
Prefer not to answer	4 (1.00)
zBMI, *M*(*SD*)	0.16 (1.08)
Physical functioning, *M*(*SD*)	83.61 (13.48)
Psychosocial functioning, *M*(*SD*)	83.77 (11.48)

Note. Not all values equal 100% due to missing data.

Table 2. Movement behaviour geometric means (mins/hr) and variation matrix.

	SED	LPA	MVPA
SED mins/hr	34.70		
LPA mins/hr	0.163	20.24	
MVPA mins/hr	0.498	0.215	5.06

SED = sedentary time, LPA = light intensity physical activity, MVPA = moderate-to -vigorous physical activity. Values on the diagonal are the geometric means for each movement behaviour, values below the diagonal are the pairwise log-ratios between two movement behaviours.

units greater *z*BMI and 1.77 units greater physical functioning. Spending a greater proportion of time in MVPA relative to other childcare movement behaviours was not associated with any outcomes.

The results from compositional isotemporal substitution models are displayed in Table 4 and Figure 1. Engaging in lower levels of sedentary time and replacing them with LPA while in childcare was also associated with greater levels of physical functioning. Replacing 5 minutes of sedentary time per hour while at childcare with 5 minutes of LPA was associated with a 3.67 unit increase in physical functioning. Replacing MVPA with LPA was also associated with higher levels of physical functioning. No significant substitution effects between two specific childcare movement behaviours were identified on psychosocial functioning or *z*BMI.

The optimal childcare movement behaviour composition for each outcome is displayed in Table 5. The optimal movement behaviour composition for *z*BMI is characterised by high levels of MVPA (11.70 mins/hr) and sedentary time (40.28 mins/hr) and low levels of LPA (9.02 mins/hr). The optimal childcare movement behaviour composition for physical functioning is characterised by high levels of LPA (30.36 mins/hr) and below average levels of MVPA (1.98 mins/hr) and sedentary time (27.65 mins/hr). The optimal childcare movement behaviour composition for psychosocial functioning is characterised by high levels of sedentary time (47.78 mins/hr) and low levels of MVPA (1.98 mins/hr) and LPA (10.24 mins/hr).

4. Discussion

This study aimed to use compositional data analysis to determine the association between childcare wake-time movement behaviour compositions with *z*BMI, physical functioning and psychosocial functioning in a sample of Canadian preschoolers. This study also aimed to explore the potential effect of replacing time spent in one wake-time childcare movement behaviour with another on each of the health outcomes of interest and determine the optimal childcare movement behaviour composition for each outcome. The findings show that spending more time engaged in LPA at the expense of other wake-time movement behaviours while at childcare was associated with higher *z*BMI. Additionally, spending less time being sedentary or engaged in MVPA and replacing it with LPA was associated with greater parent-reported physical functioning. Spending a greater proportion of time being sedentary relative to other wake-time movement behaviours was also associated with greater psychosocial functioning. The optimal childcare wake-time movement behaviour composition differed among each of the outcomes. High levels of MVPA coupled with low levels LPA was optimal to decrease *z*BMI, high levels of LPA with below average levels of MVPA and sedentary time were optimal for promoting physical functioning, and high levels of sedentary time and low levels of LPA and MVPA were optimal for supporting psychosocial functioning.

The finding that spending more time engaged in LPA at the expense of other wake-time movement behaviours is associated with greater *z*BMI is consistent with a previous study of 3.5 year old children (Taylor et al., 2018). Promisingly, results from this previous study demonstrated that the positive

Table 3. Overall model fit results from the compositional regression analysis.

Outcome	Model *p*-value	R^2	Ilr1 (SED)	*Δ SED* [a]	Ilr1(LPA)	Δ LPA [a]	Ilr1(MVPA)	Δ MVPA [a]
*z*BMI	.181	.011	−0.32(−0.73, 0.07)	−0.07 (−0.15, 0.01)	**0.58 (0.07, 1.08)**	0.07 (0.01, 0.14)	−0.25 (−0.59, 0.09)	−0.02 (−0.05, 0.01)
Physical functioning	<.001	.046	**−9.22 (−15.06, −3.39)**	−1.94 (−3.17, −0.71)	**13.84 (5.86, 21.81)**	1.77 (0.75, 2.79)	−4.61 (−9.92, 0.69)	−0.42 (−0.90, 0.06)
Psychosocial functioning	<.001	.050	**6.03 (0.08, 11.98)**	1.27 (0.02, 2.50)	−3.94 (−11.75, 3.88)	−0.50 (−1.50, 0.50)	−2.09 (−6.59, 2.41)	−0.19 (−0.60, 0.22)

Significant associations ($p < .05$) are bolded. Δ = change in the outcome associated with a 10% increase in the primary movement behaviour. [a]A 10% increase in the geometric mean equated to an increase of 3.47, 2.02, and 0.51 minutes per hour of sedentary time, LPA, and MVPA, respectively.

Table 4. Estimated changes in outcomes associated with 2-min/hr and 5-min/hr reallocations between movement behaviours.

	Δ (95% confidence interval)					
	*z*BMI		Physical functioning		Psychosocial functioning	
	2 mins/hr	5 mins/hr	2 mins/hr	5 mins/hr	2 mins/hr	5 mins/hr
SED to MVPA	−0.05 (−0.18, 0.07)	−0.10 (−0.37, 0.17)	−0.81 (−2.73, 1.11)	−1.42 (−5.63, 2.78)	−0.86 (−2.54, 0.81)	−1.94 (−5.63, 1.75)
MVPA to SED	0.09 (−0.08, 0.26)	N.E.	1.48 (−1.16, 4.13)	N.E.	1.14 (−1.15, 3.42)	N.E.
SED to LPA	0.06 (−0.01, 0.13)	0.15 (−0.02, 0.31)	**1.51 (0.50, 2.52)**	**3.67 (1.20, 6.14)**	−0.60 (−1.57, 0.38)	−1.48 (−3.85, 0.90)
LPA to SED	−0.06 (−0.13, 0.00)	−0.17 (−0.35, 0.01)	**−1.60 (−2.65, −0.55)**	**−4.22 (−6.97, −1.47)**	0.61 (−0.40, 1.63)	1.58 (−1.08, 4.23)
LPA to MVPA	−0.12 (−0.26, 0.03)	−0.27 (−0.61, 0.06)	**−2.44 (−4.69, −0.18)**	**−4.69 (−8.92, −0.46)**	−0.24 (−2.23, 1.76)	−0.26 (−4.88, 4.36)
MVPA to LPA	0.15 (−0.04, 0.37)	N.E.	**2.97 (0.04, 5.90)**	N.E.	0.56 (−2.00, 3.12)	N.E.

Δ = the estimated change in outcomes associated with the reallocation of time between behaviours; LPA = light intensity physical activity; MVPA = moderate-to-vigorous intensity physical activity; N.E. = not estimated; SED = sedentary time. Estimates for physical and psychosocial functioning controlled for participants age and sex.

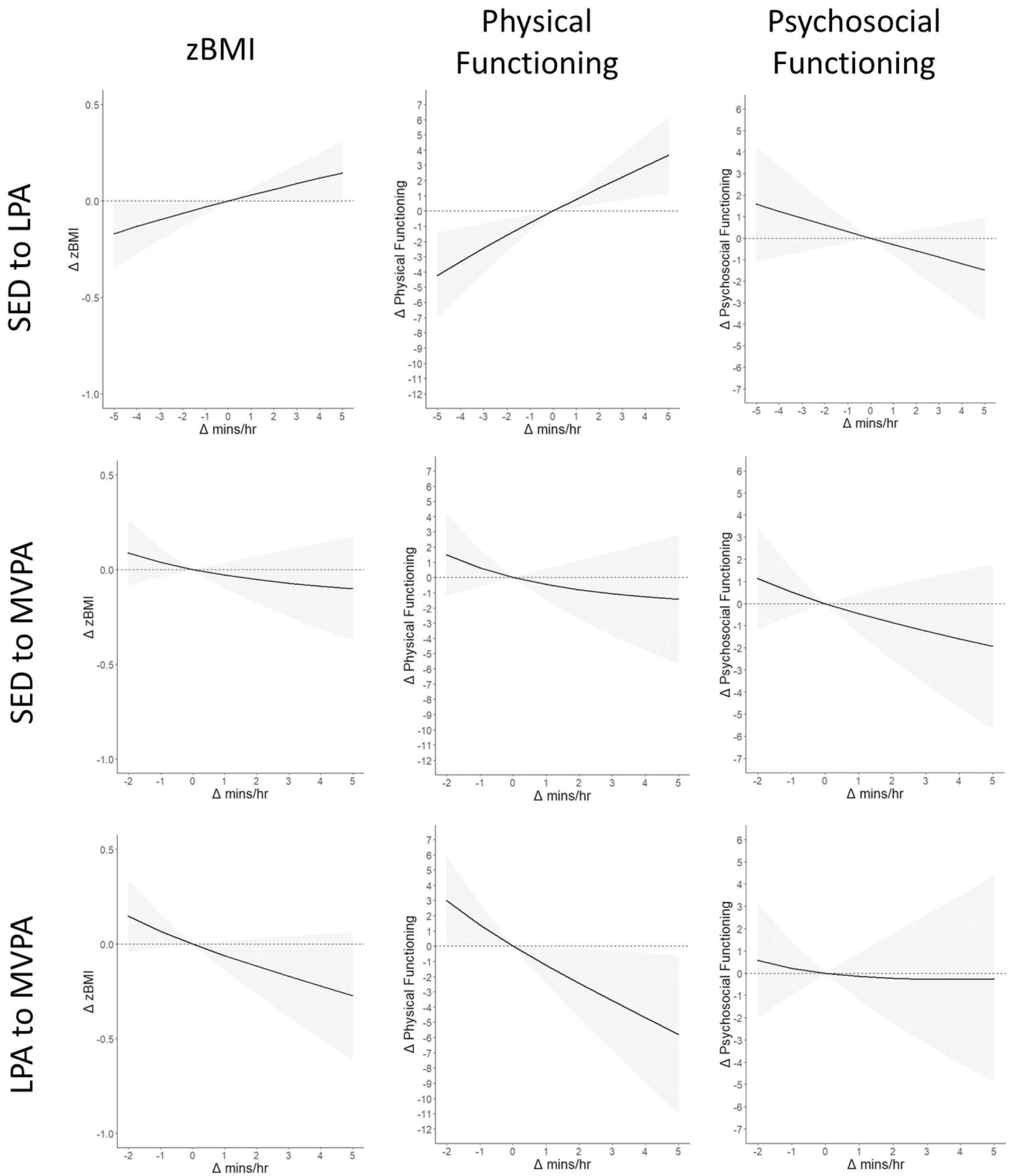

Figure 1. Results from compositional isotemporal substitution models on the effects of reallocations of time between movement behaviours on *z*BMI, physical functioning, and psychosocial functioning. SED = sedentary time, LPA = light intensity physical activity, MVPA = moderate-to-vigorous physical activity, Δ = change.

association between LPA and *z*BMI may be a result of increased lean mass rather than fat mass (Taylor et al., 2018). Given that LPA was also associated with greater physical functioning in the present study, which is likely to improve with greater muscle mass, a similar explanation could explain the results of the current study. Therefore, increasing engagement in LPA at the expense of other movement behaviours may be positively associated with body composition despite not being related to a lower *z*BMI. It is important to note, however, there is a strong association between sleep and adiposity in young

Table 5. Estimated optimal activity compositions and ranges for *z*BMI, physical functioning and psychosocial functioning.

Outcome	SED mins/hr	LPA mins/hr	MVPA mins/hr
*z*BMI	40.28 (35.70, 45.70)	9.02 (8.24, 10.24)	11.70 (6.06, 14.06)
Physical functioning	27.65 (22.70, 33.70)	30.36 (25.24, 32.24)	1.98 (1.06, 5.06)
Psychosocial functioning	47.78 (43.70, 50.70)	10.24 (8.24, 15.24)	1.98 (1.06, 5.06)

Note. Results presented as the geometric mean (range).

children (Miller et al., 2021). It is possible that only examining wake-time movement compositions while in childcare, and thus excluding sleep, could influence the results. Nevertheless, the results from the present study are consistent with multiple other studies that have used compositional data analysis to examine the association between daily movement behaviours, including sleep, and *z*BMI in young children that found that spending more time sedentary or engaged in MVPA relative to other movement behaviours was not associated with lower *z*BMI in young children (Carson, Tremblay et al., 2017; Kuzik et al., 2020; Taylor et al., 2018). A recent meta-analysis similarly concluded that physical activity is not related to BMI despite having a favourable relationship with other measures of adiposity (Wiersma et al., 2019). Therefore, future studies should consider using other measures of adiposity such as fat mass when examining the association with movement behaviour compositions in young children.

Meta-analytic evidence has demonstrated that there is a small but significant relationship between total physical activity and MVPA with motor development in the early years (Jones et al., 2020). Additionally, multiple previous studies using compositional data analysis have demonstrated that replacing time in other movement behaviours with MVPA is associated with greater gross motor development (Kuzik et al., 2020; Mota et al.,). Given that physical functioning and gross motor development are closely related constructs, (Estevan & Barnett, 2018) it was not surprising to find that replacing sedentary time with LPA was positively associated with physical functioning in the present study. It is surprising, however, to find that replacing time spent in LPA with time spent in MVPA was associated with lower physical functioning. This finding could be a consequence of using parent proxy report to measure physical functioning, as opposed to a researcher's assessment of children's motor proficiency based on standardised tests as has been done in previous studies. However, it is also possible that some forms of LPA, such as active free play may be beneficial for coordination, muscle strength, and fundamental movement skill (Johnstone et al., 2018; Truelove et al., 2017). Future studies should consider using longitudinal design to determine how movement behaviour compositions are associated with perceived improvements in children's physical functioning over time to verify these findings. Still, interventions that target childcare movement behaviours should consider implementing strategies to encourage a range of fun and enjoyable active play activities that could improve young children's physical functioning. Given the range of play equipment at children's disposal while at childcare, the childcare setting may be the ideal setting to promote active free play in children (Truelove et al., 2017).

According to the results of this study, spending more time sedentary relative to other childcare wake-time movement behaviours was associated with greater psychosocial functioning. This is inconsistent with a previous study which found replacing sedentary time with MVPA may be associated with greater sociability and less internalising problems in young children (Kuzik et al., 2020). However, non-screen based, cognitively active sedentary behaviours such as drawing and storytelling may be beneficial for young children's socio-emotional development (Poitras et al., 2017). Given that preschoolers have access to a range of resources to promote cognitively active sedentary behaviours (e.g., arts supplies, toys, books), and often engage in group-based activities, they have the opportunity to engage in a range of sedentary activities that could positively contribute to their psychosocial development. Because sedentary behaviour was measured using accelerometers in the current study, it was not possible to differentiate between cognitively active and cognitively passive sedentary activities, or screen-based and non-screen-based activities, and their association with psychosocial functioning. Future studies using compositional data analysis that further breaks down sedentary time into subcategories (e.g., social, educational, quite play, screen-time), and how these subcategories associate with a range of health outcomes in young children, are warranted. Interventions that target preschoolers' movement behaviours should focus on decreasing screen time while preserving time spent in beneficial sedentary behaviours.

The results from this study demonstrate that childcare wake-time movement behaviour compositions may have implications for the health and development of young children. However, what the optimal childcare wake-time movement behaviour composition is for health and development in preschool children remains unclear. More research is needed to determine the optimal childcare wake-time movement behaviour compositions for health and development, and to develop childcare-specific guidelines for physical activity and sedentary time. Additionally, future studies should consider the role of daytime napping while at childcare as a component of holistic movement behaviour compositions on health and development outcomes. In lieu of guidelines, early childhood educators should provide preschoolers with ample opportunities to engage in LPA through active learning, active transitions and active play, and bouts of MVPA through active outdoor play, while still recognising that providing time for children to engage in group-based cognitively active sedentary activities may be important.

This study has a number of strengths including the use of compositional data analysis, which appropriately accounts for the zero sum nature of movement behaviours, and the use of accelerometers to objectively measure physical activities and sedentary time. Nevertheless, there are limitations that must be considered when interpreting the results. First, data on preschoolers' sleep was not included in the current analysis. Given consistent evidence of the relationship between sleep and health indicators in young children, (Chaput, Gray et al., 2017) it is possible that not controlling for sleep may have modified the results of the current study. Similarly, children's movement behaviours outside of childcare were not measured which may have influenced the results. For example, some children may compensate for the time they are active in childcare by being less active outside of childcare, while the inverse may be true for other children, and some children may stay active throughout the entire day. Second, data collected on children's physical and psychosocial functioning was via parent proxy, which could potentially be influenced by biased reporting. Third, given that cross-sectional data were utilised in this study, it was not possible to draw conclusions about causality, and reverse causality cannot be ruled out. Fourth, despite random recruitment of childcare centres, participants in this study came from households with highly educated parents and high household income. Therefore, results from this study may not be generalisable to other populations. Finally, part-time enrolment of several children (e.g., half days) meant that they did not achieve the accelerometer wear time requirements to be included in the study.

5. Conclusion

This study demonstrated that unique wake-time movement behaviour compositions while at childcare were related to a range of health and developmental outcomes in preschoolers. Participating in childcare movement behaviour compositions characterised by more LPA at the expense of other wake-time movement behaviours was associated with greater *z*BMI in preschoolers. Engaging in more LPA at the expense of sedentary time and LPA was associated with greater physical functioning. Engaging in more sedentary behaviours relative to overall physical activity was associated with greater psychosocial functioning. More research is required to determine the optimal movement behaviour compositions in childcare and to develop childcare-specific guidelines for physical activity and sedentary behaviours.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The original SPACE trials were funded by the Canadian Institutes of Health Research (CIHR grant #133559) and 9) and the City of London's Child and Youth Network through the Healthy Eating Healthy Physical Activity Priority.

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