Article

School-Time Movement Behaviors and Fundamental Movement Skills in Preschoolers: An Isotemporal Reallocation Analysis

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Abstract

Little is known of how reallocations of time spent in different movement behaviors during preschool might relate to preschoolers' fundamental movement skills (FMS), a key predictor of later physical activity (PA). Thus, the aim of this study was to examine (a) whether preschoolers' school-time movement was associated with

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their FMS and (b) the effects on FMS of reallocating time between PA and sedentary behavior (SB). This was a cross-sectional study, using intervention data with Brazilian low-income preschoolers. We observed Brazilian preschoolers of both sexes ($M_{age} = 4.5$, $SD = 0.8$ years-old; 101 boys) over 10 hours of school-time and objectively assessed their PA and SB with Actigraph wGT3X and their FMS with the Test of Gross Motor Development – Second Edition. We explored the associations between school-time movement behaviors and FMS and between reallocated school-time movement behaviors and FES using compositional analysis in R (version 1.40-1), robCompositions (version 0.92-7), and lmtest (version 0.9-35) packages. This isotemporal reallocation showed that, for manipulative skills, reallocating time (5, 10, and 15 minutes, respectively) from light PA to SB was associated with increasing skill (0.14, 0.28, and 0.42 FMS units), raising questions as to whether fine motor activity occurred during SB. Thus, school-time movement significantly predicted FMS, with a modest increase in SB, at the expense of light PA eliciting improved manipulative skills.

Introduction

According to the World Health Organization (WHO, 2019), adequate amounts of physical activity (PA), reduced sedentary behavior (SB) and good quantity and quality of sleep (SLP) during early childhood (e.g., 0-5 years) are key behavioral characteristics of positive short and long-term health outcomes (WHO, 2019). For children under age five, PA has been associated with healthy skeletal, cardiometabolic, motor and cognitive skill profiles (Carson et al., 2019). Nonetheless, a large proportion of children worldwide do not engage in sufficient moderate to vigorous physical activity (MVPA) (Berglind & Tynelius, 2017; Santos et al., 2017), have excessive SB, and do not accrue adequate sleep (Chaput et al., 2016, 2017; De Craemer et al., 2018).

In early childhood, fundamental motor skills (FMS), defined as the basis for more complex movements required to participate in sports, games, or in other PA contexts (Logan et al., 2018), develop through physical maturation, and practice (Goodway et al., 2019). FMS play an essential role in the development of children's movement patterns (Hardy et al., 2012). Therefore, early childhood is a critical period for FMS development, and optimal FMS performance may facilitate subsequent participation in daily and sports activities (Stodden et al., 2008) and help determine future health and academic achievements (Jaakkola et al., 2015).

Considering that movement behaviors track from childhood to adulthood (Telama, 2009) and that school-time comprises prolonged periods each day for a large number of children (Ward et al., 2010) and provides an infrastructure for facilitating healthy behaviors (Story et al., 2009), the school has long been appointed as a place to enhance children's PA. Young children from low-income families, living in vulnerable zones, spend more than 60% of their awake time in a preschool setting. Generally speaking, preschoolers from low-income families are less likely to be engaged in other structured PA opportunities (Chang & Kim, 2017), spend a great amount of time being sedentary (Santana et al., 2017), and engage in a great deal of screen time (Carson et al., 2010). So, for these children, meeting international movement guidelines as described above (WHO, 2019) is highly influenced by the amount of PA and SB, including naps, they accumulate within preschool (Tassitano et al., 2020), meaning that preschool time may also influence their early development. Indeed, facilities for PA in socially vulnerable areas are scarce, and children living in these areas have a greater likelihood of delayed FMS (Nobre et al., 2016). Moreover, a different "quality" of recreational sedentary time, characterized by more time viewing screen media during preschool years, may pose concerns for children's neurobiological development, affecting, in turn, how children play and learn (Horowitz-Kraus & Hutton, 2018).

Recently, there has been growing support for adopting a research approach based on compositional time for understanding the effect of movement behaviors on health outcomes. In this way, analyses of time spent in various movement behaviors mirror the time-bound 24-hour nature of many international guidelines for PA (WHO, 2019). When considering any singular portion of a behavioral time-bound composition, any theoretical increase or decrease of time spent in one behavior must result in the reduction of of an equal time allocation in remaining behaviors (Aitchison, 1982). Indeed, when considering behaviors as compositionally time-bound, positive health changes have been been achieved by reallocating the time expenditures between these behaviors in varied populations of youth, adults, and the elderly (Biddle et al., 2018; García-Hermoso et al., 2017; Pelclova et al., 2020), respectively. A recent study suggested that replacing a percentage of time spent during school hours being sedentary and in light PA (LPA) with time spent in MVPA may improve FMS among low-income elementary school-aged children (Burns et al., 2019). However, to date, there has been no empirical study of preschoolers' movement behaviors, or of the impact of substituting time/intensity spent in one activity for another. Furthermore, little is known about how these reallocations might relate to preschoolers FMS. Therefore, our aims in this study were twofold: (a) to examine whether the school-time composition of movement behaviors (e.g., SB and PA) was associated with FMS development, and (b) to investigate predicted

differences in FMS when a fixed duration of time was reallocated from one movement behavior to another.

Method

This cross-sectional study relied on baseline data collected from a school-based PA intervention program called "Movement's Cool" that aims to analyze the associations between movement behaviors and health outcomes among low-income preschoolers.

Participants

In João Pessoa, Brazil, the preschool public education zone is divided into nine poles in which 86 early childhood education and care services (ECEC) are located. Within those ECECs, 50 institutions have 3-5-year-old children registered, and 10 of these, located in socially vulnerable zones, were previously selected for "Movement's Cool" research. Among a representative number of these ECECs by poles, we randomly selected six for inclusion in this study. This process yielded 573 preschoolers of varying ages, corresponding to the study's general population (Figure 1—Panel A). All six preschools were located in deprived
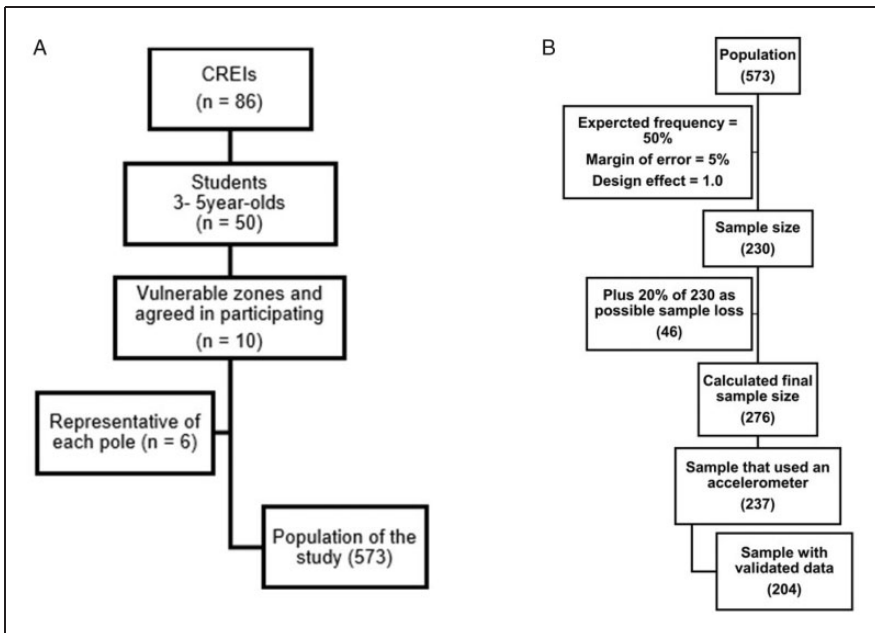

Figure 1. CREI's and Sample's Flowchart.

areas of city (Human Development Index – HDI = 0.7) with low socio-economic status (SES) in which 62.5% of the mothers or fathers were unemployed and over 45% of the mothers and 54% of the fathers had finished the 9th grade or less. The HDI of the ECEC's areas ranged from 0.3 to 0.5.

We used G*Power (3.1.0) to estimate the number of participants required for satisfactory statistical power of 0.85. We assumed a 95% confidence interval, 5% maximum tolerable error, and because there are no reference studies with a similar population, we assumed a large effect size of 1.0. This calculation yielded an estimated required sample size of 230. We increased this number by 20%, to account for participant attrition and missing data (drop out and hardware failure). Thus, we called and sought informed parental consent from 276 typically developing 3-5 year-old preschool children. As 39 parents chose not to consent for their children to participate, we entered 237 children whose parents provided informed consent into the study and obtained their accelerometer measurements as described below. After applying data reduction criteria (Figure 1—Panel B), there were 204 children (86.07%) with valid measurements.

Measurements

Anthropometric Measures. We determined the children's height (cm) and weight (kg) using a *Holtain* stadiometer and digitized weighing scales (Seca 708), while the participant was lightly dressed and barefoot, following a standardized procedure (WHO Child Growth Standards, 2009). We calculated the children's body mass index (BMI) by dividing body weight with the squared height in meters (kg/m^2).

Physical Activity (PA). We objectively assessed the children's PA using accelerometry (Actigraph, model WGT3-X, Florida). This actigraph has been shown to be a valid instrument for measuring PA in preschoolers (Bornstein et al., 2011). Parents and preschool teachers received verbal and written instructions for the children's correct use of the accelerometer, including its placement and correct positioning. The device initialization, data reduction and analysis were performed using the ActiLife software (Version 6.13.3).

As this study was part of a larger project, the children were instructed to wear the accelerometer on the right hip for seven consecutive days (Wednesday morning to Tuesday afternoon), and parents were allowed to remove the children's device during water-based activities, and during the night, and to re-attach it when children awoke. During preschool time, teachers removed accelerometers at around 11am for the children's bath and re-fastened them properly just after it. For the purpose of this study, school-time periods were delimited to 7am to 5 pm on weekdays during at least two days per week.

Accelerometers were setup to measure acceleration at a 100 Hz sampling rate, using a 15-second epoch length (Cliff et al., 2009), and data was reintegrated to

60-second epochs for analysis, as ActiGraph counts, considering the vector magnitude. Periods of ≥ 20 minutes of consecutive zero counts were defined as non-wear time, and data for these periods was removed from the analysis. First day of accelerometer data was also omitted from analysis to avoid unusual readings of movement activity that might be related to the participant's reactivity to first wearing the actigraph device (Esliger et al., 2005). Only days with a minimum of six hours of wear time between 7am and 5pm were considered valid. So, data from 33 children were not validated. The wear time ranged from 6 – 10 hours between participants, and the children's mean wear time was 8.5 hours ($SD = 2$ hours)

We used hourly average values in counts per minute (CPM) to describe the children's daily PA pattern. We estimated the time spent in the commonly defined PA intensity domains of light, moderate and vigorous using the cut-points proposed by Butte et al. (2014) with light intensity defined as 820 to 3,907 counts, moderate intensity as 3,908 to 6,111 counts and vigorous intensity as >6,112 counts. The amount of time spent as sedentary was defined as ≤ 819 counts sustained for >10 consecutive minutes as in Andersen et al. (2017). Habitual PA for the preschool time was defined as the average counts per minute for the time between 7am and 5pm.

Fundamental Movement Skills (FMS). FMS were measured using the Test of Gross Motor Development - Second Edition (TGMD-2). The TGMD-2 is valid and reliable for use with Brazilian children (Valentini, 2012). It evaluates gross motor performance in children aged 3 - 10 years old, and it consists two domains: six locomotor skills (run, gallop, hop, leap, jump and slide) and six object control skills (strike, bounce, catch, kick, throw and underhand roll). We administered the TGMD-2 according to the guidelines recommended by Ulrich (2000). Before the assessment of each skill, children were given a visual demonstration of the skill by the researcher, using the correct technique; but they were not told what components of the skill were being assessed. Children were then called individually to perform the skill twice. We gave general encouragement but no verbal feedback on performance during or after the tests. All skills were video-recorded and later assessed by one trained evaluator who did not administer the tests. After viewing each trial, the trained assessor analyzed each skill component. A "1" indicated that the component was present in the performance of the skill for that trial or a "0" indicated the component was not present. The video analysis was performed by two expert evaluators. We observed high agreement for the locomotor score: ICC = 0.93 (95% CI: 0.69–0.98), for the object control score: ICC = 0.98 (95% CI: 0.93–0.99) and for the total motor score (MS): ICC: 0.96; (95% CI: 0.82–0.99). Per the TGMD-2 manual, locomotor and object control scores were based on the presence (one) or absence (zero) of each of the performance criteria. For each subtest, the sum of the raw scores ranged from 0–48 points.

Procedure

Children enrolled in the ECEC's program attended preschool from Monday to Friday, starting at 7 am, and finishing at 5 pm. In this study, we only analyzed the accelerometer data during the preschool period. Measurements were performed during a three-month period, between March and May 2018. Time in PA and SB was observed between 7 am and 5 pm from Wednesday to Tuesday by specialized and trained project staff (PE teachers and graduate students).

All of the schools and parents were informed about the project's protocols and procedures in meetings with the project coordinator (one meeting in each school), and all agreed to participate. The children were drawn from a school list until sufficient data were obtained, according to the proportional distribution calculated for each school, and for each of the ages (3, 4 and 5 years). Socio-demographic data (children's age, birth date, parent's contact and address) were provided by the school administration. Anthropometric (body mass and stature) and movement skills data were collected at pre-schools, and the accelerometer was worn for seven consecutive days by the participating children.

Data Analysis

As noted earlier, we considered measuring each movement behavior in an isolated manner to be a flawed approach, since movement behaviors are co-exist co-dependently in a time bound analysis in which time spent in one behavior affects, and is effected by time spent in other behaviors during the defined time period (Dumuid et al., 2019). Thus, a compositional data analyses, or CoDA, considers the compositional aspect of movement behaviors within a time block and were conducted in R (http://cran.r-project.org) using the compositions (version 1.40-1) (van den Boogaart & Tolosana-Delgado, 2008), robCompositions (version 0.92-7) (Pawlowsky-Glahn & Buccianti, 2011; Templ et al., 2011), and lmtest (version 0.9-35) software packages.

The school day behavior composition (daily school time spent in SB, LPA, and MVPA) was referred to in terms of central tendency (i.e. the geometric mean of time spent in each component), linearly adjusted so that all components summed to the total school day for interpretation in minutes per day and percentages of the school day (which, for purposes of this study, was bound to 600 minutes, or 7 am – 5 pm). Multivariate dispersion of the school day composition was described using pairwise log-ratio variation (Aitchison, 1982; Chastin et al., 2015).

We used multiple linear regression models to investigate the relationship between school day activity behavior composition (explanatory variable) and each motor competence tenet (dependent variable). Prior to inclusion in the regression model, the composition was expressed as a set of two isometric log ratio (*ilr*) co-ordinates. Covariates (age, BMI, and sex) were additionally

included as explanatory variables. The outcome variables were total motor competence (MC), locomotor skill, and manipulative skill. The *ilr* multiple linear regression models were further checked for linearity, normality, homoscedasticity, and outlying observations to ensure assumptions were not violated. The significance of the school day activity behavior 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 (Fox & Weisberg, 2018).

The above *ilr* multiple linear regression models were used to predict differences in the outcome variables associated with the reallocation of a fixed duration of time (5 minutes) between two activity behaviors, whilst the third remains unchanged. This was achieved by systematically creating a range of new activity compositions to mimic the reallocation of five minutes between all activity behavior pairs, using the mean composition of the sample as the baseline, or starting composition. The new compositions were expressed as *ilr* coordinate sets, and each subtracted from the mean composition *ilr* coordinates, to generate *ilr* differences. These *ilr* differences (each representing a 5-minute reallocation between two behaviors) were used in the linear models to determine estimated differences (95% CI) in all outcomes. Predictions were repeated for pairwise reallocations of 5, 10, and 15 minutes, respectively. The decision was made to only go up to 15 minutes in reallocations so as to reflect the potential for real or actual change in MVPA. Beyond 15 minutes, there is too high a proportion of MVPA being reallocated and inferences from reallocating such a high proportion of overall MVPA will likely result in distorted outputs. The MATLAB function, alchemist/ternplot (Sandrock & Afshari, 2016), was used to produce ternary plots with a continuous response surface, where increasing red saturation represents a more favorable outcome, and increasing blue saturation less favorable association with the outcome variable.

Results

As noted above, 204 preschoolers ($M_{age} = 4.51$ years, $SD = 0.8$; $M_{BMI} = 18.17$, $SD = 3.71$ kg; $M_{height} = 106.00$, $SD = 7.06$ cm) of both sexes (101 boys) gave valid data for the study. Compositional means for SB, LPA, and MVPA, and for locomotor, manipulative and total motor competence scores showed that participants spent 69% of their school-time being sedentary, and approximately 32% of the school-period engaged in LPA, with MVPA consuming 7% of their school-time.

We explored the variability of these data in a variation matrix containing all pair-wise log-ratio variances. A value close to zero suggested that the time spent in SB and PA were highly proportional. For instance, the log variance (Sedentary/LPA) was 0.15, which reflects the (proportional) relationship or co-dependence between the two behavior types. The highest log-ratio variance
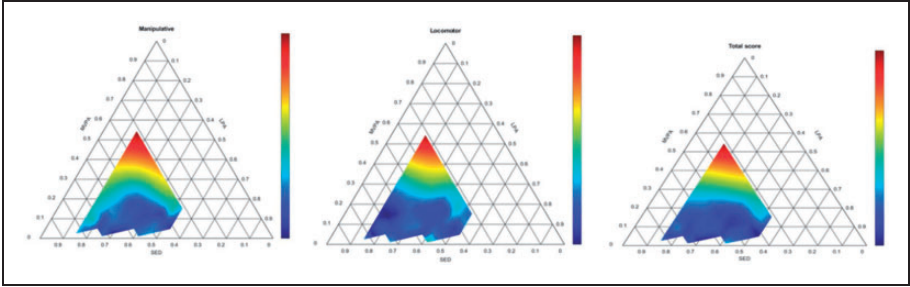
Figure 2. Ternary Plot of PA Composition and FMS Manipulative, Locomotor and Total Motor Competence Skill. Note: The edges of the triangles are the pseudo-time axes, where each grid line represents 10% of the school-time composition, i.e., 0.1 = 10% of 600 min, = 60 min. The continuous response surface is colored according to the manipulative score, where red gradation represents comparably higher scores and blue color gradation represents comparably lower scores.

involved MVPA and SB, suggesting that time spent in MVPA was the least co-dependent on SB (S1).

When data were considered as a composition, adjusted for age, BMI and sex, the school-time composition significantly predicted the FMS locomotor score ($p = 0.01$; $r^2 = 0.05$), manipulative score ($p < 0.0001$; $r^2 = 0.08$), and total MC score ($p = 0.0002$; $r^2 = 0.09$), respectively. Ternary plots for the PA composition, with a continuous response surface, where increasing red saturation represented a more favorable outcome, and increasing blue saturation equated to a less favorable association with the outcome variables, namely locomotor skill, manipulative skill, and total MC score are shown in Figure 2.

Based on the 95% CI's, total MC improved 0.18 units higher than the predicted mean when five minutes of preschool time were reallocated from LPA to SB. For manipulative skills, a 0.14, 0.28, and 0.42-unit increase in relation to the predicted mean was found after reallocating five, 10 and 15 minutes, respectively, of preschool time from LPA to SB (see Table 1).

Discussion

Prior studies have examined the isotemporal reallocation of movement behaviors and health outcomes in several age groups (Grgic et al., 2018). However, this is the first study of pre-school children to use this method to offer unique insight into whether preschool-time behavior composition was associated with FMS or to investigate predicted differences in FMS when a fixed duration of time was reallocated from one behavior to another. In addition, most prior studies have examined how the substituted time was related to body composition (García-Hermoso et al., 2017), fitness (Fairclough et al., 2017) and

Table 1. Isotemporal Substitutions for 5, 10, and 15-Minute Reallocations.

		Total MC	Locomotor	Manipulative
Add	Remove	Total (95% CI)	Total (95% CI)	Total (95% CI)
5 minutes				
Sedentary	Light PA	0.18* 0.02 0.34	0.04 −0.09 0.17	0.14* 0.01 0.26
Sedentary	MVPA	0.28 −0.22 0.78	0.22 −0.08 0.51	0.06 −0.24 0.36
Light PA	Sedentary	−0.18 −0.39 0.03	−0.04 −0.17 0.08	−0.14 −0.26 −0.01
Light PA	MVPA	0.10 −0.54 0.75	0.18 −0.21 0.56	−0.08 −0.46 0.31
MVPA	Sedentary	−0.26 −0.70 0.19	−0.20 −0.46 0.07	−0.06 −0.32 0.20
MVPA	Light PA	−0.08 −0.67 0.52	−0.16 −0.51 0.20	0.08 −0.27 0.43
10 minutes				
Sedentary	Light PA	0.36 −0.07 0.79	0.08 −0.18 0.34	0.28* 0.02 0.53
Sedentary	MVPA	0.58 −0.49 1.66	0.46 −0.18 1.10	0.12 −0.52 0.76
Light PA	Sedentary	−0.35 −0.77 0.07	−0.08 −0.33 0.17	−0.27 −0.52 −0.02
Light PA	MVPA	0.24 −1.13 1.60	0.38 −0.43 1.19	−0.15 −0.96 0.66
MVPA	Sedentary	−0.49 −1.34 0.35	−0.38 −0.87 0.12	−0.12 −0.62 0.38
MVPA	Light PA	−0.13 −1.28 1.01	−0.29 −0.97 0.38	0.16 −0.52 0.84
15 minutes				
Sedentary	Light PA	0.54 −0.11 1.19	0.12 −0.27 0.51	0.42* 0.03 0.81
Sedentary	MVPA	0.93 −0.83 2.68	0.74 −0.30 1.78	0.18 −0.86 1.22
Light PA	Sedentary	−0.53 −−1.15 0.10	−0.12 −0.49 0.25	−0.40 −0.77 −0.03
Light PA	MVPA	0.41 −1.77 2.59	0.63 −0.66 1.91	−0.21 −1.51 1.08
MVPA	Sedentary	−0.72 −1.92 0.48	−0.54 −1.25 0.17	−0.18 −0.89 0.54
MVPA	Light PA	−0.17 −1.83 1.49	−0.42 −1.40 0.57	0.25 −0.74 1.23

Note: *Significant at $p < 0.05$, based on 95% CI. MC: motor competence; MVPA: moderate-to-vigorous physical activity.

cardiometabolic (Macgregor et al., 2019) outcomes in later childhood (up to six year olds) in children from high-income countries. There has been scarce prior data concerning preschoolers from a low-income background. In accord with the aims of our study, we found that our participants spent almost 70% of their school-time in SB. When the spectrum of behaviors was treated as a composition, time spent in various behaviors significantly predicted locomotor, manipulative, and total MC FMS scores, suggesting that the composition of several behavior types during preschool time may potentiate children's MC.

Children's movement hours were predominantly comprised of SB, consistent with a review of other research regarding PA and SB in preschoolers (Hnatiuk et al., 2014) reporting that the proportion of time spent in MVPA and SB during awake hours ranged from 2-41% and 34-94%, respectively. O'Brien et al. (2018) observed that time in PA and SB in child-care hours were highly varied and inconsistent between studies, although preschoolers were noted to participate in high rates of SB in this setting. Likewise, different studies have investigated the

adherence of preschool children to 24-hour movement behaviors, with numerous reports that most children do not meet MVPA recommendations, regardless of the ethnic or geographic context (Berglind & Tynelius, 2017; Chaput et al., 2017; De Craemer et al., 2018). Evidence on the relationship between PA and FMS in childhood has been equivocal. Thus, it is conceivable that this relationship in young children has been masked by the type of data analysis.

In our isotemporal reallocation analysis, we found increased manipulative skills (0.14, 0.28, and 0.42-units) to be associated with reallocating time (five, 10 and 15 minutes, respectively) from LPA to SB. Stamatakis et al. (2013) reported that, for 2-12 year old children, TV viewing, but no other type of screen time, was associated with cardiovascular risk markers independently of PA, and using a single marker of screen time/SB may conceal specific associations. In our study, TV viewing did not feature in the typical pre-school day, as TV was forbidden in the preschool settings for these participants. Since fine-motor developmental tasks are a staple of the preschool curriculum, it will be important to better discern what was taking place during accelerometer-defined SB (Stamatakis et al., 2013).

In similar work conducted with children ($M_{age} = 8.4$, $SD = 1.8$ years), Burns et al. (2019) examined the relationships between school-time spent in these behaviors (i.e., SB, LPA and MVPA) and FMS, and these authors showed that replacing SB and LPA with MVPA during school hours was significantly associated with higher FMS total scores. Although reducing time in low intensity activities and increasing time in high intensity activities has been associated with children's improved FMS profiles, our data for preschoolers, based on a time-bound behavior compositional approach, showed only that more SB was associated with better manipulative skills. Among possible reasons for these different results are that: (a) there were methodological differences in our time-based compositional behavior approach to analysis; (b) there was an age influence on the effect of reallocating behavioral activities during school time; and/or (c) there may have been fine motor skill practice occurring preschool-based SB.

It is important to highlight that although locomotor and object control sub-scales are reasonably well correlated (r = 0.84–0.96) (Cools et al., 2009), they should be differentiated, given their independent importance towards predicting health behaviors (Robinson et al., 2015). The results of this study might suggest that time being sedentary in preschool settings may not be so deleterious, depending upon what fine motor activities may be taking place during periods when there is minimal gross motor movement as detected by actigraph or accelerometers. Thus, we could argue that a "high-quality" SB at pre-schools (i.e. playing with puzzles and blocks, painting) may have a positive impact on manipulative skills. Understanding how and which types and patterns of SB might contribute to development of which specific motor skills should be considered an area for further research exploration.

Indeed, a focus on manipulative skills is a key consideration in the context of the preschool population. Writing ability in preschoolers first develops as a gross motor activity, where finer movements are controlled by the forearm with power and strength in the shoulder and elbow pivots being central to control of movement (El-Dayem et al., 2015). This is strikingly similar to the developmental process in acquiring overarm throwing skill (Langendorfer et al., 2011), and prior studies have reported significant relationships between gross motor skills and handwriting skills in 5-6 year olds (El-Dayem et al., 2015). Consequently, the use of a shoulder, elbow, wrist pivot is key in early development of writing skill. Although the placement of the accelerometer (left hip) failed to detect any of these shoulder, elbow, or wrist movements, we might speculate that when the hip is quiet, children might still be moving their upper body. In this sense, the link between SB and apparent gross motor skills might be explained, or at least influenced by the fact that in preschoolers, writing, painting, utensil use and similar sedentary tasks tend to be more gross in nature and share some similarities in early developmental trajectory to object manipulation skills such as throwing, as both involve a complex interaction between psychomotor skills, nervous system and muscular strength (Accardo et al., 2013; Hamstra-Bletz & Blote, 1990).

We can also argue that the sedentary electronic lifestyle of young children, characterized by their frequent use of smartphones (Kabali et al., 2015) may, at least partly, explain the current results, particularly when approximating these patterns to those of preschoolers from high-income countries. In a study with Australian preschoolers, Barnett et al. (2012) showed that the use of interactive and non-interactive electronic games was positively associated with object control competence but had no association with locomotor competence. The use of smartphones is widespread and even part of life among Brazilian low-income families. Assuming that manipulative technologies help increase the manipulative skills to a certain standard, our current results suggest that this competence may be further improved by adding "non-screen" manipulation activities during school hours, especially considering the amount of daily time these children spend in preschools.

Moreover, although the preschool setting may have a meaningful influence on children's motor skills, one should not expect preschool to be the only daily available setting to allow children to be active. Nonetheless, concerning FMS as a product of preschooler's engagement in PA opportunities (Stodden et al., 2008), the contribution of preschool settings to PA engagement is even more important for our participants who had fewer other chances to participate in structured activities.

Our results showed a small but significant improvement of total MC when five minutes were reallocated from LPA to SB. Nonetheless, for the five-minute substitution, there was a narrow confidence interval for locomotor skills, and it was positive for the manipulative skills. Thus, while the total MC score

appeared to improve, that improvement was solely due to the changes in manipulative skills. FMS emerge within a dynamic system, consisting of a task performed by a learner in a particular environment (Newell, 1984). In this system, environmental considerations may influence motor development. So, relative to high-income countries, children from low-income families, as the assessed in this study, are less likely to meet WHO SB, and PA guidelines (Kracht et al., 2019), and more likely to have lower FMS proficiency (Bellows et al., 2017), perhaps attributable to a lack of local resources affording fewer developmental learning experiences. Indeed, Playford et al. (2017) indicated that SES was associated with preschool children's fine motor skills but not with their gross motor skills. Similarly, a systematic review found that the parent's economic characteristics were a confirmed correlate of preschoolers' FMS (Iivonen & Sääkslahti, 2014), although data in this field are still scarce and contradictory.

Limitations of the Study

While strengths of this study were its consideration of the entire school-day and composite time allocations of behavioral activities as predictors of FMS in preschoolers. some limitations should be highlighted. The compositional approach used here did not discriminate between the various types of activity children might be performing while sedentary, making it difficult, if not impossible, to interpret the meaning of associations between more SB and improved manipulative skills. There is evidence in the literature that classroom naps support learning in preschool children by enhancing memories acquired earlier in the day, compared with equivalent intervals spent awake (Kurdziel et al., 2013). Thus, even naps might be associated with SB. Likewise, the school-time schedule varies according to cultural context. Our study was developed with a specific low-income sample, whose PA opportunities inside and outside school are scarce. Both the age and the social experiences of our participants may challenge the generalizability of our findings to other populations. Yet, our sample's low-income background mirrors the demographic characteristics of children from other low-income geographical regions, making this an important population to study in its own right. We must also acknowledge that only 86% of children in this study met the minimum wear-time criteria for accelerometer measurement inclusion. This value is above the average observed in a study with the same age group (Hislop et al., 2016), but it remains difficult to procure sufficient data in these populations, and our usable data was below the level our power analysis suggested was necessary. The strategy we adopted to use colored belts, with images of superheroes, promoted a greater adherence of children to the devicés use, and could be easily adopted in other contexts. Nonetheless, we cannot rule out the possibility that we lacked sufficient statistical power to detect possible other significant relationships between behavioral time allocations in the preschool day and these children's FMS skills. Moreover, the time the

accelerometer was removed for bath, even accounting for some energy expenditure, was short and may not impact on the overall amount of PA levels. Each child had their bath for approximately 3-5 min, and the accelerometer was quickly fastened after that. The lack of precise information on teacher's diary to support data interpretation is another limitation that should be considered in further studies. Finally, to better understand the relationship between PA and manipulative skills, future investigators may wish to consider an alternative body placement for the accelerometer so as to better measure the extent to which children's gross motor movements reflect upper limb and torso activity.

Conclusion

The current study presented time based compositional data on school-time behaviors and FMS among preschoolers and highlighted that school-time composition was a significant predictor of FMS manipulative skills. A modest increase in sedentary behavior, at the expense of light physical activity during school-time was associated with a positive change in manipulative skills, raising new questions as to what specific activity took place during sedentary behavior time, measured by hip placement of an accelerometer. There is an urgent need to better discern the effects of different types of sedentary behavior in order to best interpret these findings. We have also detailed limitations of this study and other directions for further research.

Practically, our study contributes to a growth of evidence concerning the importance of movement behaviors during school-time and their implications for preschooler's fundamental movement skills. Interventions to promote the improvement of locomotor and object control skills should focus on reallocating the composition of all movement behaviors within preschool settings. Considering their interrelationships within the confines of a school day, short-period time reallocations between movement behaviors can have significant effects. This study illustrates that phenomenon and raises new questions for pedagogical practices and future intervention research.

Declaration of Conflicting Interests

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Ethical Approval

All the Helsinki Declarations' ethical aspects were followed (World Medical Association, 2013). The evaluation methods and procedures were approved by the Research Ethics Committee of Health Science Center of Federal University of Local University (protocol n. 2.727.698), and by the Education Board of the city.

Human Subjects Approval Statement

All the Helsinki Declarations' ethical aspects were followed (World Medical Association, 2013). The evaluation methods and procedures were approved by the Research Ethics Committee of Health Science Center of Federal University of Local University (protocol n. 2.727.698), and by the Education Board of city.

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Supplemental material

Supplemental material for this article is available online.

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