Association between sedentary behaviour inside and outside preschools and executive function in preschoolers

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Abstract

Preschool children spend a large part of their day at school, and a large part of that time they spend in sedentary behaviour (SB). Although SB negatively affects regions of the brain responsible for cognition, it is believed that the type of SB performed can favour executive functions' performance. The present study aimed to analyse the association between SB inside and outside preschools and EF tasks in preschool children. Thus, 73 pre-school children (60.3% girls) were evaluated, with a mean age of 55.0 ± 9.1 months. The SB and physical activity (PA) were objectively assessed using accelerometers. The executive function (EF) was assessed using the Go / No Go paradigm by Early Years Toolbox – YET, and for the purposes of analysis, the inverse efficiency of Go and No Go accuracy were considered. Body Mass Index (BMI) was calculated [weight/height² (kg/m²)]. The preschool secretary provided the children's sex and age. To assess possible associations between EF and SB, with sex, age, BMI and PA as covariates, a structural equation model, using multivariate linear regression analysis, was conducted. A significant and positive association between SB in weekend days and IE of Go ($b = 0.61$; $p < 0.001$) was observed. The model's general explaining 51.9% of IE, and 2% of Ac-No Go.

Conclusion: the model presented in this study showed that SB on weekend days showed a significant and adverse association with children's IE, suggesting that excessive SB on these days may be harmful to EF in early child.

1. Introduction

Excessive time spent in sedentary behaviour (SB) has been characterized as a health determinant, due to its negative influence on cardiometabolic markers and its positive association with all-cause mortality in adult population [1]. Prior researches have also shown the negative effect of SB on brain structure and cognitive skills, such as executive function (EF), in childhood and adolescence [2, 3].

EF corresponds to a series of cognitive processes (working memory, inhibitory control, and cognitive flexibility) that are responsible for systematizing behaviours to perform complex tasks [4]. In early childhood, due to the brain immaturity, it is difficult to differentiate cognitive processes. Previous studies have widely assessed the score in Go / No Go test as a measure of EF in this population [5, 6]. Nonetheless, the importance of reaction time (RT), a measure of processing information speed [7], that is also related to brain white matter development [8], should be considered. In addition, the accuracy of the No Go (Acc-No Go), the child's ability to inhibit continuous behaviour, is also an important measure to be considered, given its rapid growth in early childhood [9], and its relation with the prefrontal cortex maturation [10], the basis of higher order cognitive processes [11].

In young children, SB negatively affects white matter [12], which is related to cognitive processes [13]. However, the effects of SB on EF may vary according to the "sedentary activity" performed [14]. Indeed, activities that promote learning, such as puzzles or thinking games may improve children's EF [14]. Children attending preschools spend a great part of their daily time being sedentary [15]. Nonetheless,

this time may not necessarily be detrimental to their EF, and whether SB inside and outside preschools is associated to EF outcomes is still unknown.

Movement behaviours are interrelated [16], and physical activity (PA) may mitigate the harmful effects of excess SB [17]. Furthermore, individual characteristics, such as sex [18], age [19] and body mass index (BMI) [20], may have an important role on the relationship between SB and EF. Thus, the present study aimed to analyse the association between SB inside and outside preschools and EF tasks in preschool children. We hypothesized SB inside the preschool is positively associated with EF, while the time spent outside preschools is negatively associated with preschooler's EF.

2. Methods

This cross-sectional study used baseline data from the "Movement's Cool" project, aiming to analyze the association between movement behaviours and health outcomes in preschoolers [21]. All the ethical aspects were followed. The evaluation methods and procedures were approved by the Research Ethics Committee of Health Science Center (protocol n. 2.727.698), and by the Education Board of the João Pessoa, Brazil city. Written consents were obtained before participation from the preschools' principals and children's parents.

2.1 Context and Participants

Preschool children aged three-to-five-years-old, of both sexes, and registered in Early Education Childhood Centers (EECCs) of João Pessoa / Brazil were eligible. The preschool public education zone is organized in nine districts, where fifty-five EECCs with registered students three-to-five-years-old, are located. Ten EECCs, located in deprived areas of six different districts agreed to participate in the study. For this study, three EECCs, situated in three different districts were conveniently selected. These three preschools were located in deprived areas, with low socioeconomic status (SES): 50.5% of the mothers or fathers were unemployed, and over 71.8% of the mothers had not finished high school. The Human Development Index (HDI) from the areas where preschools are located ranges from 0.4 to 0.5. All parents of registered children (283 children) were invited, and 146 accepted to participate. Nonetheless, 73 children did not validate accelerometer data or did not perform the EF test.

2.2 Study design

Measurements were performed during four months (August to October 2019, and March 2020). All the schools and parents were informed about the project's protocols and procedures in meetings with the project coordinator and agreed to participate. All children authorized by their parents were evaluated. A prior meeting with the school's manager was conducted during the first day at schools. On the second day, the socio-demographic data (sex and age) were provided by parents in a face-to-face interview. On the third day, EF data was collected, and the accelerometer was given to each child.

2.3 Variables and protocols

2.3.1 Sedentary behaviour and physical activity

SB was objectively assessed using accelerometers (Actigraph, model WGT3-X, Florida). The preschool teachers and the parents/guardians received verbal and written instructions for the correct use of the accelerometer. Throughout the week, parents received three phone calls to remind them about the accelerometer use. The device initialization, data reduction and analysis were performed using the ActiLife software (Version 6.13.3).

The participants were instructed to wear the accelerometer on the right hip for 7 consecutive days (Wednesday morning to Tuesday afternoon). Children were allowed to remove the device during water-based activities and while sleeping (at night). During preschool time, accelerometers were removed by teachers around 11a.m for children's bath and fastened properly after it. Accelerometers were setup to measure acceleration at a 100 Hz sampling rate, and analyzed as ActiGraph counts, using a 15-s epoch length, and reintegrated to 60-second epochs for analysis. Periods of ≥ 20 min of consecutive zero counts were defined as non-wear time and removed from the analysis, and the first day of accelerometer data was omitted from analysis to avoid subject reactivity. Data with a minimum of three days (one weekend and two-week days), with a minimum of 8h of wear time was considered valid. The mean wear time was 10.9 hours (SD ± 1.4 h of wear time between children). The amount of time spent in SB was estimated as ≤ 819 counts, as proposed by Butte [22]. The time in SB inside of the school was considered from 7 am to 5 pm. The time in SB outside of school in the week was recorded from 5 pm until the moment of withdrawal to sleep. On weekends, the SB was considered from the moment the child put the accelerometer in the morning on until withdrawal for night sleep. The Moderate to Vigorous Physical Activity (MVPA), expressed as minute per day, was analyzed as the adjust variable, and was estimated as > 3.908 counts [22].

2.3.2 Body Mass Index

Height (cm) and weight (kg) were determined using a Holtain stadiometer and digitized weighing scale (Seca 708), respectively, while the participant was lightly dressed and barefoot, following a standardized procedure [23]. BMI was calculated by dividing body weight by the squared height in meters (kg/m^2).

2.3.3 Executive function

EF was assessed using Early Years Toolbox – EYT [24], which is a battery of computerized tasks that was developed to assess the EF of children aged three-to-five-years-old. The battery consists of five tasks assessed from games in an app designed for iPad.

In preschoolers' immature-brain, inhibitory control, working memory, and cognitive flexibility share common processes being challenging to disassociate [25]. Also, it is relevant to consider that in early childhood, these components are strongly related to inhibition, both at the representational level or to the maintenance of objectives [26–28]. Thus, for this study, the accuracy computed in Go, the RT in Go, and the accuracy computed in No Go tasks were considered as outcomes. Children were instructed to tap the screen whenever they saw a fish (Go) and not tap the screen when a shark appeared (No Go). Each stimulus trial remained on the screen for 1500ms0s, followed by inter stimulus interval of 1000ms0s. Children completed three blocks of 25 trials (a total of 75 trials), with 80% Go trials (60 fishes) and 20%

No Go trials (15 sharks) that were presented in randomized order. Previous studies have shown that the Go / No Go test can activate the entire prefrontal cortex (the brain region considered the basis of support for EF), and it is a more robust task than others to establish EF performance [28, 29].

For analysis, one point was assigned for each correct answer, with the score ranging from 0 to 60 points for Go and 0 to 15 points for No Go. The Inverse Efficiency (IE), computed by the ratio between Reaction time and Accuracy of Go was calculated. This measure has recently been used in EF performance surveys to consider the trade-offs between speed-accuracy [30]. The underlying assumption is that “differences in reaction time performance would decrease if differences in accuracy are large, but would remain the same if accuracy is identical” [31]. The task of Go it is considered a measure of selection attention and speed of response selection [7, 32]. Besides, the accuracy of No Go (Ac-No Go), which is related to inhibition processes, was used for analysis. This protocol presents satisfactory reliability values with Cronbach's $\alpha = 0.95$ [24]. In the current study, the composite reliability values for Go/No-Go was 0.78, which is considered an adequate value [33].

2.4 Data Analysis

To characterize the sample, mean and standard deviation were used, and the difference between sex was verified by Student's T-test. To assess possible associations between EF and SB, with sex, age, BMI and MVPA as covariates, a structural equation model, using multivariate linear regression analysis, was conducted. The presence of univariate and multivariate outliers was verified by the square distance of Mahalanobis (D^2). Variable's normality was assessed by the coefficients of asymmetry (sk) and uni and multivariate kurtosis (ku). Possible multicollinearities were investigated using VIF (Variance Inflation Factor), and $VIF > 5$ was considered a multicollinearity indicator [34]. The robust maximum likelihood method was used [35]. The Mplus program (version 8.0) was used, and values of $p < 0.05$ were considered significant.

3. Results

A total of 73 preschoolers who completed the entire assessment's protocol participated in the study. Girls showed longer time in SB within EECC compared to boys (Table 1).

Table 1
Sample's characteristics.

Variables	Boys (n = 29)		Girls (n = 44)		p	Cohen's d
	Mean	SD	Mean	SD		
Age (months)	54.3	8.9	55.5	9.2	0.612	-0.122
BMI (kg/m ²)	15.1	1.3	15.6	2.1	0.234	-0.287
MVPA (min/day)	65.2	23.0	69.5	21.2	0.413	-0.197
SB-inside (min/day)	233.7	63.1	266.2	69.9	0.047	-0.482
SB-outside (min/day)	182.0	70.6	192.8	69.4	0.522	-0.154
SB-wkn (min/day)	442.9	158.2	452.0	168.6	0.817	-0.055
SB (min/day)	858.6	252.3	911.0	257.0	0.394	-0.205
Ac-Go (score)	50.9	6.3	49.4	8.6	0.433	0.189
RT-Go (ms)	290	30	300	30	0.196	-0.312
IE (RT/Ac)	5.8	1.2	6.5	3.0	0.253	-0.277
Ac-No Go (score)	10.4	3.5	11.6	2.0	0.067	-0.445
SB-inside = Sedentary behaviour in weekdays inside; SB-outside = Sedentary behaviour in weekdays outside; SB-wkn = Sedentary behaviour in weekend days; SB = Sedentary behaviour all day; Ac-Go = Accuracy of Go; RT-Go = Reaction time in Go; Ac-No Go = Accuracy of No Go; Statistically significant values are shown in bold (p < 0.05).						

Analysing the associations between SB (i.e. SB-inside, SB-outside and SB-wkn), and EF (i.e., IE, and Ac-No Go), adjusted for sex, age, BMI and MVPA (Fig. 1), a significant and positive association between SB-wkn and IE of Go ($b = 0.61$; $p < 0.001$) was observed. The model's general explaining 51.9% of IE, and 2% of Ac-No Go.

4. Discussion

The present study analysed the association between time spent in SB in different contexts and EF in preschoolers. Although prior studies have assessed the relation between SB and EF in preschoolers [36, 37], the current study adds important findings to the existing literature, considering distinctive contexts where preschoolers are sedentary.

The study's primary results showed that time spent in SB on weekend days was positively related to children's IE, a measure to consider the trade-offs between speed-accuracy [30]. Indeed, a lower IE is associated to a more efficient task performance [30], what might indicate a harmful for children's IE. Thus, the excessive time spent being sedentary during weekend seems to be detrimental to preschoolers'

EF [14]. According to Lillard and colleagues [38], the information processing follows an inverted U shape, in such a way that the excess of information, as well as the content children are exposed, may lead to children's EF impairments [39]. Moreover, the assessed children spend twice as much time on SB during weekends than on weekdays. Excessive SB at this stage of life is associated with decreased white matter integrity in brain regions that support EF, such as the frontal and the prefrontal Thalamus [12].

It is important to highlight that the relationship between SB and EF in preschoolers is controversial [14, 40], partly due to the type of SB performed, and to the time spent being sedentary. The technology advances, and the easier access to electronic devices may predispose early age children to a greater amount of time exposed to screens [41], though specific educational TV, tablet, and computer programs developed for this public may positively contribute to children's learning process [42].

Although it is expected that sedentary time inside preschools could positively predict children's EF, the current study showed no significant association with any of the assessed EF outcomes. Preschool's context characteristics, such as inadequate material, lack of space, and teachers qualification to work with these specific age group, may influence the quality of the offered classes, and consequently, children's cognitive learning [43]. The assessed children spend 10 hours per day at public preschools, located in low-income areas of a middle-income country, where social aspects that directly interfere with child's development cannot be ignored. In addition, in several cases, parents are involved in an extensive work routine, that may contribute to a lack of quality interactions with their children, especially during week days, and consequently, on children's cognitive development [44].

The main strength of the current study is the analysis of sedentary time in different contexts and its repercussion in preschoolers' EF. As far as we know, this is the first study to report such associations in young children, considering the context where SB happens, what may provide a new insight in the research field. Besides, the studied sample covers a critical geographical gap in this research area. However, our findings should be considered with certain parsimony, as the lack of information regarding the type/quality of SB performed in each context may be determinant to the reported associations. Finally, other factors involved with preschoolers' EF (e.g., home and school environments, diet, motor skills, self-esteem, brain-derived factors, and others) [45] could be detrimental for the fit indexes, and should be further explored. Therefore, these outcomes emphasize a context-dependent influence of SB time on preschoolers' EF, and demonstrate the relevance and priority of further studies to better discern types of SB.

5. Conclusion

The model presented in this study showed that SB on weekend days showed a significant and adverse association with children's IE, suggesting that excessive SB on these days may be harmful to EF in early child. Therefore, our findings suggest that investigating the different contexts where preschoolers are engaged in SB may be decisive for ensuring enhanced children's EF profile, although strategies focusing in reducing SB in early stages of life should be a priority.

List Of Abbreviations

AC = accuracy

BMI = body mass index

EF = executive function

EECC = Early Education Childhood Centers

IE = inverse efficiency

MVPA = moderate to vigorous physical activity

SB = sedentary behaviour

Declarations

Funding: N/A

Conflicts of interest/Competing interests: N/A

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Code availability: N/A

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Ethics approval: All procedures were approved by the university committee and the board of education. The Helsinki Declarations' ethical aspects were followed (Association, 2013). The Research Ethics Committee of the Health Science Center of the Federal University of Paraiba and the local board of education approved the study (protocol n. 4.102.806).

Consent to participate: All the preschools' staff and parents were informed about the research's goals, protocols, and procedures in meetings with the project coordinator (one session in each school) and agreed to participate in the present study through an informed consent form.

Consent for publication: All preschool staff and parents were informed about the research objectives, protocols, and procedures in meetings with the project coordinator (one session at each school) and agreed to publish the data, maintaining the confidentiality of the participants, through an informed consent form.

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Figures

Figure 1

Associations between SB and EF. Legend: SB-i = Sedentary behaviour in weekdays inside; SB-o = Sedentary behaviour in weekdays outside; SB-wkn = Sedentary behaviour in weekend days; Ac = Accuracy; IE = Inverse Efficiency; BMI = Body Mass Index; MVPA = Moderate to Vigorous Physical Activity.