Original article

Effect of a school-based multicomponent intervention on time-segmented physical activity and sedentary behavior among Brazilian adolescents: The *Movimente* Study

Rafael Martins da Costa [a,b,*], Marcus Vinícius Veber Lopes [a], Bruno Gonçalves Galdino da Costa [c], Luís Eduardo Argenta Malheiros [a], Priscila Cristina dos Santos [a], Lauren Arundell [d], Kelly S. Silva [a]

[a] Research Center for Physical Activity and Health (NuPAF), School of Sports, Federal University of Santa Catarina, Florianopolis, 88040-900, Brazil

[b] Faculty of Physical Education and Physiotherapy (FEFF), Federal University of Amazonas, Manaus, 69067-005, Brazil

[c] School of Physical and Health Education, Nipissing University, North Bay, P1B 8L7, Canada

[d] Institute for Physical Activity and Nutrition (IPAN), School of Exercise & Nutrition Sciences, Deakin University, Melbourne, Victoria 3125, Australia

Abstract

Objective: To assess the effect of the *Movimente* Study on device-measured physical activity (PA) and sedentary behavior (SB) in two-time segments of the school day amongst Brazilian adolescents.

Design: Cluster-randomised controlled trial.

Methods: Six elementary schools were randomized into the intervention (*Movimente* group) or control group (CG). Participants were in 7^{th}-9^{th} grades. The present study's sample consisted of students from two small-sized schools (one from the *Movimente* group and another from the control group) since there was a limited number of accelerometers. A school year (2017) multicomponent intervention was delivered consisting of three components: 1) teacher training, 2) education curriculum, and 3) school environment. PA and SB were measured using GT3x+ ActiGraph hip-worn accelerometers at baseline and end-intervention. The segments of the day were: In-School (08:00–11:59) and Out-of-School (12:00–22:00) time. A two-level linear mixed model assessed the effect of the intervention on light-intensity PA (LPA), moderate- to vigorous-intensity PA (MVPA), SB, and MVPA/SB ratio within and between groups.

Results: There was a significant effect on the *Movimente* group compared to the control group for MVPA, SB, and MVPA/SB ratio performed in the Out-of-school segment, but not in the In-school segment. However, there were no significant differences within- nor between-group differences in LPA in both day segments.

Conclusions: The *Movimente* Study increased the MVPA, the ratio of MVPA/SB, and decreased SB of the adolescents compared to their peers in the control group in the Out-of-school segment.

Keywords: Adolescent health; Exercise; Randomized controlled trial; Sedentary time.

Introduction

Low engagement in recommended levels of physical activity (PA) has contributed to adverse health outcomes, including non-communicable diseases and poorer quality of life[1,2]. In the same way, time spent excessively in sedentary behavior (SB)[3] is harmful to health regardless of PA level[4]. In this sense, interventions have focused on evaluating effective strategies for increasing PA and reducing SB in children and adolescents[5–8], which is still a challenge mainly in low- and middle-income countries (LMIC)[9].

According to an umbrella review study[9], most PA interventions conducted in LMIC settings have targeted children and adolescents through the school setting; and methodological limitations such as lack of control groups; of randomized sample; and use of questionnaires to measure PA are observed across several studies[9], which limits the accuracy of the PA measure and SB volume compared to accelerometers, especially among children and adolescents[10]. Furthermore, using accelerometers also has the advantage of analyzing time-stamped data, which questionnaires seldom measure. A review study examined the effect of school-based interventions using accelerometers in children and adolescents and found that only one intervention used accelerometer-measured PA in an LMIC (i.e., Ecuador), with all other included studies being from high-income countries[11]. Therefore the effect of interventions in different time segments of the day, such as PA within school time[12] is poorly understood in LMIC settings.

Children and adolescents have unique opportunities for increasing PA and reducing SB in school due to the time of recess and physical education class[13,14]. This is also viable in out-of-school hours, with strategies targeting behaviors at home, in clubs, and in after-school programs[7,15]. Unlike other countries that start the school schedule around eight a.m. to three p.m., which allows for policies and interventions to target recesses/lunch breaks and class time[16,17], Brazil starts and ends the school schedule earlier, with classes in only a period (morning or afternoon), lasting for 4 hours per day. However, few studies have examined the impact of interventions on Brazilian schoolchildren during and out of school hours.

To fill this gap in the research, we carried out the *Movimente* Study, which aimed to increase the time spent on PA and decrease the time spent in SB among Brazilian 7th-9th graders (11-16 years). Intervention strategies were teacher training, improvement of the school environment, and health education for the school community. Most of them were designed to target both the mandatory class time and the out-of-school hours. Thus,

this study intends to assess the effect of the *Movimente* Study on device-measured PA and SB of Brazilian adolescents during and out-of-school hours.

Materials and Methods

Trial design and participants

The current analysis uses a subsample of the *Movimente* Study data, a cluster randomized controlled trial performed at the elementary school level. The theoretical background and methodological approach are detailed in a previous study[18]. The program was conducted over one school year (March to November 2017), having as the primary outcome to improve adolescents' PA and SB levels. The study protocol was approved by the Research Ethics Committee (No:1,259,910, CAAE: 49462015.0.0000.0121), the Board of Education of the city of Florianopolis (Southern Brazil), and the project was registered in the Clinical Trials database (NCT02944318).

The methods have been described previously[18] but briefly, seven schools accepted an invitation to participate in the study, one was selected as a pilot school to test the strategies, and the remaining six schools were matched by size and randomized to the control or intervention groups. Students in grades 7-9 from the six schools who attended the first weeks of school (1,427 students) were eligible to participate (796 in the intervention group and 631 in the control group). Students and parents/guardians provided written consent before participation, and no incentive to participate was provided. Due to the number of accelerometers available for the *Movimente* Study, the two smaller schools, randomly allocated to each group, were selected to compose a subsample of objectively measured PA behaviours. Further details regarding all the intervention procedures can be found at https://movimente.ufsc.br/.

Intervention

The *Movimente* study was based on Social Cognitive Theory[19], Socioecological framework[20] , and Health Promoting School framework[21]. The intervention consisted of three strategy components, teacher training, education curriculum, and the school environment (Table 1). After baseline data collection, face-to-face teacher training was conducted and health topics, mainly PA and SB, were addressed. In addition, two teacher training sessions were performed for 1) Physical Education teachers and 2) general teachers (e.g., Math, Portuguese, Biology, etc.). During the intervention period, the schools assigned to the control group continued their activities normally (without

researcher interference). In early 2018 (i.e., after the end of the intervention in 2017), the control group schools received all the materials of the *Movimente* Study, and a final report containing the study's main findings.

Briefly, the training for PE teachers was focused on the implementation of activities and how to discuss health concepts and lifestyle behaviors in their classes. Activities focused on how to engage a broader number of students in PE classes and providing activities that stimulate students' enjoyment of PE classes. PE teachers were also trained to discuss intrapersonal aspects (e.g., attitude, self-efficacy, enjoyment) that reinforce the relevance of PA practice in the students' routines and how to overcome barriers, and include health topics in PE classes. The general teacher's training focused on incorporating health concepts discussions and active breaks during lessons. A training handbook and educational curriculum materials were presented to teachers, and their content was discussed to demonstrate several possibilities for classroom activities. The content regarding active breaks consisted of concepts, aims, and examples (e.g., relaxation and stretching breaks; muscle activation breaks; and energizer breaks). Teachers were informed that they could incorporate any parts of the materials to suit the needs and abilities of their class.

The educational curriculum materials consisted of banners and folders containing content about PA, SB, healthy eating, and academic achievement. Four banners were provided to the school at the beginning of the year (following the face-to-face training). The school staff was advised to make these banners available strategically to reach as many students as possible. Four folders were also delivered every two months to the school staff, who were advised to read and provide the content to students during class. In addition, teachers were encouraged to perform activities involving parents to disseminate information to the students' families.

The last strategy was the environmental improvements that included the revitalization of sports courts, the creation of new spaces (i.e., empty places were filled with more than one set of line markings [e.g., volleyball, squash, and popular games]), as well as the availability of sporting equipment such as balls, rackets, and ropes. The school staff managed and used all the delivered materials without interference from the study researchers.

Table 1. Description of the intervention components, strategies, executor and receptor agents of the *Movimente* Study (Florianopolis, Brazil, 2017).

Intervention components	Actions/strategies	Executor agent	Receptor agent
Logistic support for teachers	Teacher training focused on health topics, mainly PA and SB. --- Support material (book) with proposed activities on health topics (mainly PA and SB) (mainly PA and SB) for all disciplines. --- Interactive media (Facebook and WhatsApp) for teachers to disclose and discuss their activities in relation to health topics. --- Support material (three books), specific for each grade, with proposed activities on health, PA and sports topics. --- Whatsapp group for teachers to disclose and discuss activities done by them.	Study members Study members Study members and teachers of general disciplines Study members Study members and PE teachers	All teachers Teachers of general disciplines Teachers of general disciplines PE teachers PE teachers
Environmental improvements	Creation of new spaces. --- Revitalization of old courts. --- PA equipment (balls, jump ropes, rackets, etc.) available to students during free-time in school.	Study members Study members Students and school manager	All teachers and students PE teachers and students Students
Education curriculum	Delivery of banners and folder. Topics: PA and health/academic performance, SB and health, and eating habits. It was suggested to the teachers to carry out activities with the students in order to show the folders to the parents or guardians to disseminate this information.	School manager and teachers	School community, students, and parents/legal guardians

Outcome measures

PA and SB were measured using GT3x+ ActiGraph accelerometers worn by participants on their right hip. Trained researchers helped the students secure and oriented their accelerometers with elastic bands. They were instructed to wear them during waking hours, except for aquatic activities (e.g., showering, swimming, or surfing). The accelerometers were distributed and retrieved during class time. However, there were a limited number of devices (n = 114). Participants at the control school thus wore

accelerometers for 12 days (March 15th to 27th, 2017), while participants at the intervention school wore them for 10 days (March 31st to April 9th, 2017). To improve compliance, participants at the control school who did not provide valid data or were not present when the devices were distributed were requested to wear accelerometers over a different 12-day period (May 4th to 16th, 2017), while participants in similar situations at the intervention school were requested to wear them over a different 10-day period (April 18th to 27th, 2017). Messages designed to improve compliance were sent to participant students via a messaging app during the data collection phase. Three messages were sent to each participant over the course of the accelerometer data-collection phase. At the follow-up, participants of the control and intervention schools wore the accelerometers from October 17th to 29th, and November 8th to 20th, respectively.

Accelerometer data were collected at 80 Hz and downloaded in 15-second epoch lengths using the Actilife software. The cut-points proposed by Evenson et al.[22] were used to convert the outputs into minutes of SB (≤100 cpm), LPA (101-2295 cpm) and MVPA (≥2296 cpm). Intervals of sustained 60-minutes of zero activity counts were defined as "non-wear-time," and thus excluded from the analysis[23]. Time spent in LPA and MVPA during each weekday (i.e., Monday through Friday) was summarized and categorized into two specific time-segments, as follows: In-School time (08:00–11:59, referring to the school day, which includes 15-min daily recess and 45-min PE classes two to three times per week as opportunities for PA) and Out-of-School (12:00–22:00, referring to the period without mandatory school-related activities, which may include after-school sports activities). The variable MVPA/SB ratio was calculated by dividing the time spent on MVPA (min/day) by the time spent on SB (hours/day)[24].

Weekend data was not analyzed because the accelerometer measures were collected to monitor the effect of the *Movimente* strategies implemented on school days (e.g., active breaks during class time, enhanced recesses, and more active PE classes)[18]. Preliminary analyses of accelerometer wear time revealed that many participants were not wearing the devices between 22:01–23:00 and 06:01–07:00, as the proportion of participants who wore the devices at these periods for at least two days at baseline were 20.6% and 12.4%, respectively. Acceleration data were collected for more participants during the first hour prior to school time (07:01–08:00), however this was still only observed from 58.8% of participants. Thus, these intervals were not summarized in the Out-of-School time-segment to reduce bias. Accelerometer data collected on the first and the last days of both baseline and follow-up were also excluded to reduce reactivity bias.

Valid wear time was determined for each analyzed segment using the following definitions: (a) A standard segment time was defined as the length of time that at least 70% of participants wore their monitors; (b) a time-segment was considered valid when data were available for at least 80% of the standard segment time[25]; and (c) at least two days of a valid time-segment were required for each participant to be included in the analysis (e.g., at least two measures from a valid In-School time-segment), as previously applied[16,26]. Based on these definitions, the minimum required wear time criteria were 192 and 392 minutes for the In-School and Out-of-School time segments, respectively. Sample sizes, therefore, varied according to time segment.

Covariate measures

Students were asked via survey to provide their sex (male or female) and age (completed years).

Statistical analysis

Mean and standard deviation were calculated for continuous variables, and absolute and relative frequency were calculated for categorical variables. Student's *t* test and Pearson's chi-square tests were used to compare groups at baseline in the two segments of the day. Furthermore, to verify the effect of the *Movimente* Study on the PA and SB, two-level linear mixed models were performed. The following hierarchical structures were applied to all models in each segment of the day: repeated measures (level 1) nested within participants (level 2) were included as random effects. As mixed models can accommodate unbalanced data, all available measures were included in analysis. Fitted models were evaluated according to the assumptions of homoscedasticity and residuals normality. The interaction term of groups (*Movimente* vs control) by time (pre- vs post-intervention) were included as fixed effects. Models were adjusted for sex and age in the fixed effects. Due to slightly skewed residuals observed in some models, a bootstrapping procedure was conducted to obtain corrected standard errors (2000 resamples). Linear mixed models were presented with coefficients and their respective 95% confidence intervals. All analyses were conducted in statistical software Stata, version 14.0 (StataCorp LP., College Station, TX, United States).

Sensitivity Analysis

Sensitivity analyses has been conducted by replicating all the inferential analysis in the following conditions: (a) including participants with valid and non-valid accelerometer data at baseline in both segments of the day (in-school and out-of-school); and (b) including participants who presented valid data in both segments of the day (in-school and out-of-school) simultaneously.

Results

In this study were analyzed 194 students (mean age 13.1 ± 1.0, 47.6% male) who had device-measured PA behavior assessment, being 95 students allocated to the *Movimente* group, and 99 students allocated to the control group. Of these, 84 and 71 students presented valid accelerometer data at baseline in the *Movimente* and control groups, respectively. At the end of the intervention, 34 and 33 students had valid accelerometer data in the *Movimente* and control groups, respectively. For the mixed modeling approach of analyzing unbalanced data, 84, 73, and 71 students in the *Movimente* group comprised the analytic sample of the in-school, out-of-school, and both segments, respectively. From the control group, 71, 48, and 48 students were analyzed in the in-school, out-of-school, and both segments, respectively (Figure 1).

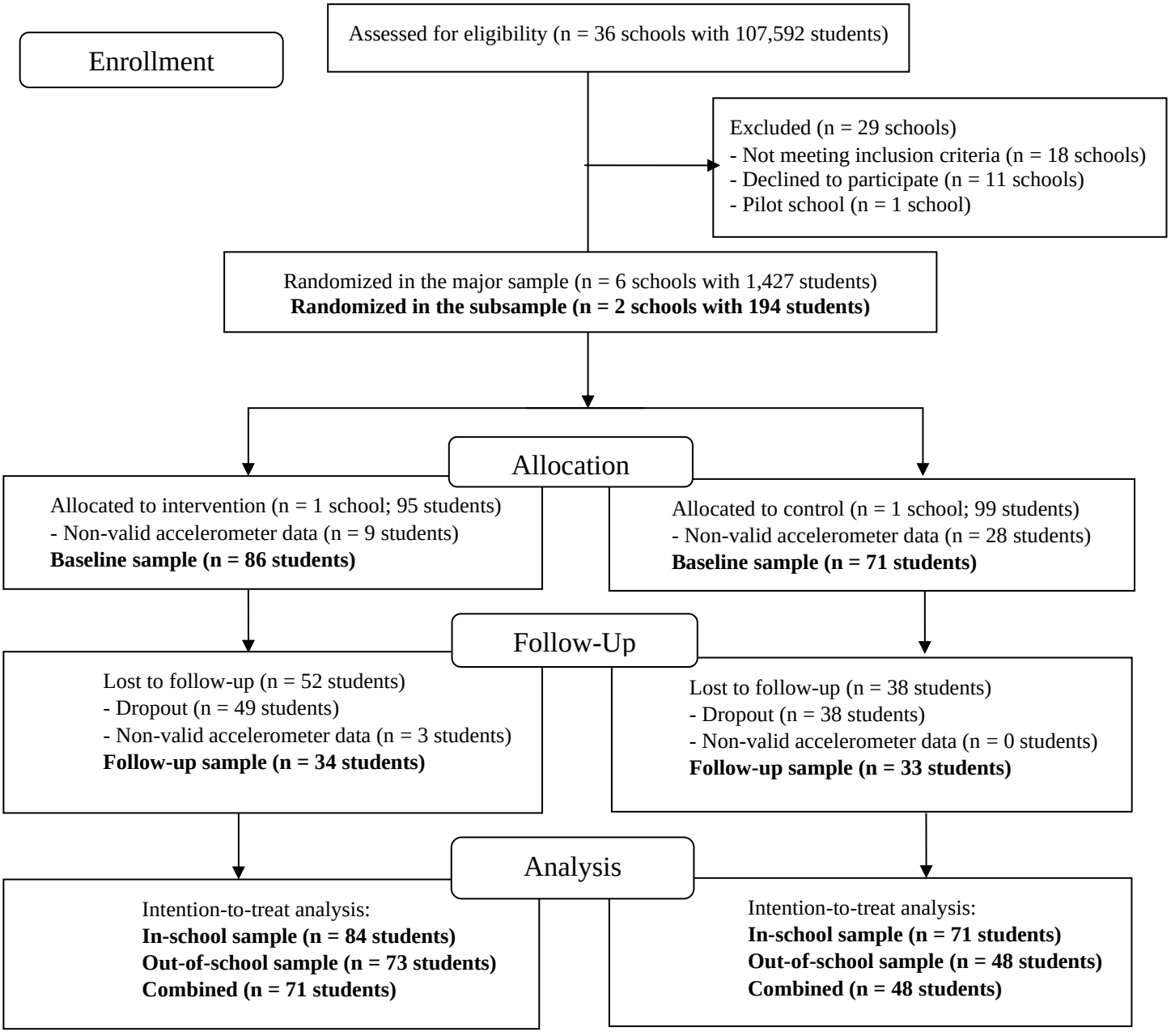

Figure 1. CONSORT flow diagram of recruitment, randomization, and participation of schools and adolescents of the subsample in the *Movimente* Study, Brazil, 2017.

At baseline, no difference was observed between groups (intervention vs control) for PA or SB in both segments of the day. However, there were a greater proportion of females in the *Movimente* group; participants in the control group were slightly older than the participants of the *Movimente* group, only in the in-school time segment (Table 1). Sensitivity analysis showed participants who withdrew before follow-up assessments practiced more MVPA at baseline in both time-segmented samples than those who completed the assessments; the proportion of males was higher among withdrawn participants when compared to those in the out-of-school sample (Supplemental Table 1). Participants without valid accelerometry data had higher MVPA/SB ratios than their peers with valid data in the school segment. Also, among the participants without valid data, females were the majority in the in-school segment and males were the majority in the out-of-school segment (Supplementary Table 2).

Table 1. Baseline characteristics of participants in different segments of the day (in-school time and out of school), according to the group (intervention and control). *Movimente* Study, Brazil, 2017.

Variables	In-school time			Out of school		
	Movimente group (n = 84) Mean ± SD	Control group (n = 71) Mean ± SD	P-value	*Movimente* group (n = 73) Mean ± SD	Control group (n = 48) Mean ± SD	P-value
Sex	n (%)	n (%)	0.047	n (%)	n (%)	0.042
Female	61 (56.0)	29 (59.2)		58 (63.7)	22 (45.8)	
Male	48 (44.0)	42 (40.8)		33 (36.2)	26 (54.2)	
Age (years)	13.0 ± 1.0	13.3 ± 0.9	0.031	12.9 ± 0.9	13.2 ± 0.9	0.065
LPA (min/day)	56.6 ± 19.7	53.3 ± 19.0	0.256	127.2 ± 32.9	123.2 ± 30.8	0.480
MVPA (min/day)	10.0 ± 5.7	10.1 ± 6.3	0.953	24.1 ± 16.6	26.4 ± 15.9	0.433
SB (min/day)	173.3 ± 22.9	176.7 ± 23.0	0.343	339.2 ± 43.7	340.9 ± 39.7	0.815
MVPA/SB ratio (min/hour)	3.72 ± 2.5	3.70 ± 2.8	0.962	4.7 ± 3.9	4.9 ± 3.4	0.691

Note: LPA – Light Physical Activity; MVPA – Moderate to Vigorous Physical Activity; SB – Sedentary Behavior; SD – Standard deviation.

According to the analysis of group-by-time interaction, there was a significant effect on the intervention group compared to the control group for MVPA, SB, and MVPA/SB ratio performed in the out-of-school segment after adjusting for sex and age. There were no significant within- nor between-group differences in LPA in the out-of-school segment (Table 2). The same associations were found in sensitivity analysis done only with participants with valid data in both segments of the day (Supplementary Table 3). There were no significant differences within- nor between- groups in any measures in the in-school time segment (Figure 2).

Table 2. Effect of the *Movimente* Study on accelerometer measured physical activity and sedentary behavior among adolescents in two segments of the day, Brazil, 2017.

Outcomes	Time effect for the *Movimente* group	Time effect for the Control group	*Movimente* vs Control Time effect contrast	
In School	Coefficient (95%CI)	Coefficient (95%CI)	Coefficient (95%CI)	P-value
LPA (min)	-2.2 (-7.6; 3.2)	1.3 (-6.3; 8.6)	-3.3 (-10.6; 3.9)	0.476
MVPA (min)	0.9 (-1.0; 2.9)	4.4 (1.0; 7.8)	-3.5 (-7.4; 0.4)	0.080
SB (min)	1.3 (-5.0; 7.6)	-5.3 (-14.7; 4.2)	6.5 (-4.7; 17.7)	0.252
MVPA/SB (min/hour)	0.3 (-0.5; 1.0)	1.7 (0.2; 3.2)	-1.4 (-3.1; 0.3)	0.098
Out of School				
LPA (min)	-6.5 (-15.4; 2.3)	-12.7 (-22.5; -2.9)	6.2 (-11.5; 23.9)	0.494
MVPA (min)	9.3 (3.2; 15.4)	-7.0 (-14.0; -0.1)	16.2 (6.9; 25.5)	0.001
SB (min)	-3.1 (-17.7; 11.6)	19.6 (3.1; 36.2)	-22.7 (-44.7; -0.7)	0.043
MVPA/SB (min/hour)	1.8 (0.3; 3.3)	-1.4 (-2.8; -0.1)	3.2 (1.2; 5.3)	0.002

Note: LPA – Light Physical Activity; MVPA – Moderate to Vigorous Physical Activity; SB – Sedentary Behavior; 95%CI – 95% Confidence Interval. All models were adjusted for sex and age.

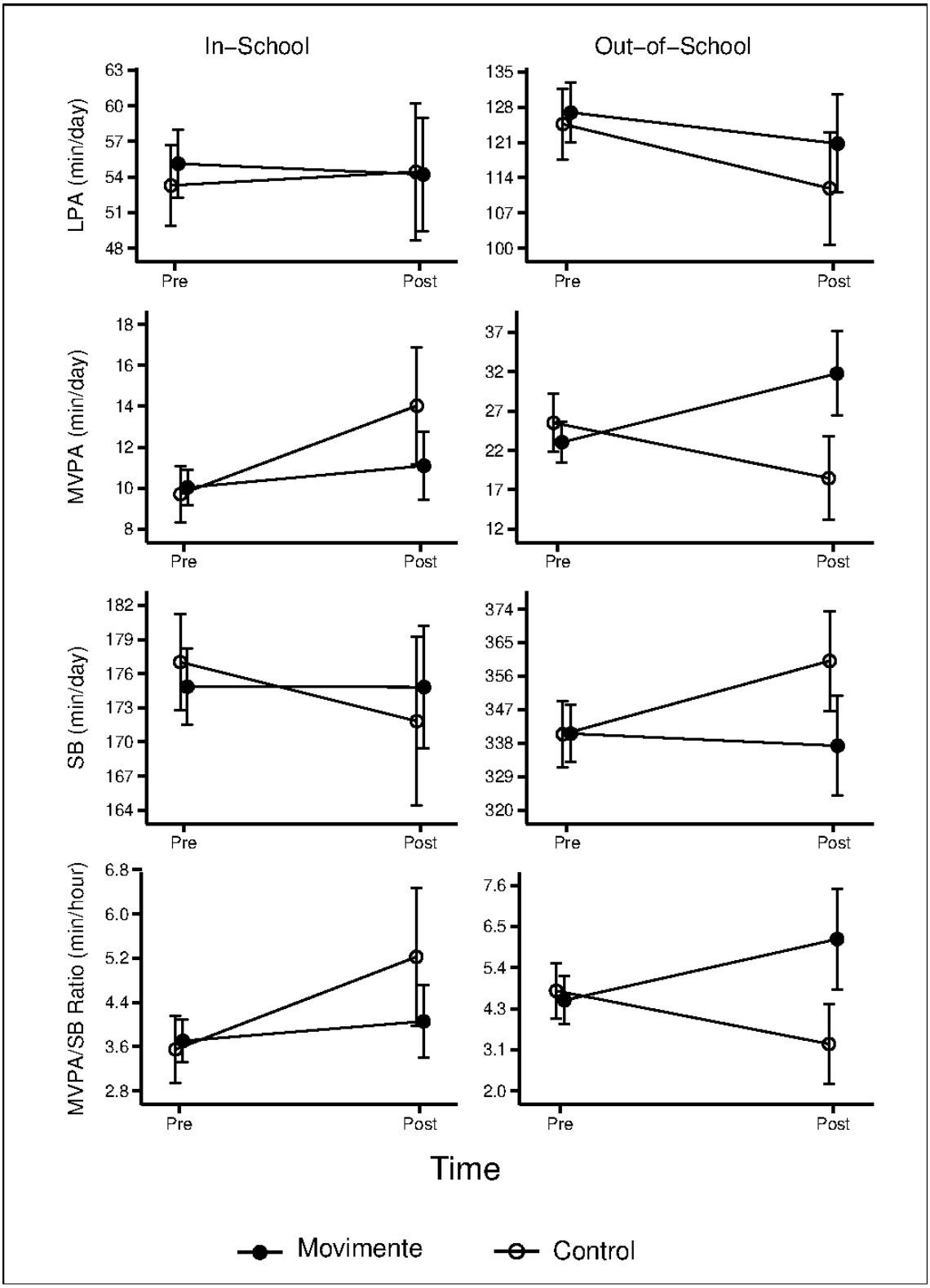

Figure 2. Marginal means of the accelerometer measured physical activity and sedentary behavior among adolescents in the pre-and post-intervention periods according to group allocation and time segments, *Movimente* Study, Brazil, 2017. Note: LPA – Light Physical Activity; MVPA – Moderate to Vigorous Physical Activity; SB – Sedentary Behavior.

Discussion

The findings of this study suggest that the Movimente Study effectively increased MVPA, reduced SB, and favorably affected the MVPA/SB ratio in adolescents in the Out-of-school period. In contrast, the intervention did not change any of the analyzed behaviors during the in-school period. Thus, the utilized strategies were efficient for promoting PA and reducing SB in the out period but not inside the school.

Our findings align with what has been found in some previous systematic reviews, both for interventions with in-school[11] and after-school[27–29] strategies, but differ from the results of other systematic reviews[6,30,31]. For instance, of the 17 studies included in a systematic review[11] (2019) only three were successful in increasing device-measured MVPA in the in-school period, and the study conducted in an LMIC (i.e., Ecuador[32]) had no significant effects on overall MVPA. Another systematic review[6] (2013) showed that out of the 14 studies included, only four were effective in improving PA in PE classes, but none used accelerometers and neither was conducted in LMICs. A systematic review and meta-analysis (2020) of interventions aimed at school recesses[31] summarized 43 studies, only two multicomponent interventions had significant changes in increasing MVPA and decreasing SB; and the study conducted in LMIC (i.e., South Africa[33]) found no significant intervention effects.

Similarly, systematic reviews[27,28,30] about after-school interventions to increase PA observed effectiveness in increasing adolescents' MVPA, none of the studies included in these reviews were conducted in LMICs. For instance, Atkin et al.[27] (2011) reviewed studies on the effectiveness of interventions for promoting PA immediately after school hours. Only three of the ten articles included (and none of them was conducted in LMICs) demonstrated positive effects on PA levels. Likewise, Mears and Jago[28] (2016) reviewed and meta-analyzed studies about the impact of after-school interventions on MVPA in children and adolescents. The review included 15 articles from the US and UK. The meta-analysis revealed an effect size of 2.57 minutes per day of MVPA (95% CI -1.74 to 6.87; and an I^2 value of 44.8% for accelerometer-based studies). However, caution is necessary for interpreting these results, as only five of the 15 articles included in the review had accelerometry data comparing MVPA between intervention groups and controls.

Further research is needed to determine the efficacy of after-school interventions on MVPA levels. In a separate umbrella review conducted by Demetriou, Gillison, and McKenzie[29] (2017), the authors identified differences and similarities among six previous reviews. While they found modest evidence supporting the effectiveness of after-school

programs in promoting PA levels in young people, the general evidence remained inconclusive. In contrast, Borde et al.[30] (2017) by focusing specifically on the impact of school-based interventions on objectively measured MVPA found that of the 13 studies included in the review, only two were conducted in LMICs (e.g., China[34] and Ecuador[32]). The authors found that while the interventions had a positive impact on objectively-measured MVPA levels, the effects were not statistically significant. Evidence on what strategies to promote PA in school settings are effective is still limited. Research to optimize these interventions is needed everywhere. Nevertheless, special attention should be given to LMICs, considering the prevalence of physical inactivity in such settings, the often-limited resources available, and that interventions and policies in high-income countries are often not feasible to be reproduced or directly translate into LMICs.

In the present study, the findings suggest (increased MVPA and decreased SB) that the adopted intervention strategies were effective in contexts where adolescents have more control over their behaviors, such as in their free time (Out-of-school time-segment). This hypothesis is supported by a previous cross-sectional analysis of this study[26], where the authors observed higher levels of out-of-school PA, but not in-school PA among adolescents with higher outcome expectations, self-efficacy, and attitude towards PA[26]. An experimental study conducted with North American children aged 9 to 12 years was effective in increasing out-of-school PA levels by changing psychosocial determinants of PA (i.e., self-regulation, self-efficacy, and mood)[35]. Although adolescents in our study were exposed to educational strategies during schooltime (i.e., teacher lessons, banners, and folders), most opportunities to put this new information into action were out of mandatory school time, when they also had access to the environmental improvements (i.e., school spaces and courts) and the provided sports materials. Our findings and previous cross-sectional analysis[26] suggest that interventions targeting psychosocial indicators and opportunities for PA in Brazil may have challenges in promoting PA and reducing SB in contexts with tight schedules (i.e. in school hours with low duration for recess and/or local school rules that make it difficult or prohibit students to access the school grounds[36]). Despite the emerging literature[24] showing that MVPA/SB ratio is an important indicator for health markers and may suggest a better health effect, the use of this ratio is relatively new and scarce in the adolescent population. This limits the ability to compare the current findings (positive effects on the MVPA/SB ratio in the out-of-school) to other studies and highlights an important gap in intervention analyses.

The lack of intervention effect observed in the current study for the In-School period may be because implementation of several components turned out to be challenging for some schools due to environmental context and resources (e.g., lack of time due to curricular demands and schedule interruptions; resources and administration or training workshops not age-appropriate/insufficient; teachers' autonomy decreased; space constraints; weather conditions)[37], beliefs about consequences (e.g., takes time out of schedule; requires extra planning and set up time; no impact on PA levels; student boredom; teachers' perception of their own competence in implementing the activities; unsure of the effect of PA on academic outcomes)[37,38], and social influences (e.g., the school system prioritizes academics activities; students do not participate and/or cannot force them to move)[37]. Previously published data on the implementation of the *Movimente* Study[36] showed that only 40% of teachers reported adopting active breaks during their lessons, 70% did not use the intervention education materials in the discussions in regular classes, and 63% reported that were difficulties in discussing the health-related topics. Most schools had 2-3 PE classes per week, and most students said that they had discussions about health in the classes and that the classes were more active[36]. Nonetheless, all PE teachers reported that the students became more likely to actively participate in the classes, but the same teachers reported that the more active classes did not result in positive and significant changes in students' lifestyles[36]. Another hypothesis for the lack of in-school intervention effects is that no matter how well the PE teachers were able to implement the strategies of the intervention, it is likely that the PE classes could already be active before the intervention strategies were implemented, so there would be no way to increase this further in class. In addition, with the 15-minute recess time, students prioritize nutrition. Thus, the time may be insufficient for them to eat and engage in enough active play to increase their PA levels.

This study has strengths worth highlighting. The main outcomes of the *Movimente* Study were objectively assessed using accelerometers. This instrument has several advantages over self-reported measures as providing time-stamped data and accurate estimates. A rigorous data validation protocol was employed to obtain more precise and comparable estimates of accelerometer-measured outcomes, including specific wear time validation criteria and excluding the first and last days of accelerometer use at each data collection phase. Analyzing time-segmented PA and SB allowed identifying when behavior change occurred, which might not have been possible if only daily averages had been considered. A second strength of this study is the analytical approach used, which

considered the nested nature of the study design and data by analyzing within-participant estimates of the outcomes. This approach is robust in analyzing unbalanced data and accounts for follow-up dropouts. Lastly, this study adds to the underrepresented body of literature on experimental studies conducted in LMIC settings, which differ significantly from high-income settings in several cultural, social, and environmental characteristics.

Moreover, our study has limitations to be acknowledged. Although nested within a cluster randomized controlled trial design, this study analyzed data of students from two out of six schools from Flarianópolis that comprised the major sample of the *Movimente* Study. Thus, findings should not be extrapolated to the overall population of students from Brazil (considering that the country has continental proportions and each macro-region has cultural specificities). Nonetheless, efforts were made to mitigate biases. For instance, both schools were selected post-group randomization and were paired according to school size (i.e., both small-sized schools) and class shift (i.e., only students from the morning shift) to avoid selection bias related to differences between schools. Another limitation was the significant sample loss due to non-valid accelerometer data. High attrition was expected as observed in other studies using accelerometers on young Brazilians[39]. Efforts to prevent such loss were performed by collecting a second wave of accelerometer data for participants who did not provide valid data and sending messages to remind them to wear the devices. Sensitivity analyses showed that demographic characteristics were similar between losses due to non-valid accelerometer data and the analytic sample, which reduced the likelihood of a selection bias. Due to applying time-segment-specific accelerometer wearing time criteria, the sample size differed between in-school and out-of-school samples. Another set of sensitivity analyses was performed by reanalyzing all data including participants with valid data for both time segments simultaneously, and findings were similar to those from uneven sample sizes. The data collection was not performed simultaneously in control and intervention schools, and seasonal differences should be considered. Although the overall daily temperature did not vary significantly between the one-to-two-week apart data collection phases, there was a variation in the number of rainy days. Thus, further sensitivity analyses were performed by excluding rainy days from accelerometer data, but no differences were observed from the reported findings (data not shown). It is worth noting that the adolescents who dropped out from the study practiced more MVPA and had higher MVPA/SB ratio values in both segments compared to the adolescents who participated in the study. In addition, there

were more males among the adolescents removed from the study when compared to their peers who participated in the study. Thus, the loss in our sample was not random.

In conclusion, the *Movimente* Study significantly increased the levels of MVPA and the ratio of MVPA/SB, and decreased the SB of their participants in comparison to their peers in the control group in the period outside of mandatory school hours. These findings demonstrate the potential of applied strategies for promoting PA and reducing SB among adolescents, particularly in settings with limited school hours. From there, we recommend that future studies need focusing on different actions/strategies during different segments of the day to identify which are most effective; implement longer-term follow-up to verify the sustainability of behavior change; test strategies with larger sample sizes; and address implementation challenges faced by teachers. Also, we recommend that government agencies focus on the implementation, maintenance, and/or creation of new health promotion strategies (focusing on PA and SB) during after-school hours, as it is more difficult to change the school timetable structure in most public schools in Brazil.

References

1. Katzmarzyk PT, Friedenreich C, Shiroma EJ, Lee IM. Physical inactivity and non-communicable disease burden in low-income, middle-income and high-income countries. Br J Sports Med. 2022;56(2):101–6.
2. Marker A, Steele R, Noser A. Physical activity and health-related quality of life in children and adolescents: A systematic review and meta-analysis. Heal Psychol. 2018;37(10).
3. Tremblay MS, Aubert S, Barnes JD, Saunders TJ, Carson V, Latimer-Cheung AE, et al. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. Int J Behav Nutr Phys Act. 2017;14(1):1–17.
4. Rezende LFM, Sá TH, Mielke GI, Viscondi JYK, Rey-López JP, Garcia LMT. All-Cause Mortality Attributable to Sitting Time: Analysis of 54 Countries Worldwide. Am J Prev Med [Internet]. 2016;51(2):253–63. Available from: http://dx.doi.org/10.1016/j.amepre.2016.01.022
5. Gelius P, Messing S, Goodwin L, Schow D, Abu-Omar K. What are effective policies for promoting physical activity? A systematic review of reviews. Prev Med Reports [Internet]. 2020;18(April):101095. Available from: https://doi.org/10.1016/j.pmedr.2020.101095
6. Lonsdale C, Rosenkranz RR, Peralta LR, Bennie A, Fahey P, Lubans DR. A systematic review and meta-analysis of interventions designed to increase moderate-to-vigorous physical activity in school physical education lessons. Prev Med (Baltim) [Internet]. 2013;56(2):152–61. Available from:

http://dx.doi.org/10.1016/j.ypmed.2012.12.004

7. Kriemler S, Meyer U, Martin E, Van Sluijs EMF, Andersen LB, Martin BW. Effect of school-based interventions on physical activity and fitness in children and adolescents: A review of reviews and systematic update. Br J Sports Med. 2011;45(11):923–30.

8. Dobbins M, Husson H, DeCorby K, LaRocca R. School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6 to 18. Cochrane Database Syst Rev. 2013;(2).

9. Barbosa Filho VC, Minatto G, Mota J, Silva KS, de Campos W, Lopes A da S. Promoting physical activity for children and adolescents in low- and middle-income countries: An umbrella systematic review. A review on promoting physical activity in LMIC. Prev Med (Baltim) [Internet]. 2016;88:115–26. Available from: http://dx.doi.org/10.1016/j.ypmed.2016.03.025

10. Sasaki JE, Silva KS, da Costa BGG, John D. Measurement of physical activity using accelerometers. In: Computer-Assisted and Web-Based Innovations in Psychology, Special Education, and Health. Elsevier; 2016. p. 33–60.

11. Love R, Adams J, van Sluijs EMF. Are school-based physical activity interventions effective and equitable? A meta-analysis of cluster randomized controlled trials with accelerometer-assessed activity. Obes Rev. 2019;20(6):859–70.

12. da Costa BGG, da Silva KS, da Silveira PM, Berria J, Machado AR, Petroski EL. The effect of an intervention on physical activity of moderate-and-vigorous intensity, and sedentary behavior during adolescents' time at school. Rev Bras Epidemiol. 2019;22(474184):1–12.

13. Bailey DP, Fairclough SJ, Savory LA, Denton SJ, Pang D, Deane CS, et al. Accelerometry-assessed sedentary behaviour and physical activity levels during the segmented school day in 10-14-year-old children: The HAPPY study. Eur J Pediatr. 2012;171(12):1805–13.

14. McKenzie TL, Lounsbery MAF. The pill not taken: Revisiting physical education teacher effectiveness in a public health context [Internet]. Vol. 85, Research Quarterly for Exercise and Sport. Taylor & Francis; 2014. p. 287–92. Available from: http://dx.doi.org/10.1080/02701367.2014.931203

15. Beets MW, Beighle A, Erwin HE, Huberty JL. After-School Program Impact on Physical Activity and Fitness. A Meta-Analysis. Am J Prev Med [Internet]. 2009;36(6):527–37. Available from: http://dx.doi.org/10.1016/j.amepre.2009.01.033

16. Aibar A, Bois JE, Zaragoza Casterad J, Generelo E, Paillard T, Fairclough S. Weekday and weekend physical activity patterns of French and Spanish adolescents. Eur J Sport Sci [Internet]. 2014;14(5):500–9. Available from: http://dx.doi.org/10.1080/17461391.2013.829127

17. Brooke HL, Atkin AJ, Corder K, Ekelund U, van Sluijs EMF. Changes in time-segment specific physical activity between ages 10 and 14 years: A longitudinal observational study. J Sci Med Sport [Internet]. 2016;19(1):29–34. Available from: http://dx.doi.org/10.1016/j.jsams.2014.10.003

18. Silva KS, Silva JA da, Barbosa Filho VC, Santos PC dos, Silveira PM da, Lopes MVV, et al. Protocol paper for the Movimente school-based program. Medicine (Baltimore). 2020;99(31):e21233.

19. Bandura A. Health promotion by social cognitive means. Heal Educ Behav. 2004;31(2):143–64.

20. Bronfenbrenner U. Ecological models of human development. In: International Encyclopedia of Education. 2nd ed. Oxford; 1994.

21. World Health Organization, WHO. Global action plan on physical activity 2018–2030: more active people for a healthier world. Who. Geneva: WHO; 2018. 104 p.

22. Evenson KR, Catellier DJ, Gill K, Ondrak KS, McMurray RG. Calibration of two objective measures of physical activity for children. J Sports Sci. 2008;26(14):1557–65.

23. Montoye AHK, Moore RW, Bowles HR, Korycinski R, Pfeiffer KA. Reporting accelerometer methods in physical activity intervention studies: A systematic review and recommendations for authors. Br J Sports Med. 2018;52(23):1507–16.

24. Chastin SFM, Mcgregor DE, Biddle SJH, Cardon G, Chaput J, Dall PM, et al. Striking the Right Balance : Evidence to Inform Combined Physical Activity and Sedentary Behavior Recommendations. 2021;631–7.

25. Catellier DJ, Hannan PJ, Murray DM, Addy CL, Conway TL, Yang S, et al. Imputation of missing data when measuring physical activity by accelerometry. Med Sci Sports Exerc. 2005;37(11 SUPPL.):555–62.

26. Lopes MVV, Da Costa BGG, Knebel MTG, Matias TS, Silva KS. Psychosocial correlates of objectively measured in-school and out-of-school physical activity among Brazilian adolescents. Transl Behav Med. 2021;11(10):1849–56.

27. Atkin AJ, Gorely T, Biddle SJH, Cavill N, Foster C. Interventions to promote physical activity in young people conducted in the hours immediately after school: A systematic review. Int J Behav Med. 2011;18(3):176–87.

28. Mears R, Jago R. Effectiveness of after-school interventions at increasing moderate-to-vigorous physical activity levels in 5- to 18-year olds: A systematic review and meta-analysis. Br J Sports Med. 2016;50(21):1315–24.

29. Demetriou Y, Gillison F, McKenzie TL. After-School Physical Activity Interventions on Child and Adolescent Physical Activity and Health: A Review of Reviews. Adv Phys Educ. 2017;07(02):191–215.

30. Borde R, Smith JJ, Sutherland R, Nathan N, Lubans DR. Methodological considerations and impact of school-based interventions on objectively measured physical activity in adolescents: a systematic review and meta-analysis. Obes Rev. 2017;18(4):476–90.

31. Parrish AM, Chong KH, Moriarty AL, Batterham M, Ridgers ND. Interventions to Change School Recess Activity Levels in Children and Adolescents: A Systematic Review and Meta-Analysis. Sport Med [Internet]. 2020;50(12):2145–73. Available from: https://doi.org/10.1007/s40279-020-01347-z

32. Andrade S, Lachat C, Ochoa-Aviles A, Verstraeten R, Huybregts L, Roberfroid D, et al. A school-based intervention improves physical fitness in Ecuadorian adolescents: A cluster-randomized controlled trial. Int J Behav Nutr Phys Act [Internet]. 2014;11(153):1–17. Available from: http://www.ijbnpa.org/home/%5Cnhttp://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=emed12&NEWS=N&AN=2015832274

33. Uys M, Draper CE, Hendricks S, De Villiers A, Fourie J, Steyn N, et al. Factors influencing break-time physical activity of South African primary school learners from low-income communities. J Phys Act Heal. 2015;12(5):618–27.

34. Ha AS, Burnett A, Sum R, Medic N, Ng JYY. Outcomes of the rope skipping "STAR" programme for schoolchildren. J Hum Kinet. 2015;45(1):233–40.

35. Annesi JJ, Walsh SM, Greenwood BL. Increasing Children's Voluntary Physical Activity Outside of School Hours Through Targeting Social Cognitive Theory Variables. J Prim Care Community Health. 2016 Oct;7(4):234–41.

36. Bandeira S, Pizani J, Caroline A, Campos F, Aragoni J, Minatto G, et al. Implementation of a school-based physical activity intervention for Brazilian adolescents : a mixed-methods evaluation. 2021;1–13.

37. Weatherson KA, Mckay R, Gainforth HL, Jung ME. Barriers and facilitators to the implementation of a school-based physical activity policy in Canada : application of the theoretical domains framework. 2017;1–16.

38. Lomsdal SA, Lyngstad IK, Lagestad PA. Teachers ' perceptions of barriers related to implementation of daily physical activity in secondary school : Academic pressure and the need for new competence. Teach Teach Educ [Internet]. 2022;115:103749. Available from: https://doi.org/10.1016/j.tate.2022.103749

39. Costa BGG da, Lopes MVV, Malheiros LEA, Sasaki JE, Silva KS da. Correlates of compliance with hip-worn accelerometer protocol in adolescents. Rev Bras Atividade Física Saúde. 2019;24:1–8.