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Effect of a school-based multicomponent intervention on time-segmented physical activity and sedentary behavior among adolescents: a cluster randomized control trial

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Abstract

Background Interventions have focused on evaluating effective strategies for increasing physical activity (PA) and reducing sedentary behavior (SB) in children and adolescents, which is still a challenge mainly in low- and middle-income countries. Thus, this study aimed to assess the effect of the *Movimente* Study on device-measured PA and SB in two-time segments of the school day amongst Brazilian adolescents.

Methods Six elementary schools were randomized into the intervention (IG) or control group (CG). Participants were in 7th -9th grades. 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 assessed using GT3x + ActiGraph hip-worn accelerometers. The trial's primary outcome was overall device-measured PA and SB. Exploratory secondary analyses examined PA and SB within in-School (08:00–11:59) and out-of-school (12:00–22:00) time segments. 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 IG compared to the CG for MVPA (Coefficient [Coef.] = 16.2; 95% Confidence Interval [95%CI] = 6.9;25.5; p-value = 0.001), SB (Coef. = -22.7; 95%CI = -44.7;-0.7; p-value = 0.043), and MVPA/SB ratio (Coef. = 3.2; 95%CI = 1.2;5.3; p-value = 0.002) 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.

Conclusion The *Movimente* Study was associated with greater increases in MVPA, improvements in the MVPA/SB ratio, and reductions in SB during the out-of-school period compared with control peers.

Trial registration Clinical Trials - NCT02944318.

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Keywords Exercise, Adolescent health, Sedentary lifestyle

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Introduction

Insufficient physical activity (PA) and excessive sedentary behavior (SB) during childhood and adolescence contribute substantially to the global burden of noncommunicable diseases and are associated with worse physical and psychosocial health outcomes across the life course [1–4]. Schools are a convenient and scalable setting for PA promotion because they reach most children and adolescents and allow for structured opportunities for activity (for example, physical education, recess, and classroom-based active breaks) [5–8]. However, achieving meaningful improvements in device-measured PA and reductions in SB remains challenging, particularly in low- and middle-income countries (LMIC), where prior interventions have often been limited by small samples, non-randomized designs and reliance on self-report instruments that provide imprecise estimates of activity and sedentary time [9–11].

Methodological shortcomings in many LMIC studies underscore the value of objective measurement [9]. Accelerometers provide valid, high-resolution, time-stamped data that reduce measurement error relative to questionnaires and enable examination of when during the day behavior changes occur (e.g., in-school versus out-of-school periods) [11]. Despite these advantages, accelerometer-based, randomized school intervention trials remain scarce in LMIC contexts: a recent systematic review identified only a single LMIC trial using device-based measures (Ecuador), with the vast majority of evidence originating from high-income countries [10]. Consequently, whether school-based strategies influence adolescents' activity and sedentary patterns within distinct day segments in LMICs remains poorly understood.

Investigating segment-specific effects is particularly relevant in contexts where school schedules limit in-class exposure to potential intervention activities. In Brazil, many public schools operate on half-day schedules (i.e., morning or afternoon), with students attending approximately four hours of formal instruction per day. This organization constrains the time available for in-school opportunities (e.g., recess and physical education) and may shift the locus of discretionary PA to out-of-school periods. As a result, an intervention delivered during school hours may either (a) generate measurable increases during those limited in-school windows, (b) produce changes that primarily manifest during after-school periods through enhanced motivation, parental engagement, or use of school facilities outside class time, or (c) produce compensatory responses whereby gains in one segment are offset by reductions in another. Understanding which of these patterns predominates is essential for designing interventions that yield net increases in total daily MVPA and reductions in SB across diverse educational settings [12–14].

Theory-driven, multicomponent interventions that integrate individual, social, and environmental strategies offer a promising approach to achieve meaningful behavior change. Such interventions (e.g., combining teacher training, curricular materials with family outreach, and improvements to the school environment) can simultaneously increase opportunities for activity, strengthen social support, and build individual skills and motivation. The intervention development was explicitly guided by complementary programmatic and behavioral frameworks to ensure theoretical coherence between the selected components and the hypothesized mechanisms of change. The World Health Organization's Health-Promoting Schools (HPS) framework informed the program's multisectoral structure by emphasizing four interrelated dimensions: incorporation of health topics into the formal curriculum, modification of the school social and physical environment to support healthy choices, active engagement of families and caregivers, and links with broader community resources [15]. Embedding the intervention within the HPS approach helped ensure that school-level changes were not limited to isolated activities but targeted broader organizational practices likely to sustain behavior change over time [15].

Socioecological models and behavior-change theories were then used to specify proximal mechanisms through which the intervention components were expected to operate. Socioecological thinking emphasizes interactions across levels as intrapersonal (e.g., attitudes, self-efficacy), interpersonal (e.g., social support, modelling) and environmental (e.g., access to facilities and equipment), and motivated the inclusion of components that simultaneously address individual skills, social norms and the physical opportunity to be active [16]. Social Cognitive Theory contributed specific, testable mechanisms (e.g., observational learning, reinforcement, self-efficacy and goal setting) that underpinned the teacher-training and school-based education components [17]. The Transtheoretical Model informed how materials and messages could be tailored to students at different readiness stages and encouraged incremental behavior changes consistent with stage-appropriate strategies [18]. Together, these frameworks shaped a multicomponent design in which curriculum content, teacher practices, family outreach and modest environmental improvements were selected to increase students' opportunities for MVPA, strengthen social support and modelling for active behaviors, and build individual skills and motivation to translate opportunities into sustained behavior change [19, 20]. Nevertheless, the degree to which these approaches affect device-measured PA and SB across time segments in LMICs has not been well established [21].

To address this research gap, we conducted 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. Therefore, this study aims to assess the impact of the *Movimente* Study on device-measured PA and SB among Brazilian adolescents, considering both school and out-of-school periods.

Methods

Trial design and participants

The current analysis utilizes a subsample of the *Movimente* Study data, a cluster-randomized controlled trial conducted at the elementary school level in Florianopolis, Southern Brazil. The theoretical background and methodological approach are detailed in a previous study [22]. The program was conducted over one school year (March to December 2017), with the primary outcome being to improve adolescents' PA and SB levels.

The study population comprised students enrolled in 7th to 9th grades of elementary education at municipal public schools in Florianópolis, Santa Catarina, Brazil. Schools were selected to participate in the program based on specific inclusion criteria: offering lower secondary education (grades 6th to 9th), to offer at least two classes per grade for 7th, 8th, and 9th grades, and the school building or sports court not being under renovation during the implementation of the intervention. Of the 36 municipal schools, 18 met these criteria and were deemed eligible [23].

An invitation letter was sent via email to all eligible schools, and seven agreed to participate in the study. One school was included in a pilot study, and the remaining six were matched in pairs. A randomization process, stratified by school size and geographic location, was then conducted to assign schools to either the control group (n = 3) or the intervention group (n = 3) [23].

All students in grades 7 to 9 from the six selected schools who were present during the first week of data collection (totaling 1,427 students: 796 in the intervention group and 631 in the control group) were considered eligible. However, adolescents with physical and/or intellectual disabilities, as identified by school staff or a *Movimente* program researcher, were excluded from participation. Among the eligible students, 370 did not return a signed informed consent form, and 58 withdrew from the study. As a result, the final baseline sample included 999 adolescents. Students and parents/guardians provided written consent before participation, and no incentive to participate was provided [23].

For the accelerometer sub-sample, the two smaller schools included 194 eligible students who were invited to wear devices; 157 (80.9%) provided valid baseline accelerometer data, while 37 (19.1%) did not provide valid baseline accelerometry (Additional File 1; Supplementary Table 3). The CONSORT flow diagram in Additional File 1 presents recruitment, non-participation, and reasons for missing accelerometer data in detail. The trial was registered on October 24, 2016, on the Clinical Trials platform (NCT02944318). Further details regarding all the intervention procedures can be found at https://movimente.ufsc.br/.

Theoretical rationale and integration

The *Movimente* Study was designed as a theory-driven, multicomponent program, integrating three complementary frameworks: on Social Cognitive Theory [17], Socioecological framework [24], and Health Promoting School framework [15]. This integration reflects two evidentiary premises: (1) adolescent physical activity and sedentary behavior are multiply determined across intrapersonal, interpersonal, institutional and environmental levels, and (2) achieving lasting behaviour change in schools requires both organizational integration and psychosocial processes that help turn opportunities into action.

First, the HPS framework supplied the high-level, organizational architecture for intervention delivery by defining four interrelated dimensions (e.g., curriculum, school social and physical environment, family engagement, and community links) that promote sustained adoption and normalization of health practices in schools (see Table 1 for operationalization) [15]. Placing the *Movimente* Study within the HPS framework supported alignment between classroom activities, teaching practices, environmental changes, and family engagement, an alignment previously linked to greater chances of school-level sustainability [15].

Second, socioecological theory guided selection of intervention targets across levels: intrapersonal (e.g., knowledge, skills, self-efficacy), interpersonal (e.g., teacher and family support, social norms), and environmental (e.g., availability of active spaces and equipment) [24]. The socioecological lens justified simultaneous actions to increase opportunities and to strengthen social supports, thereby reducing reliance on single-level strategies that frequently fail to overcome structural barriers common in LMIC [24].

Third, Social Cognitive Theory provided the proximal causal mechanisms expected to mediate behaviour change (e.g., observational learning, self-efficacy, outcome expectancies, goal setting, and self-regulation) [17]. These constructs directly informed the content and methods of teacher training and classroom materials so that the intervention not only increased opportunities for activity (socioecological/HPS) but also fostered the psychosocial capacities that enable adolescents to use those

Table 1 Description of the intervention components, strategies, executor and receptor agents of the movimente study

Intervention components	Actions/strategies	Executor agent	Receptor agent
Logistic support for teachers	Teacher training focused on health topics, mainly PA and SB.	Study members	All teachers
	Support material (book) with proposed activities on health topics (mainly PA and SB) (mainly PA and SB) for all disciplines.	Study members Study members and teachers of general disciplines	Teachers of general disciplines Teachers of general disciplines
	Interactive media (Facebook and WhatsApp) for teachers to disclose and discuss their activities in relation to health topics.	Study members Study members and PE teachers	PE teachers PE teachers
	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.		
Environmental improvements	Creation of new spaces.	Study members	All teachers and students
	Revitalization of old courts.	Study members Students and school manager	PE teachers and students
	PA equipment (balls, jump ropes, rackets, etc.) available to students during free-time in school.		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

opportunities. For example, teacher training targeted teachers' implementation self-efficacy and modelling behaviours, while student materials targeted outcome expectancies and self-regulatory strategies.

Collectively, these frameworks created a coherent program logic: HPS ensured organizational integration and sustainability; Socioecological Framework identified multilevel targets and necessary environmental supports; and SCT specified the psychosocial pathways through which school-based inputs were hypothesised to change behaviour. This combined approach is consistent with contemporary evidence indicating that multicomponent, multi-level interventions are more likely to produce meaningful increases in adolescent MVPA than single-component strategies. Operational details and process indicators supporting this mapping are available in Table 1 and the *Movimente* process evaluation [25].

Intervention

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.). The schools selected to be part of the control group maintained their normal activities, i.e., no received *Movimente* intervention training. After the intervention period ended, the control group schools received the *Movimente* teaching and educational materials offered at the participating schools, and a final report containing the study's main findings.

To avoid redundancy with Table 1, the narrative here provides a concise overview of intervention aims and domains; operational details are presented in Table 1. Briefly, The *Movimente* Study was a multicomponent, school-based intervention designed to increase opportunities for moderate-to-vigorous physical activity and reduce sedentary behavior among 7th–9th grade students. It combined three core domains: (1) teacher training (physical education and other subjects teachers) and classroom-based health education; (2) educational curriculum materials consisted of banners and folders containing content about PA, SB, healthy eating, and academic achievement; and (3) school-environment improvements to increase access to active spaces and equipment. The intervention components and their operational details (content, delivery agents, dose, and timing) are summarized in Table 1. More information about the actions of the *Movimente* Study can be found in Silva et al. [23].

Outcome measures

The PA and SB were measured using GT3x+ (ActiGraph, Pensacola, FL, USA) 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. [26] were used to convert the outputs into minutes of SB (≤ 100 cpm), light-intensity PA (LPA) (101–2295 cpm) and moderate- to vigorous-intensity PA (MVPA) (≥ 2296 cpm). Intervals of sustained 60-minutes of zero activity counts were defined as "non-wear-time," and thus excluded from the analysis [27]. 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) [28].

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) [22]. 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 [29]; 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 [30, 31]. Based on these definitions, the minimum required wear time criteria were 192 and 392 min 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).

Data 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. To analyze the effect size of the comparisons, Cohen's D and W were used for the t-tests for independent samples and the chi-square, respectively.

To evaluate the effect of the *Movimente* intervention on device-measured PA and SB, we fitted two-level linear mixed-effects models separately for each time segment (in-School and out-of-school). The hierarchical structure of these models comprised repeated measurements (level 1: pre- and post-intervention accelerometer summaries) nested within participants (level 2: individual students). Participant-level random intercepts were included to account for within-subject correlation across repeated assessments and to accommodate the unbalanced number of observations per participant. Fixed effects in the models included group allocation (*Movimente* vs. control), time (pre vs. post), and their interaction (group×time) to test intervention effects, with adjustment for sex and age. Model residuals were inspected to assess assumptions of homoscedasticity and approximate normality. No formal correction for multiple comparisons was applied. The primary outcome was overall device-measured PA and SB, and the time-segmented outcomes (in-school and out-of-school MVPA, LPA, SB, and MVPA/SB ratio) were pre-specified as secondary/exploratory outcomes in the trial protocol. Because these

outcomes are correlated, we reported exact p-values and 95% confidence intervals and interpreted the results with caution, particularly for secondary analyses. Results are presented as model coefficients with 95% confidence intervals. Analyses were conducted in Stata version 14.0 (StataCorp LP, College Station, TX, USA).

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 (Additional File 1).

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 2). 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 (Additional File 2). 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 (Additional File 3).

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 3). The same associations were found in sensitivity analysis done only with participants with valid data in both segments of the day (Additional File 4). There were no significant differences within- nor between- groups in any measures in the in-school time segment (Figure 1).

Discussion

The findings of this study suggest that the *Movimente* Study is related to increased MVPA, reduced SB, and favorably affects 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 [10] and after-school [32–34] strategies, but differ from the results of other systematic reviews [8–36]. For instance, of the 17 studies included in a systematic

Table 2 Baseline characteristics of participants in different segments of the day, according to the group, *Movimente* Study, Brazil, 2017

Variables	In-school time				Out-of-school			
	Movimente group (*n* = 84)	Control group (*n* = 71)	*P*-value	Effect size	*Movimente* group (*n* = 73)	Control group (*n* = 48)	*P*-value	Effect size
	Mean ± SD	Mean ± SD			Mean ± SD	Mean ± SD		
Sex	*n* (%)	*n* (%)	0.084	0.14[#]	*n* (%)	*n* (%)	0.087	0.16[#]
Female	46 (54.8)	29 (40.9)			45 (61.6)	22 (45.8)		
Male	38 (45.2)	42 (59.1)			28 (38.4)	26 (54.2)		
Age (years)	12.9 ± 1.1	13.3 ± 0.9	0.036	0.34[&]	12.9 ± 1.0	13.2 ± 0.9	0.052	0.36[&]
LPA (min/day)	55.4 ± 18.2	53.3 ± 19.0	0.479	−0.11[&]	127.4 ± 35.2	123.2 ± 30.8	0.495	−0.13[&]
MVPA (min/day)	10.0 ± 5.5	10.1 ± 6.3	0.898	0.02[&]	22.6 ± 15.8	26.4 ± 15.9	0.200	0.24[&]
SB (min/day)	174.7 ± 22.0	176.7 ± 23.0	0.580	0.09[&]	340.5 ± 45.4	340.9 ± 39.7	0.953	0.01[&]
MVPA/SB ratio (min/hour)	3.68 ± 2.5	3.70 ± 2.8	0.953	<0.01[&]	4.3 ± 3.8	4.9 ± 3.4	0.417	0.15[&]

Abbreviations: *LPA* Light-intensity Physical Activity, *MVPA* Moderate- to Vigorous-intensity Physical Activity, *SB* Sedentary Behavior, *SD* Standard deviation, [#] = Cohen's W, [&] = Cohen's D

Table 3 Effect of the *Movimente* Study on accelerometer measures among adolescents in 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	
	Coefficient (95%CI)	Coefficient (95%CI)	Coefficient (95%CI)	*P*-value
In-School				
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

All models were adjusted for sex and age. Abbreviations: *LPA* Light-intensity Physical Activity, *MVPA* Moderate- to Vigorous-intensity Physical Activity, *SB* Sedentary Behavior, 95% *CI* = 95% Confidence Interval

review [10] only three were successful in increasing device-measured MVPA in the in-school period, and the study conducted in an LMIC (i.e., Ecuador [37]) had no significant effects on overall MVPA. Another systematic review [8] showed that out of the 14 studies included, only 4 were effective in improving PA in PE classes, but none used accelerometers and neither was conducted in LMICs. A systematic review and meta-analysis of interventions aimed at school recesses [36] 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 [38]) found no significant intervention effects.

Similarly, systematic reviews [32, 33, 35] 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. [32] 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 [33] 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 min 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.

To help interpret this magnitude, current WHO guidance recommends that children and adolescents accumulate an average of 60 min/day of MVPA. In our sample, baseline MVPA averaged roughly 10.0 min/day during the in-school period and ~ 22–25 min/day during out-of-school hours (combined ≈ 32–35 min/day), implying that the observed 16.2-minute increase in the out-of-school window corresponds to an increase of ~ 27% of the 60-minute WHO target and represents a substantial relative increase compared with the sample's baseline total school-day MVPA. Importantly, this effect size is larger than the small average increases commonly reported in school-based trials [39], suggesting that the *Movimente* Study produced a meaningfully larger change in discretionary time than many prior programs. Epidemiologic and longitudinal evidence indicates that relatively modest sustained increases in MVPA (e.g., increases on the order of tens of minutes per day) are associated with favorable cardiometabolic and adiposity outcomes in youth, supporting the plausibility that the observed change could have measurable health benefits if sustained [40, 41]. The reported 16.2-minute estimate refers to the out-of-school segment rather than to whole-day MVPA; the net effect on total daily MVPA depends on whether compensatory changes occurred in other segments. Attrition in the accelerometer sub-sample and the limited number of clusters in that sub-sample also reduce precision and potentially affect generalizability. Nevertheless, the magnitude of the observed out-of-school increase is of practical interest and suggests that appropriately designed school-based multicomponent programs can produce substantial increases in discretionary MVPA among adolescents.

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 [34], the authors identified differences and similarities among 6 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. [35] by focusing specifically on the impact of school-based interventions on device-based measured MVPA found that of the 13 studies included in

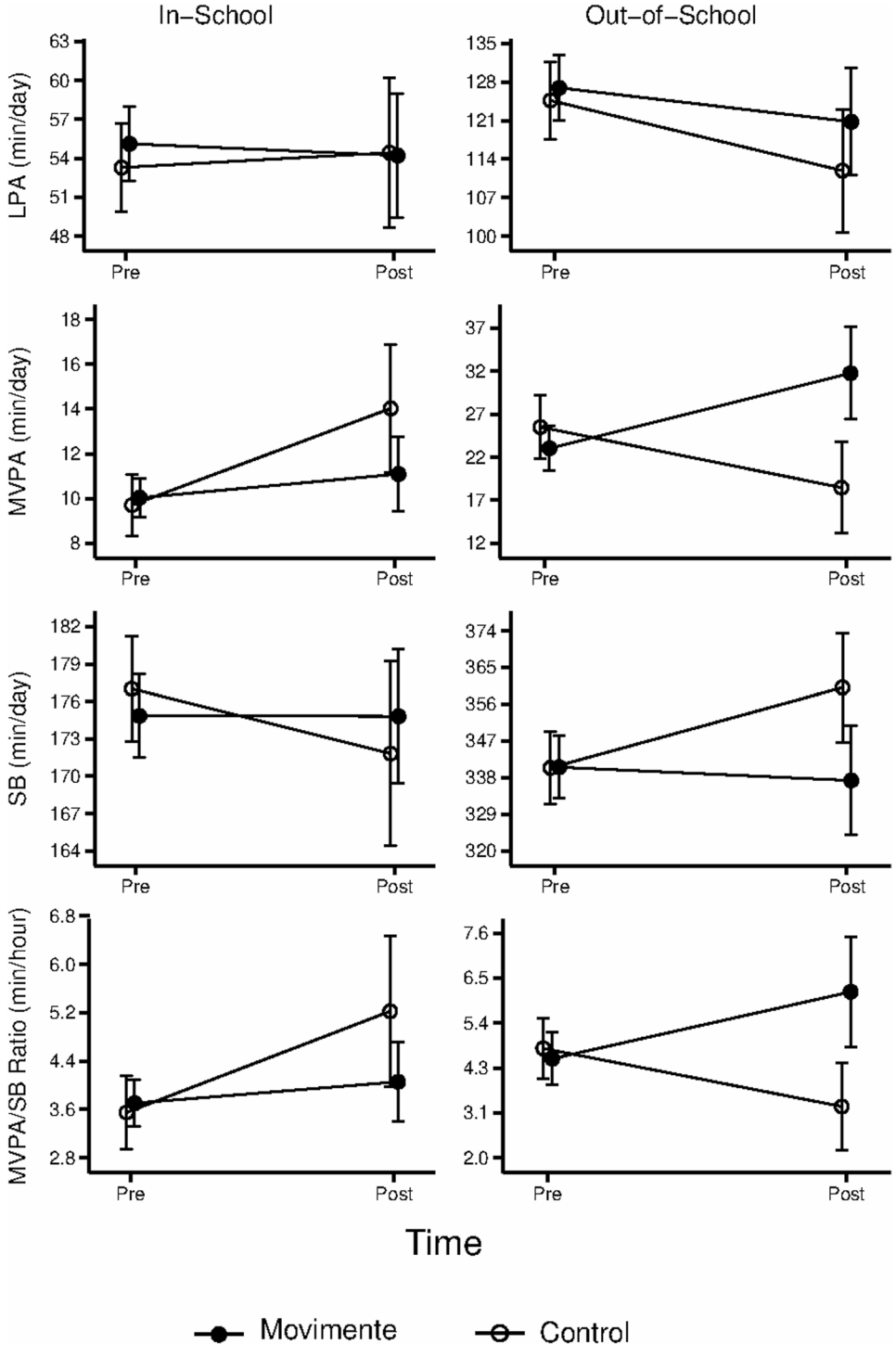

Fig. 1 Marginal means of the accelerometer measured physical activity and sedentary behavior among adolescents in the pre-and post-intervention periods according to group allocation and time segments, *Movimente* Study, Brazil, 2017.Abbreviations: LPA = Light-intensity Physical Activity; MVPA = Moderate- to Vigorous-intensity Physical Activity; SB = Sedentary Behavior

the review, only 2 were conducted in LMICs (e.g., China [42] and Ecuador [37]). The authors found that while the interventions had a positive impact on device-based 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 [30], 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 [30]. 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) [43]. 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 [30] 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 [44]). Despite the emerging literature [28] 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.

It is noteworthy that although many strategies were delivered In-school, several components were explicitly designed to influence behavior outside mandatory class hours, including educational folders and suggestions for parent–child activities, banners displayed to the school community, and the provision/revitalization of school sports facilities and equipment that students could access during non-class hours. On the other hand, while several intervention components could plausibly explain changes occurring in discretionary time, we acknowledge that alternative explanations (e.g., seasonal or measurement timing differences, selective attrition, or unmeasured external influences) cannot be fully excluded. Therefore, we interpret these findings as an association between the *Movimente* intervention and increases in out-of-school MVPA and reductions in SB, rather than definitive proof that the intervention directly caused these out-of-school changes.

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) [45], 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) [45, 46], and social influences (e.g., the school system prioritizes academics activities; students do not participate and/or cannot force them to move) [45]. Previously published data on the implementation of the *Movimente* Study [44] 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 [44]. 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 [44]. 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. According to a study by Bandeira et al. [25], a lack of involvement from the school community and parents in the *Movimente* Study was observed. Furthermore, the intervention reached only 19 of the 63 teachers (30%) who could have participated in the training. After the intervention, teachers who participated in the training were asked which topics covered during the teacher training (i.e., PA, diet, academic performance related to PA, and sedentary time) were used in their classes, and sedentary time was the least addressed. Thus, some implementation issues observed may have contributed to the lack of effect observed during the In-School period.

It is important to highlight that data collection for the *Movimente* Study was conducted in March–December 2017. Since that time, several contextual changes could influence the contemporary applicability of our findings. First, access to the internet and mobile devices in Brazil has continued to expand substantially. National surveys and child-focused studies document growing household internet penetration and frequent mobile-only access among children and adolescents [47]. Second, the COVID-19 pandemic led to significant, although partially transient, reductions in youth physical activity and changes to schooling and leisure patterns in Florianopolis [48]; several systematic reviews and meta-analyses report overall declines in children's and adolescents' activity during the pandemic period [49]. Third, global policy attention to school-based physical activity has increased [50], reinforcing the relevance of scalable school approaches despite evolving contexts.

These secular changes do not invalidate the trial's internal findings but do affect external generalizability. Increased screen access may have raised baseline out-of-school SB opportunities since 2017, potentially making interventions that successfully increase discretionary MVPA even more relevant today. At the same time, pandemic-related shifts in activity patterns and schooling modalities highlight the need for contemporary replications. We therefore interpret our out-of-school associations conservatively and recommend that future implementations and trials assess effectiveness in current cohorts and report implementation-process data to inform adaptation under present-day conditions.

Strengths and limitations

Our study has limitations to be acknowledged. A substantial proportion of eligible students did not participate or were lost to follow-up, which may have influenced both internal estimates and external generalizability. Across the six randomized schools, 428 of 1,427 eligible students (30.0%) did not take part in baseline assessments (370 did not return a signed consent; 58 withdrew prior to baseline), and in the accelerometer subsample only 67 of the 157 students with baseline valid data (~ 43%) provided valid accelerometer data at follow-up. Supplementary comparisons indicate that participants who withdrew before follow-up had higher MVPA and higher MVPA/SB ratio at baseline and differed in sex distribution in some comparisons. These patterns suggest that attrition was not completely at random and could bias estimates (e.g., by under-representing more active students at follow-up), which may affect the magnitude and the generalizability of the observed segment-specific associations. Nevertheless, we advise cautious interpretation of the segment-specific findings and recommend replication in larger subsamples or studies with higher accelerometer retention to confirm the results. 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 [51]. 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. Another methodological limitation of the present accelerometer subsample is that the inferential analyses were constrained by the small number of contributing clusters (six schools) and by relatively low participant counts per school. These sample features precluded reliable estimation of three-level hierarchical models with school- or class-level random effects, because variance components and their standard errors are known to be unstable and potentially biased when fitted with very few clusters. Consequently, our primary models used participant-level random intercepts and adjusted fixed effects, and we interpreted school-level inferences with caution. We explicitly report this limitation to assist readers in judging external validity and precision of cluster-level effect

estimates. We also provide process-evaluation details and the CONSORT flow diagram so readers can assess cluster sizes and implementation heterogeneity. Future studies with larger numbers of randomized clusters are needed to fully quantify between-school variance and to estimate school-level effect modification with confidence.

Implications for school health policy and scale-up

The intervention was associated with increased MVPA and reduced SB during the out-of-school period, but not during the in-school period, among adolescents. In contrast, the intervention was not associated with increasing LPA in both groups and periods (in-school and out-of-school). To maximize scalability in resource-constrained settings, interventions should prioritize low-cost, high-reach components that can be delivered by existing school personnel rather than external specialists. Practical activities such as structured active breaks, brief classroom-based movement prompts, and the provision of inexpensive, multipurpose equipment (e.g., jump ropes, balls, cones) can generate meaningful increases in activity while imposing minimal recurrent costs. Task-shifting (e.g., delegating core delivery functions to teachers, school coordinators, or trained community volunteers) reduces implementation costs and fosters local ownership; this approach is most effective when supported by concise, modular implementation guides and short, skills-focused training sessions that emphasise practical demonstration and in-class coaching rather than lengthy theoretical instruction.

Equally important is designing implementation supports that preserve fidelity without creating onerous monitoring burdens. Simple tools such as checklists, short fidelity logs, brief peer-observation templates, and periodic supportive supervision allow programmes to track delivery quality and identify sites needing refresher training while keeping data collection feasible for routine school use. Packaging interventions into clearly defined modules (e.g., teacher session, recess activity pack, family take-home sheet) facilitates incremental adoption, local adaptation, and phased scale-up; combined with a light-touch cost-monitoring framework, this modular, task-shifted model balances effectiveness, affordability, and sustainability in LMIC school systems.

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.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-025-25314-3.

Supplementary Material 1.

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Authors' contributions

RMC and MVVL participated in the design of the study, contributed to data collection, reduction, and analysis, and assisted with the interpretation of the results; BGGC, LEAM, and PCS contributed to data collection and interpretation of the results; LA contributed with the interpretation of the results; KSS participated in the design of the study and interpretation of the results. All authors contributed to writing the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

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Data availability

Data, script and/or other materials will be available to the corresponding author or the last co-author upon request.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Federal University of Santa Catarina's 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), all in accordance with the Declaration of Helsinki. In addition, every participant provided their consent.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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