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The effects of an active breaks intervention on physical and cognitive performance: results from the I-MOVE study

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ABSTRACT

Background The present quasi-experimental study aimed to evaluate the effects of active breaks intervention (ABs) to promote physical and cognitive improvement in primary school.

Methods The active breaks group (ABsG) performed 10 min of ABs three times per school day and the control group (CG) did normal lessons. The baseline and follow-up evaluation was conducted respectively in October 2019 and in May 2021. Cognitive performance was assessed using working memory test, physical performance was analyzed with ActiGraph accelerometers and physical fitness tests, quality of life was monitored using the Paediatric Quality of Life questionnaire (PedsQL) and classroom behavior was collected with an *ad hoc* questionnaire.

Results We enrolled 153 children (age: 7.61 ± 1.41, 54.2% males). Working memory significantly increased in the ABsG (ΔWM: 1.30 ± 1.17) than in CG (ΔWM: 0.96 ± 1.20). The 6 min Cooper test increased in the ABsG (Δ: 1.77 ± 136.03) but not in CG (Δ: −156.42 ± 187.53), $P < 0.05$. The weekly physical activity levels increased in both groups; however, the sedentary behavior significantly increased both in ABsG and CG. Children reported improvements in their quality of school life including feeling better in class and in school when using ABs; moreover, children improved their time on task behaviors in ABsG.

Conclusion The present study has proven to be effective on children's physical and cognitive performance.

Keywords health promotion, physical activity, public health

Introduction

From a perspective of educators, researchers and policy makers, physical activity has been recently defined as 'people moving, acting and performing within culturally specific spaces and contexts, and influenced by a unique array of interests, emotions, ideas, instructions and relationships'.[1] Many literature confirms that physical activity (PA) during childhood is identified as an indicator of multiple beneficial outcomes such as cardiorespiratory fitness, academic performance, cognitive function, and social and mental health.[2–5]

The World Health Organization (WHO) and several European international health agencies suggest performing at least an average of 60 min of moderate-to-vigorous physical activity (MVPA) per day in children and adolescents.[6–8] Nevertheless, the percentage of children and adolescents worldwide that meet these recommendations is very low.[9]

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According to the most recent global data, only 19% of boy and girls aged 11–17 years reach these recommendations.[9]

Regarding Europe, the prevalence of adequately active children was higher in Northern (31%), intermediate in Central (26%) and significantly lower in Southern Europe (23%).[10] Physical inactivity (PI) is defined as doing insufficient PA to meet current PA recommendations.[9] Nowadays, PI during childhood is an unhealthy lifestyle that can increase morbidity and mortality in adulthood.[11]

Defined as any waking behavior characterized by an energy expenditure of 1.5 METS or less, while in a sitting, reclining or lying posture, sedentary behaviors are more frequent in children and adolescents' daily lives.[1]

For this reason, in the more recent WHO guidelines, authors inserted recommendations on sedentary behavior that have never been included before. Sedentary behaviors can be screen-based or non-screen-based behavior.[12]

Scientific evidence suggests that higher time spent in sedentary behavior, particularly screen time, is associated with lower physical health benefits such as poorer fitness and cardiometabolic health.[13,14]

The PA levels are influenced by the opportunities to be active including limited playing spaces, unsafe environments and increased screen time habits. The most frequented environment for children is the school where they spend most of their daily time.[15] Furthermore, the school allows reaching all children regardless of age, gender, ethnicity and socioeconomic class.[15] Recent scientific literature is mainly focused on the importance of promoting PA before/during school and in the extra school time to provide additional opportunities for children to be physically active.[16–20] However, sedentary activities are still the most common habit within the school setting.[21]

Moreover, integrating PA into the school day might have not only physical health benefits.

New evidence suggests that school-based PA interventions could be beneficial for cognitive performance, working memory, attention, processing speed, classroom behavior and academic achievement in children.[22–25]

A recent publication from Sanders *et al*. suggests that to create a healthy school day, it is fundamental to break up prolonged periods of sedentary activities with both scheduled and non-scheduled breaks. In particular, in 5–11 school-aged children, it is necessary to break the sedentary time at least one time every 30 min performing movement activities.[12]

In particular, the interest in the use of PA within curricular lessons is growing during the last few years especially regarding ABs.[18,19,26,27] Active breaks involve short bouts of MVPA conducted by appropriately trained teachers and delivered during or between curricular lessons.

A recent systematic review suggests that multicomponent interventions that incorporate PA throughout the school day (e.g. physically active lessons, physical active breaks) may have the strongest impact on time spent in MVPA.[28]

To date, the ABs interventions have shown, albeit with great heterogeneity, an effect on different health outcomes including PA, cognitive health and classroom behavior. However, these results require further confirmation.[19,26,27,29] Most of the ABs studies included in recent reviews had a common limitation, consisting in short duration of the intervention from a few weeks[29,30] to a maximum of one school year.[31]

In light of these findings and of a growing body of evidence,[19–22,26–29] we started a multiple targeted quasi-experimental study in 2019: the Imola Active Breaks (I-MOVE) Study.[32] To our knowledge, the I-MOVE study is one of the first studies conducted in Italy, with a long-term follow-up and with innovative ABs intervention including high-intensity interval training (HIIT) exercises.

The goal of the study was to evaluate the effect of an ABs intervention on physical health and cognitive functioning. We hypothesized that ABs lead to improved weekly MVPA levels, improved cognitive performance and better outcomes in terms of children's classroom behavior.

Materials and methods

Study design and participants

The I-MOVE study was a quasi-experimental study[33] conducted with primary school children living in the city of Imola, Emilia-Romagna, Italy.

The Bioethics Committee of the University of Bologna approved the I-MOVE study, on 18 March 2019 (Prot. n. 0054382 of 18/03/2019-[UOR: SI017107-Classif. III/13]), and the study was endorsed by the University of Bologna (Italy). The study was conducted following the Declaration of Helsinki and approved by the school board.

School and participant recruitment was conducted in 2019 and described in detail in the research protocol.[32] First, invitation letters were sent to the principals of schools of the city of Imola. One school expressed interest in participating in the I-MOVE project and 10 teachers of 5 classes agreed to be involved in the project. Teachers interested in being part of the experimental group attended a training course of 8 h to learn the basis of the project and the practical part of the ABs intervention. The teachers who were involved in the training and then in the project taught various school subjects including mathematics, science, Italian and English.

Sample size was previously calculated based on previous pilot and feasibility study[29] considering ActiGraph accelerometers as a primary outcome measure of the study With an alpha error of 0.05 and a power of at least 0.8, the minimum size of the sample was estimated as 48 participants per group, for a total of 96 participants.

Intervention

The ABs intervention protocol was based on the previous pilot study.[29] Teachers participated in a specific training conducted by kinesiologists receiving a detailed manual of the proposed exercises. The training was focused on an initial theoretical part of scientific evidence regarding active breaks and a practical part on how to perform and manage active breaks. The Active Breaks group (ABsG) performed the ABs for 1 year and a half while the control group (CG) continued with normal curricular lessons.

The ABsG performed the I-MOVE protocol three times per school day, when the teachers thought it would be more appropriate. Each AB started with a warm-up part of 2 min focused on cardiorespiratory and mobility exercises, the central 5 min tone up part contained exercises with HIIT, consisting of 40 s of MVPA alternated with 20 s of recovery, with a specific focus on coordination, balance and cognitive task. During the last 3 cool-down minutes, children performed stretching, relaxation and breathing control exercises. After this final part, all classes re-engaged the academic lesson. The ABsG started the ABs intervention in October 2019. During the pandemic period, the interventions were administered following the same structure explained previously. However, teachers were suggested to do the ABs outside classes (i.e. garden, corridor, playground) or if they conducted the ABs inside classes, we recommended to choose a simple exercise that is easy to perform near a desk.

Data collection and outcome measures during COVID-19 pandemic

The COVID-19 pandemic and the subsequent containment restrictions inevitably led to certain design changes in the study. First of all, during the lockdown (March 2020–June 2020), the ABs protocol was conducted through distance learning. When the school academic lessons resumed in person (from September 2020), it was recommended that teachers conducted ABs in the classroom using masks and observing physical distancing. Where possible, teachers could perform ABs outdoors in the courtyards or gardens to achieve higher intensities.

The baseline and follow-up assessments were conducted in October 2019 and in May 2021 respectively. Socio-demographic information was obtained during the baseline assessment.[32] All the described questionnaires and tests were performed in a manner compliant with pandemic regulations.

Anthropometric measures

Anthropometric characteristics were collected by staff researchers using standard procedures.[34,35] Body mass index (BMI) was used to assess children's weight status according to the recommended Cole cut-off values by sex and age.[36,37] Considering the strict school rules imposed during the pandemic and the importance of maintaining physical distancing, the research team could not carry out anthropometric measurements during the final assessment. Hence, the parents of children participating in the I-MOVE study self-reported anthropometric characteristics of their child, i.e. height and weight, using an online questionnaire administered in May 2021.

Physical activity and sedentary behavior outcomes

The ActiGraph accelerometer model was GT3X (ActiGraph LCC, Pensacola, FL, USA) and it was used to monitor PA levels and sedentary behavior. We used specific inclusion criteria for wear time validation consisting of at least 3 weekdays and 1 weekend day, and for at least 10 h every day (including sleeping hours). We examined the accelerometer data through ActiLife 6.13.3 software (ActiGraph). The epoch length was settled to 10 s to allow a more detailed estimate of PA intensity.[38]

Children were instructed to wear the ActiGraph, over a 7-day period (five weekdays and two weekend days), on their right hip using a waistband[39] removing the accelerometer during water activities (e.g. showering, swimming). The data were analyzed using cut-points recommended by Evenson to calculate the minutes spent per type of PA (light, moderate and vigorous) per day.[40] During follow-up evaluation, the same procedure was applied. Physical activity levels were also calculated using the valid and reliable self-reported Physical Activity for Children Questionnaire (PAQ-C). The questionnaire is a self-administered, 7-day recall questionnaire and used to examine the reported PA during school time, leisure time and PA during sport activities.[41] This questionnaire has been shown to be valid and reliable.[41]

Classroom behavior and cognitive function outcomes

We designed an *ad hoc* self-administered Active Break Questionnaire to investigate several aspects related to classroom behavior, as well as satisfaction and motivation to comply with the instructional program. Both the children and the teachers of the ABsG completed the questionnaire. Children's questionnaire included items investigating satisfaction, feelings and pleasure in performing ABs as well as changes in their classroom behavior, attention and well-being (i.e. I feel better in school, I listen easily). The answers were divided into three qualitatively distinct answers formats (yes: If children agreed with the statement, yes/no: if children partially agreed with the statement; no: if children did not agree with the statement). The teacher questionnaire included various domains regarding the level of satisfaction, feasibility, effectiveness and management of the ABs. The questionnaire included 18 items exploring potential changes in the classroom behavior time, children's well-being, learning and attention capacity and also their personal attitude in managing, implementing and organizing ABs to facilitate the teaching activity. Teachers were asked to provide a score from 1 to 5 for each question.

The working memory cognitive test was administered taking into account of social distancing and school policy. Verbal working memory was assessed by means of the backward digit span, a subtest of the Wechsler Intelligence Scale for Children (WISC-IV).[42] The WM test consisted in a verbal presentation of digit series and requires children to repeat the series in reverse order. The score was calculated as the highest number of correct digits remembered.

Physical fitness outcomes

The health-related PF test included 6 min running test,[43,44] 6 min walking test (used only in younger children)[45] and standing long jump test.[46,47]

Quality-of-life outcomes

The Pediatric Quality of Life Questionnaire 4.0 (PedsQL)[48] was used to monitor the health-related quality of life in the children (HRQoL) and to assess important determinants of health such as daily activities, physical health, social interactions and emotional well-being. The PedsQL presents 23 items (Total-PedsQL) divided into two domains that were used to assess the children's level of Physical (PF-8 items) and Psychosocial health (PF-15 items). The PedsQL 4.0 is a reliable and a valid questionnaire for school health settings application.[48]

Statistical analysis

Statistical analysis was performed using SPSS (Statistical Package for Social Science) (SPSS Inc. Chicago, IL, USA). The Gaussian distribution of the data was ascertained through the 'explore' function. Summary descriptive statistics for continuous measures were reported as means and standard deviations and descriptive information for categorical variables was presented as frequency (percentages) for both ABsG and CG at baseline and follow-up. Differences in continuous variables from baseline to follow-up were analyzed within groups, using the paired-samples *t*-test for continuous variables and chi-square test for categorical measures. Between-group differences over time were analyzed using analysis of covariance (ANCOVA) adjusted for baseline measures.

The effect size (Cohen's *d*) was determined by calculating the mean difference between groups, and then dividing the result by the pooled standard deviation. A *P* value lower than 0.05 was considered statistically significant.

Results

Figure 1 shows the flow chart for participating children across the intervention study.

In October 2019, 153 participants were enrolled but only 133 completed the study in 2021. Parents of 16 children withdrew consent to participate in the assessment due to COVID-19 and 4 children moved to a different school.

Table 1 reports the participant's characteristics at baseline in 2019 and the differences between ABsG and CG. The mean age in ABsG was 7.66 ± 1.50 with 49.4% female while in the CG the mean age was 7.92 ± 1.26 with 44.0% female. No significant differences between groups were found regarding age, sex, anthropometric conditions and educational level of the parents/tutors.

Anthropometric and physical fitness results

Change in anthropometric measures between ABsG and CG before and after the intervention is represented in Table 2. The percentage of children in the normal weight category in the ABsG increased (from 71.6% to 74.1%), whereas the percentage of children with normal weight in the CG decreased (from 56.4% to 53.8%). Likewise, the percentage of children in the overweight/obesity category increased in CG and decreased in ABsG with significative differences between the two groups ($P = 0.02$). The 6 min Cooper test performance in the CG was significantly lower from baseline to follow-up (change: −156.42 ± 187.53, $P = 0.005$). There were significant between-group differences even with adjustment for baseline values. For the standing long jump, both children in the ABsG and CG significantly improved their performance; however, no statistically significant differences were found between the two groups.

Cognitive functioning results

Working memory performance significantly increased from baseline to follow-up in both ABsG and CG. However, the change was significantly larger for the ABsG ($P = 0.05$) (Table 2).

Objective and self-reported PA

Table 2 shows the mean activity counts registered by accelerometer for the ABsG and CG. ActiGraph results show that the weekly time spent in MVPA increased in both groups

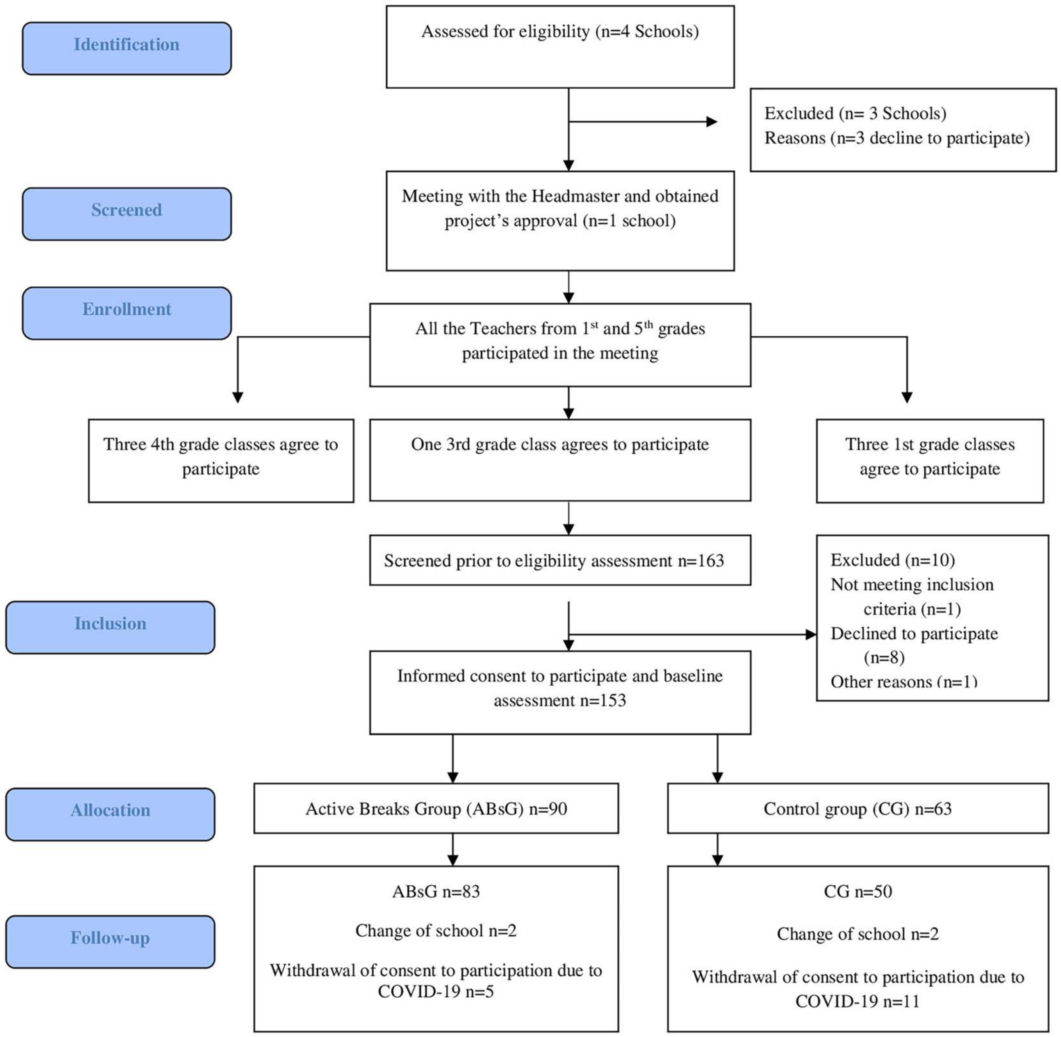

Fig 1 I-MOVE flowchart of the study participants.

from baseline to follow-up with no statistically significant difference between groups (Table 2). Examination of the difference in PA intensities from baseline to follow-up shows that both the ABsG and CG children increased their minutes spent in vigorous PA, albeit these gains were not significantly different both within and between groups.

Time spent in moderate PA significantly increased within both groups, but the between-group differences were not significant. Minutes spent in light PA significantly increased only in the ABsG (+112.91 ± 361.64, $P = 0.007$) compared to CG (+97.41 ± 430.69, $P = 0.36$). The time spent in sedentary behavior significantly increased both in ABsG and CG ($P = 0.001$), but no significant differences were observed between the groups. Both groups significantly decreased in their self-reported PA levels using the PAQ-c questionnaire from baseline to follow-up ($P = 0.05$). None of the between-group differences were significant.

Health-related quality of life

There were no significant differences between groups for the HRQoL (Ped-QL); however, within each group there were statistically significant improvements for the total score. Psychosocial health significantly improved only in the ABsG ($P = 0.012$), as shown in Table 2.

Classroom behavior

Figure 2 shows the results of the classroom behavior and satisfaction questionnaire data after 1 year and a half of the Active Breaks intervention.

Almost the entire sample of children wanted to continue with the intervention in the next year; they enjoyed and had fun with the intervention. Children reported improvements in their quality of school life including feeling better in class (75.40%) and in school (82.50%) when using active breaks. There were also improvements in their time on task behaviors:

Table 1 Baseline samples' characteristics

Variables	*ABsG (n = 83)* *Mean ± SD or %*	*CG (n = 50)* *Mean ± SD or %*	*P value*
Age (*n*, years)	7.66 ± 1.50	7.72 ± 1.25	0.812
Male (*n*, %)	42 (50.6%)	28 (56.0%)	0.336
Female (*n*, %)	41 (49.4%)	22 (44.0%)	
BMI total (score)	17.45 ± 2.78	18.01 ± 2.66	0.261
BMI IOTF category			0.075
Normal weight (*n*, %)	58 (71.6%)	22 (56.4%)	
Overweight/obese (*n*, %)	23 (28.4%)	22 (43.6%)	
Mother education			0.249
Low, middle school or lower (*n*, %)	9 (12.5)	8 (19.5%)	
Medium, high school (*n*, %)	31 (43.1%)	21 (51.2%)	
High, university degree or higher (*n*, %)	32 (43.4%)	12 (29.3%)	
Father education			0.969
Low (*n*, %)	15 (21.1%)	9 (22.5%)	
Medium (*n*, %)	39 (54.9%)	21 (52.5%)	
High (*n*, %)	18 (23.9%)	10 (25.0%)	

BMI: body mass index

52.90% reported they work easily in class, 58.80% reported they can stay seated easily, 52.90% said they could listen more clearly, and 59.60% said they learned better and were more focused after ABs.

Teacher's perception

Table 3 shows teachers' responses after the AB intervention. The classroom behavior total score significantly improved from baseline to follow-up ($P = 0.01$). Analysis of the sub-domains of classroom behavior also showed a significant improvement in the children's well-being and learning skills ($+2.57 \pm 1.90$ and $+2.43 \pm 2.44$, respectively). The last domain regarding teaching activity increased from baseline to follow-up, however, without reaching the statistical significance.

Discussion

Main finding of this study

The I-MOVE study investigated the effect of a 10 min ABs intervention on physical and cognitive health over the course of one year and a half. The program demonstrated a positive effect on the children's cognitive and cardio-fitness performance, anthropometric measures and classroom behavior.

With regard to cognitive functioning, the intervention findings show that both ABsG and CG improved working memory performance. Much of this may be age related as children in this age group undergo rapid cognitive development.[49] However, children in the ABsG obtained a statistically significant improvement post-intervention suggesting a beneficial effect of ABs in increasing working memory performance. As confirmed by recent literatures, acute and chronic PA can improve students' cognitive functioning the latter including working memory, attention and processing speed.[22,50]

What is already known on this topic

These findings are in line with other previous studies that confirmed the use of classroom-based PA as part of standard lessons can achieve positive effects on cognitive functioning.[51–53]

The results of the intervention also showed promising findings with regard to physical health. In particular, PF test showed that the ABs intervention with HIIT exercises can facilitate maintaining cardio-fitness performance. The study hypothesis suggested that high-intensity exercises provide a protective effect supporting fitness performance, which dramatically dropped over time in the control group. Very few studies have emphasized the effect of ABs in PF status[54]; however, this is a fundamental marker of health in childhood. Future interventions should continue to monitor physical fitness status using motor tests.[55] The HIIT exercises included in the middle part of ABs contained not only cardiorespiratory fitness exercises but also speed and agility games, which are fundamental in the development of physical fitness status.[55]

Both objective and reported PA measures did not significantly change between the two experimental conditions after

Table 2 Changes from baseline to follow-up after the intervention in both groups

Table 2a Changes in physical health from baseline to follow-up after the intervention in both groups

Variables	*ABsG (mean ± SD or %)*				*CG (mean ± SD or %)*					
	Baseline	*Follow-up*	*Change*	*Within P value*	*Baseline*	*Follow-up*	*Change*	*Within P value*	*Between P value*	*Effect size*
Anthropometric condition									0.02*	
Normal weight	58 (71.6%)	60 (74.1%)			22 (56.4%)	21 (53.8%)				
Overweight/obese	23 (28.4%)	21 (25.9%)			17 (43.6%)	18 (46.2%)				
Cardio-fitness test										
6 Minute Cooper (m)	902.76 ± 130.30	904.53 ± 178.28	+1.77 ± 136.03	0.94	958.77 ± 155.00	802.35 ± 127.97	+156.42 ± 187.53	0.005*	0.01*	0.66
Standing long jump	113.58 ± 23.62	127.36 ± 29.78	+13.78 ± 21.80	0.01*	110.77 ± 18.96	128.06 ± 19.31	+17.29± 12.87	0.01*	0.37	0.03
Objective PA										
Weekly MVPA (min)	348.88 ± 128.27	371.05 ± 149.14	+23.16 ± 129.82	0.12	295.60 ± 100.98	346.80 ± 136.05	+51.20 ± 115.71	0.004*	0.61	0.17
Vigorous PA (min)	120.94 ± 62.64	126.72 ± 70.70	+5.78 ± 65.84	0.44	104.16 ± 49.81	115.71 ± 61.22	+11.55 ± 52.58	0.14	0.95	0.17
Moderate PA (min)	227.95 ± 72.96	245.33 ± 87.57	+17.39 ± 74.91	0.04*	191.44 ± 59.36	231.09 ± 87.66	+39.65 ± 81.95	0.001*	0.46	0.16
Light PA (min)	1739.37 ± 317.62	1852.27 ± 519.15	+112.91 ± 361.64	0.007*	1625.90 ± 327.73	1723.31 ± 396.35	+97.41 ± 430.69	0.12	0.36	0.28
Sedentary behavior (min)	6551.74± 405.41	7760.0 ± 462.52	+1208.29 ± 416.00	0.001*	6734.00 ± 428.44	7812±828.62	+1077.97 ± 645.21	0.001*	0.59	0.08
Self-reported PA										
PAQ-c score	3.03 ± 0.74	2.75 ± 0.71	−0.28 ± 0.70	0.05*	3.32 ± 0.43	2.93 ± 0.46	−0.38 ± 0.56	0.05*	0.60	0.30

Table 2b Changes in cognitive function and quality of life from baseline to follow-up after the intervention in both groups

Variables	*ABsG (mean ± SD or %)*				*CG (mean ± SD or %)*					
	Baseline	*Follow-up*	*Change*	*Within P value*	*Baseline*	*Follow-up*	*Change*	*Within P value*	*Between P value*	*Effect size*
Cognitive function										
Working memory (point)	3.06 ± 1.11	4.36 ± 1.22	+1.30 ± 1.17	0.001*	2.98 ± 0.92	3.94 ± 1.03	+0.96 ± 1.20	0.001*	0.05*	0.37
Health-related quality of life										
PedsQL total score	72.14 ± 13.13	79.74 ± 11.00	+7.60 ± 14.28	<0.001*	69.71 ± 12.92	77.90 ± 10.49	+8.19 ± 17.43	0.022*	0.56	0.17
Physical Health	72.28 ± 15.21	82.06 ± 12.66	+9.78 ± 16.27	<0.001*	74.21 ± 12.70	83.45 ± 9.84	+9.24 ± 16.40	0.007*	0.71	0.12
Psychosocial Health	72.06 ± 15.04	78.50 ± 11.88	+6.44 ± 17.41	0.012*	67.35 ± 15.87	74.94 ± 12.43	+7.59 ± 20.28	0.06	0.28	0.29

[a]Within-group changes are compared using paired *t*-test.

[b]Between groups are compared using ANCOVA adjusting for baseline values.

*Significant *P* value < 0.05.

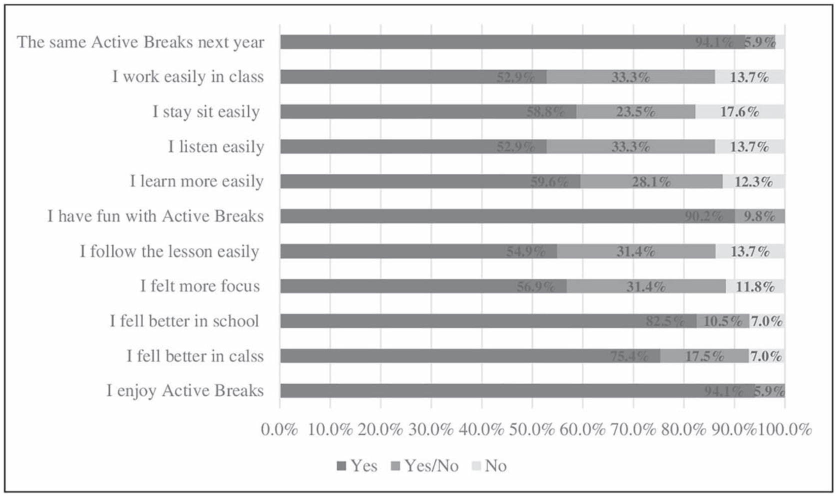

Fig 2 Classroom behavior and satisfaction questionnaire.

Table 3 Teachers' perception of classroom behavior questionnaire in ABsG

Variables (N = 7)	*Baseline Mean ± SD*	*Follow-up Mean ± SD*	*Change Mean ± SD*	*P values*
Classroom behavior (total score)	50.57 ± 9.90	56.71 ± 11.50	+6.14 ± 3.85	0.01*
Children's well-being	17.00 ± 3.87	19.57 ± 4.31	+2.57 ± 1.90	0.01*
Children's learning	16.14 ± 2.61	18.57 ± 4.20	+2.43 ± 2.44	0.04*
Teaching activity	17.43 ± 3.95	18.57 ± 3.16	+1.14 ± 1.45	0.07

Within-group changes are compared using paired *t*-test. *Significant $P < 0.05$.

the intervention although there was a trend toward improvement in both groups with increasingly higher levels of all ActiGraph values in the ABsG. Previous studies, even those with short duration, found a favorable effect of ABs on students' PA levels on the way to promote healthy lifestyle.[19,28–30,56,57] There were no ABs effects found for time spent in sedentary behavior; both ABsG and CG increased the time spent in sedentary behavior from baseline to follow-up. This result is probably related to the impact of COVID-19 on PA levels and sedentary behavior among children and adolescents.[58] Neil-Sztramko *et al*.'s Cochrane systematic review[28] found that school-based interventions promoting PA and PF in children had little to no impact on overall time spent in MVPA and may have little to no impact on time spent sedentary. However, the authors highlighted that within school-based interventions, the most effective for increasing MVPA were active breaks.[28]

What this study adds

The I-MOVE study lasted 1.5 years during which time the pandemic forced some changes regarding the ABs protocol. Most important was the health regulations regarding the lockdown, during which time children's physical activities were strictly regulated, and they engaged in distance learning. As a result, COVID-19 significantly altered habits and lifestyles, especially in children and adolescents and especially relevant to PA and sports.[58] To date, children in our sample improved their levels of PA after experiencing substantial changes during COVID-19.[58] Even then, the scores on the PAQ-c questionnaire pertaining to sport and PA out of school remained very low. Likewise, the minutes of sedentary lifestyle increased compared to 2019 and this could be a long-term effect of COVID-19.[59–61] In light of this, the potential effect of active breaks in increasing PA levels and reducing sedentary behavior during the COVID-19 pandemic remains unclear.

With respect to children's health-related quality of life, no effect between groups was found in the physical or the psychological domain.

Notwithstanding, there is still a growing interest in the effects of multicomponent intervention based on PA in the area of health-related quality of life. Kvalø *et al.* found positive effects on children's self-reported psychological well-being, social support and peers, and school environment in a randomized control trial implementing a multicomponent intervention consisting in physically active lessons, with ABs and homework.[62] Papadopoulos *et al*. indicated that the integration of brief ABs may support PA enjoyment and quality-of-life perceptions that can contribute to children's subjective well-being.[63] Findings from a recent systematic review suggest that the integration of ABs may promote children's subjective well-being and enjoyment in PA. However, it is fundamental taking into account that studies included in the systematic reviews conducted by Papadopoulos *et al.*[63] were performed before COVID-19.

Overall, in line with these results, in our study children expressed positive evaluations toward the ABs intervention. In fact, they felt better at school, were more focused, and they experienced enjoyment and a desire to continue the intervention in the future. The experimental teachers highlighted a general improvement in classroom behavior focused mainly on the children's well-being and learning skills. These positive results comport with other similar studies that analyzed ABs' effect in improving classroom behavior.[20,56,62,64–66] Teachers reported a positive but non-significant trend in improving their work using ABs; however, this outcome requires more investigation due to the small sample of teachers involved in the study.

Positive satisfaction, reported by both children and teachers, represents an important aspect of the feasibility of ABs intervention in a primary school context.

Limitations of this study

The I-MOVE study contains some limitations worth noting. First, during the COVID-19 pandemic, the Italian schools changed the structure of students' lessons, favoring either distance learning or if possible outdoor activities. These changes could explain the increase in PA levels in the control group, which then diminishes any experimental effects. Furthermore, teachers did not adhere totally to the protocol during distance learning and this deviation may diminish the potential long-term benefits of ABs. Furthermore, given COVID-19 restrictions, at one point in time we had to rely on parents to provide metrics including BMI data for their children. This change in assessment strategy erases any standardization of methods.

A further limitation of the study concerned the analysis of sedentary lifestyle through accelerometers. Although objectively monitoring the minutes spent in sedentary activity is very important, the accelerometer often does not take into account the different types of sedentary lifestyle such as screen-based sedentary behavior. As regards HRQoL, we used the PedsQL questionnaire to assess the health-related quality of life in the pediatric population; probably this questionnaire is not the gold standard for healthy population.

Conclusion

The I-MOVE study showed that the intervention was effective in improving cognitive functioning, physical health and classroom behavior. Despite various difficulties associated with the pandemic, ABs and in particular the HIIT exercises proved to be sustainable and to play a protective role with regard to physical fitness and weight status. However, additional studies are needed with larger sample sizes and with more objective measures to demonstrate a lasting anthropometric effect from ABs. In conclusion, ABs represent a cost-efficacy strategy to be implemented in the school setting in order to make the school a more dynamic environment for both physical and cognitive health.

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Conflict of Interest

The Authors declare no conflict of interest.

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Author contributions

A.M., L.D. and A.C. conceived the study. A.M., L.D., A.C., M.L., R.S., M.C.B., A.S., L.B. and A.T. contributed to the study design. A.M. drafted the manuscript, which was integrated with important intellectual content by all authors. A.M., L.D. and A.C. collected and imputed the data. A.M., S.M., G.B., A.C., S.T. and D.G. conducted the evaluation on the sample. A.M. and L.D. performed the statistical analysis. L.D. and A.C. supervised the study. The final manuscript was read and approved by all of the authors. All authors have read and agreed to the published version of the manuscript.

Data availability statement

The data presented in this study are available on request from thecorresponding author. The data are not publicly available due to ethical and privacy reasons.

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