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Effects of physical active breaks on vigilance performance in schoolchildren of 10–11 years

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ABSTRACT
Purpose. The main aim of this research analyses acute PE based on AB and how it might have an exponential affect during the school day.
Methods. A total of 46 healthy schoolchildren (age = 10.75 ± 0.65 years) participated in this study, receiving a traditional lesson of 25 min during the assigned class followed by 10 min of a free-reading task (Control Condition) or 10 min of physical activity based on motor games (Active-Break Condition). Immediately following the assigned 10-min. intervention, the participants performed the Psychomotor Vigilance Task (PVT) then finally returned to perform the traditional lesson for the remaining 15 min. Significant differences were found in the PVT.
Results. Our results show the main effect of the Active-Break Condition group responding faster (365 ms) than the students in the Control Condition group (379 ms), $F_{(1.45)} = 24.18$, $p = 0.001$, $\eta^2 = 0.34$. The present study demonstrated that a student's vigilance performance changes after of AB of 10 min (compared to the Control Condition) and that AB improves the efficiency of vigilance in schoolchildren of 10–11 years.
Conclusions. Although limited, our results could help researchers and teachers more accurately apply AB to more properly improve their students' vigilance. More studies with EEG analysis and neuroimaging are necessary to understand the effects of AB in young students.
Key words: acute exercise, active breaks, cognition, schoolchildren, neuroscience

Introduction

In recent years, several studies have shown the important effects of active breaks in the academic setting [1, 2]. This may be because schoolchildren in an hour-long class need to stay vigilant in order to respond to the unexpected questions of the teacher [3]. Vigilance is a high-order function required to maintain attention during prolonged periods and determines goal maintenance and the use of selective attention in order to respond appropriately (quickly and accurately) to relevant stimuli [4, 5]. Previous studies have demonstrated that vigilance suffers attentional fluctuations or oscillations that happen during the course of the task and normally increases the time-on-task [6]. Researchers have suggested that these changes could be produced by fatigue caused by sleep deprivation [7] or by the long duration of the task [8], among other reasons. Therefore, gaining a deep knowledge of the factors influencing vigilance is extremely important to current research. In this sense, an appropriate level of vigilance is critical during performance in various everyday activities, e.g., driving [9, 10], studying [2, 11], health control [12], professional driving [13, 14], inspection and

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detection [15], which also influence the functioning of other high-level attention mechanisms, e.g., cognitive control [16]. Thus, it can be suggested that vigilance could be exponentially modified during the school day and that AB (Acute PE) could positively influence this [17, 18].

A first look at the literature reveals that the largest group of studies were conducted to assess the influence of acute PE on performance [19–21] and to analyse the influence of attention to academic performance [22–24]. In fact, a loss of attentional focus during ordinary classes decreases students learning [25]. Thus, improvements in the functionality of attentional sets will improve memory setting and knowledge acquisition [26]. This performance is affected by the inhibitory control and executive functions, both responsible for keeping information in working memory, strategy learning and organisation, selective attention and behaviour control [27]. Consequently, further research is required to examine how to focus or activate students during class time, to improve their cognitive performance and therefore their academic performance [28].

An AB could be defined as a period of PE organised between sedentary class sessions [29]. In fact, using this traditional didactic methodology in class causes boredom, cognitive overload, monotony throughout the school day and always takes place in a completely passive situation [30]. The current scientific literature broadly supports the importance of PE within the educational context [31]. There are many fundamentals that will improve the daily life of students from a multifactorial perspective, either physical [32] or cognitive [27, 31, 33]. Remarkable was the study of González-Fernández et al. [34], which demonstrated that 8 weeks of physical training has an effect on vigilance performance and improves the efficiency of vigilance in high school students. In addition, other studies in primary schools reported that AB led to improvements in physical fitness and anthropometrical measures or improvements in students' health. In fact, an important systematic review with meta-analysis performed by Infantes-Paniagua et al. [35] about Active School Breaks and students' attention concluded that the results do not clearly point to the positive effects of AB. A moderate intensity and the facilitator of the AB (general teacher or specialist on physical education) appear to have been the main factors in obtaining positive effects. In this sense, a cursory look at the literature reveals thousands of studies investigating vigilance with participants performing at rest. This modulation of cognitive performance has been reported in a variety of tasks [ranging from simple Reaction Time (RT) tasks to cognitive control and memory tasks] and using a number of different exercise protocols [24, 36]. However, few studies have reported behavioural measures of vigilance performance after exercise in school environment with children and adolescents [37–39]. This is rather surprising, at least in the field of sport sciences, because of the maintenance of optimal performance during the course of the class. In fact, the majority of studies among adults have shown a positive effect of acute exercise on attention [40] and information processing speed [41]. In this way, we can justify that AB, via acute exercise, could be linked to momentary changes in arousal [42] induced by physiological changes (e.g., cerebral blood flow, overall increase in temperature, increase in neurotransmitters such as serotonin, noradrenaline or dopamine [43], as well as blood lactate and plasma catecholamines, cortical activation) [44, 45]. It should be added that the above-mentioned physiological changes depend on the intensity of the exercise [46]. Thus, it is generally recognised that enhancements in cognitive performance have been linked with light-to-moderate intensity exercise, while lower and higher intensities result in performance deterioration or insignificant changes [47]. In fact, this set of physiological consequences seems to cause an improvement in learning ability and the subsequent academic performance [48, 49].

Therefore, the aim of the present research was to examine the acute effects of 10-min of AB on a psychomotor vigilance task (PVT) in schoolchildren of 10–11 years. According to the literature, methodologies applied in the classroom are evolving from very directive masterclasses to more active methodologies (cooperative learning, problem-based learning, project-based learning, simulations, etc.). This situation generates a context of scientific need to search daily dynamics within schools to improve attention and which in turn are based on physical exercise. Therefore, knowing that research shows that brain health is connected to regular, showing that students could learn different subjects more easily if multiple areas of the curriculum were connected with appropriate physical activity exercises, we suggest that AB could help to maintain attention and promote the absorption of knowledge after such breaks [50].

Material and methods

Participants

A total of 46 healthy schoolchildren (age = 10.75 ± 0.65 years) from one primary school in the region of

Andalucía (Spain) were enrolled in the study (see Table 1 for the data). We found a balanced distribution by sex, with 24 females (52.17%) and 22 males (47.83%) in the group. Participants were recruited from one village in the province of Jaén with a population ranging between 5,000 and 10,000 inhabitants registered in the Spanish Statistical Office of the Spanish government (http://www.ine.es/).

This study includes participants who were selected through the advisor of the centre and the Physical Education teacher. They read and signed an informed consent statement before participating in the study. Their parents or guardians were also given information about the main aims of the investigation, and they signed an informed consent form.

Inclusion criteria for the participants in this study were (i) report normal vision and no history of any neuropsychological impairments that could affect the results of the experiment, (ii) have no health problem that could bias any result or prevent them from participating in the study's tests, (iii) obtain parental authorisation, and (iv) participate in all experimental sessions during the study period.

Table 1. Participants' characteristics (mean ± *SD*) of the present study

	Students (n = 46)
Age (years)	10.75 ± 0.65
Height (cm)	143 ± 0.06
Body Weight (kg)	41.44 ± 10.17
BMI (kg/m^2)	20.15 ± 4.08
Handgrip strength (kg)	17.96 ± 4.04
Agility test (s)	11.94 ± 0.83
Standing broad jump (cm)	152 ± 25.09
20-m shuttle run test (stage)	4.59 ± 2.55

Measures

To register the data, we followed the protocol established by González-Fernández et al. [34]. Thus, in order to characterise the sample, participants completed four types of measures: (i) questionnaires: Healthy Lifestyle Questionnaire and Physical Activity Questionnaire for Children, PAQ-C [51]; (ii) anthropometric measurements: Body weight (kg) and BMI (kg/m^2); (iii) ALPHA-Fitness test battery: 20 m shuttle run test, 4 × 10 m speed-agility test, standing broad jump and handgrip strength test [52], and (iv) Rating of Perceived Exertion (RPE). RPE was measured with the Borg scale, RPE 6–20 [53] immediately after the Active-Break Conditions and Control Conditions Psychomotor Vigilance Task (PVT) with a duration in both pre-intervention and post-intervention of ten minutes [54].

Procedure

The study used a within-participant design with one factor: the effort condition (Control Condition and Active-breaks Conditions). First, secondary school's principal was informed about the objectives of study and the methodology to be used. Subsequently, we studied and planned every structure of the day of classes together with the teachers and the secondary school's advisor. To ensure the students did not miss any classes, we used AB to improve the performance in the classroom. Every task or test was controlled by one main researcher and was assisted by a physical education teacher. Those teachers were also responsible for the groups who were specially trained to accurately and reliably record data, especially in physical fitness assessments.

The researchers visited the school on five different days, always at the same time of day, between 10:30 am and 2:30 pm, and separated by at least 48 hours and no more than 72 hours. Environmental conditions were supervised (space, temperature, and humidity) and all testing was performed in the same space and at the same time under the same humidity conditions (30–40%) and temperature (20–24°C). Each student completed five experimental sessions and before starting the sessions, all students were instructed to wear comfortable sports clothes and shoes, as they were vital for the appropriate administration of the battery and experimental sessions. In addition, the students were also asked to bring a bag for toiletries, a clean replacement shirt and a small bottle of water to the classroom.

During the first session, the participants completed the questionnaires and 10 min of PVT to determine their basal level of vigilance (Basal Level Condition). In the PVT analysis, the first five trials were excluded, as they were considered practice. Posteriorly, measurement of body composition, handgrip strength test and standing broad jump were registered.

In the second session, the schoolchildren completed the physical fitness assessment and performed the first 4 × 10 m speed-agility test and then 20 m shuttle run test.

In the third, fourth and fifth sessions, the students performed the Control Condition and Active-Break Condition (counterbalanced). Both conditions were carried out inside the classroom. The tables and chairs were moved out of the way to make space to move and perform the exercise. RPE was always measured after 10 min of AB (Active Break Condition) or 10 min or free-reading task (Control Condition). In this regard, it should be mentioned that the students had considerable experience in the use of RPE. In this sense, students received a traditional lesson of 25 min of the assigned class followed by 10 min of a free-reading task (Control Condition) or 10 min of physical activity based in motor games (Active-break Condition) in which they performed motor games based on coordination abilities, locomotor skills (run, jump, slide…) and stability skills (balance, bending, turning…). Immediately following the assigned 10-min intervention, the students performed the PVT, before returning to complete the traditional lesson for the remaining 15 min. The schoolchildren performed the Active Break Condition three times and the Control Condition the other times, however, only one instance of the PVT was used in both conditions, as described above. In this way, all children were registered one time in each condition. We repeated both conditions until all students had completed the set (see Figure 1 for more information).

Statistical analyses

The present research consisted of a one-way within-participant design with the factor Effort Condition (Basal Level Condition, Control Condition and Active-breaks Condition). The statistical analyses were carried out using the Statistica software (version 13.1; Statsoft Inc.,

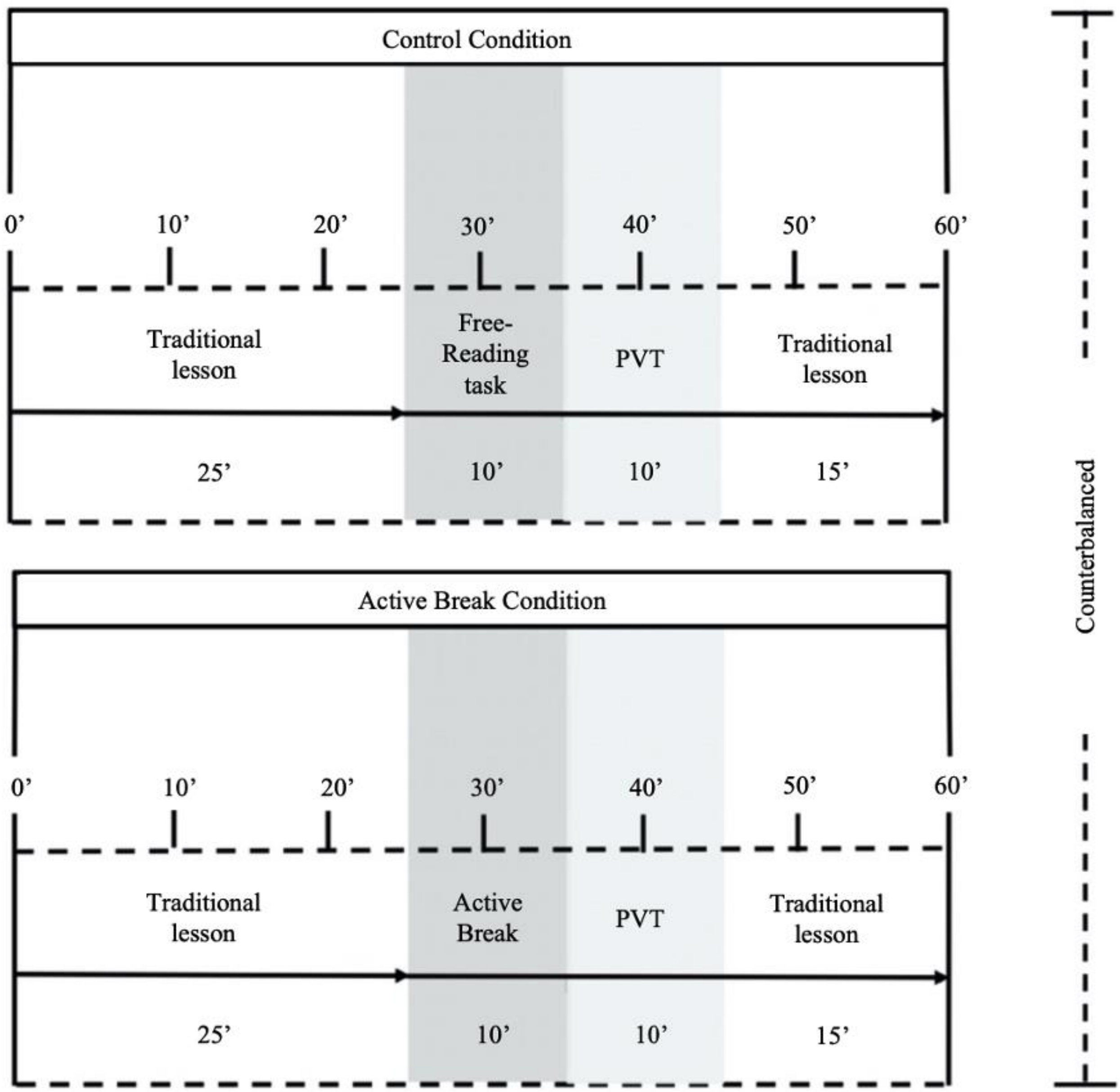

Figure 1. Schematic representation of a test day (see text for full description)

Tulsa, OK. USA). Descriptive statistics are shown as mean ± standard deviation (*SD*). Significance was accepted at $p < 0.05$ for all analyses performed. Normal distribution and homogeneity (Kolmogorov–Smirnov and Levene's, respectively) were conducted before the analysis was performed. For the treatment of the data, we use appropriate statistical methods to calculate the percentages and central and dispersion parameters (arithmetic mean and standard deviation). To establish the differences in outcomes, we used one-way analysis of variance (ANOVA) in the differences of the RTs. Statistically significant effects were further analysed by paired-sample *t*-tests [0.2 (small); 0.5 (medium) and > 0.8 (large)] corrected by Holm-Bonferroni for multiple comparisons. Effect size is indicated with Cohen's d for *t*-tests and partial eta squared for Fs. The Greenhouse-Geisser correction was applied when sphericity was violated [55]. If so, corrected probability values are reported.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Pontifical University of Comillas (approval No.: 2021/66).

Informed consent

Informed consent has been obtained from all individuals included in this study. All schoolchildren participants in this study were treated according to the American Psychological Association (APA) guidelines with the purpose of ensuring the anonymity of the students' responses.

Results

Physiological parameters

A paired sample *t*-test with RPE [Basal Level Condition (6.56 ± 0.65) and Control Condition (6.75 ± 0.61)] was not significant. However, a *t*-test with RPE [Basal Level Condition (6.56 ± 0.65) and Active-Break Condition (12.15 ± 1.31)] and [Control Condition (6.75 ± 0.61) and Active-Break Condition (12.15 ± 1.31)] showed higher values after an Active Break, $t(46) = 26{,}08$, $p < 0.001$, $d = 5.40$ and $t(46) = 25.02$, $p < 0.001$, $d = 5.24$, respectively.

Psychomotor vigilance task

RTs

The task included a single block lasting 10 minutes. The exact number of trials of each participant depended on the latency of the individual's response. Participants completed 83.21 (± 7.32) and 81.49 (± 10.38) trials in the Control Condition and Active-breaks Conditions, respectively. The results of each PVT were recorded in CSV format and sent via e-mail to the experimenter. In total, 46 × 3 PVTs were recorded for the Basal Level Condition; Control Condition and Active-Break Condition. No task was excluded from the dataset. Trials with RTs under 100 ms (0.04%) were discarded from analysis, as they were assumed to represent anticipation error. Then, the RT of each 10-minute PVT was prepared to be analysed. Note that the 10 minutes were divided into blocks of 1 minute to investigate the time course of the RT in the PVT. Different analysis of variance of repeated measures (ANOVA) were performed with the average of the participants' RTs in the condition [Basal Level Condition (382 ms); Control Condition (379 ms) and Active-Break Condition (365 ms)] and time-on-task (10 minutes).

An ANOVA with the participants' mean RT (Basal Level Condition Vs Active-Break Condition) and task time revealed a significant main effect of the effort condition, $F_{(1.45)} = 9.81$, $p = 0.001$, $\eta^2 = 0.17$. The responses of the participants were generally faster in the Active-Break Condition than in the Basal Level Condition. Finally, another ANOVA with the average of the participants' RTs with the condition (Control Condition vs. Active-Break Condition) and time-on-task revealed a significant main effect of the condition, $F_{(1.45)} = 24.18$, $p = 0.001$, $\eta^2 = 0.34$. As shown in Figure 2, the participants responded generally faster in the Active-Break Condition (365 ms) than in the Control Condition (379 ms). The effect of Time-on-task and the interaction between the Control Condition and Time-on-task was not significant $F < 1$.

Discussion

The purpose of the present study was to examine the acute effect of an AB on vigilance in schoolchildren of 10–11 years. A group of students performed the PVT for 10 min after either a traditional lesson or a traditional lesson, and following 10 min of AB. All students performed both conditions. The results showed that the participants who performed the Active-Break Condition responded faster than the participants under

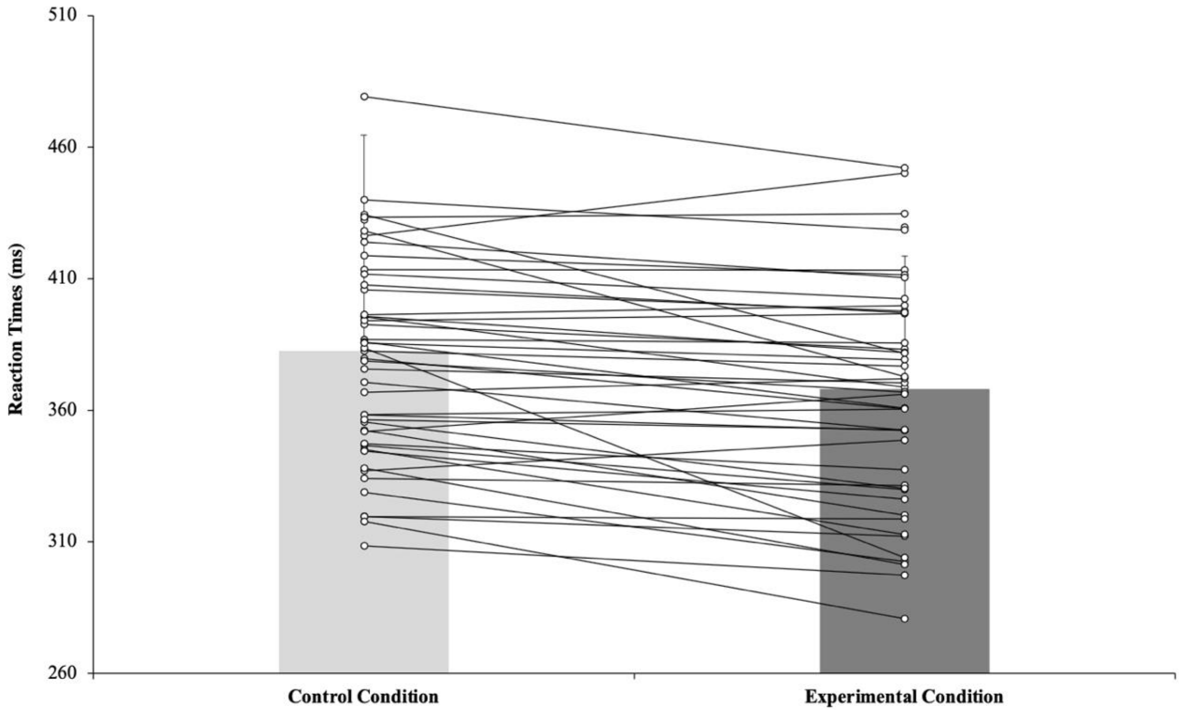

Figure 2. Participants' mean Reaction Time (± *SE*) as a function of effort condition

the Basal Level Condition. Crucially, it is important that we consider the Basal Level Condition to be the initial value of the lesson. In addition, our results found the main effect of the students under the Active Break Condition responding faster than students under the Control Condition. The outcome of the present study confirmed that students' state of vigilance changes after 10 min exercise of (compared to the Basal Level Condition and Control Condition). Interestingly, the peak vigilance performance was found at values around 12 in RPE (between Fairly light (11) and somewhat hard (13) compared with Control Condition, which was very, very light (6.75). In this respect, the time of the Active Break Condition (at moderate intensity) was enough to induce significant improvements in vigilance. Even though monitoring exercise intensity can be very difficult in a school environment, the use or RPE measures represent an appropriate solution to calculating exercise intensity in the case of students of fifth and sixth grade of a primary school. Note that the results agree with a previous hypothesis that Active Break Conditions helped to maintain attention immediately after more than a Control Condition.

Several neurological and biological mechanisms may explain the effect of velocity-agility, motor coordination and perceptive-motor skill on the improvement of cognitive performance [27]. In fact, AB could induce different physiological alterations [56] that have traditionally been associated with an increased arousal level in students [16] at moderate intensity levels [57]. Exercising at moderate intensity elicits a variety of physiological changes (e.g., core temperature, cortical blood flow, heart rate, catecholamine concentration) [58]. Most of these physiological responses have been linked to enhanced activation/arousal, which may in turn be responsible for the observed RT enhancement in the PVT. In addition, our results showed a primary effect of the condition, showing faster RTs in the Active Break Condition. These results suggest that physical exercise facilitated the performance on PVT and seem to support previous research, which has shown that moderate acute exercise has selective effects on cognitive processing and facilitates aspects such as response speed [59]. However, it is important to emphasise that PVT is a specific task designed to measure vigilance, so we can indicate that, in our study, the exercise not only enhanced the response speed in an unspecific way but also improved the performance in vigilance. Previous work could lead to a pre-activation of the cerebellum and the dorsolateral prefrontal cortex, causing a subsequent improvement in attention and academic performance, since memory is related to the activity of the dorsolateral prefrontal cortex in neural networks, being this area of great plasticity when activated through training [59]. In this way, the improvement in RTs could be explained by the control of the neuromotor system, since the conduction speed of the nerve impulse could be related to the brain processing speed [60].

The results of the present study show that the efficiency of vigilance improved after an AB of 10 min in schoolchildren of 10–11 years. Interestingly, this improvement in RTs suggests that our AB increased the arousal activation of the students, improving their vigilance efficacy, suggesting that AB can help to maintain attention, and to facilitate knowledge absorption after a considerable period of sedentary activity [61]. As mentioned previously, the benefits of physical activity during the class day likely include an improvement in vigilance. However, physiological alterations induced by moderate-to-vigorous PE directly influence the cognitive function of youth [62]. Previous literature includes studies that found improvements in cognitive functions (e.g. selective attention) with protocols of high-intensity interval activity [63]. In fact, other research has linked PE with cognitive functions [64]. Consequently, students could learn different subjects more easily if different areas of the curriculum were connected with different physical activity exercises [AB of 20 min (40 to 60% of VO_{2max})]. Therefore, if we know the potential adverse effects of a longer school day without any breaks include reduced attention of the students, this lack of attention necessarily negatively impacts their academic learning [65, 66]. We suggest that AB of at least 10 minutes during the school day could improve the vigilance of students. In fact, all kinds of learning begin with attention (vigilance) as the supporting axis, but this is not always easy to come by, especially over a long day of classes. Teachers encounter difficulties in maintaining the vigilance of their students. All this has a series of theoretical and practical implications that have a direct impact on schools: (a) need to establish an awareness in schools about the importance of building and maintaining spaces for the practice of physical activity; (b) promoting intentional dynamics in students that give them autonomy to apply active breaks as a tool in study; (c) involving families to become aware of how fundamental it is for their children to practice physical activity; (d) convincing educational administrations to encourage ongoing teacher training about active breaks and active and participatory methodologies.

For these reasons, increasing the use of these methodologies (AB, learning based on movement, and other cooperative learning techniques, among others) provides more opportunities for students to stay focused on the task. Accordingly, methodologies applied in the classroom are evolving from very directive masterclasses to more active methodologies within the classroom (cooperative learning, problem-based learning, project-based learning, simulations, among other examples). It is generally recognised that the methodologies applied and often recommended to improve the learning environment in higher education courses include cooperative learning, adding inquiry-based activities to traditional lectures, and engaging students in projects or research. Results of student surveys, course evaluations, and exam performance demonstrate that learning the subject under these conditions has improved [68]. The current study provides, for the first time, empirical evidence showing that the vigilance performance improved after an AB of 10 min in students of 10–11 years. In addition, this has repercussions on the great number of possibilities that exist when applying AB as a methodology in an educational centre, or even linked to the development of extracurricular sports activities. In fact, implementing active breaks has increased in value among schools, given their cognitive benefits. For this reason, it would be of real interest to develop these AB as a tool for students to self-regulate their studies.

Conclusions

The outcomes of the present research provide implications concerning the importance of incorporating AB thought school time, showing that it can help students' vigilance and health. In addition, using AB can help in achieving a high level of PE in favour of a healthy lifestyle. These benefits could have a direct impact on cognitive, social, physical, and psychosocial wellness. However, teachers are not academically prepared to carry out AB during the class day. For all these reasons, AB represents a positive intervention where teachers can receive academic training and integrate movement into the day.

This research also presents other limitations that should be addressed in future research. First, we need physiological measures to calculate objectively the intensity of different conditions. Although, we have RPE measures, it would be more interesting to also have heart rate data and even other physiological parameters. Thus, another object of study could be the correlation between the learning facility of different subjects with specific physiological stimuli resulting from physical activity. Secondly, prolonged lesson times influence the vigilance in elementary school. For this reason, more research is necessary to clarify the appropriate duration of the lessons and appropriate duration of AB. Accordingly, our findings contribute to the extant research on the influence of AB on schoolchildren's behaviours and open up interesting avenues for future research. On the other hand, it is essential for the teacher to link AB with the development of active methodologies that involve the student in the learning process, such as cooperative learning. This will make it possible to generate a greater awareness of what the student learns through his or her social bond with others, a fundamental aspect in obtaining a positive motivational climate. However, it is essential that teachers are trained in this type of methodologies, since carrying out AB from directive or traditional approaches could have the opposite effect to the one intended.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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