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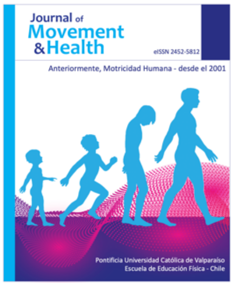

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Article

Get moving and think better: impact of an intervention involving physical activity and active breaks on children's cognition

Muévete y piensa mejor: impacto de una intervención que involucra actividad física y descansos activos en la cognición de los niños

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Abstract

Aim: To verify the effect of an intervention with active breaks and physical education (PE) classes on children's cognitive development in a high-vulnerability school setting while also determining their sedentary behavior and physical activity levels. **Methods:** This quasi-experimental study included 42 children aged 9–13 years from a public school located in Quintero, Valparaiso, Chile. Participants were divided into an Intervention Group (IG), engaging in PE classes and active breaks during 8 weeks, and a Comparison Group (CG), participating in physical education classes alone. Response inhibition was measured through the Go/No-Go test and working memory through the N-Back test. Physical activity and sedentary behavior were assessed using accelerometers. ANCOVA and propensity score matching (average treatment effect on the treated = ATET) were used for statistical analysis. **Results:** After the intervention, the IG showed an improvement in the reaction time of working memory (ΔMean=-179.30; p=0.044; d=0.89; large effect size). Also, the ATET was -153.90 seconds (95%CI: -272.01; -47.79; *p*=0.005) for reaction time, confirming a significant increase in the intervention. **Conclusion:** This study provides evidence that an active break program can enhance working memory in children, suggesting that integrating these breaks along with PE classes in the school setting should be considered to promote cognition.

Keywords: physical exercise; reaction time; working memory.

Resumen

Objetivo: verificar el efecto de una intervención con pausas activas y clases de educación física (EF) en el desarrollo cognitivo de los niños en un entorno escolar de alta vulnerabilidad, al mismo tiempo que se determinan sus niveles de comportamiento sedentario y actividad física. **Métodos**: Este estudio cuasi-experimental incluyó a 42 niños de 9 a 13 años de una escuela pública ubicada en Quintero, Valparaíso, Chile. Los participantes se dividieron en un Grupo de Intervención (GI), que participó en clases de EF junto con pausas activas, y un Grupo de Comparación (GC), que participó solo en clases de educación física. La inhibición de respuesta se midió mediante la prueba Go/No-Go y la memoria de trabajo mediante la prueba N-Back. Se evaluaron la actividad física y el comportamiento sedentario utilizando acelerómetros. Se utilizaron ANCOVA y emparejamiento por puntuación de propensión para el análisis estadístico. **Resultados**: Después de la intervención, el GI mostró una mejora en el tiempo de reacción de la memoria de trabajo (ΔMedia=-179.30; p=0.044; d=0.89; tamaño del efecto grande). Además, el efecto medio del tratamiento en los tratados fue de -153.90 segundos (IC del 95%: -272.01; -47.79; p=0.005) para el tiempo de reacción, indicando un aumento significativo en la intervención. **Conclusión**: Este estudio proporciona evidencia de que un programa de pausas activas puede mejorar la memoria de trabajo en niños, sugiriendo que integrar estas pausas junto con clases de EF en el entorno escolar debería considerarse para promover la cognición.

Palabras clave: ejercicio físico; tiempo de reacción; memoria de trabajo.

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Highlights

- The intervention group showed a significant improvement in working memory following the implementation of the active break program.
- The group exposed to active breaks exhibited reduced sedentary behavior and increased physical activity levels compared to the comparison group.
- The intervention was not effective in the response inhibition of children.

Introduction

The lack of physical activity among children is an increasingly concerning public health issue with significant implications for physical and mental well-being [1]. According to the World Health Organization (WHO) data, over 80% of adolescents worldwide do not meet recommended physical activity guidelines [2]. Moreover, studies have long shown a decline in physical activity among children due to modern lifestyles characterized by sedentary technologies and limited opportunities for outdoor physical activity [3]. This scenario is particularly concerning due to the adverse effects that physical inactivity can have on children's health. In addition to commonly known risks such as obesity and associated chronic diseases [3,4], lack of physical activity is also inversely associated with cognitive function [5].

The literature offers evidence regarding the relationship between physical activity, physical fitness, and cognitive performance in children [6,7]. Research suggests that physically active children with higher physical fitness are more likely to improve attention, memory, executive function, and cognitive skills, all essential for effective learning [8–11].

Implementing effective programs to promote physical activity and enhance cognition in children, especially in the school context, is essential due to the comprehensive benefits such interventions can bring [12,13]. Schools play a crucial role in promoting children's health and well-being, and the introduction of programs that encourage physical activity and decrease sedentary behavior can have a significant impact not only on physical health but also on the cognitive development of students [13]. Given that children spend most of their time in school environments, these settings offer an ideal opportunity to promote healthy habits [14,15]. Programs that incorporate physical activity into the school routine not only encourage active participation by students but also provide a framework for the development of fundamental skills for a healthy life [14].

In this regard, school-based physical activity programs, including regular physical education classes and active breaks during the school day, have been adopted as strategies to promote physical activity and decrease sedentary behavior among students [13,16]. These interventions have demonstrated efficacy in promoting healthy habits, as well as contributing to cognitive development that is essential for learning. The mechanisms by which physical activity affects memory and inhibitory control involve various biological and neurophysiological pathways. Firstly, physical activity is associated with increased cerebral blood flow, which enhances oxygenation and nutrient delivery to the brain, promoting neurogenesis, especially in the hippocampus, a region crucial for the formation and consolidation of memory[17]. Additionally, physical exercise stimulates the release of neurotrophins, such as brain-derived neurotrophic factor (BDNF), which play a vital role in the survival, growth, and maintenance of neurons [18]. Regarding inhibitory control, physical activity can increase the functional connectivity and efficiency of neural networks involved in executive control, particularly in the prefrontal cortex. This brain region is essential for higher cognitive functions, including inhibiting inappropriate responses and focusing attention[17].

From this, our study aimed to verify the effect of an intervention with active breaks and physical education classes on children's cognitive development in a high-vulnerability school setting while also

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determining their sedentary behavior and physical activity levels. We hypothesize that the cognition variables, mainly reaction time and physical activity, would have positive effects and, consequently, the time spent in sedentary behavior would be reduced in the intervention group.

The present study contributes to the existing literature by investigating the combined effects of active breaks and physical education classes on the cognitive development of children in a high-vulnerability school setting, which consequently has less access to interventions such as the one proposed. While previous studies have examined the benefits of these interventions separately [12,13], we focused on their combination. Our research seeks to fill this gap by assessing if the integration of active breaks throughout the school day, along with participation in structured physical education classes, can enhance the positive effects on children's cognition.

Methods

Study Design and Sample

This quasi-experimental study was developed with 42 children aged between 9 to 13 years (Mean 10.47 ± 1.13), from a public school in Quintero, Valparaiso, Chile. The school is located in an area where the School Vulnerability Index stands at approximately 95%, highlighting the socio-economic challenges faced by the community. The quasi-experimental design is justified as both the intervention and comparison groups were selected based on convenience criteria. The experimental study was not feasible because the intervention was developed in the classes in a school context, it was not possible to randomly select participants for the groups.

All students in the 4th and 5th grades were invited to participate in the study, totaling 49 students. Those who accepted (n=42) were then divided into the respective groups: 4th-grade students comprised the Intervention Group (IG), engaging in physical education classes along with active breaks, while 5th-grade students formed the Comparison Group (CG), participating in physical education classes alone. The nomination of CG was chosen once this group was also under intervention concerning the physical education classes.

Initially, discussions were held with the school principal and head of the Pedagogical and Technical Unit (UTP) to obtain approval to implement the project. Once approval was obtained, the research's objectives, scope, and purposes were communicated to the parents through parent meetings and to the educational community through a presentation. It is worth highlighting that each parent signed a consent form authorizing their child's participation in the intervention. Also, the study was approved by the Ethics Committee of the University of Playa Ancha (002_2023).

Measurements

All evaluations were conducted at the school by a team of trained researchers. Pre and post-test evaluations were carried out in the following sequence: on the first day, assessments of anthropometric measures and somatic maturation were performed on the sports court; on the second day, cognitive variables were assessed in a classroom during the first time in the morning. Thus, all measurements were taken during the school routine, but on a different day of the application of the intervention

Cognition

Before commencing the measurements of cognitive variables, the researchers addressed the participating classes of the school to explain the protocol for administering each cognitive test in a didactic manner, utilizing drawings and images. This was done to prepare the students for the assessment. Subsequently, students were organized into groups of six to undergo the evaluation in a quiet room. For

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each group, two researchers were available to address any questions or concerns from the students. The Go/No-Go test was administered first, followed by the N-Back test. These tests are available online (https://www.psytoolkit.org/experiment-library/), and were administered using laptops with internet connections. The measurements for each group took approximately 15 minutes. Upon completing the measurements for the IG, the same protocol was followed for the CG.

The response inhibition was measured through the "Go/No-Go" test. The aim was to quantify the students' response speed and accuracy. The test requires students to press the space bar as quickly as possible when a specific stimulus appears on the screen (the Go stimulus) and to refrain from responding when a different stimulus appears (the No-Go stimulus).

For working memory, the "N-Back" task was used, wherein different letters appeared on the screen for a few seconds. Participants were required to memorize whether they saw the same letter two letters back. If the participant saw the letter two letters back, they had to press the letter "M" on the keyboard. If the actions were correct, the letter would appear with a green color around it; otherwise, it would appear with a red color. It is important to note that participants were always required to remember the last two letters regardless of whether the color around the letter was green or red.

Physical Activity and Sedentary Behavior

The measurement of physical activity levels, sedentary behavior, was conducted during the implementation of the “Activa-Mente” intervention, specifically starting from week 4. Accelerometers ActiGraph (Model GT3X+, Actigraph, Illinois, USA) were used for this purpose. Participants wore the device during one school day without Physical Education and Health classes. Data were analyzed using Actilife software (ActiGraph, version 5.6, USA) and collected at a sampling rate of 100 Hz, downloaded in one-second periods, and aggregated for 15-second periods. For counting the counts for cutoff points of accelerometers, the ready cutoff of Evenson et al., (2008)[19] was used for periods of 15s.

Covariates

Height and Weight were evaluated with a digital scale (model 807 Seca®), with a resolution of up to 0.1 kg and a capacity of 150 kg, and height using a portable stadiometer (Avanutri®), with the students barefoot, feet together and on their backs, arms along the body and head positioned in the Frankfurt plane, keeping the scapulae and buttocks in contact with the stadiometer. Then, body mass index (BMI) was calculated by dividing body mass (in kilograms) by height (in square metres). Waist circumference (WC) was measured at the midpoint between the last costal arch and the iliac crest with a flexible and inelastic measuring tape with a precision of 0.1 cm. Somatic maturation was predicted by time in years to peak height velocity (PHV) using sex-specific equations [20].

Intervention Procedures

The IG was submitted to the regular physical education classes along with active breaks. Active breaks were implemented 3 times a week for 8 weeks, on Mondays, Tuesdays, and Thursdays, 3 times a day, during the first 3 classes of the day, halfway through each class (45-minute classes will have the break applied at minute 20); except for physical education class, totalling 24 sessions throughout the intervention (Figure 1). The active breaks were applied through the “Activa-Mente” program, which consists of teachers implementing active breaks through previously recorded videos specially designed for the program [21]. These videos have a duration of 4 minutes and 30 seconds. This time is divided into 1 minute of preparation (explanation and general instructions), 3 minutes of 6 activities (e.g., Jumping Jacks, Skipping, Jumping Jacks, Scissor Kicks) of moderate to high intensity, around 60% of maximum heart rate [22]. Each activity is performed for 20 seconds followed by 10 seconds of recovery; during this brief

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recovery time, the next activity is explained, and the final 30 seconds are for cooldown. There are 32 different videos following the same structure, which can be used interchangeably, at the discretion of the teacher (https://convivenciaparaciudadania.mineduc.cl/activamente/). Students do not need any type of equipment or materials to perform the activities; they can be done while standing beside their desks since no significant movement is required. All activities are designed to be accessible for students of all abilities (motor disabilities, hearing impairments, visual impairments). It's worth noting that the explanation of the activities and their execution are carried out by physical education teachers specially trained for this purpose.

In addition to the active breaks, children were engaged in physical education classes. These classes were focused on flashing games that involve motor skills with physical abilities development. For fourth and fifth grade these classes were performed twice a week. Each class has a duration of 90 minutes. The CG was only submitted to the physical education classes, with the same characteristics as the intervention group.

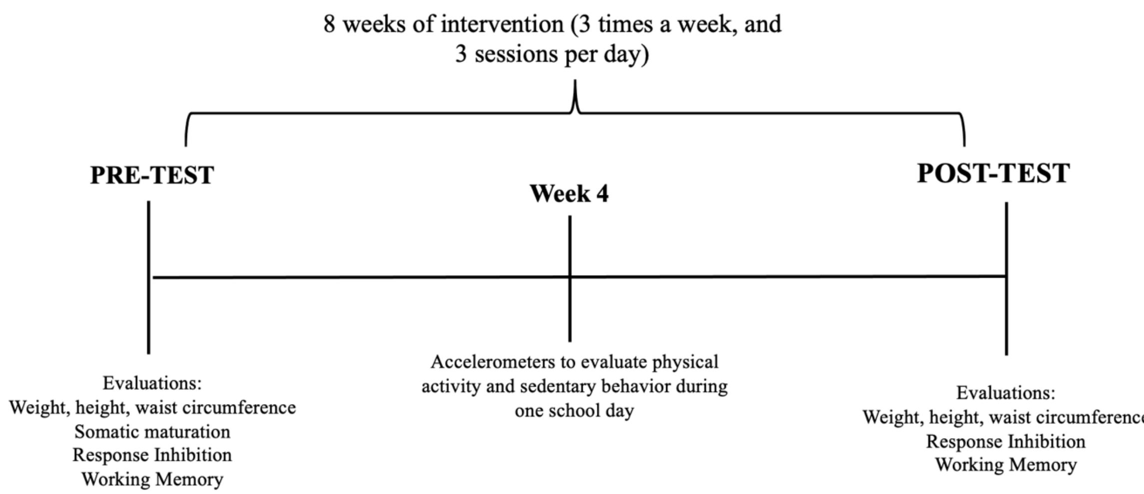

Figure 1. Timeline of evaluations and general characteristics of the intervention.

Statistical analysis

To present the characteristics of the sample, we employed means and standard deviations. Change scores for each dependent variable were derived by subtracting pretest scores from post-test scores (Δ = post-test minus pre-test scores). Effect sizes (Cohen's d) for the ANCOVAs were then determined. The following cutoff points were considered: $d < 0.49$, small effect; $0.50 < d < 0.79$ medium effect, and $d > 0.80$ large effect [23]. Analyses were conducted using the Statistical Package for the Social Sciences (SPSS, v. 23.0 IBM, Armonk, NY).

The Propensity score matching was utilized to estimate the average treatment effect on the treated (ATET) across various levels of outcome variables. This technique is commonly employed in non-randomized quasi-experimental research designs to enhance internal validity. Propensity score matching involves estimating the missing potential outcome for each participant by averaging outcomes from similar (matched) participants who receive the comparative condition. The similarity between participants is determined based on estimated treatment probabilities, known as propensity scores, or the predicted likelihood of being in the experimental group (the treatment) given a set of covariates. This study employed a logit model to predict propensity scores, utilizing age, somatic maturation, and the pretest outcome variable as covariates, with matching conducted via the single nearest neighbour approach. The ATET was computed by averaging the difference between observed and potential outcomes for

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participants within the experimental (treatment) group. A significance level of p<0.05 was adopted for all analyses, with propensity score matching executed using Stata v17.0 (StatCorp., College Station, Texas, USA).

Results

The characteristics of the sample at baseline are presented in Table 1. Participants in the CG demonstrated shorter reaction times for response inhibition and working memory tasks than the IG.

Table 1. Characteristics of the sample at baseline.

	Comparative Group		**Intervention Group**		
	Mean	**SD**	**Mean**	**SD**	*p*
Age (years)	11.30	0.94	9.78	0.73	<0.001
Weight (kg)	45.10	15.10	40.60	10.90	0.30
Height (m)	1.47	1.21	1.40	1.09	0.04
BMI (kg/m^2)	20.60	4.82	20.80	3.97	0.65
WC (cm)	68.20	13.40	69.00	8.25	0.81
PHV (years)	-1.72	1.34	-2.38	0.94	0.04
Response inhibition					
Reaction time (s)	491.00	151.00	623.00	99.90	0.003
Errors	1.21	1.18	0.81	0.91	0.59
Working memory					
Correct responses	52.60	6.87	57.50	6.40	0.11
Coincidences	11.60	7.33	12.50	4.23	0.37
Omissions	13.90	6.24	11.90	3.99	0.90
Errors	6.94	9.70	5.76	6.96	0.87
Reaction time (s)	765.00	233.00	955.00	229.00	0.04

BMI: body mass index; WC: waist circumference; PHV: peak high velocity.

Table 2 presents a comparison of sedentary behavior and physical activity levels between the IG and the CG during the active break intervention. Results indicated that the IG presented a significantly lower number of total bouts and fewer minutes spent in bouts than the comparative groups. In addition, the IG presented higher light, moderate, vigorous, and moderate to vigorous physical activity than the CG.

Table 3 presents the differences between the intervention and comparative groups in cognition. After the intervention was implemented, the intervention group presented an improvement in the reaction time of the working memory (Δ Mean = -179.30; p = 0.044; d = 0.89, large effect size).

Table 4 presents result from the propensity score matching for cognition. The ATET was -153.90 seconds (95% CI: -272.01; -47.79; *p* = 0.005) for reaction time, indicating a significant increase for the intervention group.

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Table 2. Comparison of sedentary behavior and physical activity levels between the intervention group and comparison group during the active break intervention.

	Comparative group	**Intervention group**			
	Mean (SD)	Mean (SD)	Cohen´s d	F	*p*
Response inhibition					
Δ Reaction time (s)	-57.94 (87.50)	-160.75 (136.71)	0.03	5.61	0.99
Δ Errors	-0.21 (1.22)	-0.04 (0.82)	0.05	0.01	0.89
Working memory					
Δ Correct responses	0.89 (5.42)	-1.17 (5.54)	-0.19	0.17	0.68
Δ Coincidences	-0.15 (6.61)	-2-21 (2.81)	0.73	2.88	0.09
Δ Omissions	-0.94 (5.92)	1.30 (3.71)	-0.35	0.69	0.41
Δ Errors	1.64 (4.37)	1.52 (3.02)	0.34	0.63	0.43
Δ Reaction time (s)	-42.83 (70.60)	-179.30 (230.07)	**0.89**	**4.33**	**0.04**

Δ denotes changes in the dependent variable (post-test minus pretest scores). Bold denotes the difference between experimental and comparative groups calculated using ANCOVA adjusted for age, somatic maturation, and outcome variable at pretest ($p < 0.05$).

Table 3. Delta differences between intervention and comparative groups in cognition.

	Comparative group		**Intervention Group**		
	Mean	**SD**	**Mean**	**SD**	p
Bouts (n°)	1.56	1.42	0.47	0.75	0.005
Total time in bouts (min)	24.2	22	6.47	10	0.002
Total breaks in sedentary time (n°)	0.77	1.22	0.28	0.71	0.12
Light PA	31.8	9.91	48.8	23.4	0.007
Moderate PA	5.80	2.42	8.87	3.25	0.002
Vigorous PA	6.01	3.42	9.42	4.23	0.009
Moderate to vigorous PA	12.4	5.40	18.3	7.07	0.006
Bouts (n°)	1.56	1.42	0.47	0.75	0.005
Total time in bouts (min)	24.2	22	6.47	10	0.002

PA. Physical activity.

Table 4. Propensity score analysis.

	ATET	**95% CI**	***p***
Response inhibition			
Reaction time (s)	-41.43	-172.49; 89.64	0.53
Errors	0.57	-0.49; 1.63	0.23
Working memory			
Correct responses	1.17	-0.23; 2.57	0.10
Coincidences	0.40	-6.09: 6.90	0.90
Omissions	0.02	-3.35; 3.40	0.98
Errors	-2.90	-11.54; 5.73	0.51
Reaction time (s)	**-153.03**	**-277.54; -28.53**	**0.01**

ATET. Average treatment effect on the treated; matches for groups, age, somatic maturation, and the outcome variable at pretest.

Discussion

The main findings of the present study indicate that the intervention group showed a significant improvement in reaction time of working memory following the implementation of the active break

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program. We have also noticed that the group exposed to active breaks exhibited reduced sedentary behavior and increased physical activity levels compared to the CG. It's worth noting that these observations were made on a day without physical activity classes to isolate the impact of active breaks.

These results align with previous studies that have demonstrated cognitive benefits associated with physical activity in children. For instance, Mahar et al., (2006) [23] found that short physical activity breaks during the school day improved attention and academic performance. Additionally, Donnelly & Lambourne, (2011)[25] reported improvements in executive function and working memory in children who participated in regular physical activity programs. Similarly, it has been found that integrating physical activity into the classroom improved both cognitive performance and classroom behavior in elementary school children [26]. Furthermore, a meta-analysis by Singh et al. (2019)[27] highlighted the positive effects of physical activity on various cognitive functions, including working memory, in children and adolescents.

Active breaks may contribute to improved working memory through several mechanisms. First, physical activity increases cerebral blood flow, providing more oxygen and nutrients to the brain, which is crucial for cognitive function [28]. Second, active breaks can help reduce mental fatigue, allowing students to return to cognitive tasks with greater focus and efficiency [29] . Furthermore, physical activity is associated with the release of neurotransmitters such as dopamine and serotonin, which are linked to improved mood and cognitive function [30]. In this sense, previous literature supports this, showing that physical exercise can enhance cognitive control and executive function in children [31] and also suggests that physical fitness is associated with increased hippocampal volume, which is critical for memory and learning [32,33]. It´s also important to mention that acute bouts of physical activity can lead to immediate cognitive benefits due to increased blood flow and neurotransmitter release[34], while long-term exercise training induces structural changes in the brain, such as increased hippocampal volume, which supports sustained cognitive improvements over time [35].

The lack of effect on inhibitory control after the intervention could be explained by the insufficient intensity and duration of the physical activities performed[36,37] . Studies indicate that inhibitory control is more sensitive to higher intensity and longer duration exercises, which significantly increase cerebral blood flow, elevate neurotransmitter levels (such as dopamine and norepinephrine), and promote the production of neurotrophic factors like BDNF, all crucial for executive function[17].

Implementing active break programs in educational settings has significant practical implications. Active breaks offer a structured way to integrate physical activity into the school day without interfering with instructional time, promoting a more dynamic and effective learning environment [38]. Moreover, improving working memory can translate into a better capacity to process and retain information, facilitating learning of new concepts and skills [39]. Therefore, the idea that active breaks could lead to impairment in performance is not supported by current evidence.

Schools can greatly benefit from adopting active break programs. These programs not only promote physical health but also have the potential to improve academic outcomes and students' emotional well-being [40]. Integrating active breaks can be an effective and low-cost strategy to address issues such as inattention and hyperactivity [41], thereby enhancing the overall learning environment [42]. Furthermore, the positive effects on working memory reaction time suggest that such programs could be particularly beneficial in high-vulnerability communities where students may face additional cognitive and socio-emotional challenges. Indeed, children in vulnerable contexts face significant challenges that adversely affect cognitive development. Socioeconomic disadvantages limit access to educational resources, nutritious food, and stable environments, crucial for cognitive growth [43]. Chronic stress and violence can alter brain structures, leading to cognitive and behavioral issues. Limited access to quality education and family instability further limits cognitive and emotional skills development[43,44]. Therefore, interventions like the one implemented in the present study could mitigate these effects and support healthy cognitive development.

Strength and limitations

This study has several limitations that should be considered. First, the sample size was small and limited to a single school, which may affect the generalizability of the results. Second, the intervention and comparison groups showed significant differences at baseline. Furthermore, the duration of the intervention program was short (8 weeks), which may not be sufficient to observe long-term changes. However, a significant strength of the study is the use of propensity score matching. Propensity score analysis helps to control for potential confounding variables and selection bias, which is particularly important in non-randomized studies. By matching participants on relevant covariates, this method enhances the internal validity of the findings and provides a more accurate estimate of the intervention effects [45].

Conclusion

In conclusion, the present study provides evidence that an active break program along with physical education classes can improve working memory reaction time in children, which has important implications for educational practice. Integrating active breaks into the school routine can be an effective strategy to enhance both the physical health and academic performance of students. Despite the limitations, the results highlight the need for further research in diverse contexts and with larger samples to confirm and expand these findings.

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Declaration of Authorship

Author Contributions: F-C and B-C: conceived part of the idea and wrote collaboratively; T.R-A, C.S-J: conducted the review, critiques, and contributions considered in the final version; F-C, B-C, F.F-C, and M-R: conceived part of the idea and wrote collaboratively. All authors read and approved the final version of this manuscript.

Conflict of Interest

None of the authors have a conflict of interest.