ENHANCING ATTENTION AND EXECUTIVE FUNCTIONS THROUGH PHYSICAL ACTIVITY BREAKS IN UNIVERSITY TEACHING

MIGLIORARE L'ATTENZIONE E LE FUNZIONI ESECUTIVE ATTRAVERSO PAUSE DI ATTIVITÀ FISICA NELL'INSEGNAMENTO UNIVERSITARIO

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ABSTRACT
Physical activity breaks (PABs) are short movement periods integrated into pedagogical strategies to promote learning and cognitive engagement in educational settings. This study explored the impact of PABs, as teaching strategies, on attention and executive functions in university students. A total of 17 university students completed three 10-minute interventions after 2-hour lessons: No Physical Activity (NPAB), Outdoor PAB (OPAB), and Exergame PAB (PABEx). Attention and executive functions were assessed using the Stroop and Trail Making tests. OPAB and PABEx significantly improved cognitive performance compared to NPAB. These findings highlight the pedagogical value of PABs, suggesting that incorporating movement into lessons can enhance attention and executive functions, essential for academic performance. Implementing active teaching strategies such as PABs fosters a more engaging, dynamic, and cognitively stimulating learning environment.

Le pause di attività fisica (PABs) sono brevi periodi di movimento integrati in strategie pedagogiche per promuovere l'apprendimento e l'impegno cognitivo in contesti educativi. Questo studio ha esplorato l'impatto delle PABs, come strategie didattiche, sull'attenzione e sulle funzioni esecutive negli studenti universitari. Un totale di 17 studenti universitari ha completato tre interventi di 10 minuti dopo lezioni di 2 ore: Nessuna attività fisica (NPAB), Outdoor PAB (OPAB) ed Exergame PAB (PABEx). L'attenzione e le funzioni esecutive sono state valutate utilizzando i test Stroop e Trail Making. OPAB e PABEx hanno migliorato significativamente le prestazioni cognitive rispetto a NPAB. Questi risultati evidenziano il valore pedagogico delle PABs, suggerendo che incorporare il movimento nelle lezioni può migliorare l'attenzione e le funzioni esecutive, essenziali per il rendimento scolastico. L'implementazione di strategie didattiche attive come le PABs favorisce un ambiente di apprendimento più coinvolgente, dinamico e cognitivamente stimolante.

KEYWORDS
Outdoor physical activity; exergames; cognitive functions; university students.
Attività fisica all'aperto; exergames; funzioni cognitive; studenti universitari.

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Introduction

Recent studies indicate that most college students exhibit high levels of sedentary behaviour (Castro et al., 2020; Felez-Nobrega et al., 2018). Only a small percentage of college students meet the recommended amount of physical activity, and most do not engage in any physical activity at all (Silva et al., 2022) . Physical inactivity and sedentary behaviour are linked to increased risks of chronic noncommunicable diseases, such as cardiovascular conditions, type 2 diabetes, and cancer (Gao & Mandryk, 2012; Santos-Lozano et al., 2021; Zhu, 2022). In addition to physical health consequences, evidence suggests that high levels of sedentary behaviour may negatively impact mental well-being, including increased susceptibility to anxiety, stress, and depression (Castro et al., 2020). These findings have important implications in the educational context. The university environment, while intellectually stimulating, often reinforces sedentary habits through long lectures, study sessions, and screen-based tasks. The negative effects of such behaviour are not only limited to health concerns but may also extend to students' academic performance and cognitive engagement. It is therefore increasingly evident that promoting physical activity within the academic setting is not only a matter of public health but also a pedagogical imperative.

Regular physical activity, beyond mitigating the adverse effects on physical health, has been shown to reduce stress, improve mood, and boost energy levels—factors that contribute to students' readiness to learn and engage (Chen et al., 2022). Furthermore, the growing body of literature highlighting the positive correlation between physical activity (PA), cognitive performance, and academic achievement has prompted strong scientific interest in integrating physical movement into teaching and learning processes (De Bot et al., 2020; Paulus et al., 2021). Physical activity breaks (PABs) are short periods of exercise delivered during lessons (Howie et al., 2014).

In this context, PABs during school time are emerging as a promising strategy to improve not only students' physical and mental well-being but also their academic performance. Recent studies indicate that incorporating physical activity into the academic schedule through short, structured breaks does not hinder, and may even enhance, cognitive processes such as selective attention and memory. PABs have also been associated with improved mental well-being and increased enjoyment in the learning environment (Haverkamp et al., 2020; Infantes-Paniagua et al., 2021; Peiris et al., 2021). Integrating and alternating traditional, predominantly theoretical didactics with enactive and embedded strategies allows teaching disciplines such as mathematics, geography and languages starting with practical experiences, for example in the school gym, followed by moments of classroom reflection. These strategies, based on 'learning by doing' and the theory of 'embodied cognition,' enhance the global involvement of the learner through bodily experience. Importantly, variation in the design of PABs—including differences in duration, type, and intensity—has been noted, with evidence suggesting that a duration of 5–10 minutes may be more effective and sustainable than longer sessions, frequently repeated with 2 minutes, after every 20 minutes of prolonged static setting. The type of activity performed affects the results, in fact, those with greater cognitive engagement seem to promote attention and speed of processing more than purely physical activities (Watson et al., 2019). However, the successful implementation of PABs depends heavily on the teacher's role, attitude, and motivational strategies.

Moreover, the integration of digital tools such as Exergames—interactive video games that require physical movement—has demonstrated potential for application in higher education settings. These innovative approaches have been shown to improve not only cognitive and academic performance but also stress perception and overall quality of life among university students (Gao et al., 2014; Gu et al., 2023; Staiano & Calvert, 2011; Wan Yunus et al., 2020). Given these insights, it becomes evident that the university environment should not be viewed solely as a space for intellectual development, but also as a context that supports holistic growth—cognitive, emotional, and physical. By fostering a culture of movement within higher education, institutions can play a pivotal role in promoting lifelong health and learning strategies. Therefore, this study aimed to investigate the impact of PAB interventions on the attention and cognitive functions of university students. It was hypothesized that short periods of outdoor exercise or exergames during school time would enhance students' selective attention and executive functions.

1. Material and methods

1.1 Study Design and Setting

From January to March 2025, we carried out a randomized controlled crossover study to investigate the effects of physical activity breaks (PABs) on university students’ attention and executive functioning. The crossover design enabled each participant to take part in all three experimental conditions, allowing for meaningful within-subject comparisons and reducing the influence of individual variability. The intervention spanned three weeks, during which students were assessed after completing each weekly protocol, always within the same academic environment. Cognitive testing was administered by a psychology researcher who remained blind to the condition each participant had received that week. After attending two consecutive hours of academic lessons, students took part in three different activity conditions, presented in a randomized and counterbalanced sequence across the weeks.

1. No Physical Activity Break (NPAB)
2. Outdoor Physical Activity Break (OPAB)
3. Physical Activity Break with Exergame (PABEx)

To maintain consistency and minimize external factors that could influence performance, all sessions and assessments were conducted between 9:00 AM and 12:00 PM, with a one-week interval between each trial. This specific time frame was selected to avoid extreme outdoor temperatures during the OPAB sessions. Additionally, participants were instructed to refrain from engaging in intense physical activity or consuming caffeine for 24 hours prior to and during each testing day.

1.2 Participants

The study involved 17 university students (8 males and 9 females), with an average age of 23.77 years (± 1.55), all enrolled at the University of Aldo Moro. Before participating, each student gave written informed consent after receiving a clear explanation of the study's purpose and procedures. Participants were selected according to specific eligibility criteria: they had to be full-time university students between the ages of 18 and 35 during the period of data collection, and they needed to be physically capable of standing and performing physical activities safely. Students were excluded if they showed any musculoskeletal disorders, lower limb injuries, or any acute or chronic medical conditions that could compromise safe participation. Those who were unable to adhere to the study protocol were also excluded. The entire research process was carried out in accordance with the ethical standards of the Declaration of Helsinki and received approval from the University's Ethics Committee

1.3 Physical Activity Break Interventions

We asked students to avoid vigorous activities for at least 30 minutes before participating. After 2 hours of academic class, each student engaged in the weekly condition for 10 minutes:

No Physical Activity Break (NPAB)

This was our control condition, in which students simply paused their academic work while remaining at their academic stations, essentially having a traditional "rest break" with no physical activity.

Outdoor Physical Activity Break (OPAB)

This 10-minute session was divided into three phases: Warm-up (2 minutes): Simple movements to raise heart rate and prepare major joints for activity. Outdoor walking (6 minutes): A moderate walk around campus at about 4.5 km/h. Cool down (2 minutes): Relaxation exercises and gentle stretching.

Physical Activity Break with Exergame (PABEx)

This 10-minute session followed the same three-step structure: Warm-up (2 minutes): Same activities to prepare for the OPAB condition. Exergame (6 minutes): Using the Homing® virtual reality system (Tecnobody, Bergamo, Italy) to experience interactive virtual walking at the same 4.5 km/h pace as the outdoor sessions. Cooling down (2 minutes): Relaxation and stretching activities that are the same as in the OPAB condition.

1.4 Cognitive Assessments

1.4.1 Assessment of Selective Attention

To assess selective attention, the Trail Making Test (TMT), a neuropsychological tool that helps measure the ability to move quickly from one piece of information to another and visual speed, was used. The test consists of two parts: In the first part, participants must join 25 circles numbered 1 to 25 following the ascending order as quickly as possible. The time taken gives an indication of visual processing speed. In the second, participants must alternate numbers and letters in sequence (e.g. 1-A-2-B-3-C...) always in the shortest possible time. This exercise assesses the ability to maintain attention to several stimuli at once.

1.4.2 Assessment of Executive Functions

To analyze executive functions, such as mental flexibility and the ability to handle interference, the Stroop Test (Stroop Color and Word Test) was used. The test is divided into three tests: In the first, the person must quickly read color names (such as "red," "green," and "blue"). In the second, he must name the color of some coloured dots. In the third, he must name the color of the ink with which color words are written, but which do not correspond to the color itself (e.g., the word "green" written in red).

1.5 Statistical Analysis

We analyzed our data using IBM SPSS Statistics (Version 26.0). Since the data did not follow a normal distribution (as shown by the Shapiro-Wilk test), we chose to use non-parametric methods. Specifically, we applied the Friedman test to explore differences across the three experimental conditions. For more detailed comparisons between pairs of conditions, we used the Wilcoxon signed-ranks test, and we applied a Bonferroni correction to reduce the risk of false positives due to multiple testing. We considered the results to be statistically significant when $p \leq 0.05$. These statistical methods were selected to ensure the results reliably reflected genuine changes in students' cognitive performance following different types of physical activity breaks.

Results

Friedman's non-parametric analyses of repeated measures revealed significant improvements in several key cognitive domains following physical activity interventions. Specifically, marked effects were found for visual processing speed ($p < 0.001$), divided attention ($p < 0.001$), and executive functioning, as measured through both the time-based interference ($p < 0.001$) and the error-based interference ($p < 0.001$) components of the Stroop Color and Word Test. Follow-up comparisons using Bonferroni-corrected Wilcoxon signed-rank tests revealed that both the exergaming condition (PABEx) and the outdoor physical activity condition (OPAB) were associated with significantly faster TMT-A completion times compared to the non-physical activity condition (NPAB) (PABEx vs. NPAB: Adj. $p < 0.001$; OPAB vs. NPAB: Adj. $p < 0.001$). No significant difference emerged between the PABEx and OPAB groups ($p = 0.124$), suggesting a comparable benefit across these two active modalities for basic processing speed. More nuanced findings emerged for TMT-B, which measures complex attention and task-switching. Here, all between-group comparisons reached statistical significance, indicating that both active conditions significantly outperformed the control. Participants in both the PABEx and OPAB groups had lower (i.e., better) TMT-B scores compared to NPAB (PABEx vs. NPAB: Adj. $p < 0.001$; OPAB vs. NPAB: $p < 0.001$). Interestingly, the PABEx group also performed significantly better than the OPAB group in this task (Adj. $p = 0.013$), pointing to a possible added benefit of digital interactivity in enhancing divided attention and cognitive flexibility. When evaluating executive functions through the Stroop task, specifically sensitivity to time-related interference, both active conditions once again showed significant advantages over the non-active group. Participants in the PABEx and OPAB conditions demonstrated lower interference scores (i.e., faster response times) than those in the NPAB condition (PABEx vs. NPAB: Adj. $p < 0.001$; OPAB vs. NPAB: Adj. $p < 0.001$). No significant differences were detected between the PABEx and OPAB groups in this time-based Stroop measure (Adj. $p = 1.00$), suggesting equivalent enhancements in inhibitory control and processing efficiency across both active settings. However, a different pattern emerged for the error-based interference component of the SCWT. Here, a significant difference was found between the OPAB and PABEx groups (Adj. $p < 0.001$), with the outdoor group demonstrating superior accuracy. Notably, no significant difference was observed between the PABEx and NPAB groups in terms of error-related interference (Adj. $p = 0.992$), while the OPAB group showed a marked advantage over NPAB (Adj. $p = 0.001$). These findings highlight the distinctive role of outdoor physical activity in enhancing cognitive precision, particularly in the face of conflicting or distracting stimuli.

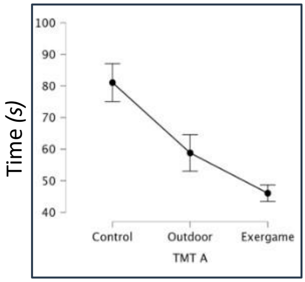

Chart 1. The mean time in TMT A is significantly lower in the Exergame condition than in the Control and between Outdoor and Control; between Exergame and Outdoor there are no statistically significant differences.

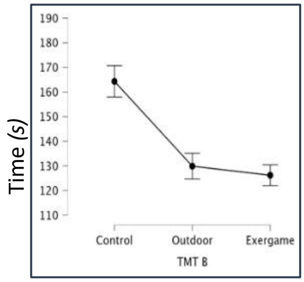

Chart 2. The mean time in TMT B is significantly lower in Outdoor and Exergame conditions than in Control; there are no significant differences between Outdoor and Exergame.

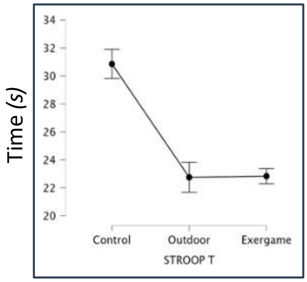

Chart 3. Mean time in STROOP T assessment is significantly lower in Outdoor and Exergame conditions than in Control but not between Outdoor and Exergame.

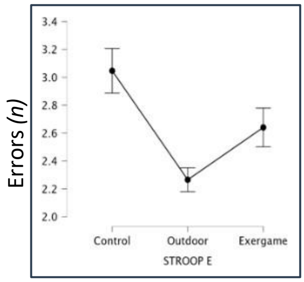

Chart 4. In STROOP E, the mean error number shows statistically significant differences between the Outdoor versus Control condition but not between Exergame and Control and between Exergame and Outdoor.

2. Discussions

The findings from our study provide compelling evidence that incorporating physical activity breaks (PABs) into the academic setting can significantly enhance university students' cognitive functioning. Our results align with and extend the growing body of literature highlighting the relationship between physical activity, cognitive performance, and academic achievement (De Bot et al., 2020; Paulus et al., 2021).

Both intervention conditions—outdoor physical activity breaks (OPAB) and exergaming (PABEx)—demonstrated significant improvements in selective attention and executive functioning compared to the control condition with no physical activity break (NPAB). These findings support previous research indicating that short, structured breaks of physical activity during school time can enhance cognitive processes (Haverkamp et al., 2020; Infantes-Paniagua et al., 2021; Peiris et al., 2021). Specifically, our results revealed that both OPAB and PABEx significantly improved visual processing speed (TMT-A) and divided attention (TMT-B) compared to NPAB, consistent with studies suggesting that PABs can positively impact attention and cognitive performance (Howie et al., 2014; Watson et al., 2019).

The significant enhancement in executive functioning following both active interventions, as measured by the time-based interference component of the Stroop task, aligns with research highlighting the potential of physical activity to improve inhibitory control and cognitive flexibility (Chen et al., 2022). This is particularly relevant given the high prevalence of sedentary behavior among college students (Castro et al., 2020; Felez-Nobrega et al., 2018) and the associated negative impacts on both physical health and mental well-being (Santos-Lozano et al., 2021; Zhu, 2022). Our findings suggest that incorporating brief 10-minute PABs between academic lessons could serve as an effective strategy to counteract these sedentary patterns while simultaneously enhancing cognitive functioning.

Interestingly, our results revealed differential effects between the two intervention modalities. While both OPAB and PABEx showed comparable benefits for visual processing speed and time-based interference, the exergaming condition demonstrated superior performance in divided attention tasks (TMT-B). This aligns with previous research highlighting the potential of exergames to enhance cognitive engagement through their interactive and immersive nature (Gao & Mandryk, 2012; Staiano & Calvert, 2011). The digital interactivity of exergames may provide additional cognitive stimulation that particularly benefits complex attention and task-switching abilities, supporting findings by Gu et al. (2023) regarding the potential applications of digital tools in higher education settings.

Conversely, the outdoor physical activity condition showed superior accuracy in the error-based interference component of the Stroop test, with participants making significantly fewer errors compared to both the exergaming and control conditions. This suggests that natural outdoor environments might offer unique benefits for cognitive precision and error management, possibly due to the restorative effects of natural settings or the additional sensory stimulation provided by outdoor environments. These findings extend previous research by Wan Yunus et al. (2020) and Gao et al. (2014) by distinguishing between the specific cognitive benefits of different PAB modalities.

Our results further emphasize the importance of the duration and structure of PABs, supporting Watson et al.'s (2019) assertion that sessions of 5–10 minutes may be particularly effective and sustainable. The 10-minute intervention protocol utilized in our study, consisting of warm-up, main activity, and cool-down phases, proved sufficient to elicit significant cognitive improvements without substantially disrupting the academic schedule. This practical approach addresses concerns about time constraints in educational settings and offers a feasible strategy for integration into university curricula.

The observed cognitive enhancements following both intervention conditions also support the notion that promoting physical activity within the academic setting is not merely a public health concern but also a pedagogical imperative. As Silva et al. (2022) noted, only a small percentage of college students meet recommended physical activity levels, with most engaging in little to no physical activity. Our findings suggest that structured PABs during academic hours could serve as an effective strategy to increase physical activity levels while simultaneously enhancing cognitive readiness for learning.

The different patterns of improvement observed between outdoor and exergaming conditions suggest that these modalities might complement each other, potentially offering a comprehensive approach to cognitive enhancement when implemented strategically. The exergaming condition may be particularly beneficial for improving complex attention and cognitive flexibility, while outdoor physical activity may offer superior benefits for accuracy and error management in executive functioning tasks. This nuanced understanding can inform the development of tailored PAB interventions that optimize specific cognitive domains based on educational objectives and contextual constraints.

Conclusions

In conclusion, this study provides strong evidence to support the integration of physical activity breaks in higher education settings as a strategy to improve students' cognitive functioning and provides a valuable strategy to improve the pedagogical and educational context during learning activities. Both outdoor physical activity and exergaming interventions demonstrated significant benefits for selective attention and executive functioning compared with traditional sedentary breaks. These findings underscore the importance of viewing the university environment not only as a space for intellectual development, but as a context that supports holistic, cognitive, emotional, and physical growth. By promoting a culture of movement within higher education, institutions can play a central role in promoting immediate cognitive benefits and lifelong health and learning strategies. Future research should explore the long-term impacts of sustained PAB interventions on academic achievement, retention, and overall well-being, as well as investigate optimal implementation strategies in different educational settings and student populations. Given the differential benefits observed between outdoor and exergaming modes, educational institutions might consider offering a variety of PAB options to maximize cognitive improvements.

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