

Physical exercise based on active breaks on cognitive function and mathematical competence in undergraduate students

Ejercicio físico basado en descansos activos sobre la función cognitiva y la competencia matemática en estudiantes universitarios de grado

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Abstract. A review of the literature has demonstrated the impact of active breaks (AB) on students' cognition and academic performance. Despite the evidence, undergraduate students seem to remain passive during the lessons as the teaching is mostly traditional and revolves around the teacher. To break with this tendency in the university context, we included physical activity (PA) breaks during lessons. This study aimed to observe the acute effect of AB on the students' attention and mathematical competence. A total of 25 undergraduate students ($M_{age} = 23.36$, $SD = 1.98$) participated in this study and performed an intervention under two conditions: i) control condition and ii) active-break condition. Results revealed that after receiving an AB (15 minutes) of moderate intensity students' attention was improved. More specifically, participants were faster at D2 and their math tasks results improved.

Keywords. Active Breaks; attention; exercise; undergraduate students; D2; mathematical competence; physical activity.

Resumen. La literatura ha demostrado el impacto de los descansos activos (AB; *active breaks* en inglés) en la cognición y el rendimiento académico de los estudiantes. A pesar de la evidencia, los estudiantes universitarios parecen permanecer pasivos durante las lecciones, ya que la enseñanza es mayoritariamente tradicional y gira en torno al profesor. Para romper con esta tendencia en el contexto universitario, incluimos pausas de actividad física (AF) durante las clases. Este estudio de casos cruzados tiene como objetivo observar el efecto agudo de los descansos activos en la atención y la competencia matemática de los estudiantes. Un total de 25 estudiantes de grado ($M_{edad} = 23,36$, $DE = 1,98$) participaron en este estudio y realizaron una intervención bajo dos condiciones: i) condición de control y ii) condición de descansos activos. Los resultados muestran que los estudiantes mejoraron su atención después de recibir una sesión de descanso activo (15 minutos) de intensidad moderada. En este sentido, los participantes fueron más rápidos en D2 y mejoraron sus resultados en la tarea de matemáticas.

Palabras clave. Descansos activos; atención; ejercicio; estudiantes universitarios; D2; competencia matemática; actividad física.

Introduction

The important technological and electronic development that our society has experienced has reduced the need for physical work, increasing sedentary lifestyle. This lack of physical activity also affects growing children and adolescents, in whom overweight, and obesity have increased alarmingly (Janssen & Leblanc, 2010).

Sedentary lifestyle and low levels of physical activity (PA) are associated with different health problems such as high blood pressure, diabetes, high cholesterol, coronary heart disease, depression, anxiety, and low self-esteem (Piercy et al., 2018). The educational field is one of the fundamental pillars through which a sedentary lifestyle can be combated. However, it has to be noted that along a regular school day, students

have few opportunities to get up from their desks, move around and exercise. In fact, these could be summarized in two: Physical Education classes and recess (González-Fernández et al., 2021; Zerf et al., 2021).

Practice of PA not only provides already known health benefits (Hardman & Stensel, 2009), but it's also positively associated with the development of motor skills (Calahorra-Canada et al., 2016), mental health, emotional regulation, cognitive performance, executive functions, encompassing memory, attention and mental planning / organization (Diamond, 2013; Hillman, Kamijo & Scudder, 2011), or with academic performance (Singh, Uijtdewilligen, Twisk, Van Mechelen and Chinapaw, 2012).

Physical activity, defined as 'any bodily movement produced by skeletal muscles that results in energy expenditure' (Caspersen et al., 1985), has been shown to be beneficial for physical, mental, and psychosocial health in children and teenagers. There is a growing interest in the effect of PA on cognitive outcomes, as

evidenced by the large number of recent reviews and meta-analyses on the topic in the last five years.

Currently, active breaks (AB) are of great interest in educational content (Watson et al., 2019), since integrating movement in academic classes not only improves the levels of moderate and vigorous physical activity of students during school day, but also increases learning facilitators (González-Fernández et al., 2021). AB are defined as PA periods between 5 and 15 minutes (Goh et al., 2016; Masini et al., 2020) inserted into the routine of the class (Daly-Smith et al., 2018; Watson et al., 2019).

Previous studies collected in different reviews, showed that moderate physical exercise and AB enhance academic achievement in some areas like math (Keeley et al., 2009; Indreica et al., 2011; Mavilidi et al., 2020).

Many authors consider that AB could be promoted within school. It would promote PA and improve academic results, since there is evidence showing that concentration, attention, processing speed and performance in the classroom are improved significantly with AB (Álvarez-Bueno et al., 2017; Haverkamp et al., 2020, Ruiz-Ariza et al., 2021).

Nowadays, most students do not meet the recommended 2020 guidelines of the World Health Organization (Bull et al., 2020), that recommends children and young people to engage in at least 60 minutes of moderate PA and vigorous exercise (mainly aerobic) per day. However, many children and teenagers do not comply with these recommendations (Ekelund et al., 2012). Parental relationships, social networks, and environmental factors such as living in urban places far from the countryside, have diminished the opportunity for young people to be active (Dollman, Norton and Norton, 2005).

However, there is some controversy regarding the cognitive benefits of AB (Masini et al., 2020). For example, Wilson et al., (2016) point out how AB are an effective tool to accumulate moderate and vigorous PA throughout the school day. In addition, it has been shown that active rest programming can lead to an improvement in behavior (attention and concentration) and subjective vitality (Mavilidi et al., 2020). In relation to this idea, Layne et al. (2020) found no effect of AB on mathematical performances. However, they point out as if a cognitive improvement could be sensed thanks to a chronic intervention. Recent Meta-analysis find positive effects in increasing PA when scheduling AB, in addition to an improvement in classroom behavior, however, it highlights the appearance of contradictory

results for cognitive functions and improvement in academic performance (Infantes-Paniagua et al., 2021; Masini et al., 2020).

Therefore, the objective of this study is to determine if AB promote the improvement of attention, concentration, and academic performances in basic mathematical processes in undergraduate university students. Our hypothesis is that AB cause increased concentration and attention and math performance.

Materials and methods

Experimental approach of the problem.

This pilot study followed a contrast analytic design. Undergraduate students were recruited from one university of Balearic Island, Palma de Mallorca, Spain with a population ranging from 30.000 to 50.000 inhabitants according to the National Institute of Statistics from the Spanish Government (Instituto Nacional de Estadística, 2021). The students recruited for the experiment declared to be inactive, which was later confirmed by the IPAQ questionnaire (Barrera, 2007). Data were collected during the month of September 2021. Attention and concentration were evaluated on the first and second day, while physical fitness on the first day.

Participants

A total of twenty-five undergraduate students (Age: 19.68 ± 2.54 years; Height: 165.25 ± 7.20 cm; Weight: 59.92 ± 11.18 Kg; BMI: 21.86 ± 3.10 ; Sex: 8% male and 92% female) participated in this study. Most students had a moderate-low level of physical activity (MET= 38.54 ± 3.10 min/week).

Measures

Body composition characteristics measurement

Students did not perform any kind of intense physical activity in the 24 h prior to experiment, they did not consume soft drinks or sugary drinks 30 min before and urinated at least 30 min before the bioimpedance measurement. Body weight (kg) was measured without shoes with a bioelectrical impedance analysis (BIA) device (Tanita BC-730) to the nearest 0.1 kg. Height (cm) was measured using a stadiometer (Type SECA 225, Hamburg, Germany) to the nearest 0.1 cm. The body mass index (BMI) was calculated by dividing body mass (kg) by body height² (in meters).

Heart Rate

A Polar M430 with a band with H10 heart rate monitor (Polar Electro Oy, Kempele, Finland) was used to monitor and record heart rate (HR) during exercise sessions. Data was downloaded into the polar flow software.

D2 test

Selective attention was measured with the D2 test individually (Brickenkamp & Zillmer, 1998; Culbertson & Sari, 1997). This test is used to measure selective attention and mental concentration. Specifically, it measures the ability to selectively attend to certain relevant aspects of a task while ignoring irrelevant ones quickly and accurately. It consists of 14 rows of 47 characters each; in total there are 658 items. The test items can be the letters «p» or «d» with one, two, three, or four dashes, arranged either individually or in pairs at the top and/or bottom of each letter. Subjects were required to scan across the lines to identify and to mark all «d's» with two dashes, which can be either above or below the letter. Subjects were allowed 20 seconds per lines and were asked to cross as many of those items as possible, without making mistakes.

The scores obtained in the D2 test were the following: Total number of items processed (TN), Total number of correct responses (CR), Omission errors (OE), Commission errors (CE), Total performance (TP), Concentration performance (CP) and Fluctuation rate (FR). With those scores, concentration and selective attention were calculated using the formulas in Brickenkamp (2012).

Mathematical competence test

The task consisted of 25 addition (15) and subtraction (10) questions in 15 minutes, for which the maximum score was 25 points (1 point per correct answer). In each section (addition and subtraction) 5 questions were carrying-over operations, which required greater attention to be solved properly. Subjects had 15 seconds



Figure 1. Experimental Set. Students performing the Mathematical competence test (see text for full description)

to answer each question, that was displayed on a screen, so they only had time to solve the operation and write down the result. To project questions and control both display time and response time, we used the Kahoot Premium application. (See Figure 1, for more information).

The preparation of the test was based on Yáñez & Bethencourt (2004). It is expected that additions (carrying over and non-carrying over) do not present significant differences, unlike subtractions that require greater attention and concentration (Baroody, 1988).

Procedure

Subjects were recruited from the faculty of education in Mallorca (Pontifical University of Comillas) via flyers. More specifically, they were from the third course of the Degree in Primary Education. Each participant obtained information about the main aims of the investigation and signed an informed consent form. None of the subjects had previously participated in any AB study.

All the undergraduate students in this study were treated according to the American Psychological Association guidelines, which ensured confidentiality of participants' responses. The study was conducted in accordance with the ethical principles of the 1964 Helsinki declaration for human research and was approved by the Research Ethics Committee of the Pontifical University of Comillas (2021/66). Inclusion criteria for the participants in this study were (i) reporting normal vision and no history of any neuropsychological impairments that could affect the results of the experiment, (ii) not presenting any injuries during the previous two months and (iii) giving consent.

The HR was assessed using the Polar M430 with a band with H10 heart rate monitor (Polar Electro Oy, Kempele, Finland). The participants of AB condition performed the AB intervention in a sports court located on the first floor of the class, whereas students of control condition were in a classroom on the second floor, where they performed the control condition.

Consequently, participants completed two sessions (active break condition and control condition) on separate weeks but on the same weekday (Wednesday from 12:00 to 13:00) and in the same location. The participant's HR, concentration and attention was monitored throughout both sessions to control the intensity of the session, especially to control the intensity of the active-break condition.

To conduct the experiment, all participants received a master class for 23 minutes (explaining algebra). Then participants in the control condition read a scientific paper about physical activity and cognition for 15', while participants in active-break condition performed 15 minutes of PA (5 minutes running, 5 minutes playing football and 5 minutes dancing) of 60-80% of HR. After doing these activities, all participants completed the D2 test during 5 minutes. Finally, all participants took a mathematical competence task (additions and subtractions).

Design, data reduction, and statistical analysis

For the treatment of the data, statistical methods were used to calculate percentages, central and dispersion parameters (arithmetic mean and standard deviation). Descriptive statistics are represented as mean \pm standard deviation (SD) with standard mean difference data. Tests of normal distribution (Kolmogorov–Smirnov and Levene's, respectively) were conducted on all data before analysis. The experiment was based on the within-participants design with the factor of effort condition (control condition and active-break condition). Paired sample *t*-test was used for determining differences as a repeated measures analysis (control Condition – Active Break Condition). The effect size (*d*) was calculated through Cohen's *d* using the following formula: $d = \frac{x_1 - x_2}{s}$.

The interpretation of the *d* regardless of the sign, followed the scale: Very small (0.01), Small (0.20), Medium (0.50), Large (0.80), Very large (1.20), Huge (2.0) as initially suggested by Cohen and expanded by Sawilowsky (Sawilowsky, 2009). Statistical analyses were performed using SPSS v.26 for Mac (SPSS Inc., Chicago, IL). For all analyses, significance was accepted at $p < .05$.

Results

HR. First, a paired sample *t*-test with participant's HR mean of first 23 minutes (Master class) in both groups, revealed no significant differences [$p = 0.75$, $d = 0.03$ (CC: 86.80 ± 9.26 vs ABC: 87.04 ± 9.44)]. Second, a paired measures *t*-test with participants' HR (traditional class vs AB) confirmed that participants had a higher HR during active break condition [$p = 0.001$, $d = 4.37$ (CC: 85.20 ± 9.31 vs ABC: 140.00 ± 15.09)]. Another, paired measures *t*-test with participants' HR (D2 in CC vs D2 in ABC) confirmed no significant differences [$p = 0.17$, $d = 0.41$ (CC: 86.29 ± 9.74 vs

ABC: 82.54 ± 8.30)]. Last, a paired measures *t*-test with participants' HR (mathematical test in CC condition vs mathematical test in ABC) confirmed no significant differences [$p = 0.37$, $d = 0.08$ (CC: 82.24 ± 8.81 , vs ABC: 82.96 ± 9.26)]. See figure 2, for more information.

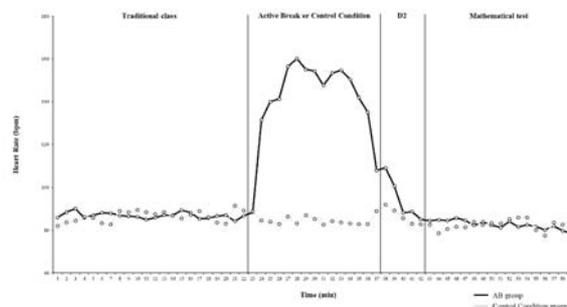


Figure 2. Schematic representation and HR of both condition (ABC vs CC). Note: CC: Control condition; ABC: Active break condition

D2. As shown in Figure 3, a paired sample *t*-test with participant's D2 attention mean score revealed significant differences between CC and ABC in Concentration and Attention [$p = 0.001^{**}$ (CC: 168.47 ± 47.79 vs ABC: 309.27 ± 911.06)] and [$p = 0.001^{**}$ (CC: 213.80 ± 47.32 vs ABC: 431.40 ± 126.23)], respectively. In other words, students of ABC were more efficient and accurate than student of CC.

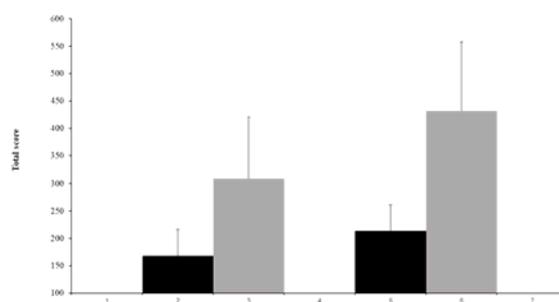


Figure 3. D2. Mean score (\pm SE) as a function of condition. Note: CC: Control condition; ABC: Active break condition

Mathematical competence test. A paired sample *t*-test with participant's Mathematical competence test score revealed no significant difference in additions [$p = 0.24$ (CC: 8.41 ± 1.66 vs ABC: 8.88 ± 1.17) $d = 0.03$] and in additions with carrying over [$p = 0.88$ (CC: 3.59 ± 1.50 , vs ABC: 3.59 ± 1.12) $d = 4.37$]. In contrast, paired sample *t*-test with participant's Mathematical test score revealed significant differences in subtraction [$p = .001^{**}$ (CC: 2.82 ± 1.29 , vs ABC: 3.94 ± 0.90) $d = 0.41$] and subtraction with carrying over [$p = 0.008^{**}$ (CC: 2.29 ± 1.61 , vs ABC: 19.07 ± 2.65 ,) $d = 0.08$]. Another similar analysis with total scores (additions and subtractions) revealed a significant difference between CC and ABC [$p = 0.04^{*}$ (CC: 17.12 ± 3.21 , Vs ABC: 19.07 ± 2.65)

$d=0.66$] where ABC performed better. (See Figure 4, for details)

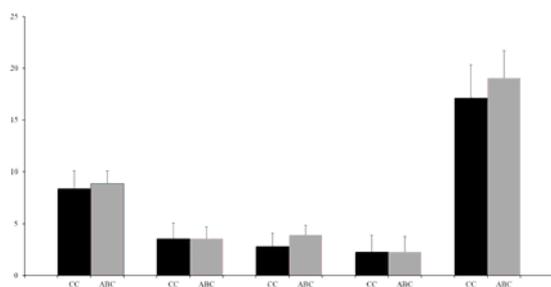


Figure 4. *Mathematical competence test. Mean score (±SE) as a function of condition.*
Note: CC: Control condition-; ABC: Active break condition

Discussion

The aim of the present study was to examine the acute effect of AB (moderate-to-vigorous intensity) on selective attention and concentration and competence in mathematics in university students. To achieve our aim, participants performed two sessions, one of CC and an ABC during 15 min after a 23 min traditional lesson. The outcome of the present study confirmed that the participants' state of concentration and selective attention (D2 test) and mathematical competence test were better in ABC than in CC. 15 minutes of Active Break seems to be enough to cause significant improvements in D2 test [concentration (83.57%, $p=0.001$) and selective attention (201.77%, $p=0.001$)] and consequently, improving results in math task (11.87%, $p=0.04$).

Physical activity at moderate intensity levels causes different physiological alterations (McMorris & Hale, 2012 & 2015) such as increased temperature, catecholamine concentration, cortical blood flow, and increased heart rate (Acevedo & Ekkekakis, 2006). Those parameters have been associated with increased arousal level in students (Langner & Eickhoff, 2013; Oken, Salinsky & Elsas, 2006) and could explain the concentration and selective attention enhancement.

In this regard, AB performed in the present study could have increased arousal activation and helped to keep attention, as observed in the results of D2 test. In addition, this kind of exercise could compensate the potential adverse effects of sedentary lifestyle (Grieco, 2016) as well as the negative effects of long school days without breaks (Betts et al., 2006; Yuretich et al., 2018). These results show that AB facilitates the performance on concentration, selective attention and mathematical competence tasks and seem to support previous research which has shown that moderate or acute exercise has

selective effects (e.g. attention and concentration) on cognitive processing (Donnelly et al., 2016; Lambourne & Tomporowski, 2011) not only in children (Ruiz et al., 2009; Ruiz-Ariza et al., 2017), but also in high-school and university students who are supposed to be at the highest level of both physical and intellectual development (Zaragoza et al., 2004).

In reference to the Mathematical competence test, it should be said that it was designed with the intention that additions did not entail any difficulty, while the two types of subtraction (carrying over, and non-carrying over) presented a bigger challenge, since, as previous studies pointed out (Baroody, 1988), they are tasks requiring more attention and concentration. In fact, the beneficial effect that were found, could be linked with improvement in working memory, a key factor for calculation (Baddeley, 1997; Morgado, 2005). An activation or training of the frontal lobes would increase working memory capacity (Edin et al., 2009) and consequently the capacity for carrying out calculations.

Finally, the literature has linked physical exercise with increasing cognitive functions (Altenburg, Chinapaw & Singh, 2016), consequently students could learn different subjects more easily in different areas of the curriculum (different subjects in school) related to different moderate physical activity exercises [AB of 15 min (40 to 60% of HR)]. However, physical activity must be controlled, since continuous training has been shown to increase dopamine receptors in the cerebral cortex, which hinders working memory processes (Macnab et al., 2009). For this reason, AB could provoke the use of dopaminergic stimulants, increasing performance and motivation during the practice and resolution of mathematical tasks, in children (even with attention deficit) and adults (Volkow et al., 2004).

Finally, the current study provides, empirical evidence indicating that AB performed at moderate intensity enhances concentration and selective attention, as well as better competences in mathematics in university students. Based on these results, and in order to improve the student's attention and academic learning, we suggest including different AB during the school day to offset poor results in Mathematical exams, and reduce long periods of time without any breaks observed in traditional schools.

Limitation and weaknesses of this study

The main limitation of this pilot study is the small sample size. For future investigation, a greater number

of participants will have to be considered. Another point would be to include students from a different degree: For instance, students from sports and physical education degrees, in order to compare them with Education degrees' student and see if there is a significant difference. It is also important to establish a step-by-step protocol for the implementation of active breaks, that can be replicated to add validity to the evidence that this pilot study found.

Conclusions

The present study provides insights regarding the importance of incorporating AB thought university day, to increase student's efficiency on attention and improve their mathematical competence. In fact, an Active Break, of 10-15 minutes, during school day could improve attention and therefore academic achievement of students, not only children. For these reasons, increasing the use of active methodologies inside the classroom would help improving the learning of university students.

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