Original Article

The effects of a moderate-to-high intensity interval exercise training programme on selective and sustained attention in schoolchildren aged 11 and 12

JAUME GELABERT[1], RICARDO DE LA VEGA[2], PERE PALOU-SAMPOL[1], ADRIÀ MUNTANER-MAS[1,3]

[1]*Research Group in Physical Activity and Sport Sciences (GICAFE), Department of Physical Education and Sports, Faculty of Education, Balearic Islands University, Mallorca, Spain*
[2]*Teaching and Evaluation of Physical Activity and Sport, Department of Physical Education, Sport, and Human Motricity, Autonomous University of Madrid, Madrid, Spain*
[3]*Research Group PROFITH "PROmoting FITness and Health through Physical Activity", Department of Physical Education and Sports, Faculty of Sports Sciences, University of Granada, Granada, Spain*

ABSTRACT

Physical activity has been shown to have positive benefits on many brain function indices. Nonetheless, evidence is scant regarding attention. This study therefore aimed to analyse the chronic effects of an interval physical exercise programme at moderate-to-high intensity on selective and sustained attention indicators amongst schoolchildren aged 11 and 12 years old. They were part of a total sample of 56 schoolchildren split evenly between the experimental and control groups. The programme ran for seven weeks with 30-minute sessions three times per week. Interval games were performed with motor, cognitive and coordination challenges at 70-80% of maximum heart rate. Selective attention was recorded via a cancellation task (d2-Test) and sustained attention via a computer vigilance task (CSAT-II). The results showed no significant changes in any selective or sustained attention indicator. In short, the implemented programme did not show it generated chronic effects on selective or sustained attention. Future research is required to provide more evidence on physical activity programmes in schools that explore changes in selective and sustained attention.
Keywords: Cognition; Youth; Physical exercise; Physical activity; Physical education; Children; Exercise.

Cite this article as:
Gelabert, J., de la Vega, R., Palou-Sampol, P., & Muntaner-Mas, A. (2023). The effects of a moderate-to-high intensity interval exercise training programme on selective and sustained attention in schoolchildren aged 11 and 12. *Journal of Human Sport and Exercise, 18*(1), 209-223. https://doi.org/10.14198/jhse.2023.181.17

Corresponding author. *Department of Physical Education and Sports, Faculty of Education, Balearic Islands University, Mallorca, Valldemossa road, km 7.5. 07122, Palma. Spain.* https://orcid.org/0000-0001-6977-9874
E-mail: adria.muntaner@uib.es
Submitted for publication September 09, 2021.
Accepted for publication November 03, 2021.
Published January 01, 2023 *(in press* January 03, 2022).
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202.

doi:10.14198/jhse.2023.181.17

INTRODUCTION

Attention is one of the main cognitive functions, linked to perception, executive functions, memory and learning (Rosa, Eliseo, & Carrillo, 2019). Nevertheless, the lack of attention amongst schoolchildren continues to rise, and it is complicated for them to remain attentive for prolonged periods (Gunnell et al., 2019). According to teachers, half of all pupils show an attention deficit (Batlle, 2009; Servera & Llabrés, 2004). Consequently, there is concern within the education system that sufficiently positive attention mechanisms are required to comply with proposed schooling objectives and offer better academic, learning and cognitive function performance (Holgado & Alonso, 2015; Leon, 2008; Monteoliva, Carrada, & Ison, 2017). It is essential for neural mechanisms to be able to select relevant stimuli, thus focusing attention on them whilst disregarding irrelevant details. It is also essential for the brain to hold a sufficiently high attention level for a prolonged period where a specific task must be performed (Bernabéu, 2017).

García (1997) defines attention as 'the mechanism directly involved in activating and operating processes and/or operations of selection, distribution and maintaining psychological activity'. Moreover, depending on the selected stimulus and concentration time, attention may be focused, selective or sustained (Guillamón, Canto, & Martínez García, 2021). Aspects such as early exposure to screens (Tamana et al., 2019), the teacher-pupil relationship (Pallini, Vecchio, Baiocco, Schneider, & Laghi, 2019) and the lack of physical activity may, amongst others, have an effect on attention. Nonetheless, neuroscience may also offer ways to improve circuits related to attention processes (Llorente, Oca, Solana, & Ortíz, 2012). As Alonso (2017) states, the education system should consider that the human brain is characterised by its neural plasticity, which refers to the ability of the nervous system to change its structure and functioning over time. Furthermore, this plasticity enables neurons to anatomically and functionally regenerate, forming new synaptic connections and, thus, varying the structural levels of the nervous system (Castrén & Hen, 2013; Kolb, Muhammad, & Gibb, 2011); as long as they are strengthened and stimulated by brain activity, with physical activity being a key factor (Alonso, 2017). In addition, it is crucial to also include neurogenesis, which refers to the creation and subsequent spread of new neurons within the nervous system thanks, in part, to physical activity (Pallotto & Deprez, 2014).

In this vein, physical activity as well as improving physical fitness may also have positive effects on attention amongst schoolchildren (Tomporowski, McCullick, Pendleton and Pesce, 2015). Some cross-cutting research has analysed the link between selective attention and physical fitness in school-age children and adolescents (Pérez-Lobato, Reigal, & Hernandez-Mendo, 2016; Reigal et al., 2020), in addition to body composition (Cadenas-Sanchez et al., 2017). This research concluded that there is a positive association between the analysed variables and contributed to the importance of promoting physical activity programmes aimed at schoolchildren and adolescents intended to have a positive impact on attention in these age groups. For this reason, there are many different interventions that attempt to analyse the effect of physical activity programmes on selective attention in schoolchildren and adolescents. Nonetheless, the scientific literature does not present conclusive evidence. Some studies show no chronic positive effects for said programmes (Gall et al., 2018); nor do others based on active rest (Van den Berg, Saliasi, De Groot, Chinapaw, & Singh, 2019), although the latter do seem to have a greater acute positive effect in schoolchildren (Altenburg, Chinapaw, & Singh, 2016; Ma, Le Mare, & Gurd, 2015). Moreover, two metanalyses should be highlighted: firstly, (De Greeff, Bosker, Oosterlaan, Visscher, & Hartman, 2018) refer to the acute positive sustained effect on selective attention after physical activity stimulus. Secondly, (Moreau & Chou, 2019) agree with this, adding that high-intensity physical activity does not significantly differ from moderate intensity in terms of having acute positive effects. With regard to sustained attention, there is little scientific literature on the matter. Nevertheless, there seems to be a greater positive effect from interventions that analyse acute

(Szabo-Reed et al., 2017) rather than chronic (Wilson, Olds, Lushington, Petkov, & Dollman, 2016) effects, where no significant improvements are evidenced.

As Singh et al. (2019) state, experimental studies are required that detail the features on which physical activity programmes should be based in order to analyse the link to cognitive performance. In terms of attention, its seems that low-to-moderate physical activity is not enough to produce positive effects (van den Berg et al., 2016); however, moderate and moderate-to-high intensities (Gallotta et al., 2012; Vanhelst et al., 2016) could positively effect attention due to aerobic work impacting the basal ganglia, which are involved in attention control (Chaddock et al., 2010). Furthermore, developing high-intensity interval physical exercise programmes could favour significant attention improvement (Alves et al., 2014; Ma et al., 2015). Finally, physical activity prior to academic activity also seems to possibly boost cognitive development in schoolchildren (Duncan & Johnson, 2014; Stylianou et al., 2016).

In this sense, the research herein aimed to analyse the chronic effects of a moderate-to-high intensity interval programme prior to academic activity on selective and sustained attention in schoolchildren.

METHODOLOGY

Table 1. Main characteristics of the sample.

Features	N	Total sample	N	Experimental group	N	Control group	*p*
Control variables							
Age (years)	56	11.74 ± 0.34		11.74 ± 0.30		11.74 ± 0.37	.969
Gender (Male)	56	53.60		53.60		53.60	.788
Peak growth	56	13.37 ± 1.07		13.15 ± 1.16		13.58 ± 0.95	.133
Level of physical activity	56	2.93 ± 0.72		2.84 ± 0.78		3.02 ± 0.67	.376
Resting heart rate (bpm)		99.07 ± 16.50		99.07 ± 16.50			
Maximum heart rate (bpm)		208.79 ± 0.42		208.79 ± 0.42			
Maternal occupation							
Low level	8	14.30		14.30		14.30	
Medium level	25	44.60		46.40		42.90	
High level		41.10		39.30		42.90	.959
Maternal education level							
Uneducated	1	1.80	1	3.60	0	0.00	
Primary Education	8	14.30		21.40		7.10	
Secondary education		17.90		14.30		21.40	
Baccalaureate/Vocational Training		41.10		39.30		42.90	
University studies		25.00		21.40	8	28.60	.444
Selective attention	**56**						
Total effectiveness		343.82 ± 55.30		335.14 ± 59.37		352.50 ± 50.48	.244
Concentration index		137.61 ± 25.68		134.14 ± 27.61		141.07 ± 23.57	.317
Sustained attention	**56**						
Number of hits		107.93 ± 43.54		117.54 ± 38.08		98.32± 47.12	.099
Number of errors		38.07 ± 33.47		45.61 ± 39.95		30.54 ± 23.85	.092
Perseverance		16.32 ± 16.08		22.43 ± 19.50		10.21 ± 8.31	.004
Distraction		2.41 ± 3.79		2.86 ± 4.70		1.96 ± 2.60	.383
Impulsivity		9.46 ± 12.28		11.21 ± 15.74		7.71 ± 7.28	.290
Azar		9.88 ± 9.72		9.11 ± 7.90		10.64 ± 11.35	.559

Note: Values are expressed as mean ± standard deviation or as relative frequency and %. Differences between groups have been analysed using a t-test for independent samples or Chi-square.

Design and participants

The intervention described herein was performed with a quantitative methodology and a quasi-experimental approach. A description of the sample characteristics is shown in Table 1. It shows the initial matching of the dependent variables for selective and sustained attention, as well as the total number of participants: 56 schoolchildren aged 11 to 12 (11.74 ± 0.34) split equally between the control group (GC) and the experimental group (GE). In terms of gender, 53.6% of the pupils were male. Two charter schools in Majorca (Balearic Islands) were selected for the research; both centres had a mid-level socioeconomic environment, similar spaces and educational methodologies, as well as the same amount of physical education sessions.

Instruments

Selective attention was analysed via the d2 attention test (Brickenkamp, 2012), with an internal consistency above 0.90). The researcher explained the test, ensuring all pupils understood it. The test comprised the performance of a cancellation task in a limited time. The aim was to measure the processing speed of each subject, their reproduction of instructions and the performance of a discrimination task between similar relevant and irrelevant visual stimuli, thus estimating selective attention and concentration.

Sustained attention was assessed via an experimental extension of the online test software Children Sustained Attention Task (CSAT) from (Servera & Llabrés, 2015). This comprised a continuous performance task based on a vigilance paradigm where the subject had to respond to the appearance of a stimulus-objective and discern the distracting stimuli. The CSAT-II version was performed individually, and recorded correct, incorrect, perseverance, distraction, impulsiveness and chance indicators.

A socio-demographic questionnaire was designed ad hoc. This enabled us to collect data on gender, hours of sleep and travel to school (van den Berg et al., 2016) and peak growth given that this is deemed a more appropriate tool than age as it considers the personal biological development of each child (Towlson, Cobley, Parkin, & Lovell, 2018). Moreover, the mother's education level was recorded by providing options on a simplified template from the National Classification of Education as well as the mother's profession, split into three broad categories based on the ten largest groups set out in the International Standard Classification of Occupations from the International Labour Organization (2008), with an additional eleventh and twelfth group to cover unemployment and homemakers respectively.

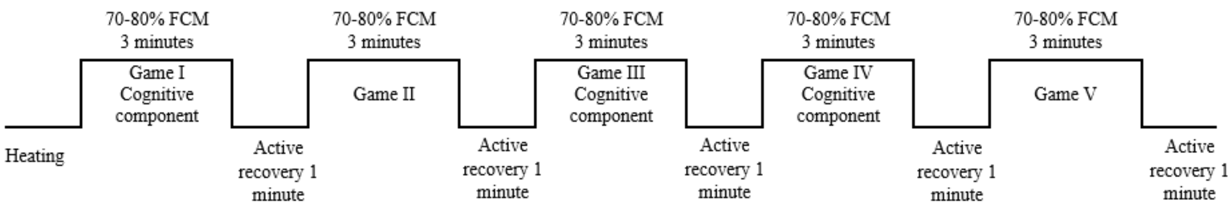
The sub-maximal intensity physical activity level was also assessed in a PAQ-C questionnaire aimed at the 8-15 age group (Manchola-González, Bagur-Calafat, & Girabent-Farrés, 2017).

Heart rate was monitored simultaneously and individually throughout the intervention, in line with the study from Muntaner-Mas, Vidal-Conti, Salmon and Palou-Sampol (2020). Each pupil used a Polar H10 heart rate sensor that showed and recorded, in real time, beats per minute (average, maximum and minimum), as well as the percentage and time taken in each of the five intensity zones. The resulting record was automatically produced and stored in the database through the Polar Team app for the iOS operating system from Apple, which was installed and used on an iPad Pro.

Procedure

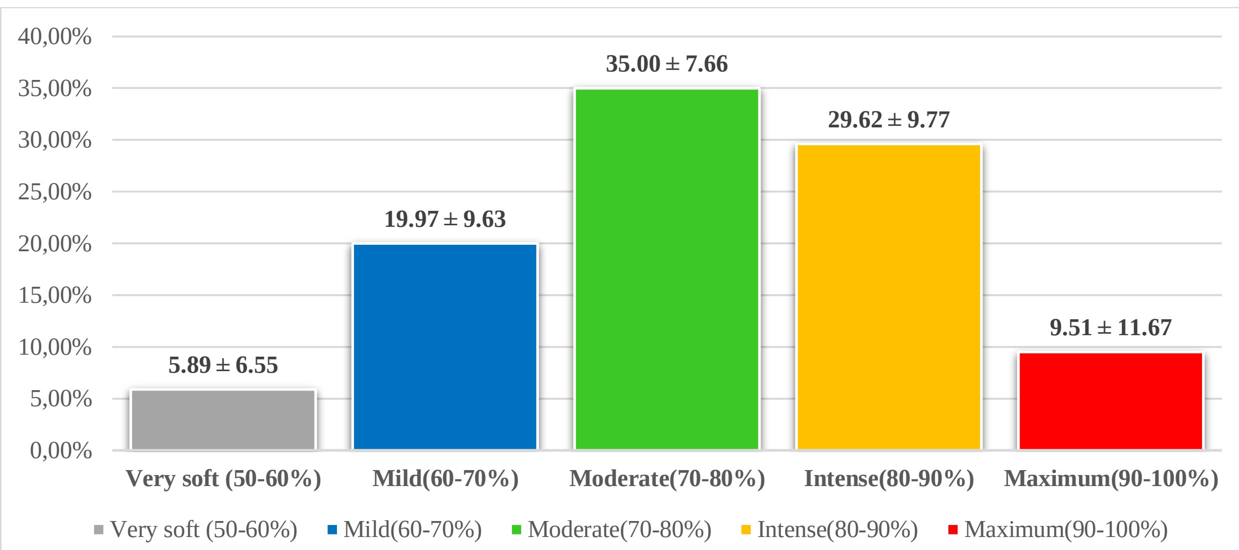
All data were recorded between the months of April and June 2018. The different tests were performed in class hours, taking into account the same time slot and clothing type for each. On the day before each measurement, the researcher reminded the schoolchildren that they needed to get enough sleep the night before the tests.

With regard to the Experimental Group (GE) intervention, the submaximal intensity interval exercise programme ran over seven weeks, with three weekly sessions and a 48-hour recovery time between each. Total compliance with the programme amongst the schoolchildren was 95.13%. The programme start time was 9 am and comprised five games which varied depending on the day of the week. All lasted three minutes with an active one-minute recovery between each game. A brief warm-up took place beforehand, based on a gentle jog and joint mobility exercises. The participants worked at submaximal intensity during the 20-minute programme session. The sensors recorded average work at 75.96% ± 4.60 for maximum heart rate (MHR) (Figure 1). Thanks to the active recovery minute, minimums of 54.84% ± 4.93 were recorded. During game time, the intensity maximums for the schoolchildren rose to 90.08% ± 4.12. The time that each child spent in each of the set intensity zones was also recorded with a view to uncovering the percentage of work time that the schoolchildren spent in each (Figure 2).



Note: MHR: Maximum Heart Rate. Source: Own elaboration.

Figure 1. Basic features of the programme.



Source: Own elaboration.

Figure 2. Percentage of time worked in each intensity zone.

Three of the five games had a cognitive element, comprising continuous 15-metre races. The distance had to be run zig-zag, moving a football with the feet, a basketball with the hands or a tennis ball with a hockey stick. Some races also included hitting a hanging volleyball or a tennis ball with the help of a racket, thus including a coordination element in each game, as well as adjusting the exercise to the desired intensity. When they reached the end, they had to solve an exercise that required attention, memory or even linguistic, mathematical or spatial intelligence. The two remaining games offered different motor challenges that the pupils had to pass either individually or collectively, moving around the play area freely to achieve the aim of the game. The total work time for the entire intervention was 7:10:32 hours ± 0:29:07 hours.

In turn, the Control Group (GC) followed their usual daily routine. The amount of physical activity and number of P.E. went unchanged.

Statistical analysis

The descriptive characteristics of the sample present a mean ± standard deviation or relative frequency of n (%). In order to compare the means from the experimental group to those of the control group, a student t-test was performed on the quantitative variables. A chi-squared test was used for the qualitative variables. An analysis of covariance (ANCOVA) was performed for the intervention effects on the studied variables and group comparison, using peak growth, mother's education level, mother's occupation, level of physical activity and travel to school as covariables. A post-hoc test was performed to compare group differences. All analyses established a level of significance of $p < .05$. All data were analysed with the SPSS statistics software package (v.24.0 for Windows by IBM, USA).

Ethical issues

This research was approved by the Ethics Committee at the Autónoma University of Madrid. The principles in the Declaration of Helsinki were followed at all times. Signed consent was received from the management teams, teachers involved and the fathers/mothers and/or legal guardians of the schoolchildren. The nature of the research was explained, as well as the proposed objectives, procedure, and benefits that the study could have for education and society; the right to withdraw from the research at any time; the researcher's commitment to ensuring the child's health at all times; the completely voluntary nature of participation; assured anonymity, and the confidentiality of all the recorded data.

RESULTS

Table 1 sets out the sample total. The control variables are presented, none of which show significant differences between the groups (p range = .133 to .959). Furthermore, there are variables referring to selective attention that show higher, albeit insignificant, values in the GC control group, both in terms of total effectiveness and the concentration index ($p = .244$ and $p = .317$, respectively). The sustained attention indicators for the GE experimental group show higher values for the number of correct answers, mistakes, perseverance, distraction and impulsiveness. In turn, the GC control group shows higher values for chance. Only perseverance shows significant differences ($p = .004$).

The intervention's effects on selective attention variables are set out in Table 2. Both groups show improved values, with the experimental group having a better ratio. Nonetheless, there are no significant differences between the groups ($p = .919$ and $p = .828$).

Table 3 shows the results for sustained attention. None of the five indicators present significant differences (p range = .386 to .937). With regard to the number of correct answers, both groups show lower values after the intervention, with the experimental group maintaining a more positive ratio compared to the control group. The four remaining indicators show the experimental group as having higher post-intervention values compared to the control group. Nevertheless, the ratio becomes favourable for the experimental group after performing a covariance and adjusted analysis (-0.78 ± 9.78 a -5.95 ± 21.76).

Table 2. Effects of intervention on selective attention.

Indicators of selective attention	N	Pre	N	Post	N	Difference (post - pre)
Total effectiveness						
Experimental group		335.14 ± 59.37		396.07 ± 65.31		54.98 ± 6.70
Control group		352.50 ± 50.48		401.02 ± 75.85		54.20 ± 5.36
Difference EG - CG						0.78 ± 7.66
p (groups)						.919
95% CI (I; S)						-14.625; 16.184
Concentration index						
Experimental group		134.14 ± 27.61		161.07 ± 30.55		24.29 ± 2.79
Control group		141.07 ± 23.57		163.46 ± 25.13		23.59 ± 2.24
Difference EG - CG						0.70 ± 3.20
p (groups)						.828
95% CI (I; S)						-5.712; 7.107

Note. The Pre and Post column values are shown as the means ± standard deviation. The Differences column values (post - pre) for the experimental and control groups are estimated marginal means adjusted for the covariables of the model ± standard error. The GE (experimental group) - GC (control group) difference is from the prior difference in means ± standard error. The differences were estimated by an analysis of covariance (ANCOVA) for a factor (dependent variable: differences between the post- and pre-intervention results. Fixed factor: group). The p < .05 values have been adjusted for gender (if there were significant differences by gender in the analysed variable), peak growth, mother's education level, mother's occupation, level of physical activity and method of travel prior to the recorded analysed variable and the pre-intervention variable of the analysed variable.

Table 3. Effects of the intervention on sustained attention.

Indicators of sustained attention	N	Pre	N	Post	N	Difference (post - pre)
Number of hits						
Experimental group		117.54 ± 38.08		83.29 ± 53.20		-25.46 ± 12.25
Control group		98.32 ± 47.12		81.46 ± 63.87		-28.09 ± 10.37
Difference EG - CG						2.63 ± 13.88
p (groups)						.850
95% CI (I; S)						-25.274; 30.535
Number of errors						
Experimental group		45.61 ± 39.95		61.96 ± 115.33		-4.95 ± 18.21
Control group		30.54 ± 23.85		19.07 ± 22.42		1.00 ± 14.79
Difference EG - CG						-5.95 ± 21.76
p (groups)						.786
95% CI (I; S)						-49.701; 37.802
Distraction						
Experimental group		2.86 ± 4.70		5.86 ± 18.04		-1.67 ± 3.09
Control group		1.96 ± 2.60		0.50 ± 1.14		1.267 ± 2.19
Difference EG - CG						-2.94 ± 3.35
p (groups)						.386
95% CI (I; S)						-9.677; 3.805
Impulsivity						
Experimental group		11.21 ± 15.74		16.64 ± 36.03		-3.73 ± 5.88
Control group		7.71 ± 7.28		4.93 ± 9.21		0.25 ± 4.52
Difference EG - CG						-3.98 ± 6.78
p (groups)						.560
95% CI (I; S)						-17.610; 9.657

Azar			
Experimental group	9.11 ± 7.90	20.61 ± 45.45	2.53 ± 8.48
Control group	10.64 ± 11.35	4.54 ± 6.06	3.30 ± 5.41
Difference EG - CG			-0.78 ± 9.78
p (groups)			.937
95% CI (I; S)			-20;433; 18.875

Note. The Pre and Post column values are shown as the means ± standard deviation. The Differences column values (post - pre) for the experimental and control groups are estimated marginal means adjusted for the covariables of the model ± standard error. The GE (experimental group) - GC (control group) difference is from the prior difference in means ± standard error. The differences were estimated by an analysis of covariance (ANCOVA) for a factor (dependent variable: differences between the post- and pre-intervention results. Fixed factor: group). The p < .05 values have been adjusted for gender (if there were significant differences by gender in the analysed variable), peak growth, mother's education level, mother's occupation, level of physical activity and method of travel prior to the recorded analysed variable and the pre-intervention variable of the analysed variable.

DISCUSSION

The main aim of this study was to determine the chronic effects of a moderate-to-high intensity interval exercise programme amongst schoolchildren aged 11 and 12 on selective and sustained attention. The research results show that the programme did not have a significant impact on any of the attention indices.

Promoting moderate-to-high intensity physical activity could have beneficial effects on selective attention in adolescents (Vanhelst et al., 2016) and in schoolchildren (De Greeff et al., 2018). In this sense, the implemented exercise programme in our research had a moderate-to-high intensity within the aerobic range, which scientific evidence most supports in terms of boosting synaptic elasticity and neurogenesis and, consequently, better attention (Alonso, 2017; Hillman, Erickson, & Kramer, 2008). The results from this study show both experimental groups improved their post-intervention records, with the experimental group showing higher, albeit non-significant, scores. As (Esteban-Cornejo et al., 2017) explain, higher levels of speed and agility, as well as aerobic capacity, are linked to several cortical and subcortical brain structures. With regard to our research, this may explain why other results from our physical activity programme that analysed the effects on physical fitness and body composition amongst the schoolchildren (Gelabert, Muntaner-Mas, & Palou, 2020) did not show any link to the two aforementioned physical fitness indicators. Thus, one could hypothesise that said changes in attention variables did not occur as there were no significant improvements in the physical fitness variables.

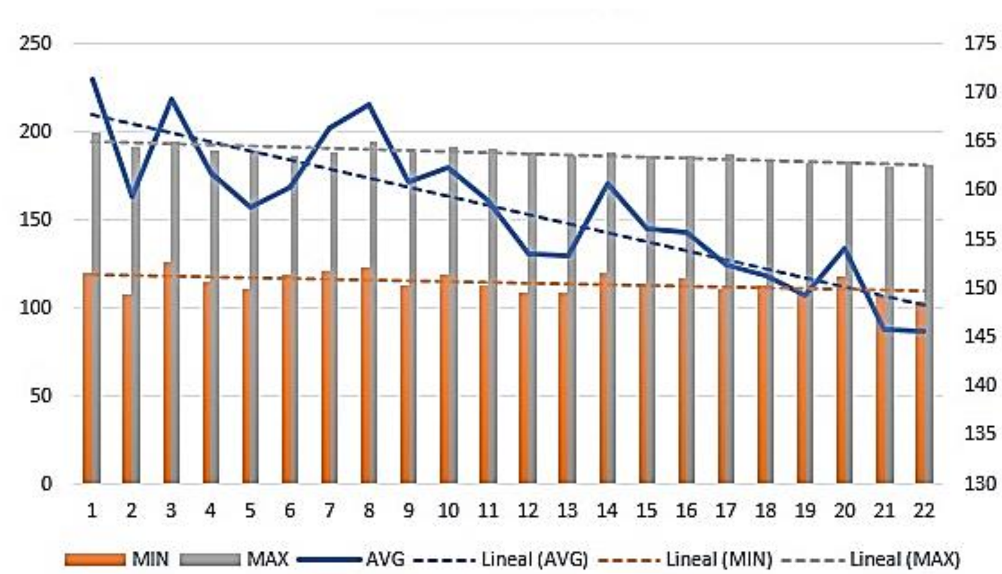
Ortega et al. (2017) add that muscle strength has a significant impact on subcortical structures and sizes, including the basal ganglia that are linked to attention (Chaddock et al., 2010). In this sense, due to the significant increase in muscle strength thanks to the implemented programme (Gelabert et al., 2020), we believe that the small increase in both analysed selective attention variables could be related to a tendency in improving these two indicators in the long term. Nevertheless, higher aerobic capacity values would also be needed to provide a solid basis for the hypothesis, as well as a significant reduction in body mass index (Cadenas-Sanchez et al., 2017). One could also look at the intervention design, specifically focusing on the length of the sessions and programme, and the impact analysis. As Kubesch et al. (2009) state in their research on young adolescents, 30 minutes of aerobic exercise (a match to our research programme) are able to generate acute positive effects on selective attention. In this sense, we are unaware of whether our programme was also able to have an acute impact since only chronic effects were analysed. Moreover, a study by Gallotta et al. (2015) did analyse the chronic effects on selective attention in schoolchildren. It ran over five months and included two weekly sessions lasting one hour each. Coordination physical activities were performed, and each session had 30 minutes of moderate-to-high intensity physical activity. Said research did indeed find positive effects. We therefore believe that the seven-week length of the programme in our research was insufficient to cause positive effects, since the length of moderate-to-high intensity physical activity and the type of physical exercise were similar to the aforementioned study.

With regard to sustained attention, the positive association with physical activity amongst adults would seem clear (Luque-Casado, Zabala, Morales, Mateo-March, & Sanabria, 2013). The same relationship is also true for adult aerobic capacity (Ciria, Perakakis, Luque-Casado, Morato, & Sanabria, 2017; Luque-Casado et al., 2016). Nonetheless, it is particularly difficult to discuss the results of a study based on an exercise programme for schoolchildren based on current scientific literature, given the scarcity thereof. The results presented in this research show worse results for the number of correct answers in both groups. Compared to the control group, the experimental group saw higher mistakes, distraction, and errors due to impulsiveness and chance. These results were surprising as they do not match current neuroscience evidence stating that in addition to boosting Brain-derived neurotrophic factor (BDNF) segregation (Watts, Andrews, & Anstey, 2018), physical activity helps increase brain blood flow and subsequent improvement in academic performance (Lambrick, Stoner, Grigg, & Faulkner, 2016; Stylianou et al., 2016), as well as improved brain structures centred on attention processes (Alonso, 2017).

Furthermore, according to Servera and Llabrés (2004), higher errors due to distraction point to a lack of concentration ability which, to a certain extent, contradicts the selective attention concentration index that showed positive results, as seen above. It is important to underline that estimated marginal measurements were taken and adjusted for different covariables after performing an analysis of covariance for the observed results. After this adjustment, the values inverted and were more favourable in the experimental group across all indicators. This leads us to suppose that sociodemographic variables such as level of education or profession, method of travel to school (which were significantly different between the groups) and the moderate-to-high intensity physical activity done outside the research may have a major impact on sustained attention. This last variable is also supported by two studies on schoolchildren and adolescents which set out the positive association between athletic participation and sustained attention (Ballester, Huertas, Molina, & Sanabria, 2018; Ballester, Huertas, Yuste, Llorens, & Sanabria, 2015), respectively. The systematic review by Hajar, Rizal and Kuan (2019) also proposes assessing the effect that gender, age and motivation may have. In the same vein, Wirt et al. (2015) believed that controlling these variables was key to undertaking their research into schoolchildren, and highlighted the significant link between body weight and response inhibition, which is related to the impulsiveness indicator in our research. These data may explain why the impulsiveness indicator did not show significant changes, given that body mass index also did not see significant changes in our research intervention (Gelabert et al., 2020).

Other cross-cutting studies on schoolchildren also conclude that there is a positive link between sustained attention and aerobic capacity (Pontifex, Scudder, Drollette, & Hillman, 2012), in addition to motor skills (Geertsen et al., 2016). Given this association, and there being no improvement in aerobic capacity from the programme in this research (Gelabert et al., 2020), this may also explain the lack of significance in the presented results. As mentioned earlier, there is scant scientific literature on experimental studies. This is underlined by the systematic review by Hajar, Rizal and Kuan (2019) that only includes five studies into schoolchildren, of which two were focused on pupils with ADHD and where only one of the remaining three was based on an experimental design. In addition, the latter looks at the acute effects of an intervention based on 10-minute active rest periods implemented three days a week over four weeks; these do not seem to have a positive impact on sustained attention either (Wilson et al., 2016).

A further experimental study is included in the aforementioned systematic review. The study attempted to discern the chronic effects on sustained attention amongst adolescents through a programme based on 60 minutes of aerobic activity twice a week over six weeks. The research showed no significant positive changes for sustained attention, although it did show some for short-term memory. These results are similar to those seen in our study, since it would seem that these programmes are not sensitive to chronic changes in sustained attention. At the same time, it is unknown whether said programme led to acute effects. Another reason that may be particularly important in discussing the results on sustained attention is motivation (Hajar et al., 2019). It is possible that the poor results were due to incorrect performance of the test through lack of motivation or accumulated fatigue throughout the school year. This assessment may be supported by the monitoring system used in each session that recorded average, minimum and maximum beats. We noted that average beats fell throughout the intervention (Figure 3), which could be due more to issues related to accumulated fatigue at the end of the year, in addition to a lack of appreciation for the programme which was given a score of 7.6 out of 10 (analysis not shown). Finally, it is important to highlight that none of the studies show contraindications in terms of sustained attention. Therefore, these programmes are at least a positive tool to increase daily physical activity amongst schoolchildren (Wilson et al., 2016) and improve physical fitness and body composition indicators (Gelabert et al., 2020).



Note. MIN: minimum beats; MAX: maximum beats; AVG: average. Source: Own elaboration.

Figure 3. Evolution of minimum, average and maximum pulse rates during the intervention.

Different factors limited the research: the performance of a short-term intervention and the difficulty in controlling physical education sessions should be underscored. In turn, not including more advanced attention tests and clinical techniques in the study, as done in other research (Chaddock et al., 2010; Esteban-Cornejo et al., 2017) limited the precise analysis of the intervention's effects on possible changes in the brain.

As far as we are aware, the findings in this research represent, for the first time, a contribution to knowledge in scientific literature on the simultaneous chronic effects of a moderate-to-high intensity interval exercise programme on selective and sustained attention amongst schoolchildren aged 11 and 12. Moreover, the exercise programme in this study could be used as a basis for future research, analysing long-term effects, as well as the impact on executive functions on academic performance.

CONCLUSION

The intervention undertaken did not lead to any significant change in selective or sustained attention. More interventions need to be performed that analyse chronic effects mainly on sustained attention, whilst considering, amongst others, different sociodemographic, physical fitness and body composition variables.

AUTHOR CONTRIBUTIONS

Jaume Gelabert participated in the research design, data collection, statistical analysis and writing of the manuscript. Ricardo de la Vega participated in writing and revising the manuscript. Pere Palou revised the manuscript. Finally, Adrià Muntaner-Mas supervised the entire research, participating in the writing and analysis.

SUPPORTING AGENCIES

This research has received funding through the extraordinary call for research grants. Preparation, implementation and transfer of knowledge (call 2020) of the Institute for Research and Innovation in Education (IRIE).

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

REFERENCES

Alonso, J. (2017). Actividad Física y Neurociencia. In I Congreso Nacional de Eduación Física, Neuromotricidad y Aprendizaje. Guadalajara: Ministerio de Educación y Formación Profesional.

Altenburg, T. M., Chinapaw, M. J. M., & Singh, A. S. (2016). Effects of one versus two bouts of moderate intensity physical activity on selective attention during a school morning in Dutch primary schoolchildren: A randomized controlled trial. Journal of Science and Medicine in Sport, 19(10), 820-824. https://doi.org/10.1016/j.jsams.2015.12.003

Alves, C. R., Tessaro, V. H., Teixeira, L. A., Murakava, K., Roschel, H., Gualano, B., & Takito, M. Y. (2014). Influence of acute high-intensity aerobic interval exercise bout on selective attention and short-term memory tasks. Perceptual & Motor Skills, 118(1), 63-72. https://doi.org/10.2466/22.06.PMS.118k10w4

Ballester, R., Huertas, F., Molina, E., & Sanabria, D. (2018). Sport participation and vigilance in children: Influence of different sport expertise. Journal of Sport and Health Science, 7(4), 497-504. https://doi.org/10.1016/j.jshs.2017.05.008

Ballester, R., Huertas, F., Yuste, F. J., Llorens, F., & Sanabria, D. (2015). The relationship between regular sports participation and vigilance in male and female adolescents. PLoS ONE, 10(4), 1-12. https://doi.org/10.1371/journal.pone.0123898

Batlle, S. (2009). Evaluación de la Atención en la Infancia y la Adolescencia. Col·legi Oficial de Psicolegs de Catalunya, 13. Retrieved from http://www.paidopsiquiatria.cat/files/evaluacion_atencion.pdf

Bernabéu, E. (2017). La atención y la memoria como claves del proceso de aprendizaje. Aplicaciones para el entorno escolar. ReiDoCrea, 6(2), 16-23. Retrieved from http://www.ugr.es/~reidocrea/6-2-3.pdf

Brickenkamp, R. (2012). D2, Test de atención. Madrid: TEA Ediciones.

Cadenas-Sanchez, C., Vanhelst, J., Ruiz, J. R., Castillo-Gualda, R., Libuda, L., Labayen, I., … Ortega, F. B. (2017). Fitness and fatness in relation with attention capacity in European adolescents: The HELENA study. Journal of Science and Medicine in Sport, 20(4), 373-379. https://doi.org/10.1016/j.jsams.2016.08.003

Castrén, E., & Hen, R. (2013). Neuronal plasticity and antidepressant actions. Trends in Neurosciences, 36(5), 259-267. https://doi.org/10.1016/j.tins.2012.12.010

Chaddock, L., Erickson, K. I., Prakash, R. S., Vanpatter, M., Voss, M. W., Pontifex, M. B., … Kramer, A. F. (2010). Basal Ganglia Volume Is Associated with Aerobic Fitness in Preadolescent Children. Developmental Neuroscience, 32, 249-256. https://doi.org/10.1159/000316648

Ciria, L., Perakakis, P., Luque-Casado, A., Morato, C., & Sanabria, D. (2017). The relationship between sustained attention and aerobic fitness in a group of young adults. PeerJ, 5, e3831. https://doi.org/https://doi.org/10.7717/peerj.3831

De Greeff, J. W., Bosker, R. J., Oosterlaan, J., Visscher, C., & Hartman, E. (2018). Effects of physical activity on executive functions, attention and academic performance in preadolescent children: a meta-analysis. Journal of Science and Medicine in Sport, 21(5), 501-507. https://doi.org/10.1016/j.jsams.2017.09.595

Duncan, M., & Johnson, A. (2014). The effect of differing intensities of acute cycling on preadolescent academic achievement. European Journal of Sport Science, 14(3), 279-286. https://doi.org/10.1080/17461391.2013.802372

Esteban-Cornejo, I., Cadenas-Sanchez, C., Contreras-Rodriguez, O., Verdejo-Roman, J., Mora-Gonzalez, J., Migueles, J. H., … Ortega, F. B. (2017). A whole brain volumetric approach in overweight/obese children: Examining the association with different physical fitness components and academic performance. The ActiveBrains project. NeuroImage, 159, 346-354. https://doi.org/10.1016/j.neuroimage.2017.08.011

Gall, S., Adams, L., Joubert, N., Ludyga, S., Müller, I., Nqweniso, S., … Gerber, M. (2018). Effect of a 20-week physical activity intervention on selective attention and academic performance in children living in disadvantaged neighborhoods: A cluster randomized control trial. PLoS ONE, 13(11), e0206908. https://doi.org/10.1371/journal.pone.0206908

Gallotta, M. C., Emerenziani, G. Pietro, Iazzoni, S., Meucci, M., Baldari, C., & Guidetti, L. (2015). Impacts of coordinative training on normal weight and overweight/obese children's attentional performance. Frontiers in Human Neuroscience, 9(577), 1-9. https://doi.org/10.3389/fnhum.2015.00577

Gallotta, M. C., Guidetti, L., Franciosi, E., Emerenzianl, G. Pietro, Bonavolontà, V., & Baldari, C. (2012). Effects of Varying Type of Exertion on Children's Attention Capacity. Medicine & Science in Sports & Exercise, 44(3), 550-555. https://doi.org/10.1249/MSS.0b013e3182305552

García Sevilla, J. (1997). Psicología de la atención. Madrid: Síntesis Psicología.

Geertsen, S. S., Thomas, R., Larsen, M. N., Dahn, I. M., Andersen, J. N., Krause-Jensen, M., … Lundbye-Jensen, J. (2016). Motor skills and exercise capacity are associated with objective measures of cognitive functions and academic performance in preadolescent children. PLoS ONE, 11(8), e0161960. https://doi.org/10.1371/journal.pone.0161960

Gelabert, J., Muntaner-Mas, A., & Palou, P. (2020). Efectos de un programa de ejercicio interválico de intensidad moderada-vigorosa sobre la condición física y la composición corporal en escolares de 11 y 12 años. Nutrición Hospitalaria, 37(3), 514-523. https://doi.org/10.20960/nh.02894

Guillamón, A. R., Canto, E. G., & Martínez García, H. A. (2021). Ejercicio físico aeróbico y atención selectiva en escolares de educación primaria. Retos, 2041(39), 421-428. https://doi.org/10.47197/retos.v0i39.81060

Gunnell, K. E., Poitras, V. J., LeBlanc, A., Shibili, K., Barbeau, K., Hedayati, N., … Tremblay, M. S. (2019). Physicalactivity and brain structure, brain function, and cognitionin children and youth: A systematic review of randomizedcontrolled trials. Mental Health and Physical Activity, 16, 105-127. https://doi.org/10.1016/j.mhpa.2018.11.002

Hajar, M. S., Rizal, H., & Kuan, G. (2019). Effects of physical activity on sustained attention: a systematic review. Scientia Medica, 29(2), e32864. https://doi.org/10.15448/1980-6108.2019.2.32864

Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: exercise effects on brain and cognition. Nature Reviews. Neuroscience, 9(1), 58-65. https://doi.org/10.1038/nrn2298

Holgado, B., & Alonso, L. (2015). Evaluación de un programa psicopedagógico para la mejora de la atención en estudiantes de educación Primaria. Revista Espanola de Orientación y Psicopedagogía, 26(3), 26-44. https://doi.org/10.5944/reop.vol.26.num.3.2015.16399

Kolb, B., Muhammad, A., & Gibb, R. (2011). Searching for factors underlying cerebral plasticity in the normal and injured brain. Journal of Communication Disorders, 44, 503-514. https://doi.org/10.1016/j.jcomdis.2011.04.007

Kubesch, S., Walk, L., Spitzer, M., Kammer, T., Lainburg, A., Heim, R., & Hille, K. (2009). A 30-Minute Physical Education Program Improves Students' Executive Attention. Mind, Brain, and Education, 3(4), 235-242. https://doi.org/10.1111/j.1751-228X.2009.01076.x

Lambrick, D., Stoner, L., Grigg, R., & Faulkner, J. (2016). Effects of continuous and intermittent exercise on executive function in children aged 8-10 years. Psychophysiology, 53(9), 1335-1342. https://doi.org/10.1111/psyp.12688

Leon, B. (2008). Atención plena y rendimiento académico en estudiantes de enseñanza secundaria. European Journal of Education and Psychology, 1(3), 17-26. https://doi.org/10.30552/ejep.v1i3.11

Llorente, C., Oca, J., Solana, A., & Ortíz, T. (2012). Mejora de la atención y de áreas cerebrales asociadas en niños de edad escolar a través de un programa neurocognitivo. Segunda Época, 1(1), 47-59.

Luque-Casado, A., Perakakis, P., Hillman, C. H., Kao, S. C., Llorens, F., Guerra, P., & Sanabria, D. (2016). Differences in Sustained Attention Capacity as a Function of Aerobic Fitness. Medicine and Science in Sports and Exercise, 48(5), 887-895. https://doi.org/10.1249/MSS.0000000000000857

Luque-Casado, A., Zabala, M., Morales, E., Mateo-March, M., & Sanabria, D. (2013). Cognitive Performance and Heart Rate Variability: The Influence of Fitness Level. PLoS ONE, 8(2), e56935. https://doi.org/10.1371/journal.pone.0056935

Ma, J. K., Le Mare, L., & Gurd, B. J. (2015). Four minutes of in-class high-intensity interval activity improves selective attention in 9- to 11-year olds. Applied Physiology, Nutrition, and Metabolism, 40(3), 238-244. https://doi.org/10.1139/apnm-2014-0309

Manchola-González, J., Bagur-Calafat, C., & Girabent-Farrés, M. (2017). Fiabilidad de la versión española del cuestionario de actividad física PAQ-C. Revista Internacional de Medicina y Ciencias de La Actividad Física y El Deporte, 17, 139-152.

Monteoliva, J. M., Carrada, M., & Ison, M. S. (2017). Test de percepción de diferencias: Estudio normativo del desempeño atencional en escolares argentinos. Interdisciplinaria, 34(1), 39-56. https://doi.org/10.16888/interd.2017.34.1.3

Moreau, D., & Chou, E. (2019). The Acute Effect of High-Intensity Exercise on Executive Function: A Meta-Analysis. Perspectives on Psychological Science, 14(5), 734-764. https://doi.org/10.1177/1745691619850568

Muntaner-Mas, A., Vidal-Conti, J., Salmon, J., & Palou-Sampol, P. (2020). Associations of heart rate measures during physical education with academic performance and executive function in children: A cross-sectional study. International Journal of Environmental Research and Public Health, 17(4307), 1-12. https://doi.org/10.3390/ijerph17124307

Organización Internacional del Trabajo. (2008). Clasificación Internacional Uniforme de Ocupaciones. Ginebra.

Ortega, F. B., Campos, D., Cadenas-Sanchez, C., Altmäe, S., Martínez-Zaldívar, C., Martín-Matillas, M., … Campoy, C. (2017). Physical fitness and shapes of subcortical brain structures in children. British Journal of Nutrition, 1-10. https://doi.org/10.1017/S0007114516001239

Pallini, S., Vecchio, G. M., Baiocco, R., Schneider, B. H., & Laghi, F. (2019). Student-Teacher Relationships and Attention Problems in School-Aged Children: The Mediating Role of Emotion Regulation. School Mental Health, 11(2), 309-320. https://doi.org/10.1007/s12310-018-9286-z

Pallotto, M., & Deprez, F. (2014). Regulation of adult neurogenesis by GABAergic transmission: signaling beyond GABA-receptors. Frontiers in Cellular Neuroscience, 8(166), 1-13. https://doi.org/10.3389/fncel.2014.00166

Pérez-Lobato, R., Reigal, R. E., & Hernandez-Mendo, A. (2016). Relaciones entre la práctica física, condición física y atención en una muestra adolescente. Revista De Psicologia Del Deporte, 25(1), 179-186.

Pontifex, M. B., Scudder, M. R., Drollette, E. S., & Hillman, C. H. (2012). Fit and Vigilant: The Relationship Between Poorer Aerobic Fitness and Failures in Sustained Attention During Preadolescence. Neuropsychology, 26(4), 407-413. https://doi.org/10.1037/a0028795

Reigal, R., Moral-campillo, L., Juárez-Ruiz de Mier, R., Morillo-Baro, J., Morales-Sánchez, V., Pastrana, J., & Hernández-Mendo, A. (2020). Physical Fitness Level Is Related to Attention and Concentration in Adolescents. Frontiers in Psychology, 11(110), 1-9. https://doi.org/10.3389/fpsyg.2020.00110

Rosa, A., Eliseo, G., & Carrillo, P. J. (2019). Relación entre capacidad aeróbica y el nivel de atención en escolares de primaria. Retos, 35, 36-41.

Servera, M., & Llabrés, J. (2004). CSAT Tarea de Atención Sostenida en la Infancia. Resumen Manual CSAT TEA.

Servera, M., & Llabrés, J. (2015). CSAT-R. Tarea de Atención Sostenida en la Infancia-Revisada. Madrid: TEA Ediciones.

Singh, A. S., Saliasi, E., Berg, V. van den, Uijtdewilligen, L., Groot, R. H. M. de, Jolles, J., … Chinapaw, M. J. M. (2019). Effects of physical activity interventions on cognitive and academic performance in children and adolescents: a novel combination of a systematic review and recommendations from an expert panel. British Journal of Sports Medicine, 53, 640-647. https://doi.org/10.1136/BJSPORTS-2017-098136

Stylianou, M., Kulinna, P. H., van der Mars, H., Mahar, M. T., Adams, M. A., & Amazeen, E. (2016). Before-school running/walking club: Effects on student on-task behavior. Preventive Medicine Reports, 3, 196-202. https://doi.org/10.1016/j.pmedr.2016.01.010

Szabo-Reed, A. N., Willis, E. A., Lee, J., Hillman, C. H., Washburn, R. A., & Donnelly, J. E. (2017). Impact of Three Years of Classroom Physical Activity Bouts on Time-on-Task Behavior. Medicine & Science in Sports & Exercise, 49(11), 2343-2350. https://doi.org/10.1249/MSS.0000000000001346

Tamana, S. K., Ezeugwu, V., Chikuma, J., Lefebvre, D. L., Azad, M. B., Moraes, T. J., … Mandhane, P. J. (2019). Screen-time is associated with inattention problems in preschoolers: Results from the CHILD birth cohort study. PLoS ONE, 14(4), e0213995. https://doi.org/10.1371/journal.pone.0213995

Tomporowski, P. D., McCullick, B., Pendleton, D. M., & Pesce, C. (2015). Exercise and children's cognition: The role of exercise characteristics and a place for metacognition. Journal of Sport and Health Science, 4, 47-55. https://doi.org/10.1016/j.jshs.2014.09.003
Towlson, C., Cobley, S., Parkin, G., & Lovell, R. (2018). When does the influence of maturation on anthropometric and physical fitness characteristics increase and subside? Scandinavian Journal of Medicine and Science in Sports, 28(8), 1946-1955. https://doi.org/10.1111/sms.13198
Van den Berg, V., Saliasi, E., De Groot, R. H., Chinapaw, M. J. M., & Singh, A. S. (2019). Improving Cognitive Performance of 9 - 12 Years Old Children: Just Dance? A Randomized Controlled Trial. Frontiers in Psychology, 10(174), 1-14. https://doi.org/10.3389/fpsyg.2019.00174
van den Berg, V., Saliasi, E., de Groot, R. H. M., Jolles, J., Chinapaw, M., & Singh, A. (2016). Physical Activity in the School Setting: Cognitive Performance Is Not Affected by Three Different Types of Acute Exercise. Frontiers in Psychology, 7(723), 1-9. https://doi.org/10.3389/fpsyg.2016.00723
Vanhelst, J., Béghin, L., Duhamel, A., Manios, Y., Molnar, D., De Henauw, S., … Gottrand, F. (2016). Physical Activity Is Associated with Attention Capacity in Adolescents. The Journal of Pediatrics, 168, 126-131. https://doi.org/10.1016/j.jpeds.2015.09.029
Watts, A., Andrews, S. J., & Anstey, K. J. (2018). Sex Differences in the Impact of BDNF Genotype on the Longitudinal Relationship between Physical Activity and Cognitive Performance. Gerontology, 64(4), 361-372. https://doi.org/10.1159/000486369
Wilson, A. N., Olds, T., Lushington, K., Petkov, J., & Dollman, J. (2016). The impact of 10-minute activity breaks outside the classroom on male students' on-task behaviour and sustained attention: A randomised crossover design. Acta Paediatrica, 105(4), e181-e188. https://doi.org/10.1111/apa.13323
Wirt, T., Schreiber, A., Kesztyus, D., & Steinacker, J. M. (2015). Early Life Cognitive Abilities and Body Weight: Cross-Sectional Study of the Association of Inhibitory Control, Cognitive Flexibility, and Sustained Attention with BMI Percentiles in Primary School Children. Journal of Obesity, 534651, 1-10. https://doi.org/10.1155/2015/534651