



Physical Education and cognitive functions in adolescents: a randomized community trial

Educação Física e funções cognitivas em adolescentes: ensaio comunitário randomizado

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ABSTRACT

Objective: To analyze the effects of an intervention with Physical Education classes on cognitive functions in adolescents. **Methods:** School-based randomized community trial, in which three groups of full-time schools were exposed to interventions: (A) schools with two extra Physical Education classes per week; (B) schools with workshop with the Physical Education teachers; (C) schools with a combination of strategies A and B; and (D) control group. A total of 1,027 high school students from Pernambuco were evaluated. Attention was measured by the d2 Test, and executive functions by the Wisconsin Card Sorting Test. Differences in change between groups were analyzed using mixed-effects linear multilevel regression for repeated measures. **Results:** An increase in the averages of attention and a reduction in the averages of low cognitive flexibility were observed in all evaluated groups; however, the adjusted analyses showed no significant effects of any of the strategies on the adolescents' attention. After stratification by biological sex, effects were observed in the executive functions of the girls who participated in intervention C ($\beta = -1.70$, CI95% -3.10: -0.29). **Conclusion:** The combination of actions in Physical Education classes is effective in improving executive functions in girls.

Keywords: Physical Education; Attention; Executive function; Adolescent.

RESUMO

Objetivo: Analisar os efeitos de uma intervenção nas aulas de Educação Física sobre funções cognitivas em adolescentes. **Métodos:** Ensaio comunitário randomizado de base escolar, no qual três grupos de escolas de tempo integral foram expostos a situações de intervenção: (A) escolas com duas aulas extras de Educação Física por semana; (B) escolas com ações de treinamento e engajamento dos professores dessa disciplina; (C) escolas com a união das estratégias A e B; e (D) um grupo de escolas controle. Foram avaliados 1.027 estudantes do Ensino Médio de Pernambuco. A atenção foi medida pelo Teste d2 e as funções executivas pelo Teste Wisconsin de Classificação de Cartas. As diferenças de mudança entre os grupos foram analisadas usando regressão multinível linear de efeitos mistos para medidas repetidas. **Resultados:** Houve aumento nas médias de atenção e redução nas médias da baixa flexibilidade cognitiva em todos os grupos avaliados, no entanto, análises ajustadas mostraram que não houve efeitos significativos de nenhuma das estratégias sobre a atenção dos adolescentes. Após estratificação por sexo, foram observados efeitos nas funções executivas das moças que participaram da intervenção C ($\beta = -1,70$, IC 95% -3,10: -0,29). **Conclusão:** A combinação de ações em aulas de Educação Física é efetiva na melhoria das funções executivas em meninas.

Palavras-chave: Educação Física; Atenção; Função executiva; Adolescente.

Introduction

Adolescence is a phase in which significant alterations occur in the functional and structural development of the brain; during this time, the maximum density of gray matter is reached, and high plasticity allows environmental influences to affect cortical circuits, making intellectual and emotional development possible¹. Also during this phase, changes occur in social interactions, increased experimentation, and cognitive development that will contribute to the acquisition of skills necessary for survival and independence in adulthood². Therefore, it is important that adolescents have access to resources that contribute to their development, and physical activity could represent a way to achieve this³.

One way to promote physical activity among adolescents is through Physical Education (PE) classes at school. These classes have been proven to be effective in increasing levels of physical activity⁴, the development of physical fitness⁵, reducing the body mass index⁶, reducing the risk of cardiovascular disease⁷, and improving motor skills⁸, in addition to having positive effects on students' cognition^{9,10}.

Recently, García-Hermoso et al.¹¹ investigated the effects of interventions aimed at optimizing the quantity and quality of PE classes on the cognition and academic performance of children and adolescents. The results demonstrated that quality-based interventions (increasing participation in physical activities during classes) improved students' cognition and academic performance. Regarding interventions based on quantity or a combination of both (quality and quantity), the authors state that the findings should be interpreted with caution, as the number of studies is small; however, their results are generally positive.

Despite the beneficial effects that PE classes can provide to students, schools have faced difficulties in allocating time for them. In Brazil, although the mandatory annual teaching hours for students have increased from 800 to 1,000, PE classes have been reduced in some Brazilian states¹². This reduction is not only misguided, but it can also be detrimental to the adolescent's development and the promotion of physical activity and health, especially since these classes may be the only opportunity for physical activity in this life stage.

International studies^{10,11} indicate that PE classes can have positive effects on students' cognition; however, it is necessary to understand which interventions can be developed in the context of Brazilian public schools,

since cultural, socioeconomic, curricular, and structural differences can generate distinct results. This makes it essential to evaluate how PE classes impact students' cognition in the real conditions of the country. The results obtained from this study will generate national scientific data that can be used to justify investments, structure curricula that value PE, and train teachers based on evidence.

Therefore, the objective of the current study was to analyze the effectiveness of a school-based intervention, focusing on actions related to PE classes, in improving cognitive functions in adolescent high school students.

Methods

This study is a school-based randomized community trial with a factorial design, and is part of the project called Intervention for Reducing Sedentary Behavior and Improving Cognitive Function through PE classes (*Intervenção para Redução do Comportamento Sedentário e Melhoria da Função Cognitiva a partir das aulas de Educação Física – SACODE*) in which three groups of schools performed interventions, and one group was followed up in the control condition.

The SACODE Project was approved by the Research Ethics Committee for Human Beings (Opinion No. 1,577,906 of 07/06/2016) and is registered on the Brazilian Clinical Trials Registry Platform (RBR-88tgky).

The target population consisted of adolescent high school students regularly enrolled in public schools designated as Reference High Schools that operate on a full-time schedule (9 classes of 50 minutes each daily). For logistical and operational reasons defined together with the Department of Education, the activities planned in the SACODE Project intervention plan were developed only in schools that are part of the Vale do Capibaribe Regional Education Management, which is composed of 16 municipalities, 11 of which have a Reference High School considered eligible to participate in the study.

For the purposes of the draw, the 11 Reference High Schools were classified into groups considering: a) physical spaces for PE classes (covered or uncovered); b) number of PE teachers; c) number of classes; and d) mean number of students per class. In the end, three groups of schools with homogeneous characteristics were obtained, two with four schools and one with three. Subsequently, the schools in each group were randomly selected for the control condition and the

planned experimental conditions. Since there were only three schools in the third group, one of the experimental conditions could not be included. After the schools in the first group were randomly selected for each condition, the schools in group 2 were randomly selected, and finally, those in group 3 were randomly selected.

Initially, a total of 1,474 first-year high school students were invited to participate in the study, but only those authorized by their parents or legal guardians were included, resulting in 1,290 adolescents with a mean age of 14.9 years (± 1.0 year). The decision was made to only include first-year students due to the intention to conduct a follow-up evaluation one year after the end of the intervention.

After randomization and initial assessment at the beginning of the school year, one school in intervention C dropped out of the study, resulting in the loss of 90 adolescents. At the end of the intervention, after accounting for losses and refusals, 1,027 adolescents were analyzed, representing approximately 85% of those who participated in the baseline assessment (Figure 1).

The sample size was determined *a priori* using the

G*Power test, considering the F-test family with analysis of variance for repeated measures. The study design was defined considering the pre- and post-intervention assessments and the four study conditions (one control condition and three intervention groups). The statistical power was set at 90%, with an alpha error of 0.05, estimating effect sizes of 0.20 or higher as significant, and assuming that the variables under analysis have an approximate tracking coefficient of 0.25. Based on these parameters, a minimum sample size of 100 cases per group was estimated. Considering that cluster sampling would be used, this initial sample size was doubled ($deff = 2$).

Intervention

The intervention took place from April to October 2017, with a three-week break in July, corresponding to the school recess. The actions consisted of: A - Increasing the number of PE classes; B - Conducting workshop with the PE teachers; C - A combination of A + B.

In intervention A, schools increased the number of

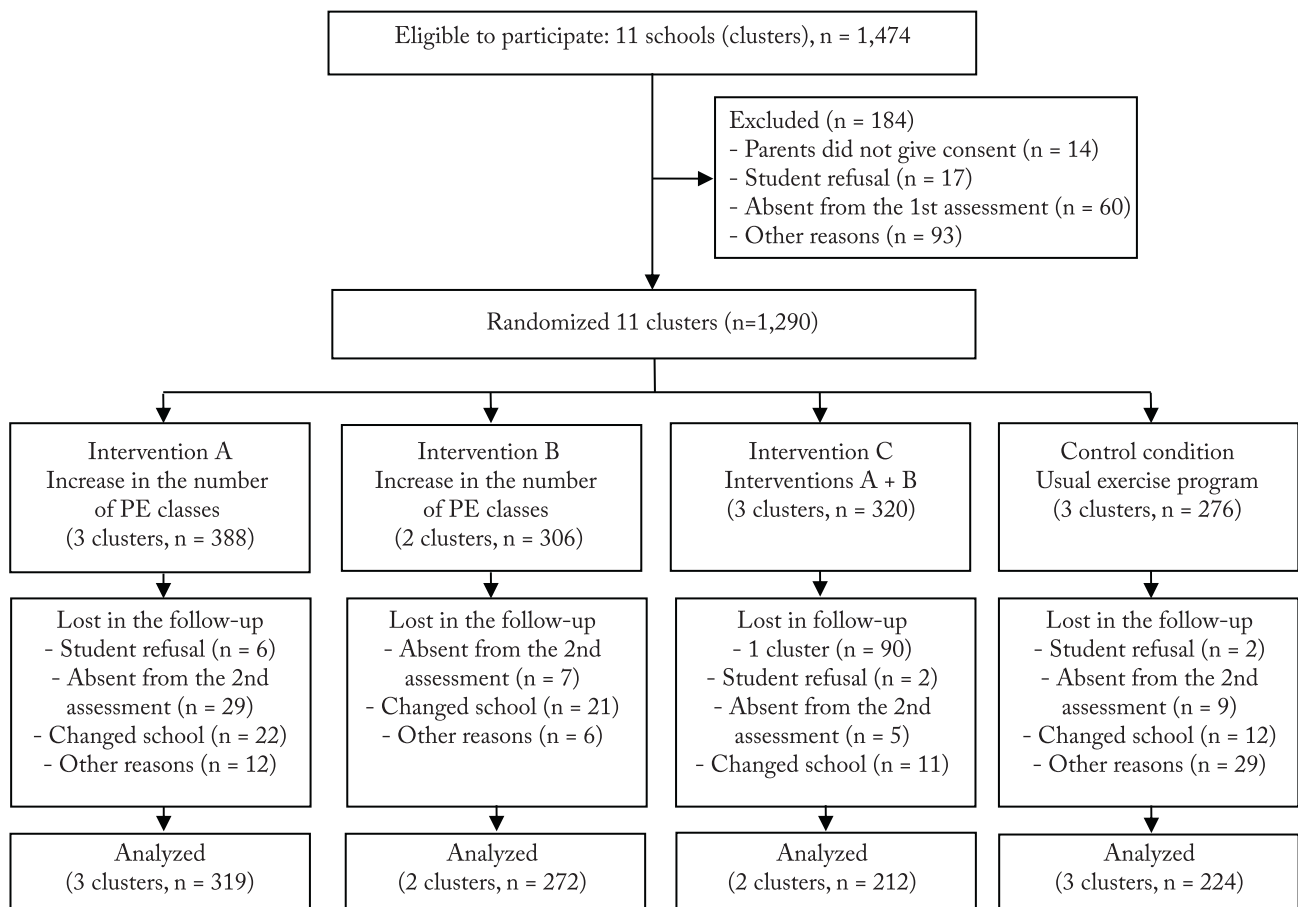


Figure 1 – Flowchart of participants

weekly PE classes from two to four, each lasting 50 minutes. The extra classes were included at any time of the school day, distributed according to the reality of each school, and taught by the PE teacher, who also had autonomy in organizing the content.

Intervention B consisted of offering workshop with the PE teachers. A 120-hour professional development course was conducted, with 30 hours divided into 6 in-person sessions. Each meeting was structured in two parts; the first part dealt with topics related to health and the outcomes evaluated in the project, such as: physical activity, sedentary behavior, physical fitness, adolescent brain function, mental health, relationships and social isolation, and sleep quality. The second part covered didactic-pedagogical content: PE in High School, development of objectives, content selection, methodological strategies, evaluation, and motivation of teachers and students. At each meeting, the teachers received supporting material with texts related to the topics, which were defined by the researchers responsible for the project and presented by members of a research group, master's or doctoral students, with experience in the subject matter.

The remaining hours were dedicated to carrying out community action projects developed by the PE teachers in conjunction with the first-grade students from their schools. The results of these projects were shared at the group's final meeting.

In intervention C, the schools received a combination of strategies A and B.

Measures

The pre-intervention assessment was conducted in March 2017, and the post-intervention assessment in November 2017, at the school itself. All measurements were collected by a trained team comprising master's or doctoral students.

The cognitive elements assessed were attention and executive functions. To assess attention, the d2 Test was used¹³. This instrument assesses focused visual attention and the ability to concentrate under time-induced stress, and was validated for use with Brazilian adolescents according to the Psychological Tests Assessment System (*Sistema de Avaliação dos Testes Psicológicos* - SATEPSI). The total test time is 8 minutes, including instructions. The test was administered collectively in the classroom, following the instructions in the manual. The analysis used the mean net scores of the test, which is a numerical variable with a positive

outcome; that is, the greater the number of correctly marked "d"s, the better the performance on the test.

Executive functions were assessed using the computerized version of the Wisconsin Card Sorting Test (WCST), run on the Insquist 5 program, both obtained from the website <https://www.millisecond.com>. The WCST is an internationally recognized instrument, considered the gold standard in the evaluation of these functions¹⁴, valid for Brazilian adolescents according to SATEPSI. The test was administered to five students at a time, and no instructions were given regarding the rules for categorizing the cards, but a brief text appeared on the screen before the start of the test explaining how to select them. The analysis used the mean of perseverative errors, which indicates low cognitive flexibility, a function considered a central aspect of executive functioning¹⁵.

In addition to these variables, others were used to verify differences between the groups. Physical activity was assessed based on responses to the questions: "During a typical (normal) week, on how many days do you engage in physical activity that, when added together, totals at least 60 minutes per day?" "In the last seven days, on how many days did you do physical activities that, added together, totaled at least 60 minutes per day?" The answers were added together and divided by two to give the final score used in the analyses.

Cardiorespiratory fitness was measured using the Progressive Aerobic Cardiovascular Endurance Run (PACER) test. The result was given based on the final completed stage, and maximum oxygen consumption (VO_{2max}) was predicted using the formula: $VO_{2max} = \text{distance (in meters)} \times 0.0084 + 36.4$ ¹⁶.

The Pittsburgh Sleep Quality Index questionnaire was used to assess sleep quality¹⁷. This instrument assesses sleep quality and disturbance over a one-month period, and was validated and translated into Portuguese by Bertolazi¹⁸. It consists of 19 questions, grouped into seven components, with scores ranging from zero (no difficulty) to three (severe difficulty). The scores of these components are added together to arrive at a total score of 0 to 21, and indicate that the higher the number, the worse the sleep quality.

The presence of depressive symptoms was determined using the Center for Epidemiologic Studies Depression Scale¹⁹. The questionnaire consists of 20 items related to the frequency of symptoms experienced in the week prior to the instrument's application. The final score ranges from 0 to 60, and the cut-off

point for the presence of depressive symptoms is > 16 points. The presence or absence of these symptoms was used in the analyses.

Waist circumference was measured using an inextensible measuring tape from the level of the navel to within 0.5 centimeters. Two measurements were taken, and if the difference between them was greater than one centimeter, a third measurement was taken. The result was given as the median.

The following confounding factors were analyzed: age, baseline, and maternal education. Sex was considered a moderating variable.

Data analysis

The data were analyzed using STATA 14 for Windows. Descriptive analysis included measures of central tendency (mean) and dispersion (standard deviation). The variation in the estimates of cognitive test scores was assessed using the delta. For variables on a nominal or ordinal scale, frequency distribution was used. Comparisons between means were performed using the t-test or analysis of variance. Bivariate analysis between qualitative variables was performed using the Chi-square test. For comparisons of means between allocation groups at baseline, a one-way ANOVA test was used.

Differences in change between groups were analyzed using repeated measures linear multilevel mixed-effects regression with three hierarchical levels. Analyses were adjusted for age, maternal education, presence of a sports court at school, and baseline, and stratified by sex. Level 1 corresponded to the students, including individual variables such as sex, age, and cognitive indicators. Level 2 represented the classes, and level 3 comprised the schools, encompassing variables related to the intervention and institutional characteristics.

The analyses did not follow the intention-to-treat principle, since the objective of the study was to evaluate the observed effects among participants with complete data. The quality of the model fit was assessed using the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), as well as the intraclass correlation coefficient (ICC), which indicates the fraction of variance attributed to differences between schools and classes. The ICC values found were low (equal to or less than 0.10), suggesting little variation between schools and classes. The significance level was set at $p < 0.05$.

Analyses regarding the adolescents who participated in the intervention and those who dropped out can

be found in Lima et al.²⁰.

Results

Among the 1,027 adolescents included in this study, 585 (57%) were female, with a mean age of 15.5 ± 1.0 years. There were no significant differences between those who remained in the intervention and those who dropped out²⁰. Figure 1 presents the reasons for the losses.

When stratified by groups, similar characteristics were observed at baseline regarding the variables: sex, maternal education, sleep quality, physical activity, and waist circumference. However, there was a statistically significant difference in the variables depressive symptoms ($p < 0.001$) and cardiorespiratory fitness ($p < 0.001$) (Table 1).

Results from the d2 Test for attention assessment indicated an increase in the mean net score in all groups, with the largest increase among students in intervention B. The observed increases were 25.3% in the control group and 22.2%, 29.7%, and 24.2% in interventions A, B, and C, respectively. When stratified by sex, an increase in mean net score was observed among students in all groups (Figure 2). However, analyses adjusted for maternal education, age, presence of a sports court at school, and baseline showed that there were no significant effects of any of the strategies on adolescent attention (Table 2).

Regarding executive functions, the WCST results demonstrated a reduction in the mean perseverative errors in all groups, but this reduction was greater among students who participated in intervention A. The reductions were 10.2% in the control group and 19.1%, 16.1%, and 15.8% in interventions A, B, and C, respectively.

When the sample was stratified by sex, a reduction in the mean perseverative errors was observed among male students in all groups. Similarly, a reduction in these mean errors was also observed among female students in interventions A, B, and C; however, there was a slight increase among the adolescent girls in the control group (Figure 3).

Analyses adjusted for maternal education, age, presence of a sports court at school, and baseline showed that there were no significant differences in executive function and attention scores in any of the intervention groups compared to the control group among male students. Among female students, no significant difference was observed in intervention groups A and B; however, in those who participated in intervention C, a

Table 1 – Demographic characteristics and health variables of students included in the project at baseline, stratified by allocation group, Pernambuco, Brazil, 2017.

Variable	Control (2 Physical Education classes) (n = 276)		+ Physical Education classes (n = 388)		Workshop with teachers (n = 306)		+ Physical Education classes and workshop (n = 320)		P
	n	%	n	%	N	%	n	%	
Sex									
Male	110	39.9	187	48.2	129	42.2	97	42.2	0.147
Female	166	60.1	201	51.8	177	57.8	133	57.8	
Maternal education									
<= 8 years	129	52.0	178	53.1	123	45.0	111	52.4	0.197
> 8 years	119	48.0	157	46.9	150	55.0	101	47.6	
Sleep quality									
Good	89	43.4	122	41.6	133	53.4	83	43.7	0.096
Bad	105	51.2	161	55.0	110	44.2	99	52.1	
Disturbed	11	5.4	10	3.4	6	2.4	8	4.2	
Depressive symptoms									
Absent	201	76.4	269	74.1	247	84.0	147	67.7	0.001
Present	62	23.6	94	25.9	47	16.0	70	32.3	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	P
Physical activity (days)	2.0	1.9	2.3	2.1	2.1	1.9	2.2	2.1	0.235
VO _{2max} (mL.kg ⁻¹ .min ⁻¹)	41.5	3.2	42.1	3.5	41.0	3.1	42.8	3.5	<0.001
Waist circumference (cm)	76.5	11.4	75.9	10.7	75.5	9.5	75.3	10.3	0.571

Table 2 – Comparisons of mean cognitive test scores among groups of adolescent participants in the project, stratified by sex., Pernambuco, Brazil, 2017.

	Perseverative Errors (WCCTS)				Net Result (d2)			
	Male*		Female*		Male*		Female*	
	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p
Control	1		1		1		1	
Intervention A	-0.42 (-1.46 - 0.62)	0.429	-1.32 (-2.67 - 0.21)	0.054	-7.68 (-50.52 - 35.16)	0.725	-17.47 (-43.27 - 8.34)	0.185
Intervention B	-0.21 (-1.21 - 0.79)	0.684	-0.56 (-1.82 - 0.70)	0.382	8.77 (-32.61 - 50.16)	0.678	0.22 (-24.25 - 24.69)	0.986
Intervention C	0.18 (-0.89 - 1.25)	0.744	-1.70 (-3.10 - -0.29)	0.018	-16.96 (-60.63 - 26.71)	0.446	-0.51 (-27.40 - 26.38)	0.970
Akaike information criteria	1695.472		2762.618		3766.698		5116.195	
Bayesian	1737.161		2807.965		3808.354		5157.198	
Intraclass correlation coefficient - school	2.21 × 10 ⁻²²		1.68 × 10 ⁻¹⁵		0.03		2.02 × 10 ⁻¹³	
Intraclass correlation coefficient - class	2.33 × 10 ⁻²²		2.04 × 10 ⁻¹⁵		0.10		0.04	

* adjusted for maternal education, age, presence of a sports court at school, and baseline.

Intervention A = Weekly offering of two extra Physical Education classes;

Intervention B = Workshop with the Physical Education teachers;

Intervention C = Weekly offering of two extra Physical Education classes + Workshop with the Physical Education teachers.

reduction of approximately 1.7 in the mean number of perseverative errors was identified when compared to the control group (Table 2).

Discussion

To the best of our knowledge, this is the first study conducted in Brazil that sought to analyze the effect of an intervention focused on modifications to PE class-

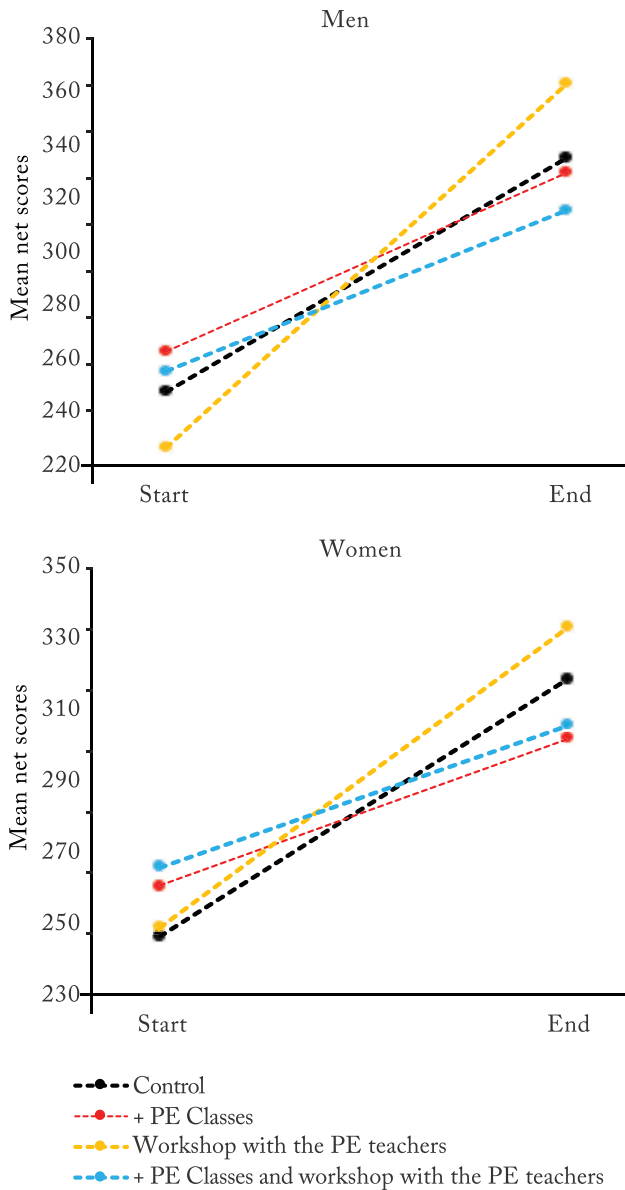


Figure 2 – Estimates of the marginal means of net outcomes in adolescents by project group: a) male; b) female, Pernambuco, Brazil, 2017.

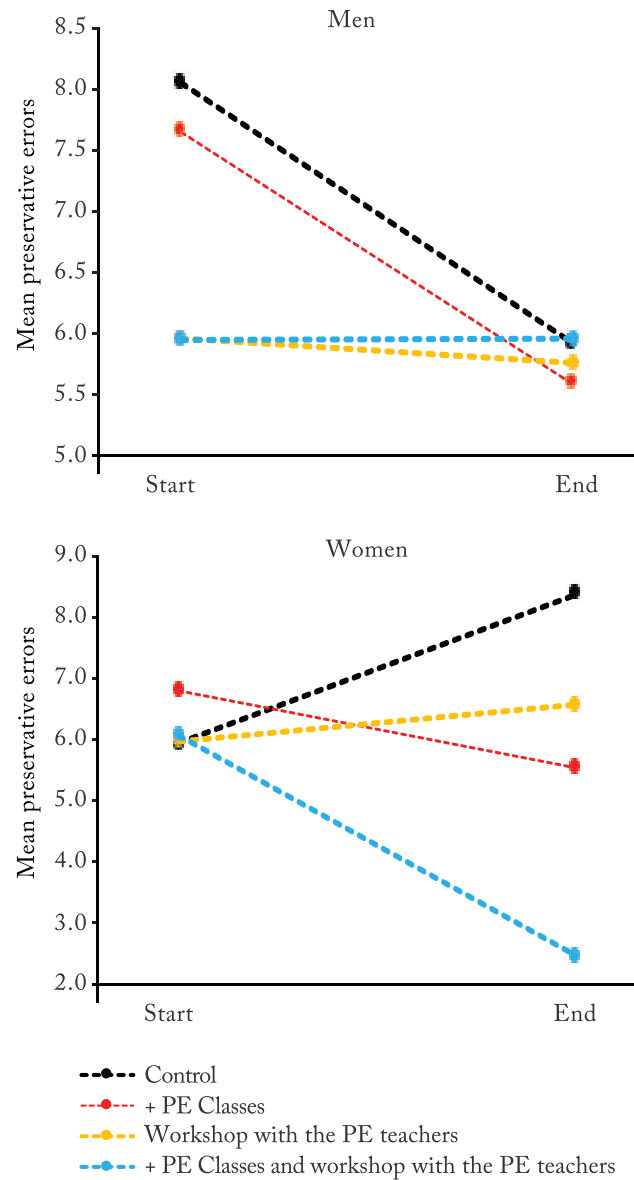


Figure 3 – Estimates of marginal means of perseverative errors in adolescents by project group: a) male; b) female, Pernambuco, Brazil, 2017.

es on the improvement of cognitive functions in high school students from full-time schools. The results demonstrate that none of the strategies had significant effects on the participants’ attention, but effects were observed on the executive functions of the adolescent girls who participated in intervention C.

Similar to the current study, other research has also found no effect of interventions carried out in PE classes on attention. For example, Gall et al.²¹ reported no effects of a twenty-week intervention program on the attention of participants (8-13 years of age). The intervention group was exposed to the following activities:

two PE classes per week, one weekly dance class, and active breaks in the classroom incorporated into the school curriculum. In the study conducted by Ericsson²² it was observed that an intervention (five PE classes and one motor training class) carried out over three years did not show any effects on attention in children.

It is probable that some aspects, such as intensity, duration, and type of physical activity performed, need to be considered when planning an intervention that aims to improve students’ attention, since studies that considered these variables demonstrated the effects of just one acute session of physical activity on the atten-

tion of children and adolescents. Furthermore, these effects may be perceived immediately after the activity was completed or could last for several minutes after the session ended^{23,24}.

Regarding executive functions, among male students, there was no significant difference in results in any of the intervention groups compared to the control group. However, among the adolescent girls who participated in intervention C, a reduction of approximately 1.7 in the mean number of perseverative errors was identified when compared to the control group.

The reason why female students obtained better results than male students is unclear and should be investigated in future studies. This may have occurred because females begin puberty earlier than males, and exposure to sex hormones influences brain development²⁵. A study conducted by Mertens et al.²⁶ showed that, during working memory, higher testosterone levels are associated with greater deactivation in the anterior cingulate cortex in younger women (<19 years) and with increased activation in the precentral gyrus in men, regardless of age. This indicates that the hormonal impact on brain activity may vary by sex and age.

In the current study, only the intervention that combined two strategies (weekly offer of two extra PE classes + workshop with the PE teachers) was effective in improving executive functions in adolescents when compared to the control group. This suggests that simply doubling the number of PE classes per week is not enough to produce effects on executive functions. These results are in line with those presented by Ardoy et al.¹⁰, who demonstrated that increasing the number of PE classes per week did not affect the cognitive performance of adolescents; however, when increasing the volume of classes was associated with increasing the intensity of the physical activities performed in the classes, the effect on cognitive performance was significant.

The current study did not verify the intensity of physical activities practiced during classes; however, workshop with the PE teachers may have contributed to changes in how they taught the classes, since the results of the process evaluation showed that 98.5% of the participants in intervention C stated that the PE classes were more active (40% - slightly more active; 43.1% - more active; and 15.4% - much more active) during the semester in which the intervention was being developed in their school.

There are difficulties in comparing these results with those presented in other research, given the lack

of studies that evaluated the effect of combining increased PE classes and workshop with the PE teachers on executive functions in adolescents. However, the literature indicates that offering extra classes in this subject has positive effects on the academic performance of children and adolescents²⁷ and other intervention strategies conducted in these classes have been effective in improving executive functions in children^{28,29}. Furthermore, an intervention involving some type of teacher training combined with other strategies (incorporating physical activity in short breaks, in schoolwork across various subjects, and in homework) was also effective in improving executive functions in children³⁰.

Although the provision of extra PE classes or workshop with the PE teachers was not sufficient to produce effects on adolescent attention in the current study, the intervention with the combination of actions produced effects on the executive functions of female students, demonstrating promising results and indicating that efforts should be made to implement public policies that guarantee at least three weekly PE classes that prioritize movement and are included in the curricular proposals of states, municipalities, and schools. It is also necessary to create continuing education programs for teachers of this subject through partnerships with Higher Education Institutions, in order to provide them with an expanded pedagogical repertoire.

Some limitations should be considered in interpreting the results. It should be noted that no evaluations were conducted on the activities performed in the PE classes. Although the process evaluation results indicated that most classes were practical, no information was collected regarding the type, intensity, and duration of the physical activities performed. Furthermore, although female students showed positive effects on executive functions after just six months of intervention, it is possible that a longer-term investigation could also be effective in improving these functions among male students, and could demonstrate the effect of the strategies evaluated in isolation.

Despite these limitations, there are strengths in this study that need to be highlighted. The regional scope is noteworthy, as it was conducted in all full-time schools within a Regional Education Management area. The study was carried out in ten schools located in ten municipalities, representing distinct sociocultural and developmental characteristics. This is a randomized study conducted in a real-world context, without researcher interference, where teachers had the freedom to devel-

op their lessons according to the school's reality and the characteristics of their students. This represents an emphasis on external validity and the replication of the intervention in other schools.

Finally, it is worth highlighting that the project constitutes an innovative, simple, low-cost intervention that is feasible to be replicated in other schools, provided it has the support of the agents involved, such as the education department and the managers of the educational institutions, and the willingness of teachers and students to participate.

Conflict of interest

The authors declare no conflict of interest.

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Authors' contribution

Mélo EN: Conceptualization; Methodology; Software development, Implementation and testing; Data and experiment validation; Data analysis; Research; Tool provision; Data curation; Supervision; Project management; Data presentation design; Funding acquisition; Original manuscript drafting; Drafting - revision and editing; Approval of the final version of the manuscript. Brito ALS: Conceptualization; Methodology; Data and experiment validation; Research; Data curation; Supervision; Project management; Writing - revision and editing; Approval of the final version of the manuscript. Santos SJ: Conceptualization; Methodology; Data and experiment validation; Research; Supervision; Project management; Writing - revision and editing; Approval of the final version of the manuscript. Soares FC: Methodology; Data and experiment validation; Data analysis; Research; Data curation; Supervision; Data presentation design; Original manuscript writing; Writing - revision and editing; Approval of the final version of the manuscript. Rangel Junior JFLB: Data curation; Supervision; Project administration; Original manuscript drafting; Writing - revision and editing; Approval of the final version of the manuscript. Barros MVG: Conceptualization; Methodology; Data and experiment validation; Data analysis; Data curation; Supervision; Project administration; Data

presentation design; Fundraising; Writing - review and editing; Approval of the final version of the manuscript.

Statement regarding the use of artificial intelligence tools in the article writing process

The authors did not use artificial intelligence tools to prepare the manuscript.

Availability of research data and other materials

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References

- Konrad K, Firk C, Uhlhaas P J. Brain development during adolescence. *Dtsch Arztebl Int.* 2013;110(25):425-31. doi: <https://doi.org/10.3238%2Faztebl.2013.0425>
- Spear LP. The adolescent brain and age-related behavioral manifestations. *Neurosci Biobehav Rev.* 2000;24(4):417-63. doi: [https://doi.org/10.1016/s0149-7634\(00\)00014-2](https://doi.org/10.1016/s0149-7634(00)00014-2)
- Esteban-Cornejo I, Tejero-Gonzalez CM, Sallis JF, Veiga OL. Physical activity and cognition in adolescents: a systematic review. *J Sci Med Sport.* 2015;18(5):534-9. doi: <https://doi.org/10.1016/j.jsams.2014.07.007>
- Ribeiro IC, Parra DC, Hoehner CM, Soares J, Torres A, Pratt M, et al. School-based physical education programs: evidence-based physical activity intervention for youth in Latin America. *Glob Health Promot.* 2010;17(2):5-15. doi: <https://doi.org/10.1177%2F1757975910365231>
- Rexen CT, Ersbøll AK, Møller NC, Klakk H, Wedderkopp N, Andersen LB. Effects of extra school-based physical education on overall physical fitness development - the CHAMPS study DK. *Scand J Med Sci Sports.* 2015;25(5):706-15. doi: <https://doi.org/10.1111/sms.12293>
- Ługowska K, Krzęcio-Nieczyporuk E, Trafiałek J, Kolanowski W. The Impact of Increased Physical Activity at School on the Nutritional Behavior and BMI of 13-Year-Olds. *Nutrients.* 2024;16(24):4329. doi: <https://doi.org/10.3390/nu16244329>
- Klakk H, Andersen LB, Heidemann M, Møller NC, Wedderkopp N. Six physical education lessons a week can reduce cardiovascular risk in school children aged 6–13 years: A longitudinal study. *Scand J Public Health.* 2014;42(2):128-36. doi: <https://doi.org/10.1177/140349481350572>
- Lorås H. The Effects of Physical Education on Motor Competence in Children and Adolescents: A Systematic Review and Meta-Analysis. *Sports.* 2020;8(6):88. doi: <https://doi.org/10.3390/sports8060088>

9. Cho O, Choi W, Shin Y. The effectiveness of school physical education on students' cognitive competence: a systematic review and meta-analysis. *J Sports Med Phys Fitness*. 2022;62(4):575-84. doi: <https://doi.org/10.23736/S0022-4707.21.11796-7>
10. Arday DN, Fernández-Rodríguez JM, Jiménez-Pavón D, Castillo R, Ruiz JR, Ortega FB. A Physical Education trial improves adolescents' cognitive performance and academic achievement: the EDUFIT study. *Scand J Med Sci Sports*. 2014;24(1):e52-61. doi: <https://doi.org/10.1111/sms.12093>
11. García-Hermoso A, Ramírez-Vélez R, Lubans DR, Izquierdo M. Effects of physical education interventions on cognition and academic performance outcomes in children and adolescents: a systematic review and meta-analysis. *Br J Sports Med*. 2021;55(21):1224-32. doi: <https://doi.org/10.1136/bjsports-2021-104112>
12. Beltrão JÁ, Teixeira DR, Taffarel CNZ. A supressão da Educação Física nas matrizes curriculares do novo Ensino Médio. *Rev. Ponto Vista*. 2024;13(2):1-20. doi: <https://doi.org/10.47328/rpv.v13i2.17037>
13. Brickenkamp R. *Teste d2: atenção concentrada: manual: instruções, avaliação, interpretação*. São Paulo: Centro Editor de Testes e Pesquisas em Psicologia, 2000.
14. Rzezak P, Fuentes D, Guimarães CA, Thome-Souza S, Kuczynski E, Guerreiro M, et al. Executive dysfunction in children and adolescents with temporal lobe epilepsy: Is the Wisconsin Card Sorting Test enough?. *Epilepsy Behav*. 2009;15(3):376-81. doi: <https://doi.org/10.1016/j.yebeh.2009.04.014>
15. Lange F, Seer C, Müller-Vahl K, Kopp B. Cognitive flexibility and its electrophysiological correlates in Gilles de la Tourette syndrome. *Dev Cogn Neurosci*. 2017;27:78-90. doi: <https://doi.org/10.1016/j.dcn.2017.08.008>
16. Wood R. "Scoring the Yo-Yo Test". The Complete Guide to the Yo-Yo Test. 2018. Available from: <https://www.theyoyotest.com/scoring.htm> [2019 June].
17. Buysse DJ, Reynolds 3rd CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res*. 1989;28(2):193-213. doi: [https://doi.org/10.1016/0165-1781\(89\)90047-4](https://doi.org/10.1016/0165-1781(89)90047-4)
18. Bertolazi AN. Tradução, adaptação cultural e validação de dois instrumentos de avaliação do sono: escala de sonolência de Epworth e Índice de qualidade de sono de Pittsburgh [dissertação de mestrado]. Porto Alegre: Faculdade de Medicina da Universidade Federal do Rio Grande do Sul (UFRGS); 2008.
19. Radloff L, Locke B. The CES-D scale: a self-report depression scale for research in the general population. *Appl Psychol Meas*. 1977;1:385-401. doi: <https://doi.org/10.1177/014662167700100306>
20. Lima RA, Barros MVG, Bezerra J, Santos SJ, Monducci E, Rodriguez-Ayllon M, Soares FC. Universal school-based intervention targeting depressive symptoms in adolescents: A cluster randomized trial. *Scand J Med Sci Sports*. 2022;32(3):622-31. doi: <https://doi.org/10.1111/sms.14115>
21. Gall S, Adams L, Joubert N, Ludyfa S, Müller I, Nqweniso S, et al. Effect of a 20-week physical activity intervention on selective attention and academic performance in children living in disadvantaged neighbor-hoods: a cluster randomized control trial. *PLoS One*. 2018; 13(11):e0206908. doi: <https://doi.org/10.1371/journal.pone.0206908>
22. Ericsson I. Motor skills, attention and academic achievement. An intervention study in school years 1-3. *Br Educ Res J*. 2008;34(3):301-13. doi: <https://doi.org/10.1080/01411920701609299>
23. Altenburg TM; Chinapaw M JM; Singh A S. Effects of one versus two bouts of moderate intensity physical activity on selective attention during a school morning in Dutch primary school children: A randomized con-trolled trial. *J Sci Med Sport*. 2016;19(10):820-4. doi: <https://doi.org/10.1016/j.jsams.2015.12.003>
24. Kulinna PH, Stylianou M, Dyson B, Banville D, Dryden C, Colby R. The effect of an authentic acute physical education session of dance on elementary students' selective attention. *Biomed Res Int*. 2018;2018:8790283. doi: <https://doi.org/10.1155/2018/8790283>
25. Neufang S, Specht K, Hausmann M, Güntürkün O, Herpertz-Dahlmann B, Fink GR, Konrad K. Sex differences and the impact of steroid hormones on the developing human brain. *Cereb. Cortex* 2009. 19(2):464-73. doi: <https://doi.org/10.1093/cercor/bhn100>
26. Mertens AT, Myers K, Sherman D, Ladouceur CD, Doucet GE. Sex and age differences on how testosterone relates to brain activity during working memory among adolescents and young adults. *Cereb Cortex*. 2025;35(8):bhaf218. doi: <https://doi.org/10.1093/cercor/bhaf218>
27. Cöster ME, Fritz J, Karlsson C, Rosengren BE, Karlsson MK. Extended physical education in children aged 6-15 years was associated with improved academic achievement in boys. *Acta Paediatr*. 2018;107(6):1083-7. doi: <https://doi.org/10.1111/apa.14278>
28. Pesce C, Masci I, Marchetti R, Vazou S, Säakslähti A, Tomporowski PD. Deliberate play and preparation jointly benefit motor and cognitive development: mediated and moderated effects. *Front Psychol*. 2016;7:349. doi: <https://doi.org/10.3389/fpsyg.2016.00349>
29. Schmidt M, Jäger K, Egger F, Roebens CM, Conzelmann A. Cognitively engaging chronic physical activity, but not aerobic exercise, affects executive functions in primary school children: a group-randomized controlled trial. *J Sport Exerc Psychol*. 2015;(6):575-91. doi: <https://doi.org/10.1123/jsep.2015-0069>
30. Aadland KN, Ommundsen Y, Anderssen SA, Brønnick KS, Moe VF, Resaland GK, et al. Effects of the Active Smarter Kids (ASK) physical activity school-based intervention on executive functions: a cluster-randomized controlled trial. *Scand J Educ Res*. 2019;63(2):214-28. doi: <https://doi.org/10.1080/00313831.2017.1336477>


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Reviewers' assessment

The reviews of this article were originally conducted in Portuguese. This version has been translated using ChatGPT and subsequently reviewed by the Chief Editors.

Reviewer A

Anonymous

- Was any indication of plagiarism observed in the manuscript?
No
- Did the authors provide clarification regarding the ethical procedures adopted for conducting the research?
Yes

Comments to the Author

Dear Editor(s) and Author(s),

- I appreciate the opportunity to review this relevant study that investigated the effects of different Physical Education (PE) strategies on executive function in adolescents from full-time schools. I would like to highlight the relevance of the topic, the methodological rigor adopted, and the robust sample size ($n = 1,027$), which lend solidity to the findings.
- Below, I present suggestions for improvement for each section of the manuscript:

Introduction

- The most recent reference in the introduction dates from 2021. With this exception, all other references are at least 10 years old. Has nothing else been published since then? Or has no new knowledge been produced on this topic? Updating the references could even change the entire logic of the introduction.
- On page 4, lines 1–8, the authors mention statistics related to PE classes, the New Upper Secondary Education Reform, and the exclusive role of schools in physical activity practice, but these statements lack references. Moreover, as data collection preceded the reform, I suggest removing or reformulating references to the New Upper Secondary Education, keeping the focus on the context in force during the data collection period.
- Stating that the study is justified solely because there are no studies on this topic among adolescents in Brazil does not seem sufficient. What is so different in Brazil compared to the rest of the world that justifies this study? The authors need to explicitly present which gaps they intend to fill.

Methods

• **Statistical details:**

- Describe which model fit statistics were calculated (AIC, BIC, ICC, log-likelihood).
- Specify the composition of each level of analysis (level 1: student – sex, age, cognitive indicators; level 2: school – intervention, institutional characteristics).
- Indicate whether an intention-to-treat analysis was conducted, even if reported in supplementary material.
- More robust models: I recommend considering Generalized Linear Mixed Models (GLMM) instead of ANOVA when the outcome is not strictly continuous or when there are hierarchical data structures, as GLMM offers greater flexibility and better correction of standard errors.

Results

- Please report the AIC/BIC of the models and the percentage of variance explained at each level (school and individual). In addition, it is necessary to clearly state how missing data were handled.

Discussion

- Terms and language: Replace the term “girls” with “adolescents” or “female students,” reinforcing the distinction between biological sex and gender.
- Physiological mechanisms: Provide more detail on the processes that may explain the findings, addressing aspects such as:
- Hormonal fluctuations and brain maturation during adolescence.
- Modulation of neurotrophic factors (BDNF, IGF-1) and cortical perfusion.
- Practical implications: Explore how the results can inform public policies and school guidelines, suggesting specific recommendations for the implementation of additional classes and teacher training.

Final recommendation (decision)

- Major revisions required.

Reviewer B

Isabela Viana Ramos 

Catholic University of Brasília, Brasília, Distrito Federal, Brazil.

- Was any indication of plagiarism observed in the manuscript?
Not applicable
- Did the authors provide clarification regarding the ethical procedures adopted for conducting the research?
Yes

Comments to the author

- The manuscript presents a proposal of great scientific and social relevance, addressing a current and necessary topic. The study demonstrates rigorous planning and careful execution, especially considering the logistical complexity of school-based interventions with multiple groups and follow-up stages. The methodological description is detailed, allowing good reproducibility. The experimental design adopted is robust and appropriate to the proposed objectives. The results are presented clearly, with appropriate use of statistical analyses and interpretations consistent with the findings. The discussion is well grounded, up to date, and engages appropriately with the national and international literature, highlighting the practical and scientific implications of the results. This is a work of high scientific merit, with excellent quality of writing and structure. The article reflects the effort of a team committed to research with practical applicability, which reinforces its relevance and originality.

Abstract

- Line 8: According to the author guidelines available on the RBAFS website: “In the case of original studies, the abstract should include the following sections: introduction, objective, methods, results,

and conclusion.”

- Line 21: Sex is the more appropriate term; gender reflects social, cultural, and psychological characteristics, which were not considered here.
- Line 22: The conclusion should address the objective; it was not a general objective to investigate differences between sexes.
- Line 25: It would be important for the keywords not to include terms already present in the article title.

Abstract

- Revise after finalizing the abstract in Portuguese.

Methods

- Page 8, line 5: What is the unit of measurement of this numerical variable? Is it a score?
- Page 8, line 16: Is this a validated assessment? If not, what was the rationale for choosing it?

Results

- Page 10, line 20: Use sex.

Discussion

- Page 12, line 6: <https://link.springer.com/article/10.1186/1471-2458-13-307>
- the PAAC study showed positive results; it would be important to mention this.
- Page 13, line 18: <https://doi.org/10.1037/bul0000200>
- In this study by Tomporowski & Pesce, the benefits of exercise on cognition can also be explained by motor and cognitive complexity, motivation, and affect; see Figure 2 of the article.

Final Decision

- Accept