Study protocol

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Chronic effects of school physical activity on cognitive performance in youngs: a systematic review protocol

Efeitos crônicos da atividade física escolar no desempenho cognitivo de jovens: um protocolo de revisão sistemática

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ABSTRACT

Recent systematic reviews point out the positive acute effects of physical activity on executive functions in children and adolescents, but the chronic effects in this age group are still uncertain. This study aims to describe a systematic review with meta-analysis protocol to elucidate the chronic effects of physical activity at school on the executive functions and attention of children and adolescents, considering the effect-moderators and examining different interventions in the school environment. A systematic search will be carried out for studies published in the PUBMED, Embase, Scopus and Cochrane Library databases. Studies that meet the following predefined criteria (PICOS criteria) will be included: 1) studies conducted with healthy children and adolescents (6-18 years-old), 2) studies with physical activity interventions in school, 3) studies conducted with a control group, and 4) studies with cognitive flexibility, working memory, inhibitory control and attention outcomes. Target outcomes will be extracted as pre-and post-test values. Intervention time, frequencies, intensity, volume, session time, and intervention type will be extracted for meta-regression analysis. For methodological quality will be using the tool for the assessment of study quality and reporting in exercise training studies. Pooled effect estimates will be calculated from the scores of changes between baseline and end of interventions. The effect size will be expressed as Cohens' and presented as standardized mean differences and calculations will be performed using random-effects models. Statistical heterogeneity will be evaluated by Cochran's Q statistic and the I^2 inconsistency test. The meta-analyses will be performed using OpenMeta[Analyst].

Keywords: Health promotion; Public health; Child; Adolescent; Executive function.

RESUMO

Revisões sistemáticas recentes apontam os efeitos agudos positivos da atividade física nas funções executivas em crianças e adolescentes, mas os efeitos crônicos nessa faixa etária ainda são incertos. Este artigo tem como objetivo descrever o protocolo de revisão sistemática e meta-análise que busca elucidar os efeitos crônicos da atividade física no ambiente escolar sobre as funções executivas e atenção de crianças e adolescentes, considerando os efeitos-moderadores e examinando diferentes tipos de intervenções no ambiente escolar. Será realizada uma busca sistemática de estudos publicados nas bases de dados PUBMED, Embase, Scopus e Cochrane Library. Serão incluídos estudos que atendam aos seguintes critérios pré-definidos (critérios PICOS): 1) estudos realizados com crianças e adolescentes saudáveis (6-18 anos), 2) estudos com intervenções de atividade física na escola, 3) estudos de intervenção, randomizados ou não, realizados com grupo controle e 4) estudos com flexibilidade, memória de trabalho, controle inibitório e resultados de atenção. Os resultados alvo serão extraídos como valores pré e pós-teste. Tempo de intervenção, frequências, intensidade, volume, tempo de sessão e tipo de intervenção serão extraídos para análise de meta-regressão. Para a qualidade metodológica será utilizado o instrumento para avaliação da qualidade do estudo e relato em estudos de treinamento físico. As estimativas de efeito agrupadas serão calculadas a partir das pontuações das mudanças entre a linha de base e o final das intervenções. O tamanho do efeito será expresso em Cohens e apresentado como diferenças médias padronizadas e os cálculos serão realizados utilizando modelos de efeitos aleatórios. A heterogeneidade estatística será avaliada pela estatística Q de Cochran e pelo teste de inconsistência I^2. As meta-análises serão realizadas usando OpenMeta[Analyst].

Palavras-chave*: Promoção da saúde, Políticas públicas; Criança; Adolescente.*

Introduction

Childhood and adolescence, commonly school-age children, is characterized by a phase of life in which there is a critical and sensitive period of brain development[1]. This process is related to socio-emotional, self--concept and mental health development[2]. This process is related to cognitive development, especially executive functions (EF)[1,2]. According to Diamond[2] EF are characterized by three main domains: 1) inhibition (i.e., decision making and impulsive responses); 2) working memory (i.e., holding and manipulating information in memory); and 3) cognitive flexibility (i.e., shifting between tasks).

Recently, studies have tried has tried to demonstrate the possible relationships between EF and physical activity in childhood and adolescence[3–5]. Although promising, as there seems to be an indirect link between physical activity, EF, well-being and academic performance, the evidence is uncertain regarding the doses, intensities, and types of physical activity. However, these evidences can often clash with the level (or amount) of physical activity in this population at a global level. The percentage of children and adolescents who regularly engage in physical activity remains at 20% globally, since the evidence presented in The Lancet - Physical Activity series in 2010[6] and reinforced in the 2021 series[7]. In less than three decades researchers have increasingly indicated a constant global need for interventions to promote physical activity in basically three contexts: social and digital environments, urban multifunctional environments and school[7].

In this sense, the school environment is one of the most relevant places for intervention in order to promote physical activity in younger ages[8]. Considering that school-age children spend a lot of time in school during the week (approximately 30 hours)[8], these can be involved in many physical activity opportunities. A good example is the comprehensive school physical activity program (CSPAP), which includes five components with potential to contribute to achieving recommended daily levels of physical activity (i.e., 60 min-day of moderate to vigorous intensity[9]): physical education classes, physical activity before, during and after school, sports clubs, and family and community activities. Thus, interventions to promote physical activity in schools are needed[10], not only to improve general health (e.., cardiorespiratory fitness, blood pressure, body image…more) but also to improve EF, attention and consequently their academic performance[4,11].

Among the various contexts, the school physical education integrates aspects of education and health, through knowledge, learning and bodily experiences that contribute to physical and motor health; psychological; social and environmental benefits[12,13]. Current evidence has also shown that school physical education classes can benefit academic performance and EFs[5]. Garcia-Hermoso et al.[5] in a meta-analysis highlighted that improving the quality (e.g. insert an exercise program, insert small-side games in the curriculum) of physical education could result in small increases in students' cognition. The same authors also showed a positive effect on academic performance, particularly in mathematics-related skills.

Additionally, other reviews[14,15] have shown that interventions in other school-related contexts (i.e., outside the school physical education class) can have a positive effect on academic performance and EFs. Contreras-Osorio et al.[15] demonstrated that sports activities (e.g. small-side games) have a positive effect on children's EFs. In addition, the authors suggest that organized sports (in school, sport clubs, etc.) may be a better option for developing EFs than simply increasing the physical activity time. Another example is the review by Liu et al.[16] which demonstrated that regular physical exercise (e.g. circuits, physical training, strength training) has chronic beneficial effects on EF, especially on working memory.

Although the aforementioned evidence points out the positive effects of physical activity on EF, the chronic effects of physical activity in this age group are still uncertain. For example, meta-analysis that calculated the chronic effects of physical activity (in different contexts than the one the present study proposes to identify) on EF have shown positive effects ranging from small to moderate. The study by Takacs and Kassai[17] showed an effect size of 0.16, Sun et al.[8] pointed to 0.44 in obese children, specifically.

The school has a high potential for promoting physical activity and a healthy lifestyle for decades. But this potential is now even greater and urgent, because, after a long period of social confinement due to the COVID-19 pandemic, the predictions are that children and adolescents may have a lower development of EFs, as well as attention and metacognition[19–21]. In addition, a globally physical inactivity lifestyle, pandemic driven, are negatively linked with psycho-cognitive health[22], depression, anxiety, suicide attempts[23,24] and a severe deficit of EF[25].

The components of EF play a critical role in the development of school-age children and their academic achievement[26]. Therefore, considering the urgent demand for the expansion of the knowledge on the chronic effects of physical activity on EF and attention[16]. This study aims to carry out a systematic review with meta-analysis and meta-regression to elucidate the chronic effects of physical activity at school on the EF and attention of children and adolescents, considering the effect-moderators and examining different interventions in the school environment (e.g. physical education classes, counter-shift sports, active breaks, etc.).

Methods

Protocol registration

The protocol of this systematic review was registered on the International Prospective Register of Systematic Reviews: PROSPERO (CRD42021274668). The final report of the present study will be carried out in accordance with the Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA) guideline[27].

Search problem

This systematic review project with meta-analysis was structured from the following questions:

What are the chronic effects of physical activity in the school environment on children and adolescents' EFs (cognitive flexibility, inhibitory control, and working memory) and attention?

What is the chronic effect of different types of intervention (e.g., physical education class, breaks, sports activities)?

Outcomes

EFs and attention will be considered in this research project as the set of cognitive skills necessary to control and self-regulate their own behaviour[28]:

Cognitive flexibility: Also known as mental change, it is the individual's ability to identify the best paths to complete a new task. Ability to find new and better alternatives based on acquired knowledge, the more developed, the greater the creative capacity to imagine the most varied solutions for a new problem or task[28].

Working memory: It is the ability to quickly store and manipulate information in our brain in response to a new situation, the ability to create new concepts about past ideas, to make a quick decision in response to a fact, and to interact with two activities or more at the same time[28].

Inhibitory control: It is the ability to inhibit (avoid) actions by impulse. Ability to define the best response to a new situation that presents itself [28].

Attention: It is the ability to concentrate and interact with the certain information or situations available in the environment. Can be called: a) Selective attention (ability to define which stimulus to concentrate on, regardless of other stimuli around it); b) divided attention (ability to perform two or more tasks simultaneously), vigilance/sustained attention (ability to stay focused on the same activity for a long period) and; c) alternating attention (ability to quickly change the focus of attention)[29].

Types of studies included (study design)

Randomized trials (RCTs) and longitudinal studies with interventions applied within the school environment, presenting a comparator/control group, will be included. Any intervention based on physical activity at schools, for instance, physical education classes or the break between classes, or breaks during classes (breaks) or the after-hours of classes. Interventions with the inclusion of structured or non-structured and supervised physical exercises, or encouragement to practice free physical activity, or sports activities (e.g. walking, running, team sports, circuits, callisthenic exercises, free weight exercises, recreational activities with and without objects, relay games, motor coordination and agility exercises, etc.).

Types of intervention (intervention)

Studies that used in their methodology the intervention within the school environment during physical education classes, during the break time between classes, during breaks and in after-school activities, through exercises will be considered. sporting and non-sporting physical (e.g., walking, running, team sports, circuits, callisthenics, free weight exercises, etc.) and through activities with cognitive complexity that work, for example, reaction time and movement (e.g., recreational activities with and without objects, relay games, motor coordination and agility exercises, etc.). Studies with a minimum weekly volume of two sessions and no requirement on the intensity of the activities performed will be considered, thus, interventions of light, moderate and vigorous intensities may be accepted. For this systematic review, the results obtained after a minimum intervention period of six weeks will be considered chronic effects, following the same period of chronic effect evaluated in recent studies[30].

Sampling Sources

A search will be carried out for studies published in the PUBMED, Embase, Scopus and Cochrane Library databases.

Eligibility criteria

Studies that meet the following predefined criteria (PICOS criteria) will be included:

- (P – Population): Studies conducted with healthy children and adolescents (unhealthy: provided they contain analysis of healthy *versus* unhealthy *versus* control child groups, thus enabling the use data from healthy children) with analyses within the age between 6-18 years of age enrolled in elementary and high school (elementary school and high school);
- (I – Intervention): Studies with interventions during physical education classes, during the break between classes, breaks during classes (break) and during the hours after classes, with the inclusion of structured and supervised physical exercises, or encouragement the practice of free physical activity, or sports activities and activities of cognitive complexity in the school curriculum during physical education classes., Intervention with a minimum weekly volume of two sessions and no requirement on the intensity of the activities performed, thus, interventions of light intensity may be accepted, moderate and vigorous;
- (C - Comparator) Studies conducted with a control group that does not participate in any structured physical exercise program just maintain their usual school routine (including physical education classes);
- (O - Outcome) Studies with main outcomes one or more of the skills that make up the EFs: cognitive flexibility, working memory, inhibitory control and attention;
- (S – Study type) Studies characterized as randomized trials of RCTs and longitudinal studies of intervention with a comparator/control group.

In addition to these criteria, the search will be restricted to English, Portuguese and Spanish, with no restriction on the year of publication. Exclusion criteria will be: (1) observational studies and literature reviews; (2) studies conducted only with unhealthy children or with some type of diagnosis of dementia, cognitive deficit or genetic malformation that results in cognitive deficits; (3) studies conducted with multiple simultaneous interventions (e.g. exercise and diet); (4) Studies that do not minimally describe the methods related to intervention planning and control ;and (5) studies not presenting pre and post data of the target outcomes in both groups (intervention and control) or the change scores and a dispersion or precision measure (e.g. standard deviation, standard error, confidence interval).

Keywords were selected by assessment of the Medical Subject Headings (MeSH) in the National Library of Medicine and relevant text to the area. The organization of search terms were carried out according to the PICOS framework (Chart 1).

Study selection planning

At first, two reviewers will independently identify, by reading the title, keywords and abstract, the eligible articles (based on the inclusion and exclusion criteria) among those obtained in the systematic search. Subsequently, for the selected articles or those in doubt, the full-text reading will be performed by the same two

Chart 1 – Keywords selected by assessment of the Medical Subject Headings (MeSH) according to the PICOS framework.

P	**Child**; Children; Adolescent; Adolescents; Adolescence; Teens; Teen; Teenagers; Teenager; Student; School Enrollment; Enrollment, School; Enrollments, School; School Enrollments.
I	**School physical education**; Primary Schools; Primary School; School, Primary; Schools, Primary; Schools, Secondary; School, Secondary; Secondary School; Secondary Schools; elementary school; high school; **Physical education**; Education, Physical; Physical Education, Training; **Exercise**; Physical exercise; Exercise, Physical; Exercises, Physical; Physical Exercise; Physical Exercises; Exercise Training; Exercise Trainings; Training, Exercise; Trainings, Exercise; **Physical activity**; Activities, Physical; Activity, Physical; Physical Activities; **Motor activity**; Activities, Motor; Activity, Motor; Motor Activities; **Sport**; sports; Athletics; Athletic; **Dancing; Gymnastics**.
C / S	**Randomized controlled trial**; Randomized clinical trials; clinical trials, randomized; Trials, Randomized Clinical; controlled clinical trials, randomized; **Controlled trial**; Controlled clinical trial; **Quasi-experimental study**; Quasi-Experimental Studies; Quasi Experimental Studies; Studies, Quasi-Experimental; Study, Quasi-Experimental; Non Randomized Controlled Trials; Controlled Clinical Trials, Non-Randomized; Controlled Clinical Trials, Non Randomized; Clinical Trials, Nonrandomized; Clinical Trial, Nonrandomized; Nonrandomized Clinical Trial; Nonrandomized Clinical Trials; Trial, Nonrandomized Clinical; Trials, Nonrandomized Clinical; Controlled Clinical Trials, Nonrandomized; Clinical Trials, Non-Randomized; Clinical Trial, Non-Randomized; Clinical Trials, Non Randomized; Non-Randomized Clinical Trial; Non-Randomized Clinical Trials; Trial, Non-Randomized Clinical; Trials, Non-Randomized Clinical; Nonrandomized Controlled Trials; **Longitudinal Study**; Studies, Longitudinal; Study, Longitudinal; Longitudinal Survey; Longitudinal Surveys; Survey, Longitudinal; Surveys, Longitudinal.
O	**Executive function**; Executive Functions; Function, Executive; Functions, Executive; Executive Control; Executive Controls; **Cognitive flexibility**; Cognitive Shifting; **Inhibitory control**; Inhibition; **Working memory**; Working Memories; Memory, Immediate; Immediate Memories; Immediate Memory; Memories, Immediate; Memories, Short-Term; Memory, Short Term; Short-Term Memories; Short-Term Memory; Memory, Shortterm; Memories, Shortterm; Shortterm Memories; Shortterm Memory; **Attention**.

independent reviewers following standard criteria that determined both the inclusion and exclusion of studies. In case of divergence between the two reviewers, a third reviewer will be called to make the final decision on eligibility. The research development process flow diagram is presented in Figure 1, according to the PRISMA guidelines[27].

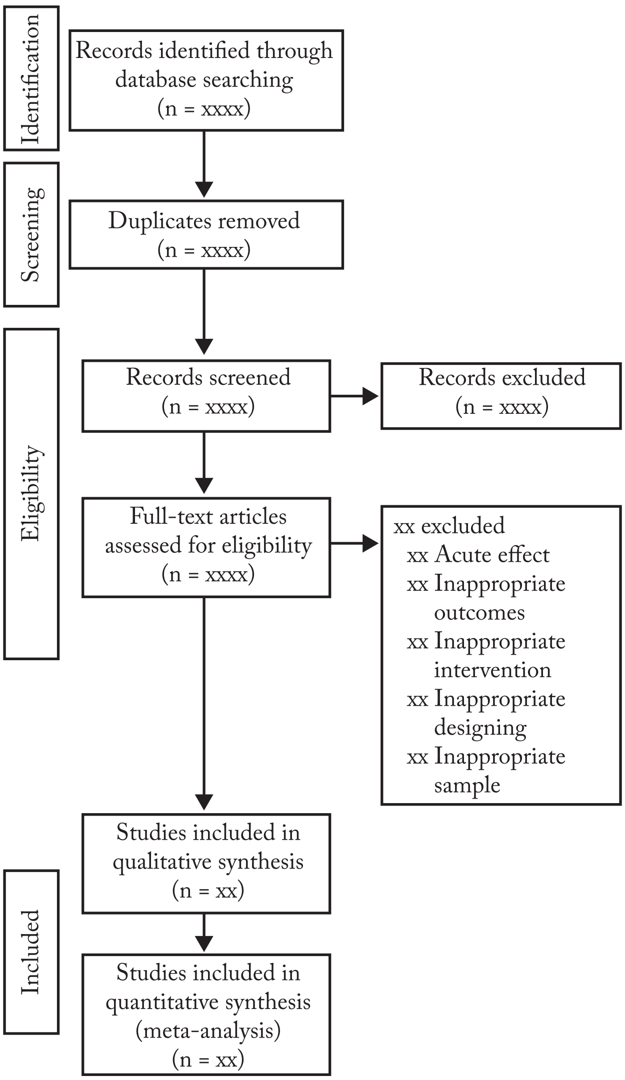

Figure 1 – Research development process according to the PRISMA flow diagram

Data Extraction Planning

The title, year of publication, authors' names, the methodological design will be extracted from the selected studies, the number of subjects involved and their characteristics, such as gender (male and female) and average age (6-12 years for children and 13-18 years for adolescents), the school year in which they are enrolled. Characteristics of the intervention protocols will be extracted, such as the types of physical activities performed, the intensities (light, moderate and vigorous) and levels of cognitive complexity of the activities (when presented), the types of interventions - physical education classes, break time between classes, breaks during classes (break) and after-school activities - the weekly frequency, the time elapsed between interventions and assessments and the total time of the same.

Target outcomes will be extracted as pre-and post-test values, with data presented as mean and some measure of dispersion or precision measure or absolute change. Intervention time, frequencies, intensity, volume, session time, and intervention type will be extracted for meta-regression analysis. Intervention time, frequencies, intensity, volume, session time, and intervention type will be extracted for this analysis. Such as to the study selection phases, data extraction will be performed in duplicate by the same two independent reviewers. In addition, in case of disagreements regarding the extracted data, a third reviewer will be activated.

All data will be tabulated in the Comprehensive Meta-Analysis V.2 program.

Planning the methodological quality assessment (risk of bias)

The same two reviewers who will independently perform the study selection and data extraction will assess the methodological quality of the included studies. For that, the tool for the assessment of study quality and reporting in exercise training studies, proposed by Smart et al.[33]. As such, the assessment will include the following items: (a) specified eligibility criteria; (b) specified randomization (randomization); (c) allocation concealment, that is, patients are unaware of which group they would be allocated; (d) similar groups at baseline, with no significant difference after randomization; (e) blinding of outcome evaluators; (f) outcome measures evaluated in at least 85% of patients; (g) intention-to-treat analysis; (h) reporting of statistical comparison between groups; (i) point measures and measures of variability for all reported outcomes; (j) monitoring of activities in the control group; (k) whether relative exercise intensity remained constant; (l) relative volume and energy expenditure of the exercise.

The quality score of the papers will be based on tertiles, where 0 to 5 points will be considered low quality, 6 to 10 points will be considered medium quality and 11to15 points will be considered high quality. The choice for this instrument is due to the fact that it is specific for interventions with physical exercise.

Planning Data Analysis

Pooled effect estimates will be calculated from the scores of changes between baseline and end of interventions, their standard deviations (or standard errors or 95% confidence intervals), and the number of participants. Data from intention-to-treat analyses will preferably be inserted whenever available in the included studies. Any possible "issue" will be consulted directly to the authors (no specific data, doubts about using error or standard deviation, doubts about a possible wrong value, etc.). Authors will be contacted by email for uninformed data and, if there is no response or the requested data is not available, the studies will be excluded.

The effect size will be expressed as Cohens' and presented as standardized mean differences (SMD - a measure of effect, recommended to be used when the study reports the effectiveness of an intervention in continuous measurements, especially in cases of different measurement methods) and calculations will be performed using random-effects models. In addition, an exploratory stratified analysis will be performed using the same procedures as the main analysis, comparing the type of methodological design (RCT and non-RCT), through a sensitivity analysis.

The analysis of subgroups will include the calculation of the effect: on children, on adolescents, only from physical education classes, only from other school environments (breaks, breaks, etc.) and only from intervention with sports. Meta-regression analyses will be performed to investigate potential moderators of physical activity in EFs and attention: mean age (years), body mass index ($kg \cdot m^{-2}$), follow-up duration (weeks), session duration, baseline score of executive function and attention.

Statistical heterogeneity will be evaluated by Cochran's Q statistic and the I^2 inconsistency test. Values > 50% will be considered as indicators of high heterogeneity[27]. Forest plots will be generated to show the combined effect and SMD with 95% confidence intervals (CIs). Statistical significance will be established with a p-value <0.05. The meta-analyses will be performed using OpenMeta[Analyst].

Discussion

EFs and attention develop mainly in childhood and are important for development and adaptive behaviour[5]. Through their good development, it is expected that a young person will improve skills such as attention, planning, organizing and controlling actions to achieve goals. Some evidence points to a relationship between the good development of these skills and the development of imagination, creativity, empathy and the ability to self-assess thoughts and actions[5,15].

The relationship between the development of EFs and the practice of aerobic, interval and high-intensity physical exercises is described in recent literature reviews[5]. However, the relationship of these variables with the practice of physical activity in the school environment, which is a potential intervention environment, has not been explored in the literature. Furthermore, to our knowledge, as of December 2021 there is no such review registered and in the progress of PROSPERO.

The future findings of this review will reinforce the discussion about the need for interventions and encouragement to practice physical activity in the daily lives of schools. Regardless of the results found, our systematic review will seek to present insights into the practice of physical activity, in different volumes and intensities, as an important factor for the development of EFs and attention in school-age children and adolescents.

Conflict of interest

The authors declare no conflict of interest.

Author's contributions

Silva FWF, Martins R, Costa RR, Cristi-Montero C, Mello JB participated in the design of the study. Martins R and Cristi-Montero C performed out the theoretical review of the project, in addition to participating in the construction of the eligibility criteria. Flores FWS, Costa RR and Mello JB performed the searches and screening process. All authors reviewed and approved the final version of the manuscript.

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