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THE ASSOCIATION BETWEEN PHYSICAL ACTIVITY AND ACADEMIC PERFORMANCE IN SCHOOLCHILDREN: A PROTOCOL FOR A SYSTEMATIC REVIEW AND META-ANALYSIS

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The association between physical activity and academic performance in schoolchildren: A protocol for a systematic review and meta-analysis.

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Key words: schoolchildren, academic performance, physical activity, child health.

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ABSTRACT

Introduction: Schools are an effective framework to improve some aspects of children's health by increasing physical activity. The interest in the relationship between physical activity programs and children's academic performance has recently increased. Evidence suggests a positive association between physical activity and academic performance, but no study has assessed this association. We will conduct a systematic review and meta-analysis to determine the relationship between long-term physical exercise and children's cognitive skills, academic behaviours and academic achievement.

Methods: This protocol was guided by Preferred Reporting Items for Systematic Review and Meta-analysis Protocols (PRISMA-P). We will use Preferred Reporting Items for Systematic Reviews (PRISMA) and the Cochrane Collaboration Handbook to guide the review. The search will be conducted in the MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, and Web of Science databases from their inception. Experimental studies written in Spanish or English will be included. We will review the relevant references included in the selected studies as supplemented sources.

The checklists recommended by the Cochrane Collaboration to assess the methodological quality of randomized and non-randomized studies of health care interventions will be used to evaluate the risk of bias in the included studies. The pre-post intervention mean differences will be the primary indicator of the intervention outcome.

Statistical analysis: A subgroup analysis will be conducted based on cognitive skills, academic areas, academic behaviours, or measurement tools.

Trial registration number: PROSPERO CDR42015029913

Strengths and limitations.

This systematic review will include only experimental studies to assess the effect of physical activity programs on children´s academic performance.

Our systemic review will provide a comprehensive overview of the effect of physical activity programs on each component of children´s academic performance.

Risk of bias of included studies and heterogeneity among studies will be assessed to reinforce measured data.

Intervention duration, age and weight of the participants, and assessment of academic performance could limit the generation of conclusions

INTRODUCTION

Academic performance describes the factors influencing students' success at school in three areas[1]: i) cognitive skills and attitudes, including basic cognitive abilities (such as executive functioning, attention, verbal comprehension, information processing or memory) and attitudes and beliefs (motivation, satisfaction, school connectedness, or self-concept); ii) academic behaviours related to students' academic performance (such as on-task behaviours, planning, scheduling, impulse control, organization or attendance); iii) and academic achievement, including subject area scores and total scores.

Physical activity has been associated with several psychological benefits in school children, such as improving anxiety, self-esteem, cognitive performance, classroom behaviour and academic achievement[2]. Additionally, in the last decade, a growing interest on the potential influence of children's physical activity on angiogenesis has emerged, increasing oxygen saturation and glucose delivery, improving cerebral blood flow and increasing neurotransmitters levels[3]. In this regard, the positive influence of children's aerobic fitness on academic achievement has been related to differences in structural brain volumes, as measured by magnetic resonance imaging[4], and brain function, as measured by electrical activity recordings[5].

Interventions with long-term exercise programs have demonstrated benefits on some aspects of children´s health[6]. Experimental studies have also reported a positive influence of physical activity on children's academic performance[7,8]; however, discrepancies persist regarding the effect size of physical activity interventions on children's academic performance[1]. Thus, this systematic review will only include experimental studies in which academic performance was reported as an outcome variable.

OBJECTIVES

This systematic review and meta-analysis has two objectives: i) to estimate the effect of long-term physical activity programs on cognition, academic achievement and academic behaviours in school children; ii) to determine which cognitive skills or areas are the most influenced by this relationship.

METHODS AND ANALYSIS

This systematic review and meta-analysis protocol was guided by Preferred Reporting Items for Systematic Review and Meta-analysis Protocols (PRISMA-P)[9] and registered in PROSPERO (registration number: CDR42015029913). Preferred Reporting Items for Systematic Reviews[10] (PRISMA) and the Cochrane Collaboration Handbook[11] will be used to guide the review methods of the systematic review.

Inclusion/exclusion criteria for study selection

Types of studies.

Randomized control trials and non-controlled trials written in English or Spanish are eligible for inclusion.

Types of participants.

Studies assessing the relationship between long-term physical activity programs and children's academic performance, regardless of the participants' age, sex, weight, ethnicity, and socioeconomic status, will be included. Studies including children with physical or mental disorders that could impede participation in physical activity programs will be excluded.

If participants are assessed more than once in the same study, data will be extracted and analysed from the different measurements as independent samples.

Types of interventions.

Studies reporting any type of physical activity program will be eligible for inclusion; however, studies with acute physical activity programs will be excluded. Studies comparing different types of physical activity programs or examining a physical activity program with or without a control group could be included.

Additionally, studies with curricular physical activity programs offered during school or afterschool hours will be included. Studies evaluating physical activity programs with other interventions, such as nutritional interventions, will be excluded.

Types of outcome assessment.

The main outcome will be a children's academic performance assessment. The performance could be assessed by total scores, individual skills or individual subject areas related to cognition skills, academic achievement and academic behaviours. In this regard, the studies could use curriculum-based marks or specific scales, such as Cognitive Assessment System (CAS), Colour-Word Stroop test, General Intelligence Test (GIT), Canadian Achievement Test, among others.

Search methods for the identification of studies.

Electronic search

The search will be conducted in the MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, and Web of Science databases from their inception. No electronic limitation on language or publication status will be added.

The following search terms will be used: physical activity, physical education, exercise, cognition, academic, academic achievement, intelligence, children, preschool, pre-schooler, young children, and trial.

Relevant references cited in the selected studies will be screened as supplemental sources.

Data collection and analysis.

Selection of studies

Two reviewers will independently check the titles and abstracts to identify eligible studies according to the inclusion criteria. Then, the identified studies will be examined. Lastly, two independent reviewers will check the included and excluded studies with the reasons for exclusion. Any discrepancies will be resolved by discussion with a third reviewer.

Two authors will independently extract data on the publication year, number and age of participants, academic performance assessment, physical activity program duration, and cognitive skills/academic achievement areas/academic behaviours.

Any disagreement will be resolved by discussion and consensus. If necessary, the authors of the included studies will be contacted to obtain relevant information.

Assessment of risk of bias in included studies

Two researchers will conduct a quality assessment according to the Cochrane Collaboration Handbook[11]. Any disagreement will be resolved by discussion. A third reviewer will resolve the discrepancy if consensus is not reached. The Jadad Scale[12] will assess the methodological quality of the randomized controlled trials. The risk of bias will be evaluated according to three domains: randomization, double blinding, and description of withdrawals and dropouts. Each domain will receive a score of one when the studies satisfy its description. Randomization will score one extra point if the method to generate the sequence is appropriate. Additionally, a double blind study will score one extra point if the double blind method is appropriately described. Based on these domains, scores can range from 0 to 5.

The Quality Assessment Tool for Quantitative Studies[13] will assess the quality of before and after studies. This tool evaluates seven domains: selection bias, study design, confounders, blinding, data collection method, withdrawals and dropouts. Each domain could be considered to be strong, moderate or weak, and the studies could be classified as strong (with no weak ratings), moderate (with one weak rating), and weak (with two or more weak ratings)

If there are insufficient or unclear data describing the required domains, the study authors will be contacted for more details.

Data synthesis

The key characteristics and important questions from the included studies in relation to the aim of this review will be summarized in tables. Reviewers will determine whether a meta-analysis is possible when data have been extracted.

If it is possible to carry out a meta-analysis, STATA 13 software will be used to combine the pooled mean differences with 95% confidence intervals. A fixed-effect model will be used if there is no evidence of heterogeneity; otherwise, a random-effects

model will be used. The study heterogeneity will be assessed with an I2 statistic. Usually, I2 values of <25, 25-50, and >50% represent small, medium, and large amounts of heterogeneity, respectively[14]. Studies with insufficient data to perform the analyses will be omitted from the data synthesis. If there is substantial heterogeneity among the studies and a meta-analysis is not possible, a descriptive analysis will be conducted.

The measure of the mean pre-post intervention differences will be the primary indicator of the intervention outcome. The mean differences (standard error (SE)) and standardized mean differences (standard deviation (SD)) will be calculated for each specific skill or area included in the tests. For example, when the SE is provided, the SD will be calculated according to the following formula, SD=SE*square root of N. The pooled effect size of the physical intervention and control groups will be compared using the mean differences and standard errors weight for the number of participants.

Subgroup analyses

A subgroup analyses will be performed based on the main factors causing heterogeneity, such as cognitive skills, academic achievement areas (non-verbal ability, spatial ability, abstract reasoning, mathematics, language, etc.), academic behaviours, or assessments (CAS, Colour-Word Stroop test, General Intelligence Test GIT, Canadian Achievement Test, curriculum based scores, etc.). Furthermore, the intervention duration, age, and weight of participants will be considered for subgroup analyses.

Sensitivity analysis

Sensitivity analyses will be conducted by excluding studies from the analysis one by one.

DISCUSSION

A positive association between physical activity and academic performance has been reported by the latest systematic review[8], which analysed this relationship; conversely, previous systematic reviews[1] found either an association or no association. These systematic reviews considered all of the studies regarding the type of study and suggested that more research is needed to clarify the role of some variables with regard to this relationship.

Other systematic reviews[15] that included only randomized controlled trials found a positive effect between aerobic exercise and cognition, academic achievement, behaviour and psychosocial functioning outcomes. These reviews did not assess the impact of the aerobic exercise programs on each academic performance component.

Given the importance of the childhood period on development, sustained information is needed for education and health professionals for policy efforts; therefore, it is important to measure the impact of long-term physical activity programs on children´s academic performance.

Ethics and dissemination

Ethical approval will not be needed because the data used in this systematic review will come from published studies and there will be no concerns about privacy. The results will be disseminated by publication of the manuscript in a peer-reviewed journal.

Authors' contribution: VMV and CAB designed the study. VMV was the Principal Investigator and Guarantor. MSL, CAB, and VMV were the main coordinators of the study. MSL, CAB, MJPG, and ICR conducted the study. ICR, CP, and MJPG provided statistical and epidemiological support. VMV wrote the article with the support of MSL, CP, and CAB. All of the authors revised and approved the final version of the manuscript.

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The association of physical activity to cognition, metacognition and academic performance in children and adolescents: A protocol for systematic review and meta-analysis.

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Primary Subject Heading:	Public health
Secondary Subject Heading:	Paediatrics
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The association of physical activity to cognition, metacognition and academic performance in children and adolescents: A protocol for systematic review and meta-analysis.

Trial registration number: PROSPERO CRD42015029913

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ABSTRACT

Introduction: Schools provide a relevant context for improving children's and adolescents' health by increasing physical activity during school hours and/or beyond. The interest in the relationship between physical activity programs and cognition during development has recently increased, with evidence suggesting a positive association. We present a protocol of systematic review and meta-analysis of experimental studies that, by determining the effects of chronic physical exercise on children's and adolescents' cognitive and metacognitive functions, cognitive life skills, academic behaviours and achievement, aims to ensure procedural objectivity and transparency and maximize the extraction of relevant information to inform policy development.

Methods: This protocol is guided by Preferred Reporting Items for Systematic Review and Meta-analysis Protocols (PRISMA-P) and by the Cochrane Collaboration Handbook. Databases to be utilized for a thorough selection of pertinent literature are MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, Web of Science, PsycINFO and ERIC. Selection is proposed to encompass an International and a national publication level, with inclusion of experimental studies written in English or in Spanish, respectively. Also relevant references included in the selected studies will be considered suitable for review as supplemental sources.

We present an integrated approach to the methodological quality assessment of the selected studies, including the Jadad Scale for the assessment of the quality of randomized controlled trials and the Quality Assessment Tool for Quantitative Studies for pre-post studies and non-randomized controlled trials of health care interventions. The pre-post intervention mean differences will be the primary indicator of the intervention outcome.

Statistical analysis: A subgroup analysis is proposed based on cognitive functions and their neural correlates, metacognitive functions and cognitive life skills, academic achievement areas and academic behaviours.

Trial registration number: PROSPERO CRD42015029913

Strengths and limitations:

The present protocol is proposed to include in the systematic review only interventional exercise and cognition studies performed with children or adolescents. We discuss how

this type of systematic review can provide a comprehensive overview of the effect of physical activity programs on main components of children´s brain health, cognitive functioning and academic performance that are relevant for policy development.

Ways to assess risk of bias of included studies and heterogeneity among studies are discussed with particular reference to individual constraints (e.g., age, weight status) task constraints (e.g., qualitative and quantitative intervention characteristics, type of cognition and assessment tools) and contextual constraints (laboratory, school, out-of-school setting) that might act as moderators of the relationship between physical activity and cognition or academic performance in children and adolescents. Possible solutions to overcome these problems and reach relevant conclusions are proposed.

INTRODUCTION

In the last decades, scientific evidence on the relationship between chronic physical activity and cognitive/academic performance during development has attracted increasing attention[1]. Chronic physical activity interventions have been defined as long lasting repeated bouts of exercise aimed to improve physical fitness.[2] Chronic physical activity participation has been associated with several mental health benefits in school children, such as improved self-perceptions (e.g., self-esteem, self-efficacy), emotional regulation (e.g., anxiety, depression), and cognitive functioning (e.g., information processing, memory, attention).[3]

Due to the relevant implications for educational policies, many researches have investigated the effects of chronic physical activity participation on students´ success at school that is on academic performance.[4-5] The latter is pooled in classroom behaviour (e.g., on-task behaviours during learning activities) and academic achievement (e.g., school notes and performance in test on school subjects). Attention has also been focused on cognitive executive functions, since their development early in life has been proven predictive of school and lifelong achievement, health and quality of life.[6] Diamond[6] distinguishes between core executive functions – that are inhibitory control, working memory and cognitive flexibility – and higher-level executive functions – as reasoning, planning, and problem solving. This higher-level cognition largely overlaps with what termed metacognition, that is the ability to supervise and manage cognitive process and to use knowledge to regulate behaviours[2].

Chronic exercise-cognition research have experienced a progressive shift toward a biochemical and neuroscientific perspective from both exercise and cognition researchers [7-8] and developmental neuroscientists.[9] In this regard, the positive influence of chronic physical activity has been related to angiogenesis, increasing oxygen saturation and glucose delivery, improving cerebral blood flow and increasing neurotransmitters levels,[10] differences in structural brain volumes, as measured by magnetic resonance imaging,[11] and brain function, as measured by electrical activity recordings.[12]

Previous systematic reviews and meta-analysis have synthetized the evidence related to the influence of exercise interventions on children's and, less frequently, adolescents' cognition and success in school, focused on quantitative exercise characteristics.[5,13-16] From them, one was focused on experimental studies only and considered both cognitive and psychosocial outcomes jointly.[15] No one presented data distinguishing between cognitive and metacognitive functions, academic behaviour and achievement. Indeed, this distinction has been recently deemed relevant to understand the potential mediational paths that underlie the relationship between physical activity and academic achievement.[2]

In the search for further mechanisms beyond the neurobiological that may explain the link between chronic physical activity and children´s cognition, recent narrative or meta-analytic reviews have focused on the qualitative characteristics of the physical activity interventions.[8,17-18] Also developmental neuroscientists interested in interventions aiding children's cognition are increasingly shifting attention toward qualitative forms of physical activity that are not only physically effortful, but also emotionally and socially engaging.[9] This kind of interventions often involve physical activities that impinge not only on core cognitive functions, but also on a broader range of cognitive skills, as goal setting, problem solving and self-regulation[1]. These are cognitive in nature and therefore fall in the field of cognitive sciences, but also belong to the broader field of life skills investigated in psychosocial and social-cognitive research and identified as essential skills to self-regulate behaviour and successfully adapt it to everyday requirements.[19] Since they are proven sensitive to designed physical activity interventions,[20] it has been recently proposed that cognitive life skills may represent a further element to be considered in the relationship between physical activity, cognition, and academic behaviour and achievement.[8]

In sum, scientific evidence on the relationship between physical activity and cognitive/academic performance, particularly as regards its possible moderators and mediators, is still currently insufficient to obtain a comprehensive view that may be useful to inform policies and decision making. Discrepancies persist regarding the effects of chronic exercise interventions on children's cognition and success in school and life and reviews still lack consideration of evidence at relevant intersection points between different research areas. Moreover, whereas several narrative and meta-analytic reviews have provided evidence syntheses that are mainly useful for setting future research priorities, they still leave open questions concerning how this evidence can be translated into god practices in ecological settings as the educational.[21]

Thus, the general aim of the present methodological article is to provide a novel protocol designed to review interventional studies addressing the chronic exercise-cognition interaction at developmental age for obtaining relevant information for policy makers and decision makers particularly in, but not limited to, the education sector. To this aim, the proposed protocol encompasses different facets of cognitive function and academic performance that, to the best of our knowledge, should be jointly considered to facilitate transitioning evidence of the cognitive benefits of physical activity for children and adolescents into good practices.

OBJECTIVES

This systematic review and meta-analysis has three objectives: i) to estimate the effects of chronic physical exercise interventions on different facets of cognitive function and academic performance of children and adolescents; ii) to determine which of those variables are most benefitted from physical activity; iii) to identify the individual, task-related and contextual moderators that may amplify physical activity effects on cognition/academic performance, with particular focus on the qualitative and quantitative characteristics of the physical activity interventions.

Specifically, this systematic review and meta-analysis protocol presents an objective and clear procedure to maximize the extraction of information from experimental studies (randomized controlled trials - RCT, non-RCT trials and controlled pre-post studies), in which data for cognition, metacognition, cognitive life skills, academic behaviour and achievement have been separately reported as outcomes.

METHODS AND ANALYSIS

This systematic review and meta-analysis protocol is based on Preferred Reporting Items for Systematic Review and Meta-analysis Protocols (PRISMA-P)[22] and the Cochrane Collaboration Handbook[23] is proposed to guide the review. This trial has been registered in PROSPERO (registration number: CRD42015029913).

Inclusion/exclusion criteria for study selection

Types of studies.

Randomized control trials (RCT), non-RCT trials and controlled pre-post studies written in international language (English) or in the national language of interest (Spanish).

Types of participants.

Studies assessing the relationship, at developmental age, between chronic physical exercise interventions and cognition, metacognition, cognitive life skills and academic performance variables will be included regardless of sex, weight, ethnicity, and socioeconomic status. Will be considered for inclusion studies including participants aged from 4 to 18 years. An exclusion criterion will be the presence of children with any physical condition or any diagnosed disorder of cognition that would impede or limit their ability to participate in school physical activity programs. If participants are assessed more than once in the same study, data will be extracted and analysed from the different measurements as independent samples.

Types of interventions.

Studies reporting any type of chronic physical exercise intervention involving multiple sessions over a number of training weeks or months will be eligible for inclusion. Instead, studies reporting the transient effects of single bouts of acute physical exercise will be excluded. Studies comparing different types of chronic physical exercise interventions or examining a chronic physical exercise intervention with or without a control group are considered eligible for inclusion.

Additionally, we will include those studies regarding chronic physical exercise interventions defined as: school based physical exercise interventions, recess time interventions, classroom-based physical activity interventions and extracurricular physical activity interventions. Studies evaluating chronic physical exercise interventions combined with other health interventions, such as nutritional interventions, will be excluded when data concerning the effectiveness of physical

activity programs on cognitive or metacognitive functions, cognitive life skills or academic performance variables could not be extracted separately.

Types of outcome assessment.

In the attempt to provide a comprehensive view of physical activity effects on the different facets of children's and adolescents' cognition, a broad array of cognitive outcome assessments is warranted, ranging from neural correlates of cognitive functioning to performance measures and observational or self-reported evaluations of cognition, metacognition, cognitive life skills and academic performance.

Indicatively, but not exhaustively, common performance measures for cognitive function assessment are tests such as Eriksen flanker task, Stroop Colour-Word task, Cognitive Assessment System (CAS), or Stenberg task. Examples of performance measures for metacognitive function assessment are the Tower of London test and creativity assessment tools as the Alternate Uses Test. Academic performance assessments regard: i) academic achievement by curriculum-based marks or specific scales such as Canadian Achievement Test, Terra Nova test, or Metropolitan achievement test; and ii) academic behaviours by measures such as on-task behaviours, organization or attendance. The assessment of cognitive life skills outcomes (goal setting, problem solving, self-regulation) can include self-report measures as the Life Skills Self Beliefs test, or multisource assessment scales that triangulate self-reports with ratings by significant others (peers, teachers). When cognitive, metacognitive or academic performance outcomes are paralleled by biochemical, brain functional and structural correlates, also such measures will be considered, as they may inform about the biochemical and neural mechanisms underlying physical activity effects on cognition.

Search methods for the identification of studies.

Electronic search

The search will be conducted in the MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, Web of Science, PsycINFO and ERIC databases from their inception. Study records will be managed by means of the Mendeley reference manager.

The following search terms (and related truncations, e.g., 'cognit' to tap cognition and cognitive) will be used: (1) physical activity, physical education, exercise, fitness, sport;

(2) cognition, executive, executive function, cognitive control, intelligence, memory, attention, metacognition; (3) life skills, goal settin, problem solving, self-regulation; (4) academic, academic achievement, academic grades, academic behaviour, academic performance, classroom behaviour; (5) brain development, brain health, neural, neuroelectric, neurotrophic, neurotrophin, hormon; (6) children, childhood, pre-schooler, schooler, preadolescent, adolescent, adolescence and (7) trial. (Appendix I for MEDLINE database search strategy).

Previous reviewers and meta-analysis will be checked for additional references and relevant references cited in the selected studies will be screened as supplemental sources.

Data collection and analysis.

Selection of studies

After excluding duplicated records, two reviewers will independently screen titles and abstracts to identify eligible studies according to the inclusion and exclusion criteria. Then, the potential eligible studies will be deeply reviewed and their reference list will be checked for additional relevant studies. Any discrepancies will be resolved by discussion with a third reviewer.

Two authors will independently extract data on the publication year, number and age of participants (control and intervention groups), physical exercise intervention characteristics, and (meta)cognition//life skills /academic performance variables.

Any disagreement will be resolved by discussion and consensus. If necessary, the authors of the included studies will be contacted to obtain additional relevant information.

Assessment of risk of bias in included studies

Two researchers will conduct a quality assessment according to the Cochrane Collaboration Handbook.[23] Any disagreement will be resolved by discussion. A third reviewer will resolve the disagreement if consensus is not reached.

Methodological quality of the randomized controlled trials will be assessed with the Jadad Scale.[24] The risk of bias will be evaluated according to three domains: randomization, double blinding, and description of withdrawals and dropouts. Each domain will receive a score of one when the studies satisfy its description.

Randomization will score one extra point if the method to generate the sequence is appropriate. Additionally, a double blind study will score one extra point if the double blind method is appropriately described. Based on these domains, scores can range from 0 to 5.

The Quality Assessment Tool for Quantitative Studies[25] is proposed to assess the quality of pre-post studies and non-randomized controlled trials. This tool evaluates seven domains: selection bias, study design, confounders, blinding, data collection method, withdrawals and dropouts. Each domain could be considered to be strong, moderate or weak, and the studies could be classified as strong (with no weak ratings), moderate (with one weak rating), and weak (with two or more weak ratings)

If there are insufficient or unclear data describing the required domains, the study authors have to be contacted for more details.

Data synthesis

The key characteristics and important questions, such as: sample size, age of participants, quantitative and qualitative intervention characteristics, and cognitive outcome observed from the included studies in relation to the aim of the review will be summarized in tables (Appendix II). Reviewers will determine whether a meta-analysis is possible when data have been extracted. At least, five observations addressing the same specific outcome will be required to conduct a meta-analysis.

If it is possible to carry out a meta-analysis, STATA 13 software will be used to combine the pooled mean differences with 95% confidence intervals. A fixed-effect model will be used if there is no evidence of heterogeneity; otherwise, a random-effects model will be used. The study heterogeneity will be assessed with an I2 statistic. Usually, I2 values of <25, 25-50, and >50% represent small, medium, and large amounts of heterogeneity, respectively.[26] Studies with insufficient data to perform the analyses regarding pre-post chronic physical exercise intervention measurements will be omitted from the data synthesis. If there is substantial heterogeneity among the studies and a meta-analysis is not possible, a descriptive analysis will be conducted.

The measure of the mean pre-post intervention differences will be the primary indicator of the intervention outcome. The mean differences (standard error (SE)) and standardized mean differences (standard deviation (SD)) will be calculated for each specific skill or area included in the tests. For example, when the SE is provided, the SD

will be calculated according to the following formula, SD=SE*square root of N. The pooled effect size on the physical intervention and control groups will be compared using the mean differences and standard errors weight for the number of participants. Lastly, publication bias will be assessed by the method proposed by Egger, as well as visually on a funnel plot.[27]

Subgroup analyses

Subgroup analyses will be performed based on the main factors that may cause heterogeneity, grouped as individual, task and contextual constraints. Main individual factors that could act as moderators of the exercise-cognition relation are age, weight status, and skill level.

Main types of task-related factors are qualitative and quantitative intervention characteristics, the type of cognition assessed and the stability of the intervention outcomes over time. Well-established quantitative parameters of the interventions are intensity, frequency, and overall and session duration.[28] The qualitative characteristics of chronic exercise interventions to aid children's and adolescents' cognition have been tentatively classified as traditional physical education, aerobic training, skill-based training, cognitively demanding/enriched physical activity, or combinations of them.[29]

The broad array of facets of cognitive functioning that may be differentially influenced by chronic exercise interventions include: (i) non-executive functions, as non-verbal ability, spatial ability; (ii) core executive functions, that are inhibition, working memory, cognitive flexibility; (iii) metacognitive functions (i.e., higher-level executive functions), as abstract reasoning, planning, problem solving); (iv) cognitive life skills, as goal setting, self-regulation; (v) academic achievement areas, as mathematics, language, reading, total scores; (vi) academic behaviours, as on-task behaviours, organization, attendance. Finally, the time of cognitive assessment after intervention cessation influences the effect size and may inform on the outcome stability.

The main contextual factor that may cause heterogeneity of results on the relationship between physical activity and cognition in children and adolescents is the intervention setting: school, out-of-school, or laboratory setting. Also in school-based studies, it must be taken into account if the physical activity intervention was enhanced/enriched

physical education, classroom-based activity breaks during curricular time, or active play during recess time.

Sensitivity analysis

Sensitivity analyses will be conducted by excluding studies from the analysis one by one. It is needed to prove that the findings from the meta-analysis are not dependent on arbitrary or unclear decisions. Main arguments for carrying out a sensitivity analysis in the present review protocol are the existence of large differences in (i) study design and (ii) type of specific assessment tools used. (i) As regards the study design, as indicated under the subheading "Type of studies", we propose to include RCT, non-RCT, control pre-post studies, that may largely differ in their ability to truly tap intervention outcomes. (ii) As concerns the specific assessment tools used, they may differ in the extent to which they specifically tap the cognitive function of interest, or may lead to spurious results. For example, academic grades represent a final outcome of achievement behaviours that are affected not only by cognitive, but also by motivational, emotional and social factors of the learning context. Furthermore, also among more narrowly focused cognitive test outcomes there may be differences due to the sensitivity issue. For example, inhibitory control - one of the most commonly studied cognitive functions in developmental exercise-cognition studies - is multifaceted[1] and has been therefore studied with different tests that tap inhibition of thoughts and memories (e.g., Random Number Generation), inhibition as perceptual interference control challenging attention (e.g., Eriksen flanker task, Stroop Colour-Word task, expressive attention scale of the Cognitive Assessment System), or inhibition at the behavioural response level (e.g., stop-signal task).

DISCUSSION

A positive association between physical exercise programs and academic performance has been reported more or less consistently by recent systematic reviews and meta-analyses[4,13,15,17,29] that analysed this relationship. The commonality of the above systematic reviews and meta-analyses is that they all included academic performance outcomes that represent a key variable for policy makers of the education sector. On the other side, they largely differed as regards other characteristics that must be considered to reach relevant conclusion.

First of all, some reviews[13-14,28] included studies with interventional, cross-sectional or observational designs; this limits the strength of conclusions in terms of causal relationship and weakens the call for more physical activity in school and out-of-school settings as a means to aid cognitive development and successful academic achievement. A narrative review[17] that was exclusively focused on interventional research included both acute and chronic exercise studies, which have a different take-home message for policy makers. The transient cognitive benefits of an acute bout of exercise support the call for more physically active breaks interspersed during the sitting learning time and for more physically active academic lessons (e.g., 'moved maths'). On the other side, the cognitive benefits of a longer-lasting chronic exercise program support the call for legislative changes in favour of enhanced physical education and physical activity promotion in out-of-school settings.

To the best of our knowledge, only one systematic review[15] included only RCT, considering a broad range of outcomes of aerobic exercise programs including cognition, academic behaviour and achievement, as well as psychosocial functioning outcomes. However, this review did not provide data for the impact of the aerobic exercise programs on each academic performance component, nor did it include, among the studies with psychosocial outcomes, those regarding physical activity outcomes on cognitive life skills that are linked to successful academic behaviour and achievement.

The lack of separate subgroup analyses of data according to the different academic performance areas or types of cognitive function assessed is common to most of the existing reviews.[4,13,15,29] This limits the possibility to obtain a differentiated view on what type of physical activity interventions work best to reap specific cognitive/academic benefits. Also, the applied conclusions that can be drawn from many of the existing reviews are limited, as explicitly acknowledged[15], by the use of different measurements tools and the paucity and diversity of follow-up periods.

The present protocol is aimed at overcoming these limitations by performing subgroup analyses that take into account these issues in combination. Particularly, we follow the call by Tomporowski et al.[2] to distinguish between cognitive and metacognitive outcomes of physical activity to investigate their role in a hypothesized mediational chain linking chronic physical activity and academic performance. The authors state that cognitive assessments in developmental exercise and cognition research prioritize tools that test the cognitive functions of interest during "on-line" processing.[2] To explain how

exercise impacts children's metacognitive processes and academic performance that develop along a wider time scale, they recommend to expand the view on exercise-cognition relations to encompass a cognitive-social focus on factors that underlie the personal awareness of own skills in achieving short- and long-term goals. The present protocol provides an attempt in this direction, expanding the usual framework for exercise-cognition reviews to encompass cognitive life skills and separately analyse cognitive, metacognitive and academic performance outcomes.

As an outlook for future research, CDC[13] encouraged analysing the same variables in any given category, to make summary statement about the magnitude of the effect of physical exercise on academic performance variables. Singh et al[16] recognized as limitation to generate conclusion the inclusion of different study designs and outcomes measured. Tomporowski et al[2] recommended to improve the information regarding the qualitative and quantitative characteristics of physical activity programs that enhance children's neurocognitive performance, and to consider the possible moderators and mediators acting on the relationship between chronic exercise and cognition/academic performance during development. Since it is common that moderator variables are included in interventional studies, it will be possible to apply the subgroup and moderation analyses proposed in the Methods section. Instead, there still is a paucity of studies addressing mediation,[8,30] which still remains an issue in need for further research before meta-analytic conclusions can be drawn.

Given the importance of the entire developmental period– from infancy to late adolescence[31] for brain development and therefore also for academic performance, a more detailed and comprehensive view on the exercise-cognition relation during development is needed for education and health professionals to orient policy efforts. This protocol provide a clear and structured procedure for maximizing the extraction of relevant information and provide summarized information regarding the impact of long-term physical activity programs on children´s cognition and academic performance.

Ethics and dissemination

Ethical approval will not be needed to apply this review protocol because the data to be used in this systematic review come from published studies and there will be no concerns about privacy. The results of such kind of review can be best disseminated by publication of the manuscript in a peer-reviewed journal that broadly reaches

researchers interested in hypotheses testing and policy makers interested in the translatability of scientific evidence into good practices.

Developing chronic physical exercise intervention is justified by the international physical activity guidelines that recommend children to participate in at least 60 minutes of daily physical activity.[32] Nonetheless, the prevalence of overweight children and the total sedentary time that children daily accumulate have risen substantially in the past three decades in most countries. Therefore, schools and communities are encouraged to implement children´s physical activity time, but it is necessary to measure how physical activity could affect cognitive function and life skills relevant to successful academic performance. The conclusions of the proposed type of systematic review and meta-analysis may support the decisions of school boards, school administrators and policy developers with scientifically grounded arguments on why to maintain or increase the time devoted to curricular or extracurricular physical activity and on what type of activities help reap largest cognitive and academic benefits.

Authors' contribution: VMV and CAB designed the study. VMV was the Principal Investigator and Guarantor. CP, CAB, and VMV were the main coordinators of the study. MSL, CAB, MJPG, and ICR conducted the study. ICR, CP, and MJPG provided statistical and epidemiological support. VMV wrote the article with the support of MSL, CP, and CAB. All of the authors revised and approved the final version of the manuscript.

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Appendix I. Search strategy for MEDLINE database.

“physical activity” OR “physical education” OR exercise OR fitness OR sport	AND	cognition OR executive OR “executive function” OR “ executive function” OR “cognitive control” OR intelligence OR memory OR attention OR metacognition	AND	academic OR “academic achievement” OR “academic grades” OR “academic behaviour” OR “academic performance” OR “classroom behaviour”	AND	“brain development” OR “brain health” OR Neural OR neuroelectric OR neurotrophic OR neurotrophin OR hormone	children OR childhood OR pre-schooler OR schooler OR preadolescent OR adolescent OR adolescence	AND	trial

Appendix II: Table for extraction data as reported by the authors.

Author and year of publication	Country	N (CG/EG1/EG2)	Age of participants	CG/EG1/EG2 characteristics (min, d/w)	Intervention components	Length (weeks)	Neurocognitive recall

CG: Control Group, EG1: Experimental Group 1, EG2: Experimental Group 2, min: minutes, d/w: days a week.

PRISMA-P (Preferred Reporting Items for Systematic review and Meta-Analysis Protocols) 2015 checklist: recommended items to address in a systematic review protocol*

Section and topic	Item No	Checklist item	Page number
ADMINISTRATIVE INFORMATION			
Title:			
Identification	1a	Identify the report as a protocol of a systematic review	Page 1; line 1-3
Update	1b	If the protocol is for an update of a previous systematic review, identify as such	NA
Registration	2	If registered, provide the name of the registry (such as PROSPERO) and registration number	Page1; line 4
Authors:			
Contact	3a	Provide name, institutional affiliation, e-mail address of all protocol authors; provide physical mailing address of corresponding author	Page 1; line 12-23
Contributions	3b	Describe contributions of protocol authors and identify the guarantor of the review	Page14; line 417-421
Amendments	4	If the protocol represents an amendment of a previously completed or published protocol, identify as such and list changes; otherwise, state plan for documenting important protocol amendments	NA
Support:			
Sources	5a	Indicate sources of financial or other support for the review	Page 14; line 422-423
Sponsor	5b	Provide name for the review funder and/or sponsor	NA
Role of sponsor or funder	5c	Describe roles of funder(s), sponsor(s), and/or institution(s), if any, in developing the protocol	NA
INTRODUCTION			
Rationale	6	Describe the rationale for the review in the context of what is already known	Page 3-5; line 80-132
Objectives	7	Provide an explicit statement of the question(s) the review will address with reference to participants, interventions, comparators, and outcomes (PICO)	Page 5; line 142-148
METHODS			
Eligibility criteria	8	Specify the study characteristics (such as PICO, study design, setting, time frame) and report characteristics (such as years considered, language, publication status) to be used as criteria for eligibility for the review	Page 6-7; line 160-208
Information sources	9	Describe all intended information sources (such as electronic databases, contact with study authors, trial registers or other grey literature sources) with planned dates of coverage	Page 7; line 211-213
Search strategy	10	Present draft of search strategy to be used for at least one electronic database, including planned limits, such that it could be repeated	Page17; Appendix I

PRISMA-P (Preferred Reporting Items for Systematic review and Meta-Analysis Protocols) 2015 checklist: recommended items to address in a systematic review protocol*

Study records:			
Data management	11a	Describe the mechanism(s) that will be used to manage records and data throughout the review	Page 7; line 213-214
Selection process	11b	State the process that will be used for selecting studies (such as two independent reviewers) through each phase of the review (that is, screening, eligibility and inclusion in meta-analysis)	Page 8; line 228-232
Data collection process	11c	Describe planned method of extracting data from reports (such as piloting forms, done independently, in duplicate), any processes for obtaining and confirming data from investigators	Page 8; line 233-235
Data items	12	List and define all variables for which data will be sought (such as PICO items, funding sources), any pre-planned data assumptions and simplifications	Page 9; line 258-261 and Appendix II
Outcomes and prioritization	13	List and define all outcomes for which data will be sought, including prioritization of main and additional outcomes, with rationale	Page 9; line 258-261 and Appendix II
Risk of bias in individual studies	14	Describe anticipated methods for assessing risk of bias of individual studies, including whether this will be done at the outcome or study level, or both; state how this information will be used in data synthesis	Page 8-9; line 242-254
Data synthesis	15a	Describe criteria under which study data will be quantitatively synthesised	Page 9; line 262-264
	15b	If data are appropriate for quantitative synthesis, describe planned summary measures, methods of handling data and methods of combining data from studies, including any planned exploration of consistency (such as I^2, Kendall's τ)	Page 9; line 264-279
	15c	Describe any proposed additional analyses (such as sensitivity or subgroup analyses, meta-regression)	Page 10; line 284-309
	15d	If quantitative synthesis is not appropriate, describe the type of summary planned	Page 9; line 271-272
Meta-bias(es)	16	Specify any planned assessment of meta-bias(es) (such as publication bias across studies, selective reporting within studies)	Page 9; line 279-280
Confidence in cumulative evidence	17	Describe how the strength of the body of evidence will be assessed (such as GRADE)	Page 10-11; line 311-329

*** It is strongly recommended that this checklist be read in conjunction with the PRISMA-P Explanation and Elaboration (cite when available) for important clarification on the items. Amendments to a review protocol should be tracked and dated. The copyright for PRISMA-P (including checklist) is held by the PRISMA-P Group and is distributed under a Creative Commons Attribution Licence 4.0.**

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The association of physical activity with cognition, metacognition and academic performance in children and adolescents: A protocol for systematic review and meta-analysis.

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The association of physical activity with cognition, metacognition and academic performance in children and adolescents: A protocol for systematic review and meta-analysis.

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ABSTRACT

Introduction. Schools provide a relevant context for improving children's and adolescents' physical and mental health by increasing physical activity during school hours and/or beyond. The interest in the relationship between physical activity programs and cognition during development has recently increased, with evidence suggesting a positive association. We present a protocol of systematic review and meta-analysis of intervention studies that, by determining the effects of chronic physical exercise on children's and adolescents' cognitive and metacognitive functions, cognitive life skills, academic behaviours and achievement, aims to ensure procedural objectivity and transparency and maximize the extraction of relevant information to inform policy development.

Methods. This protocol is guided by Preferred Reporting Items for Systematic Review and Meta-analysis Protocols (PRISMA-P) and by the Cochrane Collaboration Handbook. Databases to be utilized for a thorough selection of pertinent literature are MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, Web of Science, PsycINFO and ERIC. Selection is proposed to encompass an international and a national publication level, with inclusion of experimental studies written in English or in Spanish, respectively. Also relevant references included in the selected studies will be considered suitable for review as supplemental sources.

We present an integrated approach to the methodological quality assessment of the selected studies, including the Jadad Scale for the assessment of the quality of randomized controlled trials and the Quality Assessment Tool for Quantitative Studies for pre-post studies and non-randomized controlled trials. The pre-post interventions mean differences will be the primary indicator of the intervention outcome.

Statistical analysis. A subgroup analysis is proposed based on cognitive functions and their neural correlates, metacognitive functions and cognitive life skills, academic achievement areas and academic behaviours.

Trial registration number: PROSPERO CRD42015029913

Strengths and limitations.

Strengths of the proposed protocol are:

- A comprehensive methodology for analysing the effect of physical activity programs on main components of children´s brain health, cognitive functioning and academic performance that are relevant for policy development.
- Assessment of risk of bias of included studies and heterogeneity among studies with particular reference to individual, task and contextual factors.
- Inclusion into analysis of those factors identified as relevant potential moderators of the relation of physical activity with cognition or academic performance in children and adolescents.

Limitations of this systematic review could result from:

- The heterogeneity of the assessed outcomes or tests used for assessing the same outcome.
- The generalization of results constrained by the exclusion of children and adolescents with atypical development.

INTRODUCTION

In the last decades, scientific evidence on the relationship between chronic physical activity and cognitive/academic performance in childhood and adolescence has attracted increasing attention[1]. Chronic physical activity interventions have been defined as long lasting repeated bouts of exercise aimed to improve physical fitness.[2] Chronic physical activity participation has been associated with several mental health benefits in school children, such as improved self-perceptions (e.g., self-esteem, self-efficacy), emotional regulation (e.g., anxiety, depression), and cognitive functioning (e.g., information processing, memory, attention).[3]

Due to the relevant implications for educational policies, many researches have investigated the effects of chronic physical activity participation on students´ success at school that is on academic performance.[4-5] The latter is pooled in classroom behaviour (e.g., on-task behaviours during learning activities) and academic achievement (e.g., school notes and performance in test on school subjects). Attention has also been focused on cognitive executive functions, since their development early in life has been proven predictive of school and lifelong achievement, health and quality of life.[6] Diamond[6] distinguishes between core executive functions – that are inhibitory control, working memory and cognitive flexibility – and higher-level executive functions – as

reasoning, planning, and problem solving. This higher-level cognition largely overlaps with what is termed metacognition that is the ability to supervise and manage cognitive process and to use knowledge to regulate behaviours[2].

Chronic exercise-cognition research has experienced a progressive shift toward a biochemical and neuroscientific perspective from both exercise and cognition researchers [7-8] and developmental neuroscientists.[9] The positive influence of chronic physical activity has been related to angiogenesis, increasing oxygen saturation and glucose delivery, improving cerebral blood flow and increasing neurotransmitters levels,[10] differences in structural brain volumes, as measured by magnetic resonance imaging,[11] and brain function, as measured by electrical activity recordings.[12]

Previous systematic reviews and meta-analysis have synthetized evidence of the influence of exercise interventions on children's and, less frequently, adolescents' cognition and success in school, focused on quantitative exercise characteristics (intensity, frequency, and session duration).[5,13-16] Of these, one regarded experimental studies only and considered both cognitive and psychosocial outcomes jointly.[15] No study presented results which distinguished between cognitive and metacognitive functions, academic behaviour and achievement. Indeed, this distinction has been recently deemed relevant to understand the potential mediational paths that underlie the relationship between physical activity and academic achievement.[2]

In the search for further mechanisms beyond the neurobiological that may explain the link between chronic physical activity and children´s cognition, recent narrative or meta-analytic reviews have focused on the qualitative characteristics of the physical activity interventions.[8,17-18] The difficulty in operationalizing the breadth of the exercise quality construct in exercise and cognition research, beyond the mere metabolic and neuromuscular demands of physical exercise tasks,[19] is a main cause of the underinvestigation of the role played by qualitative exercise characteristics as coordinative and cognitive task complexity, novelty, and diversification for cognitive development promotion.[20] Also developmental neuroscientists interested in interventions aiding children's cognition are increasingly shifting attention toward qualitative forms of physical activity that are not only physically effortful, but also emotionally and socially engaging.[9] This kind of interventions often involve physical activities that impinge on core cognitive functions, as well as on a broader range of cognitive skills, as goal setting, problem solving and self-regulation[1]. These are

cognitive in nature and therefore fall in the field of cognitive sciences, but are also investigated in psychosocial and social-cognitive research as essential life skills to self-regulate behaviour and successfully adapt it to everyday requirements.[21] Since they are proven sensitive to designed physical activity interventions,[22] it has been recently proposed that cognitive life skills may represent a further element to be considered in the relationship between physical activity, cognition, and academic behaviour and achievement.[8]

In sum, scientific evidence on the relationship between physical activity and cognitive/academic performance, particularly as regards its possible moderators and mediators, is still currently insufficient to obtain a comprehensive view that may be useful to inform policies and decision-making. Discrepancies persist regarding the effects of chronic exercise interventions on children's cognition and success in school and life and reviews still lack consideration of evidence at relevant intersection points between different research areas. Moreover, whereas several narrative and meta-analytic reviews have provided evidence syntheses that are mainly useful for setting future research priorities, they still leave open questions concerning how this evidence can be translated into good practices in ecological settings as the educational.[23]

Thus, the general aim of the present methodological article is to provide a novel protocol designed to review interventional studies addressing the chronic exercise-cognition interaction in children and adolescents for obtaining relevant information for policy makers and decision makers particularly in, but not limited to, the education sector. To this aim, the proposed protocol encompasses different facets of cognitive function and academic performance that, to the best of our knowledge, should be jointly considered to facilitate transitioning evidence of the cognitive benefits of physical activity for children and adolescents into good practices.

OBJECTIVES

This systematic review and meta-analysis has three objectives: (i) to estimate the effects of chronic physical exercise interventions on different facets of cognitive function and academic performance of children and adolescents; (ii) to determine which of those variables benefit most from physical activity; (iii) to identify the individual, task-related and contextual moderators that may amplify physical activity effects on cognition/academic performance, with particular focus on the qualitative and quantitative characteristics of the physical activity interventions.

Specifically, this systematic review and meta-analysis protocol presents an objective and clear procedure to maximize the extraction of information from experimental studies (randomized controlled trials - RCT, non-RCT and controlled pre-post studies), in which data for cognition, metacognition, cognitive life skills, academic behaviour and achievement have been separately or jointly reported as outcomes.

METHODS AND ANALYSIS

This systematic review and meta-analysis protocol is based on the Preferred Reporting Items for Systematic Review and Meta-analysis Protocols (PRISMA-P)[24] and the Cochrane Collaboration Handbook[25]. This trial has been registered in PROSPERO (registration number: CRD42015029913).

Inclusion/exclusion criteria for study selection

Type of studies.

Randomized control trials (RCT), non-RCT and controlled pre-post studies written in international language (English) or in the national language of interest (Spanish).

Type of participants.

Studies assessing the relationship, at developmental age, between chronic physical exercise interventions and cognition, metacognition, cognitive life skills and academic performance variables will be included regardless of sex, weight, ethnicity, and socioeconomic status. Studies including participants aged from 4 to 18 years will be considered for inclusion. Among exclusion criteria, the one regarding participants will be the presence of children with any physical condition or any diagnosed disorder of cognition that would impede or limit their ability to participate in school physical activity programs. If participants are assessed more than once in the same study, data will be extracted and analysed from the different measurements as independent samples.

Type of interventions.

Studies reporting any type of chronic physical exercise intervention, defined as repeated bouts of exercise over time aimed to improve physical fitness, involving multiple sessions over a number of training weeks, months or years will be eligible for inclusion. Instead, studies reporting the transient effects of single bouts of acute physical exercise will be excluded. Studies comparing different types of chronic physical exercise

interventions or examining a chronic physical exercise intervention with or without a control group are considered eligible for inclusion.

Among chronic physical exercise interventions, we will include those defined as: school-based physical exercise interventions, recess time interventions, classroom-based physical activity interventions and extracurricular physical activity interventions. Studies combining physical exercise with other health interventions, such as nutritional interventions, will be excluded when data concerning the effectiveness of physical activity programs on cognitive or academic performance variables could not be extracted separately.

Type of outcome assessments.

In the attempt to provide a comprehensive view of physical activity effects on the different facets of children's and adolescents' cognition, a broad array of cognitive outcome assessments is warranted, ranging from neural correlates of cognitive functioning to performance measures and observational or self-reported evaluations of cognition, metacognition, cognitive life skills and academic performance.

Indicatively, but not exhaustively, common performance measures for cognitive function assessment are tests such as Eriksen flanker task, Stroop Colour-Word task, Cognitive Assessment System (CAS), or Stenberg task. Examples of performance measures for metacognitive function assessment are the Tower of London test and creativity assessment tools as the Alternate Uses Test. Academic performance assessments regard: (i) academic achievement by curriculum-based marks or specific scales such as Canadian Achievement Test, Terra Nova test, or Metropolitan achievement test; and (ii) academic behaviours by measures such as on-task behaviours, organization or attendance. The assessment of cognitive life skills outcomes (goal setting, problem solving, self-regulation) can include self-report measures as the Life Skills Self Beliefs test, or multisource assessment scales that triangulate self-reports with ratings by significant others (peers, teachers). When cognitive, metacognitive or academic performance outcomes are paralleled by biochemical, brain functional and structural correlates, also such measures will be considered, as they may inform about the biochemical and neural mechanisms underlying physical activity effects on cognition.

Search methods for the identification of studies.

Electronic search

The search will be conducted in the MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, Web of Science, PsycINFO and ERIC databases from their inception. Study records will be managed by means of the Mendeley reference manager.

The following search terms (and related truncations, e.g., 'cognit' to tap cognition and cognitive) will be used: (1) physical activity, physical education, exercise, fitness, sport; (2) cognition, executive, executive function, cognitive control, intelligence, memory, attention, metacognition; (3) life skills, goal setting, problem solving, self-regulation; (4) academic, academic achievement, academic grades, academic behaviour, academic performance, classroom behaviour; (5) brain development, brain health, neural, neuroelectric, neurotrophic, neurotrophin, hormon; (6) children, childhood, pre-schooler, schooler, preadolescent, adolescent, adolescence and (7) trial. (Appendix I for MEDLINE database search strategy).

Previous reviews and meta-analyses will be checked for additional references and relevant references cited in the selected studies will be screened as supplemental sources.

Data collection and analysis.

Selection of studies

After excluding duplicated records, two reviewers will independently screen titles and abstracts to identify eligible studies according to the inclusion and exclusion criteria. Then, the potential eligible studies will be comprehensively reviewed and their reference list will be checked for additional relevant studies. Any discrepancies will be resolved by discussion with a third reviewer.

Two authors will independently extract data on publication year, number and age of participants (control and intervention groups), physical exercise intervention characteristics, and (meta)cognition/life skills/academic performance variables.

Any disagreement will be resolved by discussion and consensus. If necessary, the authors of the included studies will be contacted to obtain additional relevant information.

Assessment of risk of bias in included studies

Two researchers will conduct a quality assessment according to the Cochrane Collaboration Handbook.[25] Any disagreement will be resolved by discussion. A third reviewer will resolve the disagreement if consensus is not reached.

Methodological quality of the RCT will be assessed with the Jadad Scale.[26] The risk of bias will be evaluated according to three domains: randomization, double blinding, and description of withdrawals and dropouts. Each domain will receive a score of one when the studies satisfy its description. Randomization will score one extra point if the method to generate the sequence is appropriate. A double blind study will score one extra point if the double blind method is appropriately described. Based on these domains, scores can range from 0 to 5.

The Quality Assessment Tool for Quantitative Studies[27] is proposed to assess the quality of pre-post studies and non-RCT. This tool evaluates seven domains: selection bias, study design, confounders, blinding, data collection method, withdrawals and dropouts. Each domain could be considered strong, moderate or weak, and studies could be classified as strong (with no weak ratings), moderate (with one weak rating), and weak (with two or more weak ratings). If there are insufficient or unclear data describing the required domains, the study authors have to be contacted for more details.

Data synthesis

Key characteristics and important questions, such as sample size, age of participants, quantitative and qualitative intervention characteristics, and cognitive outcome relevant to the aim of the review will be summarized in tables (Appendix II). Reviewers will determine whether a meta-analysis is possible when data have been extracted. At least five observations addressing the same specific outcome will be required to conduct a meta-analysis.

If it is possible to carry out a meta-analysis, STATA 13 software will be used to combine the pooled mean differences with 95% confidence intervals. A fixed-effect model will be used if there is no evidence of heterogeneity; otherwise, a random-effects model will be used. The study heterogeneity will be assessed with an I2 statistic. Usually, I2 values of <25, 25-50, and >50% represent small, medium, and large amounts of heterogeneity, respectively.[28] Studies with insufficient data to perform the analyses will be omitted from the data synthesis. If there is substantial heterogeneity

among the studies and a meta-analysis is not possible, a descriptive analysis will be conducted.

The measure of mean pre-post intervention difference will be the primary indicator of the intervention outcome. Mean differences (standard error, SE) and standardized mean differences (standard deviation, SD) will be calculated for each specific skill or area included in the tests. For example, when the SE is provided, the SD will be calculated according to the following formula: SD=SE*square root of N. The pooled effect size on the physical intervention and control groups will be compared using the mean differences and ES weight for the number of participants. Lastly, publication bias will be assessed by means of the method proposed by Egger, as well as visually on a funnel plot.[29]

Subgroup analyses

Subgroup analyses will be performed based on the main factors that may cause heterogeneity, grouped as individual, task and contextual constraints. Main individual factors that could act as moderators of the exercise-cognition relation are age, weight status, and skill level.

Main types of task-related factors are qualitative and quantitative intervention characteristics, the type of cognition assessed and the stability of the intervention outcomes over time. Well-established quantitative parameters of the interventions are intensity, frequency, and overall session duration.[30] The qualitative characteristics of chronic exercise interventions to aid children's and adolescents' cognition have been tentatively classified in different ways in recent reviews. One classification primarily links the physical activity type to its specific context of practice: physical education at school, active commuting in the urban route environment, individual vs. team sport participation indoor or outdoor.[31] Another classification attempts to distinguishes studies primarily focused on the metabolic demands of physical activity from those focused on or with deliberate manipulation of the coordinative and cognitive demands: aerobic training, skill-based training, cognitively demanding/enriched physical activity, traditional physical education, or combinations of them.[18]

The broad array of facets of cognitive functioning that may be differentially influenced by chronic exercise interventions include: (i) non-executive functions, as non-verbal ability, spatial ability; (ii) core executive functions, that are inhibition, working

memory, cognitive flexibility; (iii) metacognitive functions (i.e., higher-level executive functions), as abstract reasoning, planning, problem solving; (iv) cognitive life skills, as goal setting, self-regulation; (v) academic achievement areas, as mathematics, language, reading, total scores; (vi) academic behaviours, as on-task behaviours, organization, or attendance. Finally, the time of cognitive assessment after intervention cessation influences the effect size and may inform on the outcome stability.

The main contextual factor that may cause heterogeneity of results is the intervention setting: school, out-of-school, or laboratory setting. Also in school-based studies, it must be taken into account if the physical activity intervention was enhanced/enriched physical education, classroom-based activity breaks during curricular time, or active play during recess time.

Sensitivity analysis

Sensitivity analyses will be conducted excluding studies from the analysis one by one. It is needed to prove that the findings from the meta-analysis are not dependent on arbitrary or unclear decisions. The main argument for carrying out a sensitivity analysis in the present review protocol is the existence of large differences in (i) study design and (ii) type of specific assessment tools used. (i) As regards the study design, as indicated under the subheading "Type of studies", we propose to include RCT, non-RCT, control pre-post studies, that may largely differ in their ability to truly tap intervention outcomes. (ii) As concerns the specific assessment tools used, they may differ in the extent to which they specifically tap the cognitive function of interest, or may lead to spurious results. For example, academic grades represent a final outcome of achievement behaviours that are affected not only by cognitive, but also by motivational, emotional and social factors of the learning context. Furthermore, also among more narrowly focused cognitive test outcomes there may be differences due to the sensitivity issue. For example, inhibitory control - one of the most commonly studied cognitive functions in developmental exercise-cognition studies - is multifaceted[1] and has been therefore studied with different tests that tap inhibition of thoughts and memories (e.g., Random Number Generation), inhibition as perceptual interference control challenging attention (e.g., Eriksen flanker task, Stroop Colour-Word task, expressive attention scale of the Cognitive Assessment System), or inhibition at the behavioural response level (e.g., stop-signal task).

DISCUSSION

A positive association between physical exercise programs and academic performance has been reported more or less consistently by recent systematic reviews and meta-analyses[4,13-16,31] that analysed this relationship. The commonality of the above systematic reviews and meta-analyses is that they all included academic performance outcomes that represent a key variable for policy makers of the education sector. On the other side, they largely differed as regards other characteristics, that must be considered to reach relevant conclusion. Several differences among studies can render the evidence base more or less useful and the take-home message more or less meaningful and generalizable for policymakers. They regard: study design; acute/chronic exercise research type; intervention type and length of follow-up period; type and specificity of outcome measures; type of individual, task-related, and contextual moderators acting on the relationship between physical activity and cognition/academic performance.

First of all, some reviews[13-14,31] included not only interventional studies, but also those with cross-sectional or observational designs; this limits the strength of causal conclusions and of the call for more physical activity in school and out-of-school settings as a means to aid cognitive development and successful academic achievement. A narrative review[17] that was exclusively focused on interventional research included both acute and chronic exercise studies, which have a different take-home message for policy makers. The transient cognitive benefits of an acute bout of exercise support the call for more physically active breaks interspersed during the sitting learning time and for more physically active academic lessons (e.g., 'moved maths'). On the other side, the cognitive benefits of a longer-lasting chronic exercise program support the call for legislative changes in favour of enhanced physical education and physical activity promotion in out-of-school settings.

To the best of our knowledge, only one systematic review[15] included only RCT. It considered a broad range of outcomes of aerobic exercise programs including cognition, academic behaviour and achievement, as well as psychosocial functioning outcomes. However, this review did not provide data for the impact of aerobic exercise programs on each academic performance component, nor did it include, among the studies with psychosocial outcomes, those regarding physical activity effects on cognitive life skills that are linked to successful academic behaviour and achievement.

The lack of separate subgroup analyses of data according to the different academic performance areas or types of cognitive function assessed is common to most of the existing reviews. This limits the possibility to obtain a differentiated view on what type of physical activity interventions work best to reap specific cognitive/academic benefits. Also, the applied conclusions that can be drawn from many of the existing reviews are limited, as explicitly acknowledged,[15] by the use of different measurements tools and the paucity and diversity of follow-up periods.

The present protocol is aimed at overcoming these limitations by performing subgroup analyses that take into account these issues in combination. Particularly, we follow the call by Tomporowski et al[2] to distinguish between cognitive and metacognitive outcomes of physical activity in order to investigate their role in a hypothesized mediational chain linking chronic physical activity and academic performance. The authors state that cognitive assessments in developmental exercise and cognition research prioritize tools that test the cognitive functions of interest during "on-line" processing.[2] To explain how exercise impacts children's metacognitive processes and academic performance that develop along a wider time scale, they recommend to expand the view on exercise-cognition relations to encompass cognitive-social factors that underlie the personal awareness of own skills in achieving short- and long-term goals. The present protocol provides an attempt in this direction, expanding the usual framework for exercise-cognition reviews to encompass cognitive life skills and separately analyse cognitive, metacognitive and academic performance outcomes.

As an outlook for future research, CDC[13] encouraged analysing the same variables in any given category, to make summary statement about the magnitude of the effect of physical exercise on academic performance variables. Singh et al[16] recognized as limitation of conclusions the inclusion of different study designs and outcomes measures. Tomporowski et al[2] recommended to improve the information regarding the qualitative and quantitative characteristics of physical activity programs that enhance children's neurocognitive performance, and to consider the possible moderators and mediators acting on the relationship between chronic exercise and cognition/academic performance during development. Since it is common that moderator variables are included in interventional studies, it will be possible to apply the subgroup and moderation analyses proposed in the Methods section. Instead, there still is a paucity of

studies addressing mediation,[8,32,33] which still remains an issue in need for further research before meta-analytic conclusions can be drawn.

The proposed protocol presents also limitations that derive from the deliberate choice of a given trade-off setpoint between inclusion and exclusion criteria to reach relevant conclusions for policymakers of the education and health sectors. Specifically, the broad and heterogeneous array of relevant outcomes that will be included has costs and benefits. It offers the possibility to tap different—from biological to behavioural—aspects related to cognitive functioning and academic performance. Nevertheless, the fact that included studies can broadly differ in assessed outcomes or tests used for assessing the same outcome might lead to underestimation of overall effect size, or to highly variable effect sizes among outcome subsets. On the other side, heterogeneity of studies will be limited as concerns participants' characteristics, since studies involving participants with atypical development will be excluded. Nevertheless in this way, the generalizability of results will be lowered, being traded for a higher comparability of intervention outcomes.

Given the importance of the entire developmental period—from infancy to late adolescence[34] for brain development and therefore for academic performance, a more detailed and comprehensive view on the exercise-cognition relation during development is needed for education and health professionals to orient policy efforts. This protocol provides a clear and structured procedure for maximizing the extraction of relevant information and provides summarized information regarding the impact of long-term physical activity programs on children´s cognition and academic performance.

Ethics and dissemination

Ethical approval will not be needed to apply this review protocol because data will be extracted from published studies and there will be no concerns about privacy. The results of such kind of review can be best disseminated by publication in a peer-reviewed journal that broadly reaches researchers interested in hypotheses testing and policy makers interested in the translatability of scientific evidence into good practices.

Developing programs and strategies to promote physical activity is justified by the international physical activity guidelines that recommend children to participate in at least 60 minutes of daily physical activity.[35] Nonetheless, the prevalence of overweight children and the total sedentary time that children daily accumulate have risen

substantially in the past three decades in most countries. Therefore, schools and communities are encouraged to implement children´s physical activity time. However, it is necessary to further our understanding of how to capitalize on physical activity effects on cognitive function and life skills relevant to successful academic performance. The conclusions of the proposed type of systematic review and meta-analysis may support the decisions of school boards, school administrators and policy developers with scientifically grounded arguments on why to maintain or increase the time devoted to curricular or extracurricular physical activity and on what type of activities help reap largest cognitive and academic benefits.

Authors' contribution: VMV and CAB designed the study. VMV was the Principal Investigator and Guarantor. CP, CAB, and VMV were the main coordinators of the study. MSL, CAB, MJPG, and ICR conducted the study. ICR, CP, and MJPG provided statistical and epidemiological support. VMV wrote the article with the support of MSL, CP, and CAB. All of the authors revised and approved the final version of the manuscript.

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"physical activity" OR "physical education" OR exercise OR fitness OR sport	AND	cognition OR executive OR "executive function" OR " executive function" OR "cognitive control" OR intelligence OR memory OR attention OR metacognition	AND	academic OR "academic achievement" OR "academic grades" OR "academic behaviour" OR "academic performance" OR "classroom behaviour"	AND	"brain development" OR "brain health" OR Neural OR neuroelectric OR neurotrophic OR neurotrophin OR hormone	AND	children OR childhood OR pre-schooler OR schooler OR preadolescent OR adolescent OR adolescence	AND	trial

Appendix I. Search strategy for MEDLINE database.

Appendix II: Table for extraction data as reported by the authors.

Author and year of publication	Country	N (CG/EG1/EG2)	Age of participants	CG/EG1/EG2 characteristics (min, d/w)	Intervention components	Length (weeks)	Neurocognitive recall

CG: Control Group, EG1: Experimental Group 1, EG2: Experimental Group 2, min: minutes, d/w: days a week.

PRISMA-P (Preferred Reporting Items for Systematic review and Meta-Analysis Protocols) 2015 checklist: recommended items to address in a systematic review protocol*

Section and topic	Item No	Checklist item	Page number
ADMINISTRATIVE INFORMATION			
Title:			
Identification	1a	Identify the report as a protocol of a systematic review	Page 1; line 1-3
Update	1b	If the protocol is for an update of a previous systematic review, identify as such	NA
Registration	2	If registered, provide the name of the registry (such as PROSPERO) and registration number	Page1; line 4
Authors:			
Contact	3a	Provide name, institutional affiliation, e-mail address of all protocol authors; provide physical mailing address of corresponding author	Page 1; line 12-23
Contributions	3b	Describe contributions of protocol authors and identify the guarantor of the review	Page15; line 453-458
Amendments	4	If the protocol represents an amendment of a previously completed or published protocol, identify as such and list changes; otherwise, state plan for documenting important protocol amendments	NA
Support:			
Sources	5a	Indicate sources of financial or other support for the review	Page 15; line 459-460
Sponsor	5b	Provide name for the review funder and/or sponsor	NA
Role of sponsor or funder	5c	Describe roles of funder(s), sponsor(s), and/or institution(s), if any, in developing the protocol	NA
INTRODUCTION			
Rationale	6	Describe the rationale for the review in the context of what is already known	Page 3-5; line 77-150
Objectives	7	Provide an explicit statement of the question(s) the review will address with reference to participants, interventions, comparators, and outcomes (PICO)	Page 5; line 152-158
METHODS			
Eligibility criteria	8	Specify the study characteristics (such as PICO, study design, setting, time frame) and report characteristics (such as years considered, language, publication status) to be used as criteria for eligibility for the review	Page 6-7; line 170-220
Information sources	9	Describe all intended information sources (such as electronic databases, contact with study authors, trial registers or other grey literature sources) with planned dates of coverage	Page 7; line 221-225
Search strategy	10	Present draft of search strategy to be used for at least one electronic database, including planned limits, such that it could be repeated	Appendix I

PRISMA-P (Preferred Reporting Items for Systematic review and Meta-Analysis Protocols) 2015 checklist: recommended items to address in a systematic review protocol*

Study records:			
Data management	11a	Describe the mechanism(s) that will be used to manage records and data throughout the review	Page 8; line 225-226
Selection process	11b	State the process that will be used for selecting studies (such as two independent reviewers) through each phase of the review (that is, screening, eligibility and inclusion in meta-analysis)	Page 8; line 241-245
Data collection process	11c	Describe planned method of extracting data from reports (such as piloting forms, done independently, in duplicate), any processes for obtaining and confirming data from investigators	Page 8; line 246-248
Data items	12	List and define all variables for which data will be sought (such as PICO items, funding sources), any pre-planned data assumptions and simplifications	Page 9; line 271-273 and Appendix II
Outcomes and prioritization	13	List and define all outcomes for which data will be sought, including prioritization of main and additional outcomes, with rationale	Page 9; line 271-273 and Appendix II
Risk of bias in individual studies	14	Describe anticipated methods for assessing risk of bias of individual studies, including whether this will be done at the outcome or study level, or both; state how this information will be used in data synthesis	Page 9; line 252-269
Data synthesis	15a	Describe criteria under which study data will be quantitatively synthesised	Page 9; line 274-276
	15b	If data are appropriate for quantitative synthesis, describe planned summary measures, methods of handling data and methods of combining data from studies, including any planned exploration of consistency (such as I^2, Kendall's τ)	Page 10-11; line 277-294
	15c	Describe any proposed additional analyses (such as sensitivity or subgroup analyses, meta-regression)	Page 10-11; line 295-326
	15d	If quantitative synthesis is not appropriate, describe the type of summary planned	Page 9-10; line 283-285
Meta-bias(es)	16	Specify any planned assessment of meta-bias(es) (such as publication bias across studies, selective reporting within studies)	Page 11; line 327-347
Confidence in cumulative evidence	17	Describe how the strength of the body of evidence will be assessed (such as GRADE)	Page 9; line 253-269

*** It is strongly recommended that this checklist be read in conjunction with the PRISMA-P Explanation and Elaboration (cite when available) for important clarification on the items. Amendments to a review protocol should be tracked and dated. The copyright for PRISMA-P (including checklist) is held by the PRISMA-P Group and is distributed under a Creative Commons Attribution Licence 4.0.**

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