

BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2016-011065
Article Type:	Protocol
Date Submitted by the Author:	06-Jan-2016
Complete List of Authors:	<p>Álvarez-Bueno, Celia; Universidad de Castilla-La Mancha, Health and Social Research Center Pesce, Caterina; Human and Health Sciences, University of Rome "Foro Italico" , Department of Movement Cavero-Redondo, Iván; Universidad de Castilla-La Mancha, Health and Social Research Center Sánchez-López, Mairena; Universidad de Castilla-La Mancha, Health and Social Research Center; Universidad de Castilla-La Mancha, School of Education Pardo-Guijarro, Maria Jesús; Universidad de Castilla-La Mancha: , Health and Social Research Center Martínez-Vizcaino, Vicente; Universidad de Castilla-La Mancha, Centro de Estudios Sociosanitarios</p>
Primary Subject Heading:	Public health
Secondary Subject Heading:	Paediatrics
Keywords:	schoolchildren, physical activity, academic performance, child health

SCHOLARONE™
Manuscripts

1
2
3 **The association between physical activity and academic performance in**
4 **schoolchildren: A protocol for a systematic review and meta-analysis.**
5
6
7

8 **Corresponding author:**
9

10 **Vicente Martínez Vizcaíno, Professor**

11 Social and Health Care Research Center

12 Universidad de Castilla-La Mancha, Spain

13 E-mail: Vicente.Martinez@uclm.es

14 Telephone number: 969 179100 (Ext: 4683)
15
16
17
18
19

20
21 **Full name, department, institution, city and country of all co-authors**
22

23 Álvarez-Bueno, Celia¹; Caterina Pesce²; Cavero-Redondo, Iván¹; Sánchez-López,
24 Mairena^{1,3}; Pardo-Guijarro, María Jesús¹; Martínez-Vizcaíno, Vicente^{1,4}.
25
26
27

28 ¹Universidad de Castilla-La Mancha: Health and Social Research Center, Cuenca,
29 Castilla-La Mancha, España
30

31 ²Human and Health Sciences, Department of Movement, University of Rome "Foro
32 Italic", Roma, Italy.
33

34 ³Universidad de Castilla-La Mancha: School of Education, Ciudad Real, Castilla-La
35 Mancha, España
36

37 ⁴Facultad de Ciencias de la Salud, Universidad Autónoma de Chile, Talca, Chile.
38
39

40 **Key words:** schoolchildren, academic performance, physical activity, child health.
41
42
43

44 **Word count:** 1581.
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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.

1
2
3 Risk of bias of included studies and heterogeneity among studies will be assessed to
4 reinforce measured data.
5

6
7 Intervention duration, age and weight of the participants, and assessment of academic
8 performance could limit the generation of conclusions
9

10 11 12 13 **INTRODUCTION**

14
15 Academic performance describes the factors influencing students' success at school in
16 three areas¹: i) cognitive skills and attitudes, including basic cognitive abilities (such as
17 executive functioning, attention, verbal comprehension, information processing or
18 memory) and attitudes and beliefs (motivation, satisfaction, school connectedness, or
19 self-concept); ii) academic behaviours related to students' academic performance (such
20 as on-task behaviours, planning, scheduling, impulse control, organization or
21 attendance); iii) and academic achievement, including subject area scores and total
22 scores.
23
24
25
26
27
28

29
30 Physical activity has been associated with several psychological benefits in school
31 children, such as improving anxiety, self-esteem, cognitive performance, classroom
32 behaviour and academic achievement². Additionally, in the last decade, a growing
33 interest on the potential influence of children's physical activity on angiogenesis has
34 emerged, increasing oxygen saturation and glucose delivery, improving cerebral blood
35 flow and increasing neurotransmitters levels³. In this regard, the positive influence of
36 children's aerobic fitness on academic achievement has been related to differences in
37 structural brain volumes, as measured by magnetic resonance imaging⁴, and brain
38 function, as measured by electrical activity recordings⁵.
39
40
41
42
43
44

45
46 Interventions with long-term exercise programs have demonstrated benefits on some
47 aspects of children's health⁶. Experimental studies have also reported a positive
48 influence of physical activity on children's academic performance^{7,8}; however,
49 discrepancies persist regarding the effect size of physical activity interventions on
50 children's academic performance¹. Thus, this systematic review will only include
51 experimental studies in which academic performance was reported as an outcome
52 variable.
53
54
55
56
57
58
59
60

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 Reviews¹⁰ (PRISMA) and the Cochrane Collaboration Handbook¹¹ 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.

1
2
3 Additionally, studies with curricular physical activity programs offered during school or
4 afterschool hours will be included. Studies evaluating physical activity programs with
5 other interventions, such as nutritional interventions, will be excluded.
6
7

8 *Types of outcome assessment.*

9
10 The main outcome will be a children's academic performance assessment. The
11 performance could be assessed by total scores, individual skills or individual subject
12 areas related to cognition skills, academic achievement and academic behaviours. In this
13 regard, the studies could use curriculum-based marks or specific scales, such as
14 Cognitive Assessment System (CAS), Colour-Word Stroop test, General Intelligence
15 Test (GIT), Canadian Achievement Test, among others.
16
17

18 **Search methods for the identification of studies.**

19 *Electronic search*

20
21 The search will be conducted in the MEDLINE, EMBASE, Cochrane Central Register
22 of Controlled Trials, Cochrane Database of Systematic Reviews, and Web of Science
23 databases from their inception. No electronic limitation on language or publication
24 status will be added.
25
26

27 The following search terms will be used: physical activity, physical education, exercise,
28 cognition, academic, academic achievement, intelligence, children, preschool, pre-
29 schooler, young children, and trial.
30
31

32 Relevant references cited in the selected studies will be screened as supplemental
33 sources.
34
35

36 **Data collection and analysis.**

37 *Selection of studies*

38
39 Two reviewers will independently check the titles and abstracts to identify eligible
40 studies according to the inclusion criteria. Then, the identified studies will be examined.
41 Lastly, two independent reviewers will check the included and excluded studies with the
42 reasons for exclusion. Any discrepancies will be resolved by discussion with a third
43 reviewer.
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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 Handbook¹¹. Any disagreement will be resolved by discussion. A third reviewer will resolve the discrepancy if consensus is not reached. The Jadad Scale¹² 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 Studies¹³ 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

1
2
3 model will be used. The study heterogeneity will be assessed with an I² statistic.
4 Usually, I² values of <25, 25-50, and >50% represent small, medium, and large
5 amounts of heterogeneity, respectively¹⁴. Studies with insufficient data to perform the
6 analyses will be omitted from the data synthesis. If there is substantial heterogeneity
7 among the studies and a meta-analysis is not possible, a descriptive analysis will be
8 conducted.
9

10
11
12 The measure of the mean pre-post intervention differences will be the primary indicator
13 of the intervention outcome. The mean differences (standard error (SE)) and
14 standardized mean differences (standard deviation (SD)) will be calculated for each
15 specific skill or area included in the tests. For example, when the SE is provided, the SD
16 will be calculated according to the following formula, $SD = SE \times \text{square root of } N$. The
17 pooled effect size of the physical intervention and control groups will be compared
18 using the mean differences and standard errors weight for the number of participants.
19

20 21 22 *Subgroup analyses*

23
24
25 A subgroup analyses will be performed based on the main factors causing
26 heterogeneity, such as cognitive skills, academic achievement areas (non-verbal ability,
27 spatial ability, abstract reasoning, mathematics, language, etc.), academic behaviours, or
28 assessments (CAS, Colour-Word Stroop test, General Intelligence Test GIT, Canadian
29 Achievement Test, curriculum based scores, etc.). Furthermore, the intervention
30 duration, age, and weight of participants will be considered for subgroup analyses.
31
32

33 34 35 *Sensitivity analysis*

36
37
38 Sensitivity analyses will be conducted by excluding studies from the analysis one by
39 one.
40

41 42 43 **DISCUSSION**

44
45
46 A positive association between physical activity and academic performance has been
47 reported by the latest systematic review⁸, which analysed this relationship; conversely,
48 previous systematic reviews¹ found either an association or no association. These
49 systematic reviews considered all of the studies regarding the type of study and
50 suggested that more research is needed to clarify the role of some variables with regard
51 to this relationship.
52
53
54
55
56
57
58
59
60

1
2
3 Other systematic reviews¹⁵ that included only randomized controlled trials found a
4 positive effect between aerobic exercise and cognition, academic achievement,
5 behaviour and psychosocial functioning outcomes. These reviews did not assess the
6 impact of the aerobic exercise programs on each academic performance component.
7
8

9
10 Given the importance of the childhood period on development, sustained information is
11 needed for education and health professionals for policy efforts; therefore, it is
12 important to measure the impact of long-term physical activity programs on children's
13 academic performance.
14
15

16 17 18 **Ethics and dissemination**

19
20 Ethical approval will not be needed because the data used in this systematic review will
21 come from published studies and there will be no concerns about privacy. The results
22 will be disseminated by publication of the manuscript in a peer-reviewed journal.
23
24

25
26 **Authors' contribution:** VMV and CAB designed the study. VMV was the Principal
27 Investigator and Guarantor. MSL, CAB, and VMV were the main coordinators of the
28 study. MSL, CAB, MJPG, and ICR conducted the study. ICR, CP, and MJPG provided
29 statistical and epidemiological support. VMV wrote the article with the support of MSL,
30 CP, and CAB. All of the authors revised and approved the final version of the
31 manuscript.
32
33

34
35
36 **Funding statement:** This research received no specific grant from any funding agency
37 in the public, commercial or not-for-profit sectors.
38
39

40 41 42 **REFERENCES**

- 43
44 1. Rasberry CN, Lee SM, Robin L, et al. The association between school-based
45 physical activity, including physical education, and academic performance: A
46 systematic review of the literature. *Prev Med* 2011; 52:S10–20.
47
48 2. Biddle SJH, Asare M. Physical activity and mental health in children and
49 adolescents: a review of reviews. *Br J Sports Med* 2011; 45(11):886–95.
50
51 3. Diamond AB. The cognitive benefits of exercise in youth. *Curr Sports Med Rep*
52 2015; 14(4):320–6.
53
54
55
56
57
58
59
60

- 1
2
3 4. Chaddock-Heyman L, Hillman CH, Cohen NJ, et al. The importance of physical
4 activity and aerobic fitness for cognitive control and memory in children. *Monogr Soc*
5 *Res Child Dev* 2014; 79(4):25–50.
6
7
- 8 5. Hillman CH, Pontifex MB, Castelli DM, et al. Effects of the FITKids
9 randomized controlled trial on executive control and brain function. *Pediatrics* 2014;
10 134(4):e1063–71.
11
12
- 13 6. Langford R, Bonell C, Jones H, et al. The World Health Organization’s health
14 promoting schools framework: a Cochrane systematic review and meta-analysis. *BMC*
15 *Public Health* 2015; 15(1):130.
16
17
- 18 7. Torrijos-Niño C, Martínez-Vizcaíno V, Pardo-Guijarro MJ, et al. Physical
19 fitness, obesity, and academic achievement in schoolchildren. *J Pediatr* 2014; 165:104.
20
21
- 22 8. Moher D, Shamseer L, Clarke M, et al. Preferred reporting items for systematic
23 review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev* 2015; 4(1):
24 1.
25
26
- 27 9. Esteban-Cornejo I, Tejero-Gonzalez CM, Sallis JF, et al. Physical activity and
28 cognition in adolescents: A systematic review. *J Sci Med Sport* 2015; 18:534–9.
29
30
- 31 10. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic
32 reviews and meta-analyses: the PRISMA statement. *Int J Surg* 2010; 8(5):336–41.
33
34
- 35 11. Higgins JP, Green S, editors. Cochrane Handbook for Systematic Reviews of
36 Interventions 5.1.0 [Updated March 2011]. The Cochrane Collaboration, 2011.
37 <http://handbook.cochrane.org>
38
39
- 40 12. Jadad AR, Moore RA, Carroll D, et al. Assessing the quality of reports of
41 randomized clinical trials: Is blinding necessary? *Control Clin Trials* 1996; 17(1):1–12.
42
43
- 44 13. National Collaborating Centre for Methods and Tools. Quality Assessment Tool
45 for Quantitative Studies. Hamilton, ON: McMaster University 2008.
46
47
- 48 14. Higgins JPT, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat*
49 *Med* 2002; 21(11):1539–58.
50
51
52
53
54
55
56
57
58
59
60

1
2
3 15. Lees C, Hopkins J. Peer Reviewed: Effect of Aerobic Exercise on Cognition,
4 Academic Achievement, and Psychosocial Function in Children: A Systematic Review
5 of Randomized Control Trials. *Preventing chronic disease* 2013; 10.
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2016-011065.R1
Article Type:	Protocol
Date Submitted by the Author:	07-Apr-2016
Complete List of Authors:	<p>Álvarez-Bueno, Celia; Universidad de Castilla-La Mancha, Health and Social Research Center Pesce, Caterina; Human and Health Sciences, University of Rome "Foro Italico" , Department of Movement Cavero-Redondo, Iván; Universidad de Castilla-La Mancha, Health and Social Research Center Sánchez-López, Mairena; Universidad de Castilla-La Mancha, Health and Social Research Center; Universidad de Castilla-La Mancha, School of Education Pardo-Guijarro, Maria Jesús; Universidad de Castilla-La Mancha: , Health and Social Research Center; Universidad de Castilla-La Mancha, School of Education Martínez-Vizcaino, Vicente; Universidad de Castilla-La Mancha, Centro de Estudios Sociosanitarios</p>
Primary Subject Heading:	Public health
Secondary Subject Heading:	Paediatrics
Keywords:	chronic exercise, executive function, academic achievement, life skills, brain health, development

SCHOLARONE™
Manuscripts

1
2
3 1 **The association of physical activity to cognition, metacognition and academic**
4 **performance in children and adolescents: A protocol for systematic review and**
5 **meta-analysis.**
6
7

8 *Trial registration number: PROSPERO CRD42015029913*
9

10 **Corresponding author:**

11 **Vicente Martínez Vizcaíno, Professor**

12 Social and Health Care Research Center

13 Universidad de Castilla-La Mancha, Spain

14 E-mail: Vicente.Martinez@uclm.es

15 Telephone number: 969 179100 (Ext: 4683)

16
17
18
19
20
21
22
23
24
25
26 **Full name, department, institution, city and country of all co-authors**

27 Álvarez-Bueno, Celia¹; Caterina Pesce²; Cavero-Redondo, Iván¹; Sánchez-López,
28 Mairena^{1,3}; Pardo-Guijarro, María Jesús^{1,4}; Martínez-Vizcaíno, Vicente^{1,5}.

29 ¹Universidad de Castilla-La Mancha: Health and Social Research Center, Cuenca,
30 Castilla-La Mancha, España

31 ²Human and Health Sciences, Department of Movement, University of Rome "Foro
32 Italic", Roma, Italy.

33 ³Universidad de Castilla-La Mancha: School of Education, Ciudad Real, Castilla-La
34 Mancha, España.

35 ⁴Universidad de Castilla-La Mancha: School of Education, Cuenca, Castilla-La
36 Mancha, España.

37 ⁵Facultad de Ciencias de la Salud, Universidad Autónoma de Chile, Talca, Chile.

38
39
40
41
42
43
44
45
46
47
48
49 **Key words:** chronic exercise, executive function, academic achievement, life skills,
50 brain health, development.
51

52
53
54
55 **Word count:** Abstract: 284.

56
57
58
59
60 Main text: 3831.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

29 ABSTRACT

30 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.

39 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.

54 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.

57 Trial registration number: PROSPERO CRD42015029913

58 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

1
2
3 61 this type of systematic review can provide a comprehensive overview of the effect of
4 62 physical activity programs on main components of children's brain health, cognitive
5 63 functioning and academic performance that are relevant for policy development.

6 64 Ways to assess risk of bias of included studies and heterogeneity among studies are
7 65 discussed with particular reference to individual constraints (e.g., age, weight status)
8 66 task constraints (e.g., qualitative and quantitative intervention characteristics, type of
9 67 cognition and assessment tools) and contextual constraints (laboratory, school, out-of-
10 68 school setting) that might act as moderators of the relationship between physical
11 69 activity and cognition or academic performance in children and adolescents. Possible
12 70 solutions to overcome these problems and reach relevant conclusions are proposed.

13
14
15
16
17
18
19
20
21

22 **INTRODUCTION**

23
24
25 73 In the last decades, scientific evidence on the relationship between chronic physical
26 74 activity and cognitive/academic performance during development has attracted
27 75 increasing attention¹. Chronic physical activity interventions have been defined as long
28 76 lasting repeated bouts of exercise aimed to improve physical fitness.² Chronic physical
29 77 activity participation has been associated with several mental health benefits in school
30 78 children, such as improved self-perceptions (e.g., self-esteem, self-efficacy), emotional
31 79 regulation (e.g., anxiety, depression), and cognitive functioning (e.g., information
32 80 processing, memory, attention).³

33
34
35
36
37
38
39 81 Due to the relevant implications for educational policies, many researches have
40 82 investigated the effects of chronic physical activity participation on students' success at
41 83 school that is on academic performance.⁴⁻⁵ The latter is pooled in classroom behaviour
42 84 (e.g., on-task behaviours during learning activities) and academic achievement (e.g.,
43 85 school notes and performance in test on school subjects). Attention has also been
44 86 focused on cognitive executive functions, since their development early in life has been
45 87 proven predictive of school and lifelong achievement, health and quality of life.⁶
46 88 Diamond⁶ distinguishes between core executive functions – that are inhibitory control,
47 89 working memory and cognitive flexibility – and higher-level executive functions – as
48 90 reasoning, planning, and problem solving. This higher-level cognition largely overlaps
49 91 with what termed metacognition, that is the ability to supervise and manage cognitive
50 92 process and to use knowledge to regulate behaviours².

1
2
3 93 Chronic exercise-cognition research have experienced a progressive shift toward a
4 94 biochemical and neuroscientific perspective from both exercise and cognition
5 95 researchers⁷⁻⁸ and developmental neuroscientists.⁹ In this regard, the positive influence
6 96 of chronic physical activity has been related to angiogenesis, increasing oxygen
7 97 saturation and glucose delivery, improving cerebral blood flow and increasing
8 98 neurotransmitters levels,¹⁰ differences in structural brain volumes, as measured by
9 99 magnetic resonance imaging,¹¹ and brain function, as measured by electrical activity
10 100 recordings.¹²

11 101 Previous systematic reviews and meta-analysis have synthesized the evidence related to
12 102 the influence of exercise interventions on children's and, less frequently, adolescents'
13 103 cognition and success in school, focused on quantitative exercise characteristics.^{5,13-16}
14 104 From them, one was focused on experimental studies only and considered both
15 105 cognitive and psychosocial outcomes jointly.¹⁵ No one presented data distinguishing
16 106 between cognitive and metacognitive functions, academic behaviour and achievement.
17 107 Indeed, this distinction has been recently deemed relevant to understand the potential
18 108 mediational paths that underlie the relationship between physical activity and academic
19 109 achievement.²

20 110 In the search for further mechanisms beyond the neurobiological that may explain the
21 111 link between chronic physical activity and children's cognition, recent narrative or
22 112 meta-analytic reviews have focused on the qualitative characteristics of the physical
23 113 activity interventions.^{8,17-18} Also developmental neuroscientists interested in
24 114 interventions aiding children's cognition are increasingly shifting attention toward
25 115 qualitative forms of physical activity that are not only physically effortful, but also
26 116 emotionally and socially engaging.⁹ This kind of interventions often involve physical
27 117 activities that impinge not only on core cognitive functions, but also on a broader range
28 118 of cognitive skills, as goal setting, problem solving and self-regulation¹. These are
29 119 cognitive in nature and therefore fall in the field of cognitive sciences, but also belong
30 120 to the broader field of life skills investigated in psychosocial and social-cognitive
31 121 research and identified as essential skills to self-regulate behaviour and successfully
32 122 adapt it to everyday requirements.¹⁹ Since they are proven sensitive to designed physical
33 123 activity interventions,²⁰ it has been recently proposed that cognitive life skills may
34 124 represent a further element to be considered in the relationship between physical
35 125 activity, cognition, and academic behaviour and achievement.⁸

1
2
3 126 In sum, scientific evidence on the relationship between physical activity and
4 127 cognitive/academic performance, particularly as regards its possible moderators and
5 128 mediators, is still currently insufficient to obtain a comprehensive view that may be
6 129 useful to inform policies and decision making. Discrepancies persist regarding the
7 130 effects of chronic exercise interventions on children's cognition and success in school
8 131 and life and reviews still lack consideration of evidence at relevant intersection points
9 132 between different research areas. Moreover, whereas several narrative and meta-analytic
10 133 reviews have provided evidence syntheses that are mainly useful for setting future
11 134 research priorities, they still leave open questions concerning how this evidence can be
12 135 translated into good practices in ecological settings as the educational.²¹

13 136 Thus, the general aim of the present methodological article is to provide a novel
14 137 protocol designed to review interventional studies addressing the chronic exercise-
15 138 cognition interaction at developmental age for obtaining relevant information for policy
16 139 makers and decision makers particularly in, but not limited to, the education sector. To
17 140 this aim, the proposed protocol encompasses different facets of cognitive function and
18 141 academic performance that, to the best of our knowledge, should be jointly considered
19 142 to facilitate transitioning evidence of the cognitive benefits of physical activity for
20 143 children and adolescents into good practices.

21 144 **OBJECTIVES**

22 145 This systematic review and meta-analysis has three objectives: i) to estimate the effects
23 146 of chronic physical exercise interventions on different facets of cognitive function and
24 147 academic performance of children and adolescents; ii) to determine which of those
25 148 variables are most benefitted from physical activity; iii) to identify the individual, task-
26 149 related and contextual moderators that may amplify physical activity effects on
27 150 cognition/academic performance, with particular focus on the qualitative and
28 151 quantitative characteristics of the physical activity interventions.

29 152 Specifically, this systematic review and meta-analysis protocol presents an objective
30 153 and clear procedure to maximize the extraction of information from experimental
31 154 studies (randomized controlled trials - RCT, non-RCT trials and controlled pre-post
32 155 studies), in which data for cognition, metacognition, cognitive life skills, academic
33 156 behaviour and achievement have been separately reported as outcomes.

34 157 **METHODS AND ANALYSIS**

1
2
3 158 This systematic review and meta-analysis protocol is based on Preferred Reporting
4 159 Items for Systematic Review and Meta-analysis Protocols (PRISMA-P)²² and the
5
6 160 Cochrane Collaboration Handbook²³ is proposed to guide the review. This trial has been
7
8 161 registered in PROSPERO (registration number: CRD42015029913).
9

10 162 **Inclusion/exclusion criteria for study selection**

11 163 *Types of studies.*

12
13
14 164 Randomized control trials (RCT), non-RCT trials and controlled pre-post studies written
15
16 165 in international language (English) or in the national language of interest (Spanish).
17

18 166 *Types of participants.*

19
20 167 Studies assessing the relationship, at developmental age, between chronic physical
21
22 168 exercise interventions and cognition, metacognition, cognitive life skills and academic
23
24 169 performance variables will be included regardless of sex, weight, ethnicity, and
25
26 170 socioeconomic status. Will be considered for inclusion studies including participants
27
28 171 aged from 4 to 18 years. An exclusion criterion will be the presence of children with
29
30 172 any physical condition or any diagnosed disorder of cognition that would impede or
31
32 173 limit their ability to participate in school physical activity programs. If participants are
33
34 174 assessed more than once in the same study, data will be extracted and analysed from the
35
36 175 different measurements as independent samples.
37

38 176 *Types of interventions.*

39
40 177 Studies reporting any type of chronic physical exercise intervention involving multiple
41
42 178 sessions over a number of training weeks or months will be eligible for inclusion.
43
44 179 Instead, studies reporting the transient effects of single bouts of acute physical exercise
45
46 180 will be excluded. Studies comparing different types of chronic physical exercise
47
48 181 interventions or examining a chronic physical exercise intervention with or without a
49
50 182 control group are considered eligible for inclusion.

51
52 183 Additionally, we will include those studies regarding chronic physical exercise
53
54 184 interventions defined as: school based physical exercise interventions, recess time
55
56 185 interventions, classroom-based physical activity interventions and extracurricular
57
58 186 physical activity interventions. Studies evaluating chronic physical exercise
59
60 187 interventions combined with other health interventions, such as nutritional
188 188 interventions, will be excluded when data concerning the effectiveness of physical

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

191 *Types of outcome assessment.*

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

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

213 **Search methods for the identification of studies.**

214 *Electronic search*

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

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

1
2
3 221 (2) cognition, executive, executive function, cognitive control, intelligence, memory,
4 222 attention, metacognition; (3) life skills, goal setting, problem solving, self-regulation; (4)
5 223 academic, academic achievement, academic grades, academic behaviour, academic
6 224 performance, classroom behaviour; (5) brain development, brain health, neural,
7 225 neuroelectric, neurotrophic, neurotrophin, hormone; (6) children, childhood, pre-
8 226 schooler, schooler, preadolescent, adolescent, adolescence and (7) trial. (Appendix I for
9 227 MEDLINE database search strategy).

10
11 228 Previous reviewers and meta-analysis will be checked for additional references and
12 229 relevant references cited in the selected studies will be screened as supplemental
13 230 sources.

21 231 **Data collection and analysis.**

22 232 *Selection of studies*

23 233 After excluding duplicated records, two reviewers will independently screen titles and
24 234 abstracts to identify eligible studies according to the inclusion and exclusion criteria.
25 235 Then, the potential eligible studies will be deeply reviewed and their reference list will
26 236 be checked for additional relevant studies. Any discrepancies will be resolved by
27 237 discussion with a third reviewer.

28 238 Two authors will independently extract data on the publication year, number and age of
29 239 participants (control and intervention groups), physical exercise intervention
30 240 characteristics, and (meta)cognition//life skills /academic performance variables.

31 241 Any disagreement will be resolved by discussion and consensus. If necessary, the
32 242 authors of the included studies will be contacted to obtain additional relevant
33 243 information.

34 244 *Assessment of risk of bias in included studies*

35 245 Two researchers will conduct a quality assessment according to the Cochrane
36 246 Collaboration Handbook.²³ Any disagreement will be resolved by discussion. A third
37 247 reviewer will resolve the disagreement if consensus is not reached.

38 248 Methodological quality of the randomized controlled trials will be assessed with the
39 249 Jadad Scale.²⁴ The risk of bias will be evaluated according to three domains:
40 250 randomization, double blinding, and description of withdrawals and dropouts. Each
41 251 domain will receive a score of one when the studies satisfy its description.

1
2
3 252 Randomization will score one extra point if the method to generate the sequence is
4 253 appropriate. Additionally, a double blind study will score one extra point if the double
5 254 blind method is appropriately described. Based on these domains, scores can range from
6 255 0 to 5.

7
8
9
10 256 The Quality Assessment Tool for Quantitative Studies²⁵ is proposed to assess the
11 257 quality of pre-post studies and non-randomized controlled trials. This tool evaluates
12 258 seven domains: selection bias, study design, confounders, blinding, data collection
13 259 method, withdrawals and dropouts. Each domain could be considered to be strong,
14 260 moderate or weak, and the studies could be classified as strong (with no weak ratings),
15 261 moderate (with one weak rating), and weak (with two or more weak ratings)

16
17
18
19
20 262 If there are insufficient or unclear data describing the required domains, the study
21 263 authors have to be contacted for more details.

22 23 24 264 *Data synthesis*

25
26 265 The key characteristics and important questions, such as: sample size, age of
27 266 participants, quantitative and qualitative intervention characteristics, and cognitive
28 267 outcome observed from the included studies in relation to the aim of the review will be
29 268 summarized in tables (Appendix II). Reviewers will determine whether a meta-analysis
30 269 is possible when data have been extracted. At least, five observations addressing the
31 270 same specific outcome will be required to conduct a meta-analysis.

32
33
34
35
36
37 271 If it is possible to carry out a meta-analysis, STATA 13 software will be used to
38 272 combine the pooled mean differences with 95% confidence intervals. A fixed-effect
39 273 model will be used if there is no evidence of heterogeneity; otherwise, a random-effects
40 274 model will be used. The study heterogeneity will be assessed with an I² statistic.
41 275 Usually, I² values of <25, 25-50, and >50% represent small, medium, and large
42 276 amounts of heterogeneity, respectively.²⁶ Studies with insufficient data to perform the
43 277 analyses regarding pre-post chronic physical exercise intervention measurements will be
44 278 omitted from the data synthesis. If there is substantial heterogeneity among the studies
45 279 and a meta-analysis is not possible, a descriptive analysis will be conducted.

46
47
48
49
50 280 The measure of the mean pre-post intervention differences will be the primary indicator
51 281 of the intervention outcome. The mean differences (standard error (SE)) and
52 282 standardized mean differences (standard deviation (SD)) will be calculated for each
53 283 specific skill or area included in the tests. For example, when the SE is provided, the SD

1
2
3 284 will be calculated according to the following formula, $SD=SE*\text{square root of } N$. The
4 285 pooled effect size on the physical intervention and control groups will be compared
5 286 using the mean differences and standard errors weight for the number of participants.
6 287 Lastly, publication bias will be assessed by the method proposed by Egger, as well as
7 288 visually on a funnel plot.²⁷
8
9
10
11
12

13 289

14 290

15 291 *Subgroup analyses*

16 292 Subgroup analyses will be performed based on the main factors that may cause
17 293 heterogeneity, grouped as individual, task and contextual constraints. Main individual
18 294 factors that could act as moderators of the exercise-cognition relation are age, weight
19 295 status, and skill level.

20 296 Main types of task-related factors are qualitative and quantitative intervention
21 297 characteristics, the type of cognition assessed and the stability of the intervention
22 298 outcomes over time. Well-established quantitative parameters of the interventions are
23 299 intensity, frequency, and overall and session duration.²⁸ The qualitative characteristics
24 300 of chronic exercise interventions to aid children's and adolescents' cognition have been
25 301 tentatively classified as traditional physical education, aerobic training, skill-based
26 302 training, cognitively demanding/enriched physical activity, or combinations of them.²⁹

27 303 The broad array of facets of cognitive functioning that may be differentially influenced
28 304 by chronic exercise interventions include: (i) non-executive functions, as non-verbal
29 305 ability, spatial ability; (ii) core executive functions, that are inhibition, working
30 306 memory, cognitive flexibility; (iii) metacognitive functions (i.e., higher-level executive
31 307 functions), as abstract reasoning, planning, problem solving); (iv) cognitive life skills,
32 308 as goal setting, self-regulation; (v) academic achievement areas, as mathematics,
33 309 language, reading, total scores; (vi) academic behaviours, as on-task behaviours,
34 310 organization, attendance. Finally, the time of cognitive assessment after intervention
35 311 cessation influences the effect size and may inform on the outcome stability.

36 312 The main contextual factor that may cause heterogeneity of results on the relationship
37 313 between physical activity and cognition in children and adolescents is the intervention
38 314 setting: school, out-of-school, or laboratory setting. Also in school-based studies, it
39 315 must be taken into account if the physical activity intervention was enhanced/enriched
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 316 physical education, classroom-based activity breaks during curricular time, or active
4 317 play during recess time.

5
6
7 318 ***Sensitivity analysis***

8
9 319 Sensitivity analyses will be conducted by excluding studies from the analysis one by
10 320 one. It is needed to prove that the findings from the meta-analysis are not dependent on
11 321 arbitrary or unclear decisions. Main arguments for carrying out a sensitivity analysis in
12 322 the present review protocol are the existence of large differences in (i) study design and
13 323 (ii) type of specific assessment tools used. (i) As regards the study design, as indicated
14 324 under the subheading “Type of studies”, we propose to include RCT, non-RCT, control
15 325 pre-post studies, that may largely differ in their ability to truly tap intervention
16 326 outcomes. (ii) As concerns the specific assessment tools used, they may differ in the
17 327 extent to which they specifically tap the cognitive function of interest, or may lead to
18 328 spurious results. For example, academic grades represent a final outcome of
19 329 achievement behaviours that are affected not only by cognitive, but also by
20 330 motivational, emotional and social factors of the learning context. Furthermore, also
21 331 among more narrowly focused cognitive test outcomes there may be differences due to
22 332 the sensitivity issue. For example, inhibitory control - one of the most commonly
23 333 studied cognitive functions in developmental exercise-cognition studies - is
24 334 multifaceted¹ and has been therefore studied with different tests that tap inhibition of
25 335 thoughts and memories (e.g., Random Number Generation), inhibition as perceptual
26 336 interference control challenging attention (e.g., Eriksen flanker task, Stroop Colour-
27 337 Word task, expressive attention scale of the Cognitive Assessment System), or
28 338 inhibition at the behavioural response level (e.g., stop-signal task).

29 339 **DISCUSSION**

30 340 A positive association between physical exercise programs and academic performance
31 341 has been reported more or less consistently by recent systematic reviews and meta-
32 342 analyses^{4,13,15,17,29} that analysed this relationship. The commonality of the above
33 343 systematic reviews and meta-analyses is that they all included academic performance
34 344 outcomes that represent a key variable for policy makers of the education sector. On the
35 345 other side, they largely differed as regards other characteristics that must be considered
36 346 to reach relevant conclusion.

1
2
3 347 First of all, some reviews^{13-14,28} included studies with interventional, cross-sectional or
4 348 observational designs; this limits the strength of conclusions in terms of causal
5 349 relationship and weakens the call for more physical activity in school and out-of-school
6 350 settings as a means to aid cognitive development and successful academic achievement.
7
8
9 351 A narrative review¹⁷ that was exclusively focused on interventional research included
10 352 both acute and chronic exercise studies, which have a different take-home message for
11 353 policy makers. The transient cognitive benefits of an acute bout of exercise support the
12 354 call for more physically active breaks interspersed during the sitting learning time and
13 355 for more physically active academic lessons (e.g., ‘moved maths’). On the other side,
14 356 the cognitive benefits of a longer-lasting chronic exercise program support the call for
15 357 legislative changes in favour of enhanced physical education and physical activity
16 358 promotion in out-of-school settings.

17
18
19
20
21
22
23 359 To the best of our knowledge, only one systematic review¹⁵ included only RCT,
24 360 considering a broad range of outcomes of aerobic exercise programs including
25 361 cognition, academic behaviour and achievement, as well as psychosocial functioning
26 362 outcomes. However, this review did not provide data for the impact of the aerobic
27 363 exercise programs on each academic performance component, nor did it include, among
28 364 the studies with psychosocial outcomes, those regarding physical activity outcomes on
29 365 cognitive life skills that are linked to successful academic behaviour and achievement.

30
31
32
33
34
35 366 The lack of separate subgroup analyses of data according to the different academic
36 367 performance areas or types of cognitive function assessed is common to most of the
37 368 existing reviews.^{4,13,15,29} This limits the possibility to obtain a differentiated view on
38
39
40
41 369 what type of physical activity interventions work best to reap specific
42 370 cognitive/academic benefits. Also, the applied conclusions that can be drawn from
43 371 many of the existing reviews are limited, as explicitly acknowledged¹⁵, by the use of
44 372 different measurements tools and the paucity and diversity of follow-up periods.

45
46
47 373 The present protocol is aimed at overcoming these limitations by performing subgroup
48 374 analyses that take into account these issues in combination. Particularly, we follow the
49 375 call by Tomporowski et al.² to distinguish between cognitive and metacognitive
50 376 outcomes of physical activity to investigate their role in a hypothesized mediational
51 377 chain linking chronic physical activity and academic performance. The authors state that
52 378 cognitive assessments in developmental exercise and cognition research prioritize tools
53 379 that test the cognitive functions of interest during “on-line” processing.² To explain how
54
55
56
57
58
59
60

1
2
3 380 exercise impacts children's metacognitive processes and academic performance that
4 381 develop along a wider time scale, they recommend to expand the view on exercise-
5 382 cognition relations to encompass a cognitive-social focus on factors that underlie the
6 383 personal awareness of own skills in achieving short- and long-term goals. The present
7 384 protocol provides an attempt in this direction, expanding the usual framework for
8 385 exercise-cognition reviews to encompass cognitive life skills and separately analyse
9 386 cognitive, metacognitive and academic performance outcomes.

10 387 As an outlook for future research, CDC¹³ encouraged analysing the same variables in
11 388 any given category, to make summary statement about the magnitude of the effect of
12 389 physical exercise on academic performance variables. Singh et al¹⁶ recognized as
13 390 limitation to generate conclusion the inclusion of different study designs and outcomes
14 391 measured. Tomporowski et al² recommended to improve the information regarding the
15 392 qualitative and quantitative characteristics of physical activity programs that enhance
16 393 children's neurocognitive performance, and to consider the possible moderators and
17 394 mediators acting on the relationship between chronic exercise and cognition/academic
18 395 performance during development. Since it is common that moderator variables are
19 396 included in interventional studies, it will be possible to apply the subgroup and
20 397 moderation analyses proposed in the Methods section. Instead, there still is a paucity of
21 398 studies addressing mediation,^{8,30} which still remains an issue in need for further research
22 399 before meta-analytic conclusions can be drawn.

23 400 Given the importance of the entire developmental period— from infancy to late
24 401 adolescence³¹ for brain development and therefore also for academic performance, a
25 402 more detailed and comprehensive view on the exercise-cognition relation during
26 403 development is needed for education and health professionals to orient policy efforts.
27 404 This protocol provide a clear and structured procedure for maximizing the extraction of
28 405 relevant information and provide summarized information regarding the impact of long-
29 406 term physical activity programs on children's cognition and academic performance.

30 407 **Ethics and dissemination**

31 408 Ethical approval will not be needed to apply this review protocol because the data to be
32 409 used in this systematic review come from published studies and there will be no
33 410 concerns about privacy. The results of such kind of review can be best disseminated by
34 411 publication of the manuscript in a peer-reviewed journal that broadly reaches

1
2
3 412 researchers interested in hypotheses testing and policy makers interested in the
4 413 translatability of scientific evidence into good practices.

5
6 414 Developing chronic physical exercise intervention is justified by the international
7 415 physical activity guidelines that recommend children to participate in at least 60
8 416 minutes of daily physical activity.³² Nonetheless, the prevalence of overweight children
9 417 and the total sedentary time that children daily accumulate have risen substantially in
10 418 the past three decades in most countries. Therefore, schools and communities are
11 419 encouraged to implement children's physical activity time, but it is necessary to
12 420 measure how physical activity could affect cognitive function and life skills relevant to
13 421 successful academic performance. The conclusions of the proposed type of systematic
14 422 review and meta-analysis may support the decisions of school boards, school
15 423 administrators and policy developers with scientifically grounded arguments on why to
16 424 maintain or increase the time devoted to curricular or extracurricular physical activity
17 425 and on what type of activities help reap largest cognitive and academic benefits.

18
19 426 **Authors' contribution:** VMV and CAB designed the study. VMV was the Principal
20 427 Investigator and Guarantor. CP, CAB, and VMV were the main coordinators of the
21 428 study. MSL, CAB, MJPG, and ICR conducted the study. ICR, CP, and MJPG provided
22 429 statistical and epidemiological support. VMV wrote the article with the support of MSL,
23 430 CP, and CAB. All of the authors revised and approved the final version of the
24 431 manuscript.

25
26 432 **Funding statement:** This research received no specific grant from any funding agency
27 433 in the public, commercial or not-for-profit sectors.

28
29 434

30 435 REFERENCES

31 436 1- Howie EK, Pate RR. Physical activity and academic achievement in children: a
32 437 historical perspective. *J Sport Health Sci* 2012;1:160e9.

33 438 2- Tomporowski PD, McCullick B, Pendleton DM, et al. Exercise and children's
34 439 cognition: The role of exercise characteristics and a place for metacognition. *Journal of*
35 440 *Sport and Health Science* 2015; 4(1): 47-55.

36 441 3- Biddle SJH, Asare M. Physical activity and mental health in children and
37 442 adolescents: a review of reviews. *Br J Sports Med* 2011;45:886–95.

38 443 4- Rasberry CN, Lee SM, Robin L, et al. The association between school-based physical
39 444 activity, including physical education, and academic performance: A systematic review
40 445 of the literature. *Prev Med (Baltim)* 2011; 52:S10–20.

- 1
2
3 446 5- Donnelly JE, Lambourne K. Classroom-based physical activity, cognition, and
4 447 academic achievement. *Preventive Medicine* 2011; 52: S36–S42.
- 5
6 448 6- Diamond A. Executive functions. *Annual review of psychology* 2013; 64: 135.
- 7
8 449 7- Khan NA; and Hillman CH. The relation of childhood physical activity and aerobic
9 450 fitness to brain function and cognition: a review. *Pediatric Exercise Science* 2014; 26:
10 451 138-146.
- 11
12 452 8- Pesce C, and Ben-Soussan D. 'Cogito ergo sum' or 'ambulo ergo sum'? New
13 453 perspectives in developmental exercise and cognition research. *Exercise-Cognition*
14 454 *Interaction: Neuroscience Perspectives*. In T. McMorris: Elsevier, 2016.
- 15
16 455 9- Diamond A, Ling DS. Conclusions about interventions, programs, and approaches
17 456 for improving executive functions that appear justified and those that, despite much
18 457 hype, do not. *Developmental Cognitive Neuroscience* 2015.
- 19
20 458 10- Diamond AB. The cognitive benefits of exercise in youth. *Curr Sports Med Rep*
21 459 2015; 14:320–6.
- 22
23 460 11- Chaddock-Heyman L, Hillman CH, Cohen NJ, et al. the Importance of physical
24 461 activity and aerobic fitness for cognitive control and memory in children. *Monogr Soc*
25 462 *Res Child Dev* 2014; 79:25–50.
- 26
27 463 12- Hillman CH, Pontifex MB, Castelli DM, et al. Effects of the FITKids randomized
28 464 controlled trial on executive control and brain function. *Pediatrics* 2014; 134:e1063–71.
- 29
30 465 13- Centers for Disease Control and Prevention (CDC). The association between
31 466 school-based physical activity, including physical education, and academic
32 467 performance. Atlanta, GA: US. Department of Health and Humans Services, 2010.
- 33
34 468 14- Fedewa AL, Ahn S. The Effects of Physical Activity and Physical Fitness on
35 469 Children's Achievement and Cognitive Outcomes. *Res Q Exerc Sport* 2011; 82:521–35.
- 36
37 470 15- Lees C, Hopkins J. Effect of aerobic exercise on cognition, academic achievement,
38 471 and psychosocial function in children: a systematic review of randomized control trials.
39 472 *Prev Chronic Dis* 2013; 10:E174.
- 40
41 473 16- Singh A, Uijtdewilligen L, Twisk JWR, et al. Physical Activity and Performance at
42 474 School. *Arch Pediatr Adolesc Med* 2012; 166:49–55.
- 43
44 475 17- Tomporowski PD, Lambourne K, and Okumura MS. Physical activity interventions
45 476 and children's mental function: An introduction and overview. *Preventive Medicine*
46 477 2011; 52: 3-9.
- 47
48 478 18- Vazou S, Pesce C, Lakes K, and Smiley-Owen A. More than one road leads to
49 479 Rome: A narrative review and meta-analysis of physical activity intervention effects on
50 480 children's cognition. *Int. J. Sport Exerc. Psychol* (submitted).
- 51
52 481 19- Hodge K, Danish S, and Martin J. Developing a conceptual framework for life skills
53 482 interventions. *The Counseling Psychologist* 2012; 20: 1-28.
- 54
55 483 20- Goudas M. Prologue: a review of life skills teaching in sport and physical
56 484 education. *Hellenic Journal of Psychology* 2010; 7: 241-258.

- 1
2
3 485 21- Kriemler S, Meyer U, Martin E, et al. Effect of school-based interventions on
4 486 physical activity in children and adolescents: a review of reviews and systematic update.
5 487 Br J Sports Med 2011; 45:923e30.
- 6
7 488 22- Moher D, Shamseer L, Clarke M, et al. Preferred Reporting Items for Systematic
8 489 Review and Meta-Analysis Protocols (PRISMA-P) 2015 statement. Syst Rev 2015; 4:1.
- 9
10 490 23- Higgins JP, Green S, editors. Cochrane Handbook for Systematic Reviews of
11 491 Interventions. 5.1.0 [Updated March 2011]. The Cochrane Collaboration, 2011.
12 492 <http://handbook.cochrane.org>
- 13
14 493 24- Jadad AR, Moore RA, Carroll D, et al. Assessing the quality of reports of
15 494 randomized clinical trials: Is blinding necessary? Control Clin Trials 1996; 17:1–12.
- 16
17 495 25- National Collaborating Centre for Methods and Tools. Quality Assessment Tool for
18 496 Quantitative Studies. Hamilton, ON: McMaster University, 2008 [Updated 13 April,
19 497 2010]
- 20
21 498 26- Higgins JPT, Thompson SG. Quantifying heterogeneity in a meta-analysis. Stat
22 499 Med 2002; 21(11):1539–58.
- 23
24 500 27- Sterne JA, Egger M, and Smith GD. Systematic reviews in health care:
25 501 Investigating and dealing with publication and other biases in meta-analysis. BMJ 2001;
26 502 323:101–5.
- 27
28 503 28- Tremblay MS, LeBlanc AG, Carson V, et al. Canadian physical activity guidelines
29 504 for the early years (aged 0–4 years). Applied Physiology, Nutrition, and
30 505 Metabolism, 2012; 37(2): 345-356.
- 31
32 506 29- Esteban-Cornejo I, Tejero-Gonzalez CM, Sallis JF, et al. Physical activity and
33 507 cognition in adolescents: A systematic review. J Sci Med Sport 2015; 18:534–9.
- 34
35 508 30- Lambourne K, Hansen DM, Szabo AN, et al. Indirect and direct relations between
36 509 aerobic fitness, physical activity, and academic achievement in elementary school
37 510 students. Mental Health and Physical Activity 2013;6: 165e171
- 38
39 511 31- Andersen SL. Trajectories of brain development: point of vulnerability or window
40 512 of opportunity?. Neuroscience & Biobehavioral Reviews 2003; 27(1): 3-18.
- 41
42 513 32-Ekelund U, Luan JA, Sherar LB, et al. Moderate to vigorous physical activity and
43 514 sedentary time and cardiometabolic risk factors in children and adolescents. Jama 2012;
44 515 307(7): 704-712.
- 45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Appendix I. Search strategy for MEDLINE database.

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

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47

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	Page 1; 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	Page 14; 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	Page 17; 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.

From: Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, Shekelle P, Stewart L, PRISMA-P Group. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. *BMJ*. 2015 Jan 2;349(jan02 1):g7647.

BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2016-011065.R2
Article Type:	Protocol
Date Submitted by the Author:	09-May-2016
Complete List of Authors:	<p>Álvarez-Bueno, Celia; Universidad de Castilla-La Mancha, Health and Social Research Center Pesce, Caterina; Italian University Sport and Movement "Foro Italico" Cavero-Redondo, Iván; Universidad de Castilla-La Mancha, Health and Social Research Center Sánchez-López, Mairena; Universidad de Castilla-La Mancha, Health and Social Research Center; Universidad de Castilla-La Mancha, School of Education Pardo-Guijarro, Maria Jesús; Universidad de Castilla-La Mancha: , Health and Social Research Center; Universidad de Castilla-La Mancha, School of Education Martínez-Vizcaino, Vicente; Universidad de Castilla-La Mancha, Centro de Estudios Sociosanitarios</p>
Primary Subject Heading:	Public health
Secondary Subject Heading:	Paediatrics
Keywords:	chronic exercise, executive function, academic achievement, life skills, brain health, development

SCHOLARONE™
Manuscripts

1
2
3 1 **The association of physical activity with cognition, metacognition and academic**
4 **performance in children and adolescents: A protocol for systematic review and**
5 **meta-analysis.**
6
7

8 *Trial registration number: PROSPERO CRD42015029913*
9

10 **Corresponding author:**

11 **Vicente Martínez Vizcaíno, Professor**

12 Social and Health Care Research Center

13 Universidad de Castilla-La Mancha, Spain

14 E-mail: Vicente.Martinez@uclm.es

15 Telephone number: 969 179100 (Ext: 4683)

16
17
18
19
20
21
22
23
24
25
26 **Full name, department, institution, city and country of all co-authors**

27 Álvarez-Bueno, Celia¹; Caterina Pesce²; Cavero-Redondo, Iván¹; Sánchez-López,
28 Mairena^{1,3}; Pardo-Guijarro, María Jesús^{1,4}; Martínez-Vizcaíno, Vicente^{1,5}.

29 ¹Universidad de Castilla-La Mancha: Health and Social Research Center, Cuenca,
30 Castilla-La Mancha, España

31 ²Department of Movement, Human and Health Sciences, Italian University Sport and
32 Movement “Foro Italico”, Rome, Italy.

33 ³Universidad de Castilla-La Mancha: School of Education, Ciudad Real, Castilla-La
34 Mancha, España.

35 ⁴Universidad de Castilla-La Mancha: School of Education, Cuenca, Castilla-La
36 Mancha, España.

37 ⁵Facultad de Ciencias de la Salud, Universidad Autónoma de Chile, Talca, Chile.

38
39
40
41
42
43
44
45
46
47
48
49 **Key words:** chronic exercise, executive function, academic achievement, life skills,
50 brain health, development.

51
52
53
54
55 **Word count:** Abstract: 278.

56
57
58
59
60 Main text: 4033.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

29 ABSTRACT

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

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

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

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

57 **Trial registration number:** PROSPERO CRD42015029913

58 **Strengths and limitations.**

59 Strengths of the proposed protocol are:

- 1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
- 60 • A comprehensive methodology for analysing the effect of physical activity
 - 61 programs on main components of children's brain health, cognitive functioning
 - 62 and academic performance that are relevant for policy development.
 - 63 • Assessment of risk of bias of included studies and heterogeneity among studies
 - 64 with particular reference to individual, task and contextual factors.
 - 65 • Inclusion into analysis of those factors identified as relevant potential
 - 66 moderators of the relation of physical activity with cognition or academic
 - 67 performance in children and adolescents.

68 Limitations of this systematic review could result from:

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

74 INTRODUCTION

75 In the last decades, scientific evidence on the relationship between chronic physical
76 activity and cognitive/academic performance in childhood and adolescence has attracted
77 increasing attention¹. Chronic physical activity interventions have been defined as long
78 lasting repeated bouts of exercise aimed to improve physical fitness.² Chronic physical
79 activity participation has been associated with several mental health benefits in school
80 children, such as improved self-perceptions (e.g., self-esteem, self-efficacy), emotional
81 regulation (e.g., anxiety, depression), and cognitive functioning (e.g., information
82 processing, memory, attention).³

83 Due to the relevant implications for educational policies, many researches have
84 investigated the effects of chronic physical activity participation on students' success at
85 school that is on academic performance.⁴⁻⁵ The latter is pooled in classroom behaviour
86 (e.g., on-task behaviours during learning activities) and academic achievement (e.g.,
87 school notes and performance in test on school subjects). Attention has also been
88 focused on cognitive executive functions, since their development early in life has been
89 proven predictive of school and lifelong achievement, health and quality of life.⁶
90 Diamond⁶ distinguishes between core executive functions – that are inhibitory control,
91 working memory and cognitive flexibility – and higher-level executive functions – as

1
2
3 92 reasoning, planning, and problem solving. This higher-level cognition largely overlaps
4 93 with what is termed metacognition that is the ability to supervise and manage cognitive
5 94 process and to use knowledge to regulate behaviours².

6
7
8 95 Chronic exercise-cognition research has experienced a progressive shift toward a
9 96 biochemical and neuroscientific perspective from both exercise and cognition
10 97 researchers⁷⁻⁸ and developmental neuroscientists.⁹ The positive influence of chronic
11 98 physical activity has been related to angiogenesis, increasing oxygen saturation and
12 99 glucose delivery, improving cerebral blood flow and increasing neurotransmitters
13 100 levels,¹⁰ differences in structural brain volumes, as measured by magnetic resonance
14 101 imaging,¹¹ and brain function, as measured by electrical activity recordings.¹²

15
16
17
18
19
20
21 102 Previous systematic reviews and meta-analysis have synthesized evidence of the
22 103 influence of exercise interventions on children's and, less frequently, adolescents'
23 104 cognition and success in school, focused on quantitative exercise characteristics
24 105 (intensity, frequency, and session duration).^{5,13-16} Of these, one regarded experimental
25 106 studies only and considered both cognitive and psychosocial outcomes jointly.¹⁵ No
26 107 study presented results which distinguished between cognitive and metacognitive
27 108 functions, academic behaviour and achievement. Indeed, this distinction has been
28 109 recently deemed relevant to understand the potential mediational paths that underlie the
29 110 relationship between physical activity and academic achievement.²

30
31
32
33
34
35
36 111 In the search for further mechanisms beyond the neurobiological that may explain the
37 112 link between chronic physical activity and children's cognition, recent narrative or
38 113 meta-analytic reviews have focused on the qualitative characteristics of the physical
39 114 activity interventions.^{8,17-18} The difficulty in operationalizing the breadth of the exercise
40 115 quality construct in exercise and cognition research, beyond the mere metabolic and
41 116 neuromuscular demands of physical exercise tasks,¹⁹ is a main cause of the
42 117 underinvestigation of the role played by qualitative exercise characteristics as
43 118 coordinative and cognitive task complexity, novelty, and diversification for cognitive
44 119 development promotion.²⁰ Also developmental neuroscientists interested in
45 120 interventions aiding children's cognition are increasingly shifting attention toward
46 121 qualitative forms of physical activity that are not only physically effortful, but also
47 122 emotionally and socially engaging.⁹ This kind of interventions often involve physical
48 123 activities that impinge on core cognitive functions, as well as on a broader range of
49 124 cognitive skills, as goal setting, problem solving and self-regulation¹. These are

1
2
3 125 cognitive in nature and therefore fall in the field of cognitive sciences, but are also
4 126 investigated in psychosocial and social-cognitive research as essential life skills to self-
5 127 regulate behaviour and successfully adapt it to everyday requirements.²¹ Since they are
6 128 proven sensitive to designed physical activity interventions,²² it has been recently
7 129 proposed that cognitive life skills may represent a further element to be considered in
8 130 the relationship between physical activity, cognition, and academic behaviour and
9 131 achievement.⁸

10
11
12
13
14
15 132 In sum, scientific evidence on the relationship between physical activity and
16 133 cognitive/academic performance, particularly as regards its possible moderators and
17 134 mediators, is still currently insufficient to obtain a comprehensive view that may be
18 135 useful to inform policies and decision-making. Discrepancies persist regarding the
19 136 effects of chronic exercise interventions on children's cognition and success in school
20 137 and life and reviews still lack consideration of evidence at relevant intersection points
21 138 between different research areas. Moreover, whereas several narrative and meta-analytic
22 139 reviews have provided evidence syntheses that are mainly useful for setting future
23 140 research priorities, they still leave open questions concerning how this evidence can be
24 141 translated into good practices in ecological settings as the educational.²³

25
26
27
28
29
30
31
32 142 Thus, the general aim of the present methodological article is to provide a novel
33 143 protocol designed to review interventional studies addressing the chronic exercise-
34 144 cognition interaction in children and adolescents for obtaining relevant information for
35 145 policy makers and decision makers particularly in, but not limited to, the education
36 146 sector. To this aim, the proposed protocol encompasses different facets of cognitive
37 147 function and academic performance that, to the best of our knowledge, should be jointly
38 148 considered to facilitate transitioning evidence of the cognitive benefits of physical
39 149 activity for children and adolescents into good practices.

40 41 42 43 44 45 46 150 **OBJECTIVES**

47
48 151 This systematic review and meta-analysis has three objectives: (i) to estimate the effects
49 152 of chronic physical exercise interventions on different facets of cognitive function and
50 153 academic performance of children and adolescents; (ii) to determine which of those
51 154 variables benefit most from physical activity; (iii) to identify the individual, task-related
52 155 and contextual moderators that may amplify physical activity effects on
53 156 cognition/academic performance, with particular focus on the qualitative and
54 157 quantitative characteristics of the physical activity interventions.

1
2
3 158 Specifically, this systematic review and meta-analysis protocol presents an objective
4 159 and clear procedure to maximize the extraction of information from experimental
5 160 studies (randomized controlled trials - RCT, non-RCT and controlled pre-post studies),
6 161 in which data for cognition, metacognition, cognitive life skills, academic behaviour
7 162 and achievement have been separately or jointly reported as outcomes.

11 163 **METHODS AND ANALYSIS**

14 164 This systematic review and meta-analysis protocol is based on the Preferred Reporting
15 165 Items for Systematic Review and Meta-analysis Protocols (PRISMA-P)²⁴ and the
16 166 Cochrane Collaboration Handbook²⁵. This trial has been registered in PROSPERO
17 167 (registration number: CRD42015029913).

21 168 **Inclusion/exclusion criteria for study selection**

23 169 *Type of studies.*

25 170 Randomized control trials (RCT), non-RCT and controlled pre-post studies written in
26 171 international language (English) or in the national language of interest (Spanish).

29 172 *Type of participants.*

31 173 Studies assessing the relationship, at developmental age, between chronic physical
32 174 exercise interventions and cognition, metacognition, cognitive life skills and academic
33 175 performance variables will be included regardless of sex, weight, ethnicity, and
34 176 socioeconomic status. Studies including participants aged from 4 to 18 years will be
35 177 considered for inclusion. Among exclusion criteria, the one regarding participants will
36 178 be the presence of children with any physical condition or any diagnosed disorder of
37 179 cognition that would impede or limit their ability to participate in school physical
38 180 activity programs. If participants are assessed more than once in the same study, data
39 181 will be extracted and analysed from the different measurements as independent samples.

47 182 *Type of interventions.*

49 183 Studies reporting any type of chronic physical exercise intervention, defined as repeated
50 184 bouts of exercise over time aimed to improve physical fitness, involving multiple
51 185 sessions over a number of training weeks, months or years will be eligible for inclusion.
52 186 Instead, studies reporting the transient effects of single bouts of acute physical exercise
53 187 will be excluded. Studies comparing different types of chronic physical exercise

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

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

197 *Type of outcome assessments.*

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

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

219 **Search methods for the identification of studies.**

1
2
3 220 ***Electronic search***
4

5 221 The search will be conducted in the MEDLINE, EMBASE, Cochrane Central Register
6 222 of Controlled Trials, Cochrane Database of Systematic Reviews, Web of Science,
7 223 PsycINFO and ERIC databases from their inception. Study records will be managed by
8 224 means of the Mendeley reference manager.

9
10
11 225 The following search terms (and related truncations, e.g., ‘cognit’ to tap cognition and
12 226 cognitive) will be used: (1) physical activity, physical education, exercise, fitness, sport;
13 227 (2) cognition, executive, executive function, cognitive control, intelligence, memory,
14 228 attention, metacognition; (3) life skills, goal setting, problem solving, self-regulation;
15 229 (4) academic, academic achievement, academic grades, academic behaviour, academic
16 230 performance, classroom behaviour; (5) brain development, brain health, neural,
17 231 neuroelectric, neurotrophic, neurotrophin, hormon; (6) children, childhood, pre-
18 232 schooler, schooler, preadolescent, adolescent, adolescence and (7) trial. (Appendix I for
19 233 MEDLINE database search strategy).

20
21
22 234 Previous reviews and meta-analyses will be checked for additional references and
23 235 relevant references cited in the selected studies will be screened as supplemental
24 236 sources.

25
26
27 237 **Data collection and analysis.**
28

29
30
31 238 ***Selection of studies***
32

33
34
35 239 After excluding duplicated records, two reviewers will independently screen titles and
36 240 abstracts to identify eligible studies according to the inclusion and exclusion criteria.
37 241 Then, the potential eligible studies will be comprehensively reviewed and their
38 242 reference list will be checked for additional relevant studies. Any discrepancies will be
39 243 resolved by discussion with a third reviewer.

40
41
42 244 Two authors will independently extract data on publication year, number and age of
43 245 participants (control and intervention groups), physical exercise intervention
44 246 characteristics, and (meta)cognition/life skills/academic performance variables.

45
46
47 247 Any disagreement will be resolved by discussion and consensus. If necessary, the
48 248 authors of the included studies will be contacted to obtain additional relevant
49 249 information.

50
51
52 250 ***Assessment of risk of bias in included studies***
53
54
55
56
57
58
59
60

1
2
3 251 Two researchers will conduct a quality assessment according to the Cochrane
4 252 Collaboration Handbook.²⁵ Any disagreement will be resolved by discussion. A third
5
6 253 reviewer will resolve the disagreement if consensus is not reached.
7

8 254 Methodological quality of the RCT will be assessed with the Jadad Scale.²⁶ The risk of
9
10 255 bias will be evaluated according to three domains: randomization, double blinding, and
11
12 256 description of withdrawals and dropouts. Each domain will receive a score of one when
13
14 257 the studies satisfy its description. Randomization will score one extra point if the
15
16 258 method to generate the sequence is appropriate. A double blind study will score one
17
18 259 extra point if the double blind method is appropriately described. Based on these
19
20 260 domains, scores can range from 0 to 5.

21 261 The Quality Assessment Tool for Quantitative Studies²⁷ is proposed to assess the quality
22
23 262 of pre-post studies and non-RCT. This tool evaluates seven domains: selection bias,
24
25 263 study design, confounders, blinding, data collection method, withdrawals and dropouts.
26
27 264 Each domain could be considered strong, moderate or weak, and studies could be
28
29 265 classified as strong (with no weak ratings), moderate (with one weak rating), and weak
30
31 266 (with two or more weak ratings). If there are insufficient or unclear data describing the
32
33 267 required domains, the study authors have to be contacted for more details.

34 268 ***Data synthesis***

35 269 Key characteristics and important questions, such as sample size, age of participants,
36
37 270 quantitative and qualitative intervention characteristics, and cognitive outcome relevant
38
39 271 to the aim of the review will be summarized in tables (Appendix II). Reviewers will
40
41 272 determine whether a meta-analysis is possible when data have been extracted. At least
42
43 273 five observations addressing the same specific outcome will be required to conduct a
44
45 274 meta-analysis.

46 275 If it is possible to carry out a meta-analysis, STATA 13 software will be used to
47
48 276 combine the pooled mean differences with 95% confidence intervals. A fixed-effect
49
50 277 model will be used if there is no evidence of heterogeneity; otherwise, a random-effects
51
52 278 model will be used. The study heterogeneity will be assessed with an I² statistic.
53
54 279 Usually, I² values of <25, 25-50, and >50% represent small, medium, and large
55
56 280 amounts of heterogeneity, respectively.²⁸ Studies with insufficient data to perform the
57
58 281 analyses will be omitted from the data synthesis. If there is substantial heterogeneity
59
60

1
2
3 282 among the studies and a meta-analysis is not possible, a descriptive analysis will be
4 283 conducted.

5
6
7 284 The measure of mean pre-post intervention difference will be the primary indicator of
8 285 the intervention outcome. Mean differences (standard error, SE) and standardized mean
9 286 differences (standard deviation, SD) will be calculated for each specific skill or area
10 287 included in the tests. For example, when the SE is provided, the SD will be calculated
11 288 according to the following formula: $SD=SE*\text{square root of } N$. The pooled effect size on
12 289 the physical intervention and control groups will be compared using the mean
13 290 differences and ES weight for the number of participants. Lastly, publication bias will
14 291 be assessed by means of the method proposed by Egger, as well as visually on a funnel
15 292 plot.²⁹

21 293 *Subgroup analyses*

22 294 Subgroup analyses will be performed based on the main factors that may cause
23 295 heterogeneity, grouped as individual, task and contextual constraints. Main individual
24 296 factors that could act as moderators of the exercise-cognition relation are age, weight
25 297 status, and skill level.

26 298 Main types of task-related factors are qualitative and quantitative intervention
27 299 characteristics, the type of cognition assessed and the stability of the intervention
28 300 outcomes over time. Well-established quantitative parameters of the interventions are
29 301 intensity, frequency, and overall session duration.³⁰ The qualitative characteristics of
30 302 chronic exercise interventions to aid children's and adolescents' cognition have been
31 303 tentatively classified in different ways in recent reviews. One classification primarily
32 304 links the physical activity type to its specific context of practice: physical education at
33 305 school, active commuting in the urban route environment, individual vs. team sport
34 306 participation indoor or outdoor.³¹ Another classification attempts to distinguishes studies
35 307 primarily focused on the metabolic demands of physical activity from those focused on
36 308 or with deliberate manipulation of the coordinative and cognitive demands: aerobic
37 309 training, skill-based training, cognitively demanding/enriched physical activity,
38 310 traditional physical education, or combinations of them.¹⁸

39 311 The broad array of facets of cognitive functioning that may be differentially influenced
40 312 by chronic exercise interventions include: (i) non-executive functions, as non-verbal
41 313 ability, spatial ability; (ii) core executive functions, that are inhibition, working

1
2
3 314 memory, cognitive flexibility; (iii) metacognitive functions (i.e., higher-level executive
4 315 functions), as abstract reasoning, planning, problem solving; (iv) cognitive life skills, as
5 316 goal setting, self-regulation; (v) academic achievement areas, as mathematics, language,
6 317 reading, total scores; (vi) academic behaviours, as on-task behaviours, organization, or
7 318 attendance. Finally, the time of cognitive assessment after intervention cessation
8 319 influences the effect size and may inform on the outcome stability.

9
10
11
12
13 320 The main contextual factor that may cause heterogeneity of results is the intervention
14 321 setting: school, out-of-school, or laboratory setting. Also in school-based studies, it
15 322 must be taken into account if the physical activity intervention was enhanced/enriched
16 323 physical education, classroom-based activity breaks during curricular time, or active
17 324 play during recess time.

21 325 *Sensitivity analysis*

22
23
24 326 Sensitivity analyses will be conducted excluding studies from the analysis one by one. It
25 327 is needed to prove that the findings from the meta-analysis are not dependent on
26 328 arbitrary or unclear decisions. The main argument for carrying out a sensitivity analysis
27 329 in the present review protocol is the existence of large differences in (i) study design
28 330 and (ii) type of specific assessment tools used. (i) As regards the study design, as
29 331 indicated under the subheading “Type of studies”, we propose to include RCT, non-
30 332 RCT, control pre-post studies, that may largely differ in their ability to truly tap
31 333 intervention outcomes. (ii) As concerns the specific assessment tools used, they may
32 334 differ in the extent to which they specifically tap the cognitive function of interest, or
33 335 may lead to spurious results. For example, academic grades represent a final outcome of
34 336 achievement behaviours that are affected not only by cognitive, but also by
35 337 motivational, emotional and social factors of the learning context. Furthermore, also
36 338 among more narrowly focused cognitive test outcomes there may be differences due to
37 339 the sensitivity issue. For example, inhibitory control - one of the most commonly
38 340 studied cognitive functions in developmental exercise-cognition studies - is
39 341 multifaceted¹ and has been therefore studied with different tests that tap inhibition of
40 342 thoughts and memories (e.g., Random Number Generation), inhibition as perceptual
41 343 interference control challenging attention (e.g., Eriksen flanker task, Stroop Colour-
42 344 Word task, expressive attention scale of the Cognitive Assessment System), or
43 345 inhibition at the behavioural response level (e.g., stop-signal task).

1
2
3 346 **DISCUSSION**
4

5 347 A positive association between physical exercise programs and academic performance
6
7 348 has been reported more or less consistently by recent systematic reviews and meta-
8
9 349 analyses^{4,13-16,31} that analysed this relationship. The commonality of the above
10
11 350 systematic reviews and meta-analyses is that they all included academic performance
12
13 351 outcomes that represent a key variable for policy makers of the education sector. On the
14
15 352 other side, they largely differed as regards other characteristics, that must be considered
16
17 353 to reach relevant conclusion. Several differences among studies can render the evidence
18
19 354 base more or less useful and the take-home message more or less meaningful and
20
21 355 generalizable for policymakers. They regard: study design; acute/chronic exercise
22
23 356 research type; intervention type and length of follow-up period; type and specificity of
24
25 357 outcome measures; type of individual, task-related, and contextual moderators acting on
26
27 358 the relationship between physical activity and cognition/academic performance.

28
29 359 First of all, some reviews^{13-14,31} included not only interventional studies, but also those
30
31 360 with cross-sectional or observational designs; this limits the strength of causal
32
33 361 conclusions and of the call for more physical activity in school and out-of-school
34
35 362 settings as a means to aid cognitive development and successful academic achievement.
36
37 363 A narrative review¹⁷ that was exclusively focused on interventional research included
38
39 364 both acute and chronic exercise studies, which have a different take-home message for
40
41 365 policy makers. The transient cognitive benefits of an acute bout of exercise support the
42
43 366 call for more physically active breaks interspersed during the sitting learning time and
44
45 367 for more physically active academic lessons (e.g., 'moved maths'). On the other side,
46
47 368 the cognitive benefits of a longer-lasting chronic exercise program support the call for
48
49 369 legislative changes in favour of enhanced physical education and physical activity
50
51 370 promotion in out-of-school settings.

52
53 371 To the best of our knowledge, only one systematic review¹⁵ included only RCT. It
54
55 372 considered a broad range of outcomes of aerobic exercise programs including cognition,
56
57 373 academic behaviour and achievement, as well as psychosocial functioning outcomes.
58
59 374 However, this review did not provide data for the impact of aerobic exercise programs
60
375 on each academic performance component, nor did it include, among the studies with
376 psychosocial outcomes, those regarding physical activity effects on cognitive life skills
377 that are linked to successful academic behaviour and achievement.

1
2
3 378 The lack of separate subgroup analyses of data according to the different academic
4 379 performance areas or types of cognitive function assessed is common to most of the
5
6 380 existing reviews. This limits the possibility to obtain a differentiated view on what type
7
8 381 of physical activity interventions work best to reap specific cognitive/academic benefits.
9
10 382 Also, the applied conclusions that can be drawn from many of the existing reviews are
11 383 limited, as explicitly acknowledged,¹⁵ by the use of different measurements tools and
12 384 the paucity and diversity of follow-up periods.

13
14
15 385 The present protocol is aimed at overcoming these limitations by performing subgroup
16 386 analyses that take into account these issues in combination. Particularly, we follow the
17 387 call by Tomporowski et al² to distinguish between cognitive and metacognitive
18 388 outcomes of physical activity in order to investigate their role in a hypothesized
19 389 mediational chain linking chronic physical activity and academic performance. The
20 390 authors state that cognitive assessments in developmental exercise and cognition
21 391 research prioritize tools that test the cognitive functions of interest during “on-line”
22 392 processing.² To explain how exercise impacts children’s metacognitive processes and
23 393 academic performance that develop along a wider time scale, they recommend to
24 394 expand the view on exercise-cognition relations to encompass cognitive-social factors
25 395 that underlie the personal awareness of own skills in achieving short- and long-term
26 396 goals. The present protocol provides an attempt in this direction, expanding the usual
27 397 framework for exercise-cognition reviews to encompass cognitive life skills and
28 398 separately analyse cognitive, metacognitive and academic performance outcomes.

29
30
31
32
33
34
35
36
37
38
39 399 As an outlook for future research, CDC¹³ encouraged analysing the same variables in
40 400 any given category, to make summary statement about the magnitude of the effect of
41 401 physical exercise on academic performance variables. Singh et al¹⁶ recognized as
42 402 limitation of conclusions the inclusion of different study designs and outcomes
43 403 measures. Tomporowski et al² recommended to improve the information regarding the
44 404 qualitative and quantitative characteristics of physical activity programs that enhance
45 405 children’s neurocognitive performance, and to consider the possible moderators and
46 406 mediators acting on the relationship between chronic exercise and cognition/academic
47 407 performance during development. Since it is common that moderator variables are
48 408 included in interventional studies, it will be possible to apply the subgroup and
49 409 moderation analyses proposed in the Methods section. Instead, there still is a paucity of
50
51
52
53
54
55
56
57
58
59
60

1
2
3 410 studies addressing mediation,^{8,32,33} which still remains an issue in need for further
4 411 research before meta-analytic conclusions can be drawn.
5
6

7 412 The proposed protocol presents also limitations that derive from the deliberate choice of
8 413 a given trade-off setpoint between inclusion and exclusion criteria to reach relevant
9 414 conclusions for policymakers of the education and health sectors. Specifically, the broad
10 415 and heterogeneous array of relevant outcomes that will be included has costs and
11 416 benefits. It offers the possibility to tap different—from biological to behavioural—
12 417 aspects related to cognitive functioning and academic performance. Nevertheless, the
13 418 fact that included studies can broadly differ in assessed outcomes or tests used for
14 419 assessing the same outcome might lead to underestimation of overall effect size, or to
15 420 highly variable effect sizes among outcome subsets. On the other side, heterogeneity of
16 421 studies will be limited as concerns participants' characteristics, since studies involving
17 422 participants with atypical development will be excluded. Nevertheless in this way, the
18 423 generalizability of results will be lowered, being traded for a higher comparability of
19 424 intervention outcomes.
20
21
22
23
24
25
26
27

28
29 425 Given the importance of the entire developmental period—from infancy to late
30 426 adolescence³⁴ for brain development and therefore for academic performance, a more
31 427 detailed and comprehensive view on the exercise-cognition relation during development
32 428 is needed for education and health professionals to orient policy efforts. This protocol
33 429 provides a clear and structured procedure for maximizing the extraction of relevant
34 430 information and provides summarized information regarding the impact of long-term
35 431 physical activity programs on children's cognition and academic performance.
36
37
38
39

40 432 **Ethics and dissemination**

41
42
43 433 Ethical approval will not be needed to apply this review protocol because data will be
44 434 extracted from published studies and there will be no concerns about privacy. The
45 435 results of such kind of review can be best disseminated by publication in a peer-
46 436 reviewed journal that broadly reaches researchers interested in hypotheses testing and
47 437 policy makers interested in the translatability of scientific evidence into good practices.
48
49

50 438 Developing programs and strategies to promote physical activity is justified by the
51 439 international physical activity guidelines that recommend children to participate in at
52 440 least 60 minutes of daily physical activity.³⁵ Nonetheless, the prevalence of overweight
53 441 children and the total sedentary time that children daily accumulate have risen
54
55
56
57
58
59
60

1
2
3 442 substantially in the past three decades in most countries. Therefore, schools and
4 443 communities are encouraged to implement children's physical activity time. However, it
5 444 is necessary to further our understanding of how to capitalize on physical activity
6 445 effects on cognitive function and life skills relevant to successful academic
7 446 performance. The conclusions of the proposed type of systematic review and meta-
8 447 analysis may support the decisions of school boards, school administrators and policy
9 448 developers with scientifically grounded arguments on why to maintain or increase the
10 449 time devoted to curricular or extracurricular physical activity and on what type of
11 450 activities help reap largest cognitive and academic benefits.

12
13 451 **Authors' contribution:** VMV and CAB designed the study. VMV was the Principal
14 452 Investigator and Guarantor. CP, CAB, and VMV were the main coordinators of the
15 453 study. MSL, CAB, MJPG, and ICR conducted the study. ICR, CP, and MJPG provided
16 454 statistical and epidemiological support. VMV wrote the article with the support of MSL,
17 455 CP, and CAB. All of the authors revised and approved the final version of the
18 456 manuscript.

19
20 457 **Funding statement:** This research received no specific grant from any funding agency
21 458 in the public, commercial or not-for-profit sectors.

22 459

23 460 REFERENCES

- 24 461 1- Howie EK, Pate RR. Physical activity and academic achievement in children: a
25 462 historical perspective. *J Sport Health Sci* 2012;1:160e9.
- 26 463 2- Tomporowski PD, McCullick B, Pendleton DM, et al. Exercise and children's
27 464 cognition: The role of exercise characteristics and a place for metacognition. *Journal of*
28 465 *Sport and Health Science* 2015; 4(1): 47-55.
- 29 466 3- Biddle SJH, Asare M. Physical activity and mental health in children and
30 467 adolescents: a review of reviews. *Br J Sports Med* 2011;45:886–95.
- 31 468 4- Rasberry CN, Lee SM, Robin L, et al. The association between school-based physical
32 469 activity, including physical education, and academic performance: A systematic review
33 470 of the literature. *Prev Med (Baltim)* 2011; 52:S10–20.
- 34 471 5- Donnelly JE, Lambourne K. Classroom-based physical activity, cognition, and
35 472 academic achievement. *Preventive Medicine* 2011; 52: S36–S42.
- 36 473 6- Diamond A. Executive functions. *Annual review of psychology* 2013; 64: 135.
- 37 474 7- Khan NA; and Hillman CH. The relation of childhood physical activity and aerobic
38 475 fitness to brain function and cognition: a review. *Pediatric Exercise Science* 2014; 26:
39 476 138-146.

- 1
2
3 477 8- Pesce C, and Ben-Soussan D. 'Cogito ergo sum' or 'ambulo ergo sum'? New
4 478 perspectives in developmental exercise and cognition research. *Exercise-Cognition*
5 479 *Interaction: Neuroscience Perspectives*. In T. McMorris: Elsevier, 2016.
- 6
7 480 9- Diamond A, Ling DS. Conclusions about interventions, programs, and approaches
8 481 for improving executive functions that appear justified and those that, despite much
9 482 hype, do not. *Developmental Cognitive Neuroscience* 2016; 18: 34-48.
- 10
11 483 10- Diamond AB. The cognitive benefits of exercise in youth. *Curr Sports Med Rep*
12 484 2015; 14:320–6.
- 13
14 485 11- Chaddock-Heyman L, Hillman CH, Cohen NJ, et al. the Importance of physical
15 486 activity and aerobic fitness for cognitive control and memory in children. *Monogr Soc*
16 487 *Res Child Dev* 2014; 79:25–50.
- 17
18 488 12- Hillman CH, Pontifex MB, Castelli DM, et al. Effects of the FITKids randomized
19 489 controlled trial on executive control and brain function. *Pediatrics* 2014; 134:e1063–71.
- 20
21 490 13- Centers for Disease Control and Prevention (CDC). The association between
22 491 school-based physical activity, including physical education, and academic
23 492 performance. Atlanta, GA: US. Department of Health and Humans Services, 2010.
- 24
25 493 14- Fedewa AL, Ahn S. The Effects of Physical Activity and Physical Fitness on
26 494 Children's Achievement and Cognitive Outcomes. *Res Q Exerc Sport* 2011; 82:521–35.
- 27
28 495 15- Lees C, Hopkins J. Effect of aerobic exercise on cognition, academic achievement,
29 496 and psychosocial function in children: a systematic review of randomized control trials.
30 497 *Prev Chronic Dis* 2013; 10:E174.
- 31
32 498 16- Singh A, Uijtdewilligen L, Twisk JWR, et al. Physical Activity and Performance at
33 499 School: a systematic review of the literature including a methodological quality
34 500 assessment. *Arch Pediatr Adolesc Med* 2012; 166:49–55.
- 35
36 501 17- Tomporowski PD, Lambourne K, and Okumura MS. Physical activity interventions
37 502 and children's mental function: An introduction and overview. *Preventive Medicine*
38 503 2011; 52: 3-9.
- 39
40 504 18- Vazou S, Pesce C, Lakes K, and Smiley-Owen A. More than one road leads to
41 505 Rome: A narrative review and meta-analysis of physical activity intervention effects on
42 506 children's cognition. *Int J Sport Exerc. Psychol*. In press.
- 43
44 507 19- Pesce C. Shifting the focus from quantitative to qualitative exercise characteristics
45 508 in exercise and cognition research. *J Sport Exerc Psych* 2012; 34: 766 – 786.
- 46
47 509 20- Pesce C, Croce R, Ben-Soussan TD, et al. Variability of practice as an interface
48 510 between motor and cognitive development promotion. *Int J Sport Exerc. Psychol*. In
49 511 press.
- 50
51 512 21- Hodge K, Danish S, and Martin J. Developing a conceptual framework for life skills
52 513 interventions. *The Counseling Psychologist* 2012; 20: 1-28.
- 53
54 514 22- Goudas M. Prologue: a review of life skills teaching in sport and physical
55 515 education. *Hellenic J Psychol* 2010; 7: 241-258.

- 1
2
3 516 23- Kriemler S, Meyer U, Martin E, et al. Effect of school-based interventions on
4 517 physical activity in children and adolescents: a review of reviews and systematic update.
5 518 *Br J Sports Med* 2011; 45:923e30.
- 7 519 24- Moher D, Shamseer L, Clarke M, et al. Preferred Reporting Items for Systematic
8 520 Review and Meta-Analysis Protocols (PRISMA-P) 2015 statement. *Syst Rev* 2015; 4:1.
- 10 521 25- Higgins JP, Green S, editors. *Cochrane Handbook for Systematic Reviews of*
11 522 *Interventions*. 5.1.0 [Updated March 2011]. The Cochrane Collaboration, 2011.
12 523 <http://handbook.cochrane.org>
- 14 524 26- Jadad AR, Moore RA, Carroll D, et al. Assessing the quality of reports of
15 525 randomized clinical trials: Is blinding necessary? *Control Clin Trials* 1996; 17:1–12.
- 17 526 27- National Collaborating Centre for Methods and Tools. *Quality Assessment Tool for*
18 527 *Quantitative Studies*. Hamilton, ON: McMaster University, 2008 [Updated 13 April,
19 528 2010]
- 21 529 28- Higgins JPT, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat*
22 530 *Med* 2002; 21(11):1539–58.
- 24 531 29- Sterne JA, Egger M, and Smith GD. Systematic reviews in health care:
25 532 Investigating and dealing with publication and other biases in meta-analysis. *BMJ* 2001;
26 533 323:101–5.
- 28 534 30- Tremblay MS, LeBlanc AG, Carson V, et al. Canadian physical activity guidelines
29 535 for the early years (aged 0–4 years). *Applied Physiology, Nutrition, and*
30 536 *Metabolism*, 2012; 37(2): 345-356.
- 32 537 31- Esteban-Cornejo I, Tejero-Gonzalez CM, Sallis JF, et al. Physical activity and
33 538 cognition in adolescents: A systematic review. *J Sci Med Sport* 2015; 18:534–9.
- 35 539 32- Lambourne K, Hansen DM, Szabo AN, et al. Indirect and direct relations between
36 540 aerobic fitness, physical activity, and academic achievement in elementary school
37 541 students. *Mental Health and Physical Activity* 2013; 6: 165e171
- 39 542 33- Pesce C, Masci C, Marchetti R, et al. Deliberate play and preparation jointly benefit
40 543 motor and cognitive development: mediated and moderated effects. *Frontiers in*
41 544 *Psychology* 2016; 7: 349.
- 43 545 34- Andersen SL. Trajectories of brain development: point of vulnerability or window
44 546 of opportunity? *Neuroscience & Biobehavioral Reviews* 2003; 27(1): 3-18.
- 46 547 35- Ekelund U, Luan JA, Sherar LB, et al. Moderate to vigorous physical activity and
47 548 sedentary time and cardiometabolic risk factors in children and adolescents. *Jama* 2012;
48 549 307(7): 704-712.
- 51 550

6/bmjopen-2016-011065 on 28 June 2016. Downloaded from <http://bmjopen.bmj.com/> on April 17, 2024 by guest. Protected by copyright.

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

Appendix I. Search strategy for MEDLINE database.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47

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	Page 1; 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	Page 15; 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.

From: Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, Shekelle P, Stewart L, PRISMA-P Group. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. *BMJ*. 2015 Jan 2;349(jan02 1):g7647.