Association between movement behaviours, cognition, and academic achievement in children and adolescents: a systematic review

Dissertação apresentada com vista à obtenção do 2º ciclo em Atividade Física, Exercício e Saúde, da Faculdade de Desporto da Universidade do Porto, ao abrigo do Decreto-Lei nº 74/2006, de 24 de março, na redação dada pelo Decreto-Lei nº 65/2018 de 16 de agosto.

Orientador: Professora Doutora Rute Marina Roberto dos Santos

Coorientador: Professor Doutor Luís Carlos Oliveira Lopes

João Pedro Antunes Gonçalves

Porto, 2023

Ficha de catalogação

Gonçalves, J.P. **Association between movement behaviours, cognition, and academic achievement in children and adolescents: a systematic review.** Dissertação de Mestrado em Atividade Física, Exercício e Saúde apresentada à Faculdade de Desporto da Universidade do Porto.

Palavras-Chave: CHILDREN, ADOLESCENTS, MOVEMENT BEHAVIOURS, COGNITION, ACADEMIC ACHIEVEMENT

Aos meus pais. Por serem os melhores pais do mundo. Pelo apoio e o amor que me dão todos os dias, e pelo esforço que fazem diariamente que me fez chegar até aqui.

“The only difference between success and failure is the ability to take action.”

Alexander Graham Bell

Agradecimentos

Novamente aos meus pais, porque nunca conseguirei agradecer e retribuir o que eles fizeram e continuam a fazer por mim.

À Carlota, minha namorada, por todo o apoio incondicional, pelas opiniões sinceras, pelo apoio nos meus receios e principalmente por todo o amor e carinho que me dá todos os dias.

À Professora Doutora Rute Santos. Por toda a partilha e apoio dado ao longo desta dissertação, por toda a disponibilidade demonstrada, por todas as manhãs bem passadas a trabalhar e principalmente pela confiança demonstrada em mim e nas minhas capacidades.

Ao Professor Doutor Luís Lopes, meu coorientador, por toda a disponibilidade, brincadeiras e boleias para as conferências no Porto.

À Gabriela pelos post-its coloridos, as canetas divertidas, por todo o apelo à minha sanidade mental e por todo o apoio no processo desta dissertação, um muito obrigado.

E por último a toda a gente que de alguma forma me motivou a voltar a estudar e a perseguir o meu sonho.

Contents

List of figures

List of tables

RESUMO

Introdução: Comportamentos de movimento (por exemplo, sono, comportamento sedentário e atividade física) são fatores importantes do estilo de vida para a cognição e o rendimento académico na infância e adolescência. Não foram realizadas revisões sistemáticas que avaliassem as associações entre os três comportamentos de movimento e a cognição e rendimento académico como conclusão. O objetivo desta revisão sistemática foi sumariar a literatura sobre as associações entre comportamentos de movimento com cognição e rendimento académico em jovens.

Métodos: Foram pesquisadas quatro bases de dados (PubMed, Embase, PsycINFO e SPORTDiscus) desde o seu início até novembro de 2022. Esta revisão sistemática foi registada no PROSPERO (CRF42023416572).

Resultados: Esta revisão sistemática incluiu 22 estudos, representando 48.558 jovens com idades entre 6 e 17,9 anos. Dez dos estudos mostraram alto risco de viés. Não se encontraram trabalhos que avaliassem as associações entre sono e cognição e apenas um trabalho avaliou as associações entre sono e rendimento académico, revelando associações benéficas. O comportamento sedentário demonstrou associações benéficas relativamente ao funcionamento cognitivo em apenas um trabalho e, relativamente ao rendimento académico em 29% dos trabalhos. Quarenta e três por cento dos trabalhos relataram associações nulas entre comportamento sedentário e rendimento académico. Seis trabalhos avaliaram as associações entre a atividade física e a cognição. Um relato observacional mostrou associações benéficas e um longitudinal mostrou associações prejudiciais. Cinquenta por cento dos ensaios clínicos randomizados mostraram efeitos benéficos. Dezassete relatos avaliaram as associações entre atividade física e rendimento académico e 53% mostraram associações benéficas, enquanto 29% apresentaram associações nulas.

Conclusões: Existe alguma evidência sobre os benefícios da atividade física, e dos malefícios do tempo de ecrã para a cognição e o rendimento académico. No

entanto, existem muitas inconsistências nos resultados do comportamento sedentário. Existe muito pouca evidência acerca dos efeitos do sono na cognição e no rendimento académico e por isso não se podem retirar conclusões.

Palavras-chave: CRIANÇAS, ADOLESCENTES, COMPORTAMENTOS DE MOVIMENTO, COGNIÇÃO, RENDIMENTO ACADÉMICO.

ABSTRACT

Introduction: Movement behaviours (e.g., sleep, sedentary behaviour, and physical activity) are important lifestyle factors for cognition and academic achievement in youth. There were no systematic reviews assessing the associations between movement behaviors and cognition and academic achievement as outcomes.

The aim of this systematic review was to summarize the literature on the associations between movement behaviours and cognition and academic achievement in children and adolescents.

Methods: Four electronic databases (PubMed, Embase, PsycINFO, and SPORTDiscus) were searched from inception until November 2022. This systematic review was registered in PROSPERO (CRF42023416572).

Results: This systematic review included 22 studies, representing 48,558 youth aged between 6 and 17.9 years. Ten of the studies showed a high risk of bias. There were no reports assessing the associations between sleep and cognition and only one report between sleep and academic achievement was included, revealing beneficial associations. Sedentary behavior was beneficially associated with cognition in only one report and with academic achievement in 29% of the reports. Regarding the latter, 43% of the reports showed null associations between sedentary behavior and academic achievement. Six reports assessed the associations between physical activity and cognition. One observational report showed beneficial associations and a longitudinal showed detrimental associations. Fifty percent of the randomized controlled trials showed beneficial effects between physical activity and cognition. Seventeen reports assessed the associations between physical activity and academic achievement and 53% showed beneficial associations, while 29% showed null associations.

Conclusions: Overall, this systematic review showed that some evidence points out to the beneficial associations of physical activity on cognition and academic

achievement as well as for the detrimental effects of screen time. Although many inconsistent results were found for sedentary behaviour. The evidence regarding the associations of sleep duration and cognition and academic achievement in children and adolescents is scarce and doesn’t allow to draw conclusions.

Keywords: CHILDREN, ADOLESCENTS, MOVEMENT BEHAVIOURS, COGNITION, ACADEMIC ACHIEVEMENT

List of Abbreviations

AA = Academic Achievement

BMI = Body Mass Index

GPA = Grade Point Average

GRADE = Grading of Recommendations, Assessment, Development and Evaluations

HDL = High Density Lipoprotein

LDL = Low Density Lipoprotein

MET = Metabolic Equivalent of Task

MVPA = Moderate to Vigorous Physical Activity

PA = Physical Activity

PICO = Population, Intervention, Comparator and Outcome

PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses

PROSPERO = International Prospective Register of Systematic Reviews

RCT = Randomized Controlled Trial

RoB = Risk of Bias

SB = Sedentary Behaviour

TV = Television

VPA = Vigorous Physical Activity

WHO = World Health Organization

1. Introduction

1. INTRODUCTION

1.1. Cognition and Academic achievement

Cognition is the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses. It encompasses various aspects of high-level intellectual functions and processes such as attention, memory, knowledge, decision-making, planning, reasoning, judgment, perception comprehension, language, and visuospatial function. (Dhakal & Bobrin, 2023) Cognitive abilities have profound consequences for shaping quality of life, educational and career opportunities, and decision-making abilities. (Lövdén et al., 2020)

Cognition, and academic performance/academic achievement (AA) are well connected, both in childhood and in adulthood, being important predictors of life achievements, socioeconomic attainment, health, and longevity. (Batty et al., 2007; Gottfredson & Deary, 2004; Peng & Kievit, 2020) Indeed cognition contributes with a set of important factors that influence AA, including working memory (simultaneous information storage and manipulation); (Peng et al., 2018), reasoning (the capacity to solve novel and complex problems; (Sternberg, Kaufman, et al., 2008), and executive function (cognitive and social-emotional processes that underlie goal-directed behaviour such as flexible thinking, self-control, and self-regulation); (Best & Miller, 2010).

Most of the research consider cognitive abilities as foundational constructs, presupposing that cognitive abilities are the primary cause for academic outcomes (Sternberg, Grigorenko, et al., 2008) resulting in a unidirectional relation between cognitive abilities and AA. This can be explained by two cognitive theories: the investment theory and the dual process theory. Investment theory poses that, cognitive abilities are influenced mostly by biological, genetic and health factors and not by education (Cattell, 1987; Deary et al., 2010). Therefore, AA are a result of cognitive abilities and the environmental stimulation, which cognitive abilities are assumed to be the basis of the development. (Cattell, 1987) Equally, the dual process theory claims that processing familiar information in an autonomous way requires few to none

cognitive resources, but processing new information, requires many cognitive resources.(Evans & Stanovich, 2013)

In recent research, the unidirectional relationship between cognition and academic performance/AA has been challenged by the theory of mutualism, which claims that various skills and abilities become bidirectionally related during human development because of mutually interactions between uncorrelated cognitive processes. (van der Maas et al., 2006) Thus, cognitive abilities and AA should influence each other equally trough a person's development, therefore the relationship between cognitive abilities and academic performance/AA should increase with age, i.e. AA and cognitive abilities should predict each other from a longitudinal perspective; Likewise interventions targeting cognitive abilities should result in improved academic performance and vice versa.(Peng & Kievit, 2020)

1.2. Movement behaviours

Movement behaviours across the whole 24h span have gathered the attention of recent research. These consists of sleep, sedentary behaviour and physical activity (PA) (Rollo et al., 2020). Recently has been shown that desirable movement behaviours and their optimal combination (e.g., appropriate amount of sleep, less sedentary behaviour and more PA) are beneficially associated with several health indicators in children and adolescents. (Mark S. Tremblay et al., 2017; M. S. Tremblay, J. P. Chaput, et al., 2017)

This evidence has led to the launch of 24H movement guidelines by several research groups, i.e., Canada and Australia and the WHO for children and adolescents. The recommendations of ≥60 min/day of moderate-to-vigorous physical activity (MVPA), ≤2 h/day of recreational screen time, and 9 to 11 h of sleep per day for 5- to 13-year-olds or 8 to 10 h of sleep per day for 14- to 17-year-olds and vigorous-intensity aerobic activities, as well as those that strengthen muscle and bone, should be incorporated at least 3 days a week. are suggested with the objective to support healthy growth and development, for school-aged children and adolescents (6 to 17.9 years of age)(Chaput et al., 2020; M. S. Tremblay, J. P. Chaput, et al., 2017)

It has been shown that children and adolescents who meet all the 24h movement guidelines generally have more favourable measures of adiposity; mental, social, emotional and cardiometabolic health; fitness; perceived health; cognition and healthier dietary patterns. (Rollo et al., 2020) Likewise, children and adolescents meeting 1 or 2 of the 24h movement guidelines have more favourable measures of health parameters when compared to those meeting none of the guidelines.(Chaput et al., 2020; M. S. Tremblay, J. P. Chaput, et al., 2017)

1.2.1. Sleep

Sleep is an important behaviour throughout all stages of life. It is usually defined as a frequent, reversible neurobehavioural state of relative perceptual disconnection from and unresponsiveness to the environment typically accompanied by a postural change, behavioural inactivity and closed eyes. Sleep also reflects coordinated alterations in the brain's dynamic functional organization that optimize physiology, behaviour and health. (Carskadon & Dement, 1989) Conceptualizing sleep as a health behaviour is useful because it highlights how behaviour and neurobiology interact, and how individuals can modify their health through sleep. (Grandner, 2017)

Sleep loss is associated with many adverse health outcomes including obesity, type 2 diabetes, depression, suicidal ideation, and poor academic performance (Arora & Grey, 2019; Owens, 2014). Cognitive function and emotional changes are all altered by sleep loss and can influence desire and self-control, motivation and energy to engage in health behaviours (Baron & Culnan, 2019) and appears to have a multifaceted impact on both neural and behavioural measures. These impacts affect specific aspects of cognition. This, in part, is due to the differential responsiveness of the interconnected brain regions fundamental for each specific cognitive task. Sleep loss consistently impairs vigilant attention performance, resulting in increased lapses of attention and slowed response times. (Satterfield & Killgore, 2019)

Research has shown that sleep plays an important role in learning processes and memory consolidation (Ahrberg et al., 2012). Since memory processes and learning are central for academic performance and AA we can

assume that sleep is an important behaviour in this matter. Sleep deprivation and/or fragmentation usually impairs these functions. (Curcio et al., 2006)

Results from research investigating the effects of different sleep patterns on academic performance have shown that children and adolescents who sleep less, with an elevated sleep fragmentation, with later bedtimes and early awakenings, usually have a decreased academic performance (Carskadon, 1990; Fallone et al., 2002). Moreover, research has shown that an increasing daytime sleepiness, because of poor sleep quality, can also have the same results. Nonetheless, this decrease in neurocognitive functioning can easily be reverted by adopting healthy sleep schedules, and by limiting psychosocial and environmental pressure. (Curcio et al., 2006)

1.2.2. Sedentary Behavior

Sedentary behaviour is defined as any waking behaviour characterized by an energy expenditure ≤1.5 metabolic equivalents while in a sitting, reclining or lying posture. (Mark S. Tremblay et al., 2017)

Sedentary behaviour is an important consideration alongside physical activity when examining the contribution of both behaviours to the health of children and adolescents as it is known that excessive sedentary time may be health damaging, but not all sedentary behaviours may be detrimental of healthy growth and development. Indeed, there are some sedentary activities positively associated with cognition such as doing homework, reading and other school related sedentary activities; this positive association can be explained by the high levels of cognitive engagement needed for the tasks. (Aggio et al., 2016)

Besides common sedentary school-related activities, common sedentary behaviours include smartphone/tablet use, TV viewing, video game playing and computer use, driving or riding in a car, and reading/studying while sitting. Excessive sedentary time is an epidemic among children and adolescents around the world, and there is a growing body of evidence on the negative health effects and the potential public health burden associated with high levels of sedentary behaviour. (Chaput et al., 2020)

Recent evidence shows that excessive sedentary behaviour, particularly screen-based sedentary behaviour has unfavourable effects on various health indicators in children and adolescents such as: higher body fat and skinfolds, higher weight and BMI, obesity, higher LDL and lower HDL and higher blood pressure (Mark S. Tremblay et al., 2017; van Ekris et al., 2016). According to research, time spent viewing TV playing videogames and using the Internet, has the higher negative association with AA during childhood. (Adelantado-Renau et al., 2019)

Nevertheless higher levels of objectively measured sedentary time can be associated with better cognitive performance if the sedentary behaviours are school related and/or require high levels of cognitive engagement. (Aggio et al., 2016)

1.2.3. Physical Activity

PA is vital to the physical, psychological/ social, and cognitive health of school-aged children and youth (Janssen & LeBlanc, 2010). All patterns of PA provide multiple health-related benefits in children and adolescents, these include healthy levels of adiposity, healthy cardio metabolic biomarkers, physical fitness, bone health, motor skill development, and psychological distress. (Poitras et al., 2016)

During childhood and adolescence, participation in PA is particularly important. The effects of PA on cognitive function can related to physiological leads to better circulation and oxygen supply to the brain and promotion of brain changes, such as increased levels of the neurotrophic factors, proteins that facilitates learning and maintains cognitive function by improving synaptic plasticity. (Bidzan-Bluma & Lipowska, 2018; Vanhelst et al., 2016)

In addition to these health benefits, PA has a beneficial effect on academic performance in children and youth. (Estrada-Tenorio et al., 2020; Have et al., 2018; Maher et al., 2016; Resaland et al., 2018; Syväoja et al., 2013; Tapia-Serrano et al., 2022). In fact, PA is not detrimental to school-age children and adolescents academic achievement. Different types and intensities of PA appear

to have different effects on AA, with the most benefit gained from longitudinal programs incorporating aerobic exercise. (Barbosa et al., 2020)

2. Objectives

2. OBJECTIVES

This thesis aims to summarize, in a systematic manner, how do different levels, and patterns of sleep duration, sedentary time and PA associate with cognition and AA, in children and adolescents.

3. Methods

3. METHODS

A systematic literature review was conducted to summarize the evidence regarding the effects of sleep, PA, and sedentary behaviour on cognition and AA in children and adolescents. This study was adapted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols (PRISMA) (Page et al., 2021). The review protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO). The methodological details of this work are presented in the following chapter.

4. Paper

4. PAPER

Gonçalves, J.P; Ferreira, G.; Lopes, L. & Santos, R. (2023). **Associations between movement behaviours, cognition, and academic achievement in children and adolescents: a systematic review**

ABSTRACT

Title: Associations between movement behaviours, cognition, and academic achievement, in children and adolescents: a systematic review.

Authors: Gonçalves, J.P[1]; Ferreira, G. [1]; Lopes, L.[1] & Santos, R[2,3].

[1] Research Centre in Physical Activity, Health and Leisure, Faculty of Sport, University of Porto, Portugal.

[2] Institute of Education, University of Minho, Portugal.

[3] Research Centre in Child Studies, University of Minho, Portugal.

Introduction: Movement behaviours (e.g., sleep, sedentary behaviour, and physical activity) are important lifestyle factors for cognition and academic achievement in youth. There were no systematic reviews assessing the associations between movement behaviours and cognition and academic achievement as outcomes.

The aim of this systematic review was to summarize the literature on the associations between movement behaviors and cognition and academic achievement in children and adolescents.

Methods: Four electronic databases (PubMed, Embase, PsycINFO, and SPORTDiscus) were searched from inception until November 2022. This systematic review was registered in PROSPERO (CRF42023416572).

Results: This systematic review included 22 studies, representing 48,558 youth aged between 6 and 17.9 years. Ten of the studies showed a high risk of bias. There were no reports assessing the associations between sleep and cognition and only one report between sleep and academic achievement was included, revealing beneficial associations. Sedentary behaviour was beneficially associated with cognition in only one report and with academic achievement in 29% of the reports. Regarding the latter, 43% of the reports showed null associations between sedentary behavior and academic achievement. Six

reports assessed the associations between physical activity and cognition. One observational report showed beneficial associations and a longitudinal showed detrimental associations. Fifty percent of the randomized controlled trials showed beneficial effects between physical activity and cognition. Seventeen reports assessed the associations between physical activity and academic achievement and 53% showed beneficial associations, while 29% showed null associations.

Conclusions: Overall, this systematic review showed that some evidence points out to the beneficial associations of physical activity on cognition and academic achievement as well as for the detrimental effects of screen time. Although many inconsistent results were found for sedentary behaviour. The evidence regarding the associations of sleep duration and cognition and academic achievement in children and adolescents is scarce and doesn't allow to draw conclusions

Introduction

Movement behaviours, i.e., sleep, sedentary behaviour and physical activity (PA), are important lifestyle factors for cognition and academic achievement (AA) in children and adolescents.

Sedentary time is defined as the time spent for any duration in sedentary behaviours. The amount of time people spend in sedentary activities has become a public health concern. Sedentary activities can be defined as any behaviour characterized by an expenditure of energy less than 1.5 METs (M. S. Tremblay, S. Aubert, et al., 2017). PA, is defined as any bodily movement produced by skeletal muscles that results in energy expenditure superior to resting levels (Caspersen et al., 1985), has emerged as one of the most promising methods for positively influencing cognitive function across the lifespan and reducing the risk of age-related cognitive decline. (Erickson et al., 2019). Indeed, PA is a modifiable health behaviour often associated with numerous health benefits. Engaging in PA is associated with many physical and mental health benefits and has been found to enhance brain development and cognition. PA also has the capacity to improve executive functions, which are cognitive processes that govern self-regulation, problem solving, and inhibition of impulse. (Mandolesi et al., 2018)

Sleep is essential for health, and development in early childhood. Evidence suggests that short total sleep duration in children is associated with a higher level of adiposity, inferior emotional regulation, impaired growth, and higher risk of injuries. Achieving high levels of physical activity, low levels of sedentary behaviour, and getting sufficient sleep have been individually associated with better mental health among children and adolescents. (Chaput, Gray, et al., 2017).

Scientific, educational, and public health communities have demonstrated great interest in investigating approaches that might enhance cognitive and brain function throughout the lifespan. Indeed, improvements in cognitive and brain

health may have profound consequences for shaping quality of life, educational and career opportunities, and decision-making abilities. (Erickson et al., 2019).

Academic achievement plays an important role in child development because academic skills, especially in reading and mathematics, affect many outcomes, including educational attainment, performance and income at work, physical and mental health, and longevity. (Calvin et al., 2017; Kuncel & Hezlett, 2010; Peng & Kievit, 2020; Wrulich et al., 2014).

Previous systematic reviews showed that sleeping the appropriate amount of time, positively associated with cognition in children and adolescents, spending time in sedentary behaviour when not in academic tasks, specially media use (Mössle et al., 2010; Sharif & Sargent, 2006), time spent viewing TV (Ennemoser & Schneider, 2007; Espinoza, 2009), playing videogames (Jackson et al., 2011), and browsing in the Internet have negative associations with AA in childhood and adolescence. (Syväoja et al., 2013). Regarding PA, previous reviews showed that lack of PA has been shown to be associated with obesity, metabolic, and cardiovascular risk factors, depression symptoms, and lower physical fitness in children (Chaput et al., 2020). However, adequate PA may benefit them, to these health benefits, PA can positively contribute to academic performance in children and youth. (Booth et al., 2014; Estrada-Tenorio et al., 2020; Haapala et al., 2014; Have et al., 2018; Ishihara et al., 2020; Kari et al., 2017; Maher et al., 2016; Muntaner-Mas et al., 2021; Resaland et al., 2018; Syväoja et al., 2013; Tapia-Serrano et al., 2022).

However, the majority of the previous systematic reviews only included articles published in English or French language (Valerie Carson et al., 2016; V. Carson et al., 2016; Carson et al., 2017; Chaput, Gray, et al., 2017; Chaput et al., 2016; Poitras et al., 2016; Poitras et al., 2017). Others did not account for gender group differences (Valerie Carson et al., 2016; V. Carson et al., 2016; Carson et al., 2017; Chaput, Gray, et al., 2017; Chaput et al., 2016; Poitras et al., 2016; Poitras et al., 2017; Timmons et al., 2012);

Thus, the aim of this review was to systematically compile the evidence regarding the association between sleep, sedentary behaviour and PA with cognition and AA in children and adolescents.

2. Methods

This review follows the PRISMA statement for reporting systematic reviews and meta-analyses (Page et al., 2021) and was registered in PROSPERO (CRF42023416572)

2.1. Eligibility Criteria

In this systematic review, the included studies had to meet the *a priori* determined Population, Intervention, Comparator and Outcome (PICO) study criteria:

Population: studies with children and adolescents aged 6 to 17.9 years, without established chronic disease at baseline, living in the community. Studies conducted solely with clinical populations or athletes were not considered.

Intervention/Exposure: (i) valid and reliable objective (e.g. polysomnography, actigraphy, inclinometers, heart rate monitor, pedometers, etc) or subjective (e.g. self-reported) assessments of sleep, sedentary time and physical activity; (ii) for experimental studies the interventions must have targeted sleep duration or sedentary time or physical activity, not multiple health behaviours (e.g., physical activity and sedentary time and diet).

Physical activity defined as any body movement generated by the skeletal muscles that results in energy expenditure above the resting level (Caspersen et al., 1985).

Sedentary behaviour defined as any waking behaviour characterized by an energy expenditure ≤1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture (M. S. Tremblay, S. Aubert, et al., 2017).

Sleep defined as a physiological state that occurs in alternation with wakefulness. It is generally defined as a naturally recurring state of body and mind characterized by altered consciousness, relatively inhibited sensory activity, inhibition of nearly all voluntary muscles and reduced interactions with surroundings (Chaput, Saunders, et al., 2017).

Comparator: various levels of sleep, sedentary behaviour or physical activity.

Outcomes: brain health (cognition and executive functions) and academic achievement

Inclusion Criteria: (i) only studies written in Portuguese, English, French, Spanish, Italian, German or Chinese were included; (ii) observational studies had to have a minimum sample size of 30 participants. For prospective studies, the follow-up length had to be, at least, 12 weeks and with participants having, at least, one measure of sleep, sedentary behaviour or physical activity, between the age of 6 and 17.9 years; (iii) for experimental studies, the interventions had to target sleep, sedentary behaviour or physical activity and not multiple health behaviours (e.g. sleep and physical activity, or sedentary behaviour and diet), and be a randomized controlled trial (RCT) (control group without intervention/usual movement behaviour or waiting list). The RCTs needed to have a minimum sample size of 15 participants in each group and at least 12-weeks duration.

Exclusion Criteria :(i) Studies reporting physical activity data on total energy expenditure, as measured by doubly labelled water or direct/indirect calorimetry were not included; (ii) grey literature (thesis/book chapters), reviews, meta-analyses, methods papers, conference abstracts or proceedings, editorials, commentaries, case-studies, validation studies, cost-effectiveness studies, pilot-studies, qualitative studies were not included; (iii) Interventions conducted in clinical settings, such as hospitals were not considered; (iv) when, for a given outcome, several studies were published based on the same sample/population, only the study reporting prospective analysis, or the study reporting the longest follow-up, or the study using the largest sample (in cross-sectional analysis) were included.

2.2. Information Sources

The searches were performed on the following electronic databases: PUBMED, PSYCINFO, EMBASE and SPORT DISCUS, by GJP and RS, from inception until 10th November 2022. PSYCINFO and SPORT DISCUS were accessed through Ovid platform. We screened reference list from key systematic reviews on this field for potentially relevant studies.

2.3. Search Strategy

The full search strategy can be found in Supplementary file 1.

2.4. Selection Process

After deletion of duplicate records, GJP and RS independently screened the titles and abstracts of the first 100 records, and inconsistencies were discussed until consensus was reached. After this, the same authors independently screened the rest of the titles and abstracts, and then full texts. Any doubts regarding inclusion/exclusion of any given record were solved by agreement. These were conducted using CADIMA software (CADIMA. Quedlinburg, Germany: Julius Kühn-Institut; 2017, www.cadima.info) (Kohl et al., 2018)

2.5. Data Collection Process

The authors GJP, GF and RS extracted the data from each full text independently, then author RS checked the data extracted; inconsistencies were discussed until agreement was reached.

2.6. Data Items

For each included report, we registered: authors' names, publication year, study design, country/region (and study name), number of participants, participants' age range (or mean age), exposure and outcome characteristics, and main findings. For RCTs, intervention description was also registered.

2.7. Study Risk of Bias Assessment

Risk of bias (RoB) assessment was based on the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) framework (Guyatt, Oxman, Vist, et al., 2011). For each of the included studies, RoB considered the following characteristics: (i) selection bias, (ii) detection bias (iii) performance bias, and (iv) attrition bias, for observational studies; and, for RCTs we considered the same characteristics, as well as reporting bias. In

compliance with GRADE framework, overall RoB for each study was classified as (i) No serious limitations; (ii) Serious limitation or (iii) Very serious limitations.

RoB was evaluated by the authors GJP, GF and RS and checked by RS and inconsistencies were discussed until agreement was obtained. Preceding RoB assessments, the GJP, GF and RS showed >95% agreement with criterion assessments piloted on 20 randomly selected studies.

2.8. Effect Measures

Due to the variety of study designs, assessments and categorization of the exposure and the outcomes, all effect sizes reported in the studies were considered.

2.9. Synthesis Methods

For each outcome, meta-analyses were planned if there were, at least, 3 reports homogenously enough regarding study design, effect sizes reported and exposure metrics and categorization. In this review meta-analyses were not possible; therefore, a narrative synthesis by exposure and outcome was performed using summary of findings tables.

2.10. Quality Assessment

RoB and quality of evidence were performed by GJP and LL independently, and verified by RS. RoB (Guyatt, Oxman, Vist, et al., 2011) and quality of evidence (Guyatt, Oxman, Kunz, Brozek, et al., 2011; Guyatt, Oxman, Kunz, Woodcock, Brozek, Helfand, Alonso-Coello, Falck-Ytter, et al., 2011; Guyatt, Oxman, Kunz, Woodcock, Brozek, Helfand, Alonso-Coello, Glasziou, et al., 2011; Guyatt, Oxman, Montori, et al., 2011) for each outcome and by study design was assessed based on the GRADE framework. Quality of evidence scores start at “high” for RCTs and “low” for all other study designs (Balshem et al., 2011). Quality of evidence can be downgraded or upgraded. The quality of evidence was downgraded, if there were serious limitations in any of the following: RoB, inconsistency, indirectness, imprecision or other factors. On the other hand, the quality of evidence was upgraded if there were a large effect size,

a dose-response gradient or if all plausible confounders increased confidence in estimated effects. (Guyatt, Oxman, Sultan, et al., 2011)

3. Results

3.1 Study Selection

The searches generated 8,172 records and after duplicate removal 7,867 records were kept. After the screening of titles and abstracts, 178 records were retained for full text assessment and of this, 23 papers (reports) representing 22 unique studies were included in this review (Figure 1).

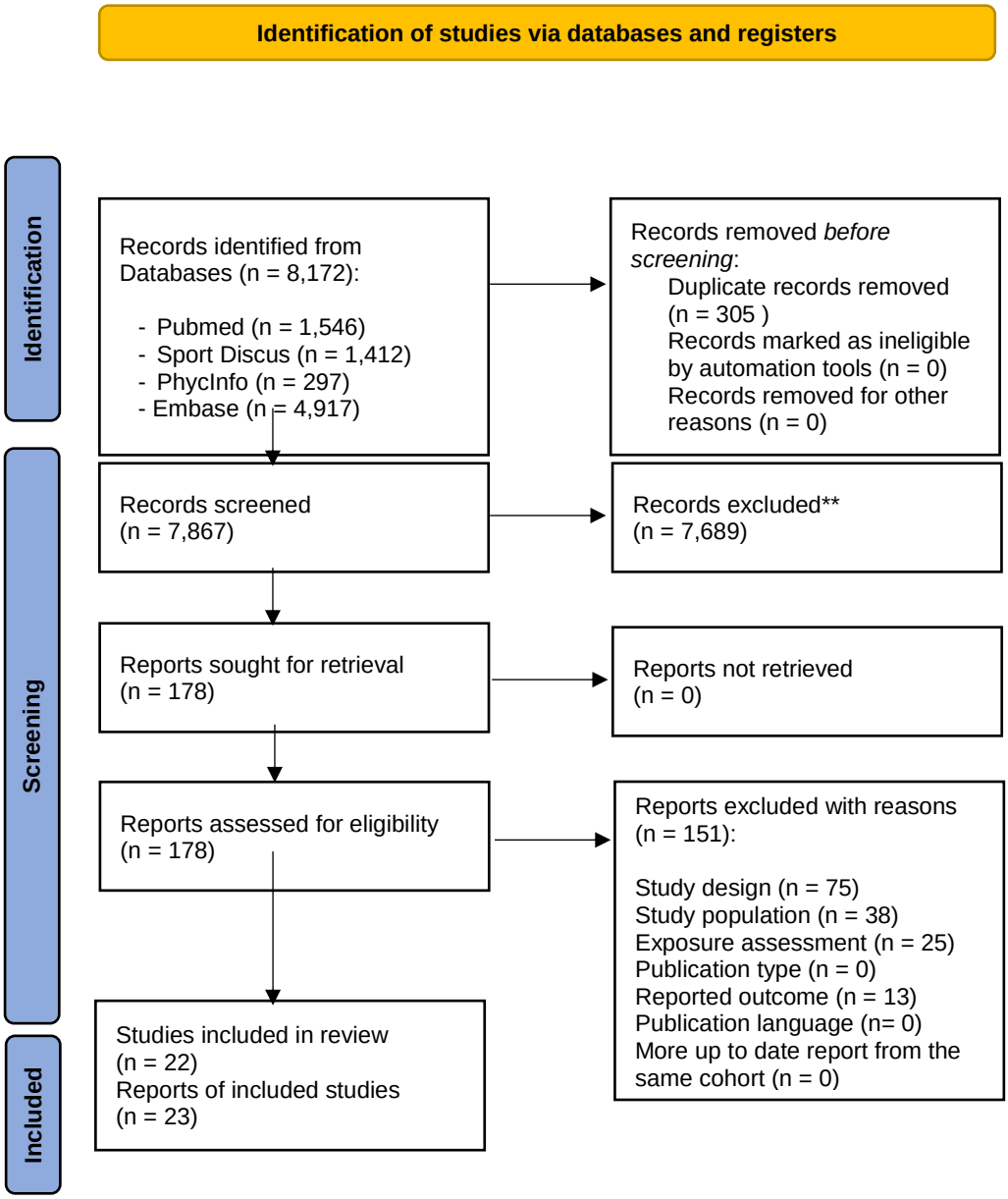

Figure 1. Flow chart of the included studies

Table 1. Summary of findings of the RCTs included in the systematic review on the association between physical activity and academic achievement and cognition, in children and adolescents.

Study Details		Participants		Follow-up duration	Exposure	Outcome	Intervention	Results [c]	Direction of the association [d]
Authors (year)	**Country (study name)**	**Number (% girls)**	**Age**						
(Have et al., 2018)	Denmark (n.r.)	505 (50%)	7.2 ± 0.3 yrs.	9 months	PA, accelerometry (4 days; 10h/day)	**Maths scores:** Standard math test developed from Danish National tests (Hoegrefe Forlag)	Intervention: 15min of PA spread over a 45min Math lesson. SB activities were limited to maximum bouts of 20min. Controls regular classroom instructions.	Math skills were significantly affected by the 9-month active math intervention. While the mean score on the math skill test improved in both groups, the intervention group improved math score by 1.2 points more than the control.	++
(Hecht & Garber, 2021)	USA (n.r.)	133 (50%)	9-10 yrs.	3 months	PA, accelerometry (15 days)	**Maths scores:** STAR math test performance	Intervention: Teachers were trained to deliver POWER (prioritize, organize, work, exercise, and regulate) during a 6-hour session. PA is a core component of POWER, as it is both a mechanism for teaching the POWER skills and an end in itself. Each morning began with a ‘‘morning mindfulness’’ session. After participating in several sessions, students were empowered to create and lead their own activity and	Student math test scores increased significantly for both schools, but there was no significant main effect for group.	0

Study Details		Participants		Follow-up duration	Exposure	Outcome	Intervention	Results [c]	Direction of the association [d]
Authors (year)	Country (study name)	Number (% girls)	Age						
							mindfulness breaks in their classroom. Controls: usual care.		
(Resaland et al., 2018)	Norway [Active Smarter Kids (ASK))	1,129 (48%)	10.2 ± 0.3 yrs.	7 months	PA, accelerometry (4 days; 8h/day)	**Academic Scores:** Scores in mathematics, reading and English national test.	Intervention: The ASK intervention is designed to increase PA (165 min/week above normal activity curriculum) and was comprised of three components: 1) PA educational lessons (3 × 30 min each week); academic lessons in the core subjects, Norwegian, mathematics and English (second language) carried out mostly in the school playground; 2) PA breaks during classroom lessons (5 min × 5 days each week); 3) PA homework prepared by the teachers (10 min daily; 5 × 10 min each week). Controls: usual care.	Results suggested a trend where low performing children in academic performance benefited the most academically from the ASK-intervention. Furthermore, a trend was observed where boys seemed to benefit over girls.	+
(Tarp et al., 2016)	Denmark (The Learning, Cognition & Motion (LCoMotion))	632 (51.1%).	12 - 14 yrs.	5 months	PA, accelerometry (4 days; 10h/day)	**Maths skills:** 50 question test on arithmetic, algebra, problem solving and geometry.	Intervention: 60 min/day of PA classes + PA incorporating in PA academic classes + PA homework + short	No significant effect of the intervention was observed on mathematics skills.	0

Study Details		Participants		Follow-up duration	Exposure	Outcome	Intervention	Results [c]	Direction of the association [d]
Authors (year)	**Country (study name)**	**Number (% girls)**	**Age**						
							message service-tracking. Controls: usual care.		
(Bartholomew et al., 2018)	USA [Children's Activity and Nutrition (I-CAN!)]	2,716 (54%)	9 - 10 yrs.	3 yrs.	PA, accelerometry (1 day; 6h/day)	**Planning /decision making:** TOT - Time on Task	Intervention: 10-15min/day for 5 days of PA academic classes (Active learning). Controls: usual care.	Students in the intervention schools spent significantly more Time On Task than their counterparts in control schools (β= 5,53, SE=1,73, p<0.001)	+
(Hecht & Garber, 2021)	USA (n.r.)	133 (50%)	9 - 10 yrs.	3 months.	PA, accelerometry (15 days)	**Executive Function**: 3 tests from the NIH Toolbox. Flanker Inhibitory Control and Attention test, the List Sorting Working Memory test and the Dimensional Change Card Sort Test.	Intervention: Teachers were trained to deliver POWER (prioritize, organize, work, exercise, and regulate) during a 6-hour session. PA is a core component of POWER, as it is both a mechanism for teaching the POWER skills and an end in itself. Each morning began with a ‘‘morning mindfulness’’ session. After participating in several sessions, students were empowered to create and lead their own activity and mindfulness breaks in their classroom. Controls: Usual care	POW’s NIH Toolbox score increased 3 percentiles more than controls.	+

Study Details		Participants		Follow-up duration	Exposure	Outcome	Intervention	Results [c]	Direction of the association [d]
Authors (year)	**Country (study name)**	**Number (% girls)**	**Age**						
(Tarp et al., 2016)	Denmark [The Learning, Cognition & Motion (LCoMotion)]	632 (51.1%).	12 - 14 yrs.	5 months.	PA, accelerometry (4 days; 10h/day)	**Inhibition:** Modified version of the Flanker test.	Intervention: 60 min/day of PA classes + PA incorporating in PA academic classes + PA homework + short message service-tracking; Controls: usual care.	No significant differences in change between intervention and control schools were observed for response accuracy or reaction time on congruent or incongruent trials.	0
(Wassenaar et al., 2021)	England (The Fit to Study)	18,261 (n.r)	12 -13 yrs.	12 months	PA, self-reported (Set of questions)	Processing speed: Simple reaction time. Visual relational memory: Relational memory task. Inhibitory control: Modified Flanker test. Working memory: Visual two-back task.	PE teachers were instructed to incorporate two elements of additional VPA bursts into lessons, consisting of: 4 min of VPA as part of an active 10-min warm-up, and three 2-min, infusions per hour of PE, where VPA was defined as activity that raises the heart rate to 71–85% of the maximum heart rate. Controls: usual care.	The one-academic year HIIT-style VPA intervention delivered during regular school PE did not significantly improve cognitive performance.	0

PA – Physical Activity; PE – Physical Education

Table 2. Summary of findings of the observational studies included in the systematic review on the association between physical activity and academic achievement and cognition, in children and adolescents.

Study Details		Participants						
Authors (year)	**Country (study name)**	**Number (% girls)**	**Age**	**Follow-up duration**	**Exposure**	**Outcome**	**Results [c]**	**Direction of the association [d]**
Cross-sectional Studies								
(Bueno et al., 2021)	Brazil (n.r.)	394 (52%)	10 - 14 yrs.		PA, accelerometry (7 days; 8h/day	**GPA - Grade point averages:** Grades of 5 disciplines, language, mathematics, science, history and geography.	MVPA was not significantly associated with GPA.	0
(Cosgrove & Castelli, 2018)	USA (n.r.	160 (74.4%)	8 - 12 yrs.		PA, accelerometry (5 school days)	**GPA - Grade point average:** Scores from student final grade averages for English, math, science and social studies	The amount of time spent on very vigorous PA was negatively associated with academic performance. Total LPA, MVPA and daily steps were not associated with academic performance.	-
(Esteban-Cornejo et al., 2014)	Spain (UP&DOWN)	1,779 (48, 9%	6 - 18 yrs.		PA, accelerometry (3 days; 10h/day)	**Academic Scores and GPA score:** Academic performance at the end of the academic year in four main indicators and the GPA score.	MPA, VPA and MVPA were inversely associated with all academic performance indicators.	--
(Estrada-Tenorio et al., 2020)	Spain (n.r.)	301 (53.5%)	13 - 15 yrs.		PA, accelerometry (4 days; 10h/day)	**Academic Scores:** Students marks for all school subjects in a scale of 0 to 10.	MVPA on weekdays was negatively associated with academic achievement. According to the curvilinear relationship, those students whose MVPA levels were closer to the daily recommendation	+ For boys 0 For girls

						were more likely to obtain higher academic achievement. However, a significant association was only shown in boys.	
(Maher et al., 2016)	Australia [International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE)]	285 (n.r.)	9 - 11 yrs.	PA, accelerometry (7 days; 24h/day)	**Academic Scores:**Academic performance was determined from participants in National Assessment Program – Literacy and Numeracy (NAPLAN) grade 5 results in five academic domains, reading, writing, spelling, language and numeracy	Higher academic performance was only related to higher MVPA in two academic domains and was not related to language, reading and spelling performance.	+
(Syväoja et al., 2013)	Finland (n.r.)	277 (56%)	12.2 yrs.	PA, self-reported (WHO Health Behavior in School-Aged Children), PA, accelerometry (7 days)	**Academic Scores and GPA score:** Academic scores and GPA in native language, mathematics, physics/chemistry, biology, history, geography, religion or ethics, visual arts, music and physical education.	Objectively measured MVPA was not associated with GPA. However, self-reported MVPA had an inverse U-shaped curvilinear association with grade point average.	+
(Tapia-Serrano et al., 2022)	Spain (n.r.)	1,277 (44.2%)	11 - 16 yrs.	PA, self-reported (Physical Activity Questionnaire for Adolescents (PAQ-A))	**Academic Scores:** Academic Scores in three subjects, Spanish (first language), English and Mathematics.	Meeting physical activity guidelines was associated with higher academic achievement.	++
(Vanhelst et al., 2016)	France, Spain, Austria, Germany	273 (53.8%)	12.5-17.5 yrs.	PA, accelerometry (7 consecutive days at least 3 days 8h/day)	**Attention Capacity:** D2 Test of Attention.	Adolescents' attention capacity test performances were significantly and positively associated with longer time	+

	, Hungary and Greece [Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA STUDY)						spent in moderate or MVPA in free-living conditions (P < .05).	
Longitudinal Studies								
(Booth et al., 2014; Tapia-Serrano et al., 2022)	England [Avon Longitudinal Study of Parents and Children (ALSPAC)]	4,755 (55%)	11 - 16 yrs.	5 yrs.	PA, accelerometry (7 days; 10h/day	**Academic attainment at 16 yrs. old:** Grades of 3 disciplines, English, Mathematics and Science.	In Maths at 16 years, percentage of time in MVPA predicted increased performance for males and females. For females the percentage of time spent in MVPA at 11 years predicted increased Science scores at 11 and 16 yrs	++
(Elish et al., 2022)	USA (Health Empowers You!)	4,936 (50%)	8 - 10 yrs.	24 months.	PA, accelerometry (5 days, 80% of the day)	**Academic Scores:** Course grades and test scores each semester for math, reading, spelling and writing in Georgia Milestone test.	MVPA was not associated with academic achievement.	0
(Haapala et al., 2014)	Finland [Physical Activity	186 (42%)	6 - 8 yrs.	5 yrs.	PA, self-reported (PANIC - Physical	**Academic Skills:** ALLU test battery for reading fluency and	Total PA, physically active school transportation was associated with better reading	+ For boys - For girls

	and Nutrition in Children (PANIC)]				Activity Questionnaire)	comprehension, basic arithmetic test for arithmetic skills.	comprehension in boys, and lower reading fluency and comprehension in boys. Total PA and organized exercise other than sports was associated with lower arithmetic skills in girls.	
(Ishihara et al., 2020)	Japan (n.r.)	463 (49%)	12 - 13 yrs. at baseline	24 months.	PA, self-reported (set of questions)	**GPA - Grade point averages:** Academic performance in the total grade points in five school subjects, Japanese, Mathematics, Social Studies, Sciences and English.	Participation in all sports activity was positively associated with improvement of academic performance from baseline to follow-up, and that these associations were mediated by cardiorespiratory fitness gains. Participation in sports activities that require more complex motor skills and individual sports activity was directly associated with an improvement of academic performance from baseline to follow-up. Furthermore, quitting sports activities was negatively associated with academic performance via a reversal in cardiorespiratory fitness gains.	+
(Kari et al., 2017)	Finland (Cardiovascular Risk in Young Fins Study)	2,445 (52%)	12 - 15 yrs. at baseline.	31 yrs.	PA, self-reported (set of questions). PA Index ranging from 5 to 14 points.	**Educational attainment at the age of 33 - 45 yrs.:** educational attainment ascertained through the Finnish Longitudinal Employer-Employee Data (FLEED)	Among women, a one-unit increase in the PA index was related to a 0.11 unit increase in GPA and 0.17 additional yrs. of education. Among men, the coefficients were 0.06 for GPA and 0.17 for yrs. of education. In terms of educational attainment, the most physically active girls and boys (PA index =14 at the age of 15 yr) had approximately	++

							1.5 more years of education in adulthood compared with their least physically active counterparts (PAI = 5 at the age of 15 yrs.).	
(Muntaner-Mas et al., 2021)	Spain (UP&DOWN)	1046 (n.r.)	6 - 18 yrs.	24 months.	PA, accelerometry (3 days at least 10h per day)	**Academic Scores and GPA - Grade point averages:** GPA and the mathematics and language scores reported on the transcript at the end of the academic year.	Engaging in approximately 250 mins/day of total PA volume at baseline was associated with a better academic performance 2 years later, specifically with GPA.	+
(E. E. Wickel, 2017)	USA (Study of Early Child Care and Youth Development	1,364 (36.8%)	9 - 15 yrs.	6 yrs.	PA, accelerometry (7 days; 17h/day)	**Executive Function:** Scores in three tests, Inhibition: modified version of the Weinberger Adjustment Inventory. Working memory: Operation Span (OSPAN). Fluid intelligence: Tower of London test.	Among girls, higher levels of light PA predicted lower fluid intelligence whereas among boys increased vigorous PA predicted lower inhibition.	--

Table 3. Summary of findings of the observational studies included in the systematic review on the association between sleep and academic achievement, in children and adolescents.

Study Details		Participants						
Authors (year)	**Country (study name)**	**Number (% girls)**	**Age**	**Follow-up duration**	**Exposure**	**Outcome**	**Results [c]**	**Direction of the association [d]**
Cross-sectional Studies								
(Tapia-Serrano et al., 2022)	Spain (n.r.)	1,277 (44.2%)	11 - 16 yrs.		Sleep Duration, self-reported (set of questions).	**Academic Scores:** Academic Scores in three subjects, Spanish (first language), English and Mathematics.	Meeting the Sleep duration guidelines was positively associated with Academic Achievement,	++

Table 4. Summary of findings of the observational studies included in the systematic review on the association between sedentary behaviour and academic achievement and cognition, in children and adolescents.

Study Details		**Participants**						
Authors (year)	**Country (study name)**	**Number (% girls)**	**Age**	**Follow-up duration**	**Exposure**	**Outcome**	**Results [c]**	**Direction of the association [d]**
Cross-sectional Studies								
(Correa-Burrows et al., 2014**)**	Chile (n.r.)	620 (51%)	14 - 15 yrs.		SB, self-reported (Godard questionnaire)	**Academic Scores:** Academic achievement in the System for the Assessment of Educational Quality test (SIMCE)	SB was positively associated with sufficiency and proficiency in Mathematics and Language.	++
(Cosgrove & Castelli, 2018)	USA (n.r.)	160 (74.4%)	8 - 12 yrs.		SB, accelerometry (5 school days).	**GPA - Grade point averages:** GPA scores from student final grade averages for English, Math, Science and Social Studies.	The proportion of time spent on sedentary was not associated with academic performance.	0
(Lopes et al., 2017)	Portugal (Bracara Study)	213 (51.6%)	9 - 10 yrs.		SB, accelerometry (5 days)	**Academic Scores:** Performance in Portuguese Language and Mathematics National Exam.	Total sedentary time was not associated with Academic Achievement.	0
(Maher et al., 2016)	Australia [International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE)]	285 (n.r.)	9 - 11 yrs.		SB, accelerometry (7 days; 24h/day)	**Academic Scores:** Determined from participants in National Assessment Program – Literacy and Numeracy (NAPLAN) grade 5 results in five academic domains, reading, writing, spelling, language and numeracy.	Higher academic performance was strongly and consistently related to higher sedentary time, with significant relationships seen across all five academic domains.	++

Study Details		Participants						
Authors (year)	**Country (study name)**	**Number (% girls)**	**Age**	**Follow-up duration**	**Exposure**	**Outcome**	**Results [c]**	**Direction of the association [d]**
(Syväoja et al., 2013)	Finland (n.r.)	277 (56%)	12.2		Screen time, self-reported	**Academic Scores and GPA score:** Academic scores and GPA in Native Language, Mathematics, Physics/Chemistry, Biology, History, Geography, Religion or Ethics, Visual Arts, Music and Physical Education.	Sedentary time was not associated with GPA. Screen time had a linear negative association with GPA.	-
(Tapia-Serrano et al., 2022)	Spain (n.r.)	1,277 (44.2%)	11 - 16 yrs.		Recreational Screen Time, self-reported [Youth-Leisure-Time Sedentary Behaviour Questionnaire (YLSBQ)]	**Academic Scores**: Academic Scores in three subjects, Spanish (first language), English and Mathematics.	Meeting the Screen time guidelines was not associated with academic scores.	0
Longitudinal Studies								
(Haapala et al., 2014)	Finland [Physical Activity and Nutrition in Children (PANIC)]	186 (42%)	6 - 8 yrs.	5 yrs.	SB, self-reported (PANIC - Physical Activity Questionnaire)	**Academic Skills:** ALLU test battery for reading fluency and comprehension, basic arithmetic test for arithmetic skills.	SB related to academic skills may be beneficial for the development of reading fluency in boys, whereas factors that are independent of SB may be more important for academic skills in girls.	+
(Hunter et al., 2018)	Canada [Cohort for Obesity, Marijuana use,	4,408 (55.7%)	13 - 18 yrs. at baseline	3 yrs.	SB, self-reported (set of questions)	**Academic Scores**: Self-reported grades of mathematics and English.	If a student shifted from the first quartile (Q1) of watching/streaming television shows/movies to Q4, on average, he or she	-- Communication based SB

Study Details		Participants						
Authors (year)	**Country (study name)**	**Number (% girls)**	**Age**	**Follow-up duration**	**Exposure**	**Outcome**	**Results [c]**	**Direction of the association [d]**
	Physical Activity, Alcohol use, Smoking and Sedentary Behaviour (COMPASS)]						was more likely to surpass the provincial math standard. On the other hand, if a student shifted from Q1 to Q2, Q3, or Q4 for watching/streaming TV shows/movies, on average they would be less likely to surpass the provincial English standard. If a student shifted from Q1 to Q3 for surfing the internet, on average, he or she was less likely to surpass the provincial English standard. If a student's status in doing homework shifted from Q1 to Q4, on average he or she was more likely to surpass the provincial English standard. If a student shifted from Q1 to Q2 in communication-based SB, on average, he or she was less likely to surpass the provincial math standard. Time spent playing video/computer games, texting, messaging, emailing, and talking on the phone, screen-based SB, and average total SB were not	-- TV viewing for English -- Internet surfing for English ++ Homework ++ TV viewing for Maths 0 Total SB 0 Computer games, emailing and phone texting

Study Details		Participants						
Authors (year)	**Country (study name)**	**Number (% girls)**	**Age**	**Follow-up duration**	**Exposure**	**Outcome**	**Results [c]**	**Direction of the association [d]**
							significant predictors of academic achievement.	
(E. E. Wickel, 2017)	USA (Study of Early Child Care and Youth Development)	1,364 (36.80%)	9 - 15 yrs.	6 yrs.	SB, accelerometry (7 days; 17h per day)	**Executive Function**: Scores in three tests, Inhibition: Modified version of the Weinberger Adjustment Inventory. Working memory Operation Span (OSPAN). Fluid intelligence Tower of London test.	Overall, increased sedentary time from 9 to 15 yrs. predicted higher inhibition, working memory, and fluid intelligence.	++

Table 5. Study limitations (Risk of bias) of the RCTs included in the systematic review on the association between physical activity and academic achievement and cognition, in children and adolescents.

Authors (year)	Randomization	Study limitations (Risk of Bias)						
		Selection Bias	Performance Bias	Attrition Bias		Reporting Bias	Other	Overall
		Allocation Concealment	Blinding	Loss to follow-up	Analysis	Selective outcome reporting bias		
Academic Achievement								
(Have et al., 2018)	Stratified Randomization (unclear method)	Adequate (sealed opaque envelopes)	Single blind (research team)	10.80%	IT	Unlikely	None suspected	No serious limitations
(Hecht & Garber, 2021)	Simple Randomization (unclear method)	Unclear or not reported	Single blind (research team)	37%	Per protocol	Unlikely	None suspected	Very serious limitation
(Resaland et al., 2018)	Simple Randomization (unclear method)	Unclear or not reported	Single blind (research team)	Uncertain	Per protocol	Unlikely	None suspected	Very serious limitations
(Tarp et al., 2016)	Simple Randomization	Unclear or not reported	Open label	10% intervention and 11% controls	Missing imputation	Unlikely	None suspected	Serious limitations
Cognition								
(Bartholomew et al., 2018)	Simple Randomization (unclear method)	Participants were aware of the group in which they were enrolled	Open label	20%	IT	Unlikely	None suspected	Serious limitations
(Have et al., 2018)	Stratified Randomization (unclear method)	Adequate (sealed opaque envelopes)	Single blind (research team)	10.8%	IT	Unlikely	None suspected	No serious limitations

Authors (year)	Randomization	Study limitations (Risk of Bias)						
		Selection Bias	Performance Bias	Attrition Bias		Reporting Bias	Other	Overall
		Allocation Concealment	Blinding	Loss to follow-up	Analysis	Selective outcome reporting bias		
(Hecht & Garber, 2021)	Simple Randomization (unclear method)	Unclear or not reported	Single blind (research team)	37%	Per protocol	Unlikely	None suspected	Very serious limitations
(Tarp et al., 2016)	Simple Randomization	Unclear or not reported	Open label	10% intervention and 11% controls	Missing imputation	Unlikely	None suspected	Serious limitations
(Wassenaar et al., 2021)	Adequate, Simple Randomization (computer-generated random numbers)	Participants were aware of the group in which they were enrolled	Open label	33.40%	IT	Unlikely	None suspected	Serious limitations

IT – Intention-to-treat

Table 6. Study limitations (Risk of Bias) of the observational studies included in the systematic review on the association between physical activity and academic achievement, in children and adolescents.

Authors (year)	Study limitations (Risk of Bias)				
	Selection Bias	Detection Bias	Performance Bias	Attrition Bias	Overall
	Eligibility criteria	Validity of the exposure	Controlling factors	Incomplete follow-up	
Cross-sectional Studies					
(Bueno et al., 2021)	Convenient sample, eligibility criteria defined.	Valid	Yes	Unclear, per protocol, no drop out analysis	Serious limitations
(Cosgrove & Castelli, 2018)	Convenient sample, eligibility criteria defined.	Valid	In part	N.r %, per protocol no drop out analysis	Very serious limitations
(Esteban-Cornejo et al., 2014)	Convenient sample, eligibility criteria defined.	Valid	Yes	21%, per protocol, no drop out analysis	Serious limitations
(Estrada-Tenorio et al., 2020)	Convenient sample, eligibility criteria defined.	Valid	Yes	Unclear, per protocol, no drop out analysis	Serious limitations
(Maher et al., 2016)	Convenient sample, eligibility criteria defined.	Valid	In part	46%, per protocol, no drop out analysis	Very serious limitations
(Syväoja et al., 2013)	Convenient sample, eligibility criteria defined.	Valid	In part	42%, per protocol, no drop out analysis	Very serious limitations
(Tapia-Serrano et al., 2022)	Convenient sample, eligibility criteria defined.	Valid	Yes	42,3%, per protocol, no drop out analysis	Serious limitations
Longitudinal Studies					
(Booth et al., 2014)	Convenient sample, eligibility criteria defined.	Valid	Yes	33.7% per protocol, no drop out analysis	Serious limitations

Authors (year)	Study limitations (Risk of Bias)				
	Selection Bias	Detection Bias	Performance Bias	Attrition Bias	Overall
	Eligibility criteria	Validity of the exposure	Controlling factors	Incomplete follow-up	
(Elish et al., 2022)	Convenient sample, eligibility criteria defined.	Valid	Yes	27.4% per protocol, no drop out analysis	Serious limitations
(Haapala et al., 2014)	Convenient sample, eligibility criteria defined.	Valid	Yes	10.14%, per protocol, drop out analysis performed	No serious limitations
(Ishihara et al., 2020)	Convenient sample, eligibility criteria defined.	Valid	Yes	51,1%, per protocol, no drop out analysis	Serious limitations
(Kari et al., 2017)	Convenient sample, eligibility criteria defined.	Unclear	Yes	46 to 66%, per protocol, no drop out analysis	Very serious limitations
(Muntaner-Mas et al., 2021)	Convenient sample, eligibility criteria defined.	Valid	In part	41.2%, per protocol, no drop out analysis	Very serious limitations
(Vanhelst et al., 2016)	Convenient sample, eligibility criteria defined.	Valid	Yes	Unclear, per protocol, no drop out analysis	Serious limitations
(E. E. Wickel, 2017)	Convenient sample, eligibility criteria defined.	Valid	In part	N.r %, per protocol, no drop out analysis	Very serious limitations

Table 7. Study limitations (Risk of Bias) of the observational studies included in the systematic review on the association between sleep and academic achievement, in children and adolescents.

Authors (year)	Study limitations (Risk of Bias)				
	Selection Bias	Detection Bias	Performance Bias	Attrition Bias	Overall
	Eligibility criteria	Validity of the exposure	Controlling factors	Incomplete follow-up	
Cross-sectional Studies					
(Tapia-Serrano et al., 2022)	Convenient sample, eligibility criteria defined.	Valid	Yes	42.3%, per protocol, no drop out analysis	Serious limitations

Table 8. Study limitations (Risk of Bias) of the observational studies included in the systematic review on the association between sedentary behaviour and academic achievement and cognition, in children and adolescents.

Authors (year)	Study limitations (Risk of Bias)				
	Selection Bias	Detection Bias	Performance Bias	Attrition Bias	Overall
	Eligibility criteria	Validity of the exposure	Controlling factors	Incomplete follow-up	
Cross-sectional Studies					
(Correa-Burrows et al., 2014)	Convenient sample, eligibility criteria defined	Valid	Yes	4% per protocol, no drop out analysis	No serious limitations
(Cosgrove & Castelli, 2018)	Convenient sample, eligibility criteria defined	Valid	In part	N.r %, per protocol no drop out analysis	Very serious limitations
(Lopes et al., 2017)	Convenient sample, eligibility criteria defined	Valid	Yes	36%, per protocol, no drop out analysis	Serious limitations
(Maher et al., 2016)	Convenient sample, eligibility criteria defined	Valid	In part	46%, per protocol, no drop out analysis	Very serious limitations
(Syväoja et al., 2013)	Convenient sample, eligibility criteria defined	Valid	In part	42%, per protocol, no drop out analysis	Very serious limitations
(Tapia-Serrano et al., 2022)	Convenient sample, eligibility criteria defined	Valid	Yes	42.3%, per protocol, no drop out analysis	Serious limitations
Longitudinal Studies					
(Haapala et al., 2014)	Convenient sample, eligibility criteria defined	Valid	Yes	10.14%, per protocol, drop out analysis performed	No serious limitations

Authors (year)	Study limitations (Risk of Bias)				
	Selection Bias	Detection Bias	Performance Bias	Attrition Bias	Overall
	Eligibility criteria	Validity of the exposure	Controlling factors	Incomplete follow-up	
(Hunter et al., 2018)	Convenient sample, eligibility criteria defined	Valid	In part	11%, per protocol, drop out analysis performed	Serious limitations
(E. E. Wickel, 2017)	Convenient sample, eligibility criteria defined	Valid	In part	N.r %, per protocol no drop out analysis	Very serious limitations

Table 9. Quality and summary of the evidence on the association between physical fitness and cognition and academic achievement in children and adolescents.

Subjects (reports)	Study Design	Risk of Bias	Inconsistency	Indirectness	Imprecision	Other	Overall quality of the Evidence	Summary of findings
Cognition								
273 (1)	Cross-sectional	Serious risk of bias	N/A	No serious indirectness	Serious imprecision	None	Very Low	N=1/1 report showed beneficial associations between PA and cognition.
1,364 (1)	Longitudinal	Very serious risk of bias	N/A	No serious indirectness	No serious imprecision	None	Very Low	N=1/1 report showed detrimental associations between PA and cognition.
21,742 (4)	RCT	Serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	None	Moderate	N=2/4 reports showed beneficial associations between PA and cognition. N=2/4 reports showed null findings.
Academic Achievement								
4,473 (7)	Cross-sectional	Serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	None	Very Low	N=3/7 reports showed beneficial associations between PA and academic achievement. N=2/7 reports showed null findings. N=1/7 reports showed detrimental associations between PA and academic achievement. N=1/7 reports showed beneficial associations between PA and academic achievement for boys and null for girls.

Subjects (reports)	Study Design	Risk of Bias	Inconsistency	Indirectness	Imprecision	Other	Overall quality of the Evidence	Summary of findings
18,831 (6)	Longitudinal	Serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	None	Very Low	N=4/6 reports showed beneficial associations between PA and academic achievement. N=1/6 reports showed null findings. N=1/6 reports showed beneficial associations between PA and academic achievement for boys and detrimental for girls.
2,399 (4)	RCT	Very serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	None	Moderate	N=2/4 reports showed beneficial associations between PA and academic achievement. N=2/4 reports showed null findings.

Table 10. Quality and summary of the evidence on the association between sedentary behaviours and cognition and academic achievement, in children and adolescents.

Subjects (reports)	Study Design	Risk of Bias	Inconsistency	Indirectness	Imprecision	Other	Overall quality of the Evidence	Summary of findings
Cognition								
1,364 (1)	Longitudinal	Very Serious risk of bias	N/A	No serious indirectness	No serious imprecision	None	Very Low	N=1/1 report showed beneficial associations between SB and cognition.
Academic Achievement								
2,832 (5)	Cross-sectional	Very serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	None	Very Low	N=3/5 reports showed null findings. N=2/5 reports showed beneficial associations between SB and academic achievement.
4,594 (2)	Longitudinal	Serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	None	Low	N=1/2 reports showed beneficial associations between SB and academic achievement.

Table 11. Quality and summary of the evidence on the association between sleep and academic achievement, in children and adolescents.

Subjects (reports)	Study Design	Risk of Bias	Inconsistency	Indirectness	Imprecision	Other	Overall quality of the Evidence	Summary of findings
Academic Achievement								
1,277 (1)	Cross-sectional	Serious risk of bias	N/A	No serious indirectness	No serious imprecision	None	Very Low	N=1/1 reports showed beneficial associations between Sleep and academic achievement.

Table 12. High-level summary of findings on the associations between movement behaviours and cognition and academic achievement.

Outcomes	Quality of the evidence	Number of reports	Summary of Findings		
			Beneficial Associations [a]	Null Findings	Detrimental Associations [b]
Cognition	Very Low to Moderate	7	4	2	1
Academic Achievement	Very Low to Moderate	25	15	8	2

[a] – Beneficial associations in at least one group of participants (example, gender)

[b] – Detrimental associations in at least one group of participants (example, gender)

3.1 Study Characteristics

As showed in tables 1, 2, 3 and 4, the reports included in this review were conducted mainly in Europe (61%) and North America (22%), were published between 2013 and 2022. The included studies represented 48,558 participants, aged 6 to 18 years. The sample sizes of the included reports varied from 133 to 18,261 participants. Ten (44%) reports were cross-sectional, 8 (35%) longitudinal and 5 (21%) RCTs.

3.2 Main Results

Exposure: Sleep

Outcome: Cognition

There were no reports analysing the associations between **sleep** and **cognition**.

Outcome: Academic Achievement

There was one cross sectional report analysing the associations between **sleep** and **academic achievement**. The study of (Tapia-Serrano et al., 2022) showed beneficial associations between meeting sleep guidelines and AA. **(Table 3)**

Exposure: Sedentary behaviour

Outcome: Cognition

One report analysed the relation between **sedentary behaviour** and **cognition** (longitudinal). The report of (E. E. Wickel, 2017) showed beneficial associations between sedentary time and inhibition, working memory and fluid intelligence.

Outcome: Academic Achievement

Eight reports analysed the associations between **sedentary behaviour** and **academic achievement** (six cross-sectional and two longitudinal).

Observational reports

Among the cross-sectional reports, the reports of (Cosgrove & Castelli, 2018; Lopes et al., 2017; Tapia-Serrano et al., 2022) showed null associations between objectively measured sedentary behaviour and AA, while the report of (Correa-Burrows et al., 2014), (Maher et al., 2016) revealed beneficial associations. The report of (Syväoja et al., 2013) revealed detrimental associations between screen time and GPA. In addition, the reports of (Correa-Burrows et al., 2014) displayed beneficial associations between self-reported sedentary behaviour and academic scores in mathematics and language.

The report of (Hunter et al., 2018) showed null associations between total sedentary behaviour, computer use, emailing, phone texting and AA; detrimental associations between TV viewing or internet use and English AA and between communication-based sedentary behaviour and Maths AA; beneficial associations between TV viewing and maths AA and between doing homework and English AA. The other report revealed beneficial associations between self-reported sedentary behaviour and reading fluency, in boys (Haapala et al., 2014).

Overall, 43% of the reports showed null associations between sedentary behaviour and AA, and 29% beneficial associations between sedentary behaviour and AA. **(Table 4)**

Exposure: Physical Activity

Outcome: Cognition

The associations between **physical activity** and **cognition** were examined in six reports (one cross-sectional, one longitudinal, and four RCTs).

Observational Reports

As showed in table 2, only one cross-sectional report showed beneficial associations between objectively measured moderate or moderate-to-vigorous PA and attention capacity (Vanhelst et al., 2016). The only longitudinal report showed detrimental associations between objectively measured light PA and fluid intelligence in girls, and detrimental associations between vigorous PA and inhibition in boys (E. E. Wickel, 2017).

RCTs

As depicted in table 1, among the RCTs, the PA interventions ranged from three months to three years of duration; three assessed PA with accelerometer (Bartholomew et al., 2018; Hecht & Garber, 2021; Tarp et al., 2016) and one through self-report (Wassenaar et al., 2021).

Two RCTs reported null effects of PA intervention on cognitive performance – processing speed, visual-relational memory performance, inhibitory control, working memory performance, and cognitive flexibility (Wassenaar et al., 2021) and on inhibition – response accuracy or reaction time on congruent and incongruent trials, and for accuracy interference scores (Tarp et al., 2016). However, a detrimental effect was found, in the PA group compared to controls, on reaction time interference scores (Tarp et al., 2016).

Two RCTs reported beneficial effects in PA group compared to controls on time-on-task (Bartholomew et al., 2018) and executive functioning (Hecht & Garber, 2021)

Overall, 50% of the reports showed beneficial associations between PA and cognitions, and 33% null associations.

Outcome: Academic Achievement

Seventeen reports analysed the associations between **physical activity** and **academic achievement** (seven cross-sectional, six longitudinal, and four RCTs).

Observational reports

Among the cross-sectional reports, four showed null associations between objectively measured MVPA and grade point average (GPA) (Bueno et al., 2021; Cosgrove & Castelli, 2018; Syväoja et al., 2013) or language, reading and spelling performance (Maher et al., 2016)

Three studies reported detrimental associations between objectively measured very vigorous PA and GPA (Cosgrove & Castelli, 2018), between objectively measured moderate PA, vigorous PA and MVPA and academic performance indicators (Esteban-Cornejo et al., 2014).

The report of (Tapia-Serrano et al., 2022) showed beneficial associations between meeting PA guidelines and AA, one report showed beneficial associations between objectively measured MVPA and academic domains of writing and numeracy (Maher et al., 2016).

Among the longitudinal reports, one showed null associations between objectively measured MVPA and AA (Elish et al., 2022) and one report showed beneficial associations between objectively measured total PA and academic performance (Muntaner-Mas et al., 2021). Another report showed beneficial associations between self-reported participation in sports activities and academic performance and detrimental associations between the non-participation and academic performance (Ishihara et al., 2020). The report of (Syväoja et al., 2013) showed beneficial associations between MVPA and AA.

The report of (Booth et al., 2014) showed beneficial associations between objectively measured MVPA and science's grades only for girls and math's grades for boys and girls. The report of (Kari et al., 2017) showed beneficial associations between being physically active and GPA only for girls, and between being physically active and educational attainment for boys and girls. One report

revealed beneficial associations between self-reported total PA or active school transportation and reading fluency and comprehension, in boys, and detrimental associations for reading fluency and comprehension or arithmetic skills, in girls (Haapala et al., 2014)

RCTs

Among the RCTs, the PA interventions ranged from three to nine months of duration and all assessed PA through accelerometery. Two RCTs reported null effects of PA intervention on math skills (Tarp et al., 2016) or maths performance (Hecht & Garber, 2021). Two RCTs reported beneficial effects in PA group compared to controls on math skills (Have et al., 2018) or academic performance, particularly in boys (Resaland et al., 2018).

Overall, out of 17 reports, 53% showed beneficial associations between PA and AA and 29% null findings. **(Table 1 and 2)**

4. Discussion

4.1 Academic Achievement

The results indicate a beneficial association between PA, AA and cognition. Our results are with abidance with the increasing evidence that higher levels of PA are associated with a better AA in children and adolescents. However, our findings suggest that some types and intensities of PA were associated with even better results (Haapala et al., 2014)**.** PA has been shown to impact AA by modifying both function and structure of the brain. (Davis et al., 2011; Donnelly et al., 2017), although this physiological response can justify some of the results, it has been shown that PA also acts in a psychological manner, by enhancing the enjoyment of academic lessons, improve academic motivation (Vazou & Smiley-Oyen, 2014) and increase the engagement with academic materials (Grieco et al., 2016)**.** PA integrated in the curriculum showed improvements in decreasing social gradients in academic performance and that helps children in need of adapted education to benefit the most. (Resaland et al., 2018)**.** Engaging in PA was positively associated with improvement of academic performance, and those associations were mediated by cardiorespiratory fitness gains. (Ishihara et al., 2020). We discover that the most beneficial associations appeared when children and adolescents met all the PA guidelines (Tapia-Serrano et al., 2022), or when some type of active class protocol was used in the intervention; however, when protocols used MVPA and vigorous PA the results were beneficial only in some class subjects, they were often null or even detrimental. Although these associations were weak, these results may indicate that more physically active children and adolescents are, less time they spent on studying. (Esteban-Cornejo et al., 2014).

Since the most active children had approximately 1.5 more years of education in adulthood compared with their least active counterpart (Kari et al., 2017), it is also possible to assume, that engaging in PA is particularly important in disadvantaged families.

Some of the studies (Estrada-Tenorio et al., 2020) showed considerable differences in the results between genders, suggesting that further investigation regarding the underlying mechanisms would be important disclose the potential for gender responses. These results highlight the need to provide the school system with the tools that guarantee boys and girls equal education opportunities. We can assume that PA can contribute to decrease social gradients and benefit the children in need of higher levels of attention and concern.

Concerning sedentary behaviour, the majority of the studies showed beneficial or null associations the only negative outcome was when screen time sedentary behaviour was studied. However, most studies assessed the total amount of time spent in sedentary behaviour and not the several types of sedentary behaviour. Indeed, some studies indicate that sedentary behaviour spent reading and doing homework may be beneficial for AA.

We can conclude that more time spent in sedentary behaviour, related with academic skills, was linked to better grades, these findings support the Time Displacement Theory. Time Displacement Theory suggests that the time spent in front of the screen may simply relocate time spent in other activities such as doing homework or reading books, which may independently affect academic performance (Sharif et al., 2010). In general, some factors such engagement in lessons, parent involvement, study habits and school attendance can contribute in a large way to these results.

4.2 Cognition

Regarding cognition, it has been shown, that increased sedentary behaviour from 9 to 15 years old, predicted a higher inhibition, working memory and fluid intelligence. (E. E. Wickel, 2017) These results contribute to the hypothesis that PA may displace time spent in activities that may benefit cognitive outcomes, (E. E. Wickel, 2017) but evidence suggests PA and school based extra activities are able to coexist. (Atkin et al., 2008; Ruiz et al., 2010).

In respect of PA, our results are in conformity with the evidence on the subject, PA has demonstrated very positive effects on cognitive function in humans, (Ahrberg et al., 2012; Erickson et al., 2019). It is known that the two most important measures of cognition in children and adolescents are attention and concentration; these are indispensable elements in comprehension and learning processes. (Pesce et al., 2009). Experimental studies involving adolescent populations report improvements in some executive functions after structured exercise. (Eric E. Wickel, 2017).

In our review, children and adolescents spent more time on task after exercise (Bartholomew et al., 2018) and achieved better results in cognition-based tests.(Hecht & Garber, 2021; Vanhelst et al., 2016). Nevertheless, in girls, higher levels of light PA was found to be detrimental, and vigorous PA can be detrimental in boys (E. E. Wickel, 2017), especially in inhibition and fluid intelligence.

4.3 Sleep

Regarding Sleep, the results are concerning, given that there is a lack of evidence considering this movement behaviour. The amount of research using sleep in healthy population is scarce, and therefore no conclusions can be drawn at this point in time.

5. Strengths and Limitations

The strengths of our systematic review include the fact that we counted in all papers published so far, potentially written in seven different languages, and included both subjective and objective assessment of the exposures.

Given the heterogeneity of the included studies, meta-analyses were not possible. In addition, the findings of this systematic review should be interpreted with caution given the various forms of assessment of both exposures and outcomes used in the included studies; the use of different cofounders and the fact that most of the studies were conducted in developed countries.

6. Conclusions

Overall, this systematic review showed that some evidence points out to the beneficial associations of PA on cognition and AA as well as for the detrimental effects of screen time. Although many inconsistent results were found for sedentary behaviour. The evidence regarding the associations of sleep duration and cognition and AA in children and adolescents is scarce and doesn't allow to draw conclusions.

The quality of the evidence of the studies reviewed varied from very low to moderate. More studies with stronger designs are needed to confirm or rule out our findings, particularly RCT's. Indeed, further efforts are needed to better understand the associations between movement behaviours and cognition and AA, mainly particularly well designed RCT's; additional research on the effects of sleep duration on cognition and AA; and further studies exploring the effects of different types of sedentary behaviour on cognition and AA.

The findings of this systematic review may help design better health and education policies.

BIBLIOGRAPHY

Adelantado-Renau, M., Moliner-Urdiales, D., Cavero-Redondo, I., Beltran-Valls, M. R., Martínez-Vizcaíno, V., & Álvarez-Bueno, C. (2019). Association Between Screen Media Use and Academic Performance Among Children and Adolescents: A Systematic Review and Meta-analysis. *JAMA Pediatr*, *173*(11), 1058-1067. https://doi.org/10.1001/jamapediatrics.2019.3176

Aggio, D., Smith, L., Fisher, A., & Hamer, M. (2016). Context-Specific Associations of Physical Activity and Sedentary Behavior With Cognition in Children. *Am J Epidemiol*, *183*(12), 1075-1082. https://doi.org/10.1093/aje/kww031

Ahrberg, K., Dresler, M., Niedermaier, S., Steiger, A., & Genzel, L. (2012). The interaction between sleep quality and academic performance. *J Psychiatr Res*, *46*(12), 1618-1622. https://doi.org/10.1016/j.jpsychires.2012.09.008

Arora, T., & Grey, I. (2019). Chapter 31 - Sleep, obesity and cardiometabolic disease in children and adolescents. In M. A. Grandner (Ed.), *Sleep and Health* (pp. 421-433). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-815373-4.00031-9

Atkin, A. J., Gorely, T., Biddle, S. J., Marshall, S. J., & Cameron, N. (2008). Critical hours: physical activity and sedentary behavior of adolescents after school. *Pediatr Exerc Sci*, *20*(4), 446-456. https://doi.org/10.1123/pes.20.4.446

Balshem, H., Helfand, M., Schunemann, H. J., Oxman, A. D., Kunz, R., Brozek, J., Vist, G. E., Falck-Ytter, Y., Meerpohl, J., Norris, S., & Guyatt, G. H. (2011). GRADE guidelines: 3. Rating the quality of evidence. *J Clin Epidemiol*, *64*(4), 401-406. https://doi.org/10.1016/j.jclinepi.2010.07.015

Barbosa, A., Whiting, S., Simmonds, P., Scotini Moreno, R., Mendes, R., & Breda, J. (2020). Physical Activity and Academic Achievement: An Umbrella Review. *Int J Environ Res Public Health*, *17*(16). https://doi.org/10.3390/ijerph17165972

Baron, K. G., & Culnan, E. (2019). Sleep and healthy decision making. In *Sleep and health.* (pp. 359-369). Elsevier Academic Press. https://doi.org/10.1016/B978-0-12-815373-4.00027-7

Bartholomew, J. B., Golaszewski, N. M., Jowers, E., Korinek, E., Roberts, G., Fall, A., & Vaughn, S. (2018). Active learning improves on-task behaviors in 4th grade children. *Prev Med*, *111*, 49-54. https://doi.org/10.1016/j.ypmed.2018.02.023

Batty, G. D., Deary, I. J., & Gottfredson, L. S. (2007). Premorbid (early life) IQ and later mortality risk: systematic review. *Ann Epidemiol*, *17*(4), 278-288. https://doi.org/10.1016/j.annepidem.2006.07.010

Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Dev*, *81*(6), 1641-1660. https://doi.org/10.1111/j.1467-8624.2010.01499.x

Bidzan-Bluma, I., & Lipowska, M. (2018). Physical Activity and Cognitive Functioning of Children: A Systematic Review. *Int J Environ Res Public Health*, *15*(4). https://doi.org/10.3390/ijerph15040800

Booth, J. N., Leary, S. D., Joinson, C., Ness, A. R., Tomporowski, P. D., Boyle, J. M., & Reilly, J. J. (2014). Associations between objectively measured physical activity and academic attainment in adolescents from a UK cohort. *Br J Sports Med*, *48*(3), 265-270. https://doi.org/10.1136/bjsports-2013-092334

Bueno, M. R. O., Zambrin, L. F., Panchoni, C., Werneck, A. O., Fernandes, R. A., Serassuelo, H., Jr., Romanzini, M., & Ronque, E. R. V. (2021). Association Between Device-Measured Moderate-to-Vigorous Physical Activity and Academic Performance in Adolescents. *Health Educ Behav*, *48*(1), 54-62. https://doi.org/10.1177/1090198120954390

Calvin, C. M., Batty, G. D., Der, G., Brett, C. E., Taylor, A., Pattie, A., Čukić, I., & Deary, I. J. (2017). Childhood intelligence in relation to major causes of death in 68 year follow-up: prospective population study. *BMJ*, *357*, j2708. https://doi.org/10.1136/bmj.j2708

Carskadon, M., & Dement, W. (1989). Normal Human Sleep: An Overview. Principles and Practice of Sleep Medicine. M.H. Kryger (Ed.). *W.B. Saunders, Philadelphia*, 3-13.

Carskadon, M. A. (1990). Patterns of sleep and sleepiness in adolescents. *Pediatrician*, *17*(1), 5-12.

Carson, V., Hunter, S., Kuzik, N., Gray, C. E., Poitras, V. J., Chaput, J.-P., Saunders, T. J., Katzmarzyk, P. T., Okely, A. D., Connor Gorber, S., Kho, M. E., Sampson, M., Lee, H., & Tremblay, M. S. (2016). Systematic review of sedentary behaviour and health indicators in school-aged children and youth: an update. *Applied Physiology, Nutrition & Metabolism*, *41*, S240-S265. http://ezproxy.uow.edu.au/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=116280613&site=ehost-live

Carson, V., Hunter, S., Kuzik, N., Wiebe, S. A., Spence, J. C., Friedman, A., Tremblay, M. S., Slater, L., & Hinkley, T. (2016). Systematic review of physical activity and cognitive development in early childhood. *J Sci Med Sport*, *19*(7), 573-578. https://doi.org/10.1016/j.jsams.2015.07.011

Carson, V., Lee, E. Y., Hewitt, L., Jennings, C., Hunter, S., Kuzik, N., Stearns, J. A., Unrau, S. P., Poitras, V. J., Gray, C., Adamo, K. B., Janssen, I., Okely, A. D., Spence, J. C., Timmons, B. W., Sampson, M., & Tremblay, M. S. (2017). Systematic review of the relationships between physical activity and health indicators in the early years (0-4 years). *BMC Public Health*, *17*(Suppl 5), 854. https://doi.org/10.1186/s12889-017-4860-0

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep*, *100*(2), 126-131.

Cattell, R. B. (1987). *Intelligence: Its structure, growth and action*. North-Holland.

Chaput, J.-P., Willumsen, J., Bull, F., Chou, R., Ekelund, U., Firth, J., Jago, R., Ortega, F. B., & Katzmarzyk, P. T. (2020). 2020 WHO guidelines on physical activity and sedentary behaviour for children and adolescents aged 5–17 years: summary of the evidence. *International Journal of Behavioral Nutrition and Physical Activity*, *17*(1), 141. https://doi.org/10.1186/s12966-020-01037-z

Chaput, J. P., Gray, C. E., Poitras, V. J., Carson, V., Gruber, R., Birken, C. S., MacLean, J. E., Aubert, S., Sampson, M., & Tremblay, M. S. (2017).

Systematic review of the relationships between sleep duration and health indicators in the early years (0-4 years). *BMC Public Health*, *17*(Suppl 5), 855. https://doi.org/10.1186/s12889-017-4850-2

Chaput, J. P., Gray, C. E., Poitras, V. J., Carson, V., Gruber, R., Olds, T., Weiss, S. K., Connor Gorber, S., Kho, M. E., Sampson, M., Belanger, K., Eryuzlu, S., Callender, L., & Tremblay, M. S. (2016). Systematic review of the relationships between sleep duration and health indicators in school-aged children and youth. *Appl Physiol Nutr Metab*, *41*(6 Suppl 3), S266-282. https://doi.org/10.1139/apnm-2015-0627

Chaput, J. P., Saunders, T. J., & Carson, V. (2017). Interactions between sleep, movement and other non-movement behaviours in the pathogenesis of childhood obesity. *Obes Rev*, *18 Suppl 1*, 7-14. https://doi.org/10.1111/obr.12508

Correa-Burrows, P., Burrows, R., Orellana, Y., & Ivanovic, D. (2014). Achievement in mathematics and language is linked to regular physical activity: a population study in Chilean youth. *J Sports Sci*, *32*(17), 1631-1638. https://doi.org/10.1080/02640414.2014.910606

Cosgrove, J., & Castelli, D. (2018). Physical Activity and Academic Performance Among Adolescents in Low-SES Schools. *American Journal of Health Education*, *49*, 1-7. https://doi.org/10.1080/19325037.2018.1516167

Curcio, G., Ferrara, M., & De Gennaro, L. (2006). Sleep loss, learning capacity and academic performance. *Sleep Med Rev*, *10*(5), 323-337. https://doi.org/10.1016/j.smrv.2005.11.001

Davis, C. L., Tomporowski, P. D., McDowell, J. E., Austin, B. P., Miller, P. H., Yanasak, N. E., Allison, J. D., & Naglieri, J. A. (2011). Exercise improves executive function and achievement and alters brain activation in overweight children: a randomized, controlled trial. *Health Psychol*, *30*(1), 91-98. https://doi.org/10.1037/a0021766

Deary, I. J., Penke, L., & Johnson, W. (2010). The neuroscience of human intelligence differences. *Nat Rev Neurosci*, *11*(3), 201-211. https://doi.org/10.1038/nrn2793

Dhakal, A., & Bobrin, B. D. (2023). Cognitive Deficits. In *StatPearls*. StatPearls Publishing

Donnelly, J. E., Hillman, C. H., Greene, J. L., Hansen, D. M., Gibson, C. A., Sullivan, D. K., Poggio, J., Mayo, M. S., Lambourne, K., Szabo-Reed, A. N., Herrmann, S. D., Honas, J. J., Scudder, M. R., Betts, J. L., Henley, K., Hunt, S. L., & Washburn, R. A. (2017). Physical activity and academic achievement across the curriculum: Results from a 3-year cluster-randomized trial. *Prev Med*, *99*, 140-145. https://doi.org/10.1016/j.ypmed.2017.02.006

Elish, P. N., Bryan, C. S., Boedeker, P. J., Calvert, H. G., Kay, C. M., Meyer, A. M., & Gazmararian, J. A. (2022). The longitudinal association between objectively-measured school-day physical activity and academic achievement in US elementary school students. *International Journal of Behavioral Nutrition and Physical Activity*, *19*(1), 90. https://doi.org/10.1186/s12966-022-01328-7

Ennemoser, M., & Schneider, W. (2007). Relations of television viewing and reading: Findings from a 4-year longitudinal study. *Journal of Educational Psychology*, *99*, 349-368. https://doi.org/10.1037/0022-0663.99.2.349

Erickson, K. I., Hillman, C., Stillman, C. M., Ballard, R. M., Bloodgood, B., Conroy, D. E., Macko, R., Marquez, D. X., Petruzzello, S. J., & Powell, K. E. (2019). Physical Activity, Cognition, and Brain Outcomes: A Review of the 2018 Physical Activity Guidelines. *Med Sci Sports Exerc*, *51*(6), 1242-1251. https://doi.org/10.1249/mss.0000000000001936

Espinoza, F. (2009). Using Project-Based Data in Physics to Examine Television Viewing in Relation to Student Performance in Science. *Journal of Science Education and Technology*, *18*, 458-465. https://doi.org/10.1007/s10956-009-9163-5

Esteban-Cornejo, I., Tejero-González, C. M., Martinez-Gomez, D., Cabanas-Sánchez, V., Fernández-Santos, J. R., Conde-Caveda, J., Sallis, J. F., & Veiga, O. L. (2014). Objectively measured physical activity has a negative but weak association with academic performance in children

and adolescents. *Acta Paediatr*, *103*(11), e501-506. https://doi.org/10.1111/apa.12757

Estrada-Tenorio, S., Julián, J. A., Aibar, A., Martín-Albo, J., & Zaragoza, J. (2020). Academic Achievement and Physical Activity: The Ideal Relationship to Promote a Healthier Lifestyle in Adolescents. *J Phys Act Health*, *17*(5), 525-532. https://doi.org/10.1123/jpah.2019-0320

Evans, J. S. B. T., & Stanovich, K. E. (2013). Dual-Process Theories of Higher Cognition:Advancing the Debate. *Perspectives on Psychological Science*, *8*(3), 223-241. https://doi.org/10.1177/1745691612460685

Fallone, G., Owens, J. A., & Deane, J. (2002). Sleepiness in children and adolescents: clinical implications. *Sleep Med Rev*, *6*(4), 287-306. https://doi.org/10.1053/smrv.2001.0192

Gottfredson, L. S., & Deary, I. J. (2004). Intelligence Predicts Health and Longevity, but Why? *Current Directions in Psychological Science*, *13*(1), 1-4. https://doi.org/10.1111/j.0963-7214.2004.01301001.x

Grandner, M. A. (2017). Sleep, Health, and Society. *Sleep Med Clin*, *12*(1), 1-22. https://doi.org/10.1016/j.jsmc.2016.10.012

Grieco, L. A., Jowers, E. M., Errisuriz, V. L., & Bartholomew, J. B. (2016). Physically active vs. sedentary academic lessons: A dose response study for elementary student time on task. *Prev Med*, *89*, 98-103. https://doi.org/10.1016/j.ypmed.2016.05.021

Guyatt, G. H., Oxman, A. D., Kunz, R., Brozek, J., Alonso-Coello, P., Rind, D., Devereaux, P. J., Montori, V. M., Freyschuss, B., Vist, G., Jaeschke, R., Williams, J. W., Jr., Murad, M. H., Sinclair, D., Falck-Ytter, Y., Meerpohl, J., Whittington, C., Thorlund, K., Andrews, J., & Schunemann, H. J. (2011). GRADE guidelines 6. Rating the quality of evidence--imprecision. *J Clin Epidemiol*, *64*(12), 1283-1293. https://doi.org/10.1016/j.jclinepi.2011.01.012

Guyatt, G. H., Oxman, A. D., Kunz, R., Woodcock, J., Brozek, J., Helfand, M., Alonso-Coello, P., Falck-Ytter, Y., Jaeschke, R., Vist, G., Akl, E. A., Post, P. N., Norris, S., Meerpohl, J., Shukla, V. K., Nasser, M., Schunemann, H. J., & Group, G. W. (2011). GRADE guidelines: 8. Rating the quality of

evidence--indirectness. *J Clin Epidemiol*, *64*(12), 1303-1310. https://doi.org/10.1016/j.jclinepi.2011.04.014

Guyatt, G. H., Oxman, A. D., Kunz, R., Woodcock, J., Brozek, J., Helfand, M., Alonso-Coello, P., Glasziou, P., Jaeschke, R., Akl, E. A., Norris, S., Vist, G., Dahm, P., Shukla, V. K., Higgins, J., Falck-Ytter, Y., Schunemann, H. J., & Group, G. W. (2011). GRADE guidelines: 7. Rating the quality of evidence--inconsistency. *J Clin Epidemiol*, *64*(12), 1294-1302. https://doi.org/10.1016/j.jclinepi.2011.03.017

Guyatt, G. H., Oxman, A. D., Montori, V., Vist, G., Kunz, R., Brozek, J., Alonso-Coello, P., Djulbegovic, B., Atkins, D., Falck-Ytter, Y., Williams, J. W., Jr., Meerpohl, J., Norris, S. L., Akl, E. A., & Schunemann, H. J. (2011). GRADE guidelines: 5. Rating the quality of evidence--publication bias. *J Clin Epidemiol*, *64*(12), 1277-1282. https://doi.org/10.1016/j.jclinepi.2011.01.011

Guyatt, G. H., Oxman, A. D., Sultan, S., Glasziou, P., Akl, E. A., Alonso-Coello, P., Atkins, D., Kunz, R., Brozek, J., Montori, V., Jaeschke, R., Rind, D., Dahm, P., Meerpohl, J., Vist, G., Berliner, E., Norris, S., Falck-Ytter, Y., Murad, M. H., . . . Group, G. W. (2011). GRADE guidelines: 9. Rating up the quality of evidence. *J Clin Epidemiol*, *64*(12), 1311-1316. https://doi.org/10.1016/j.jclinepi.2011.06.004

Guyatt, G. H., Oxman, A. D., Vist, G., Kunz, R., Brozek, J., Alonso-Coello, P., Montori, V., Akl, E. A., Djulbegovic, B., Falck-Ytter, Y., Norris, S. L., Williams, J. W., Jr., Atkins, D., Meerpohl, J., & Schunemann, H. J. (2011). GRADE guidelines: 4. Rating the quality of evidence--study limitations (risk of bias). *J Clin Epidemiol*, *64*(4), 407-415. https://doi.org/10.1016/j.jclinepi.2010.07.017

Haapala, E. A., Poikkeus, A. M., Kukkonen-Harjula, K., Tompuri, T., Lintu, N., Väistö, J., Leppänen, P. H., Laaksonen, D. E., Lindi, V., & Lakka, T. A. (2014). Associations of physical activity and sedentary behavior with academic skills--a follow-up study among primary school children. *PLoS One*, *9*(9), e107031. https://doi.org/10.1371/journal.pone.0107031

Have, M., Nielsen, J. H., Ernst, M. T., Gejl, A. K., Fredens, K., Grøntved, A., & Kristensen, P. L. (2018). Classroom-based physical activity improves

children's math achievement - A randomized controlled trial. *PLoS One*, *13*(12), e0208787. https://doi.org/10.1371/journal.pone.0208787

Hecht, M. F., & Garber, C. E. (2021). Effectiveness of the POWER Program in Improving Physical Activity and Executive Function in Fifth Grade Students. *J Sch Health*, *91*(7), 574-583. https://doi.org/10.1111/josh.13035

Hunter, S., Leatherdale, S. T., & Carson, V. (2018). The 3-Year Longitudinal Impact of Sedentary Behavior on the Academic Achievement of Secondary School Students. *J Sch Health*, *88*(9), 660-668. https://doi.org/10.1111/josh.12672

Ishihara, T., Nakajima, T., Yamatsu, K., Okita, K., Sagawa, M., & Morita, N. (2020). Relationship of participation in specific sports to academic performance in adolescents: A 2-year longitudinal study. *Scand J Med Sci Sports*, *30*(8), 1471-1482. https://doi.org/10.1111/sms.13703

Jackson, L., Eye, A., Witt, E., Zhao, Y., & Fitzgerald, H. (2011). A longitudinal study of the effects of Internet use and videogame playing on academic performance and the roles of gender, race and income in these relationships. *Computers in Human Behavior*, *27*, 228–239. https://doi.org/10.1016/j.chb.2010.08.001

Janssen, I., & LeBlanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity*, *7*(1), 40. https://doi.org/10.1186/1479-5868-7-40

Kari, J. T., Pehkonen, J., Hutri-Kähönen, N., Raitakari, O. T., & Tammelin, T. H. (2017). Longitudinal Associations between Physical Activity and Educational Outcomes. *Med Sci Sports Exerc*, *49*(11), 2158-2166. https://doi.org/10.1249/mss.0000000000001351

Kohl, C., McIntosh, E. J., Unger, S., Haddaway, N. R., Kecke, S., Schiemann, J., & Wilhelm, R. (2018). Online tools supporting the conduct and reporting of systematic reviews and systematic maps: a case study on CADIMA and review of existing tools. *Environ Evid*, *7*(8).

Kuncel, N. R., & Hezlett, S. A. (2010). Fact and Fiction in Cognitive Ability Testing for Admissions and Hiring Decisions. *Current Directions in*

Psychological Science, *19*(6), 339-345. https://doi.org/10.1177/0963721410389459

Lopes, L., Santos, R., Mota, J., Pereira, B., & Lopes, V. (2017). Objectively measured sedentary time and academic achievement in schoolchildren. *J Sports Sci*, *35*(5), 463-469. https://doi.org/10.1080/02640414.2016.1172724

Lövdén, M., Fratiglioni, L., Glymour, M. M., Lindenberger, U., & Tucker-Drob, E. M. (2020). Education and Cognitive Functioning Across the Life Span. *Psychological Science in the Public Interest*, *21*(1), 6-41. https://doi.org/10.1177/1529100620920576

Maher, C., Lewis, L., Katzmarzyk, P. T., Dumuid, D., Cassidy, L., & Olds, T. (2016). The associations between physical activity, sedentary behaviour and academic performance. *J Sci Med Sport*, *19*(12), 1004-1009. https://doi.org/10.1016/j.jsams.2016.02.010

Mandolesi, L., Polverino, A., Montuori, S., Foti, F., Ferraioli, G., Sorrentino, P., & Sorrentino, G. (2018). Effects of Physical Exercise on Cognitive Functioning and Wellbeing: Biological and Psychological Benefits. *Front Psychol*, *9*, 509. https://doi.org/10.3389/fpsyg.2018.00509

Mössle, T., Kleimann, M., Rehbein, F., & Pfeiffer, C. (2010). Media use and school achievement--boys at risk? *Br J Dev Psychol*, *28*(Pt 3), 699-725. https://doi.org/10.1348/026151009x475307

Muntaner-Mas, A., Martínez-Gómez, D., Castro-Piñero, J., Fernandez-Santos, J. R., Salmon, J., Veiga Ó, L., & Esteban-Cornejo, I. (2021). Objectively measured physical activity and academic performance in school-aged youth: The UP&DOWN longitudinal study. *Scand J Med Sci Sports*, *31*(12), 2230-2240. https://doi.org/10.1111/sms.14036

Owens, J. (2014). Insufficient sleep in adolescents and young adults: an update on causes and consequences. *Pediatrics*, *134*(3), e921-932. https://doi.org/10.1542/peds.2014-1696

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., . . . Moher, D. (2021).

The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, *372*, n71. https://doi.org/10.1136/bmj.n71

Peng, P., Barnes, M., Wang, C., Wang, W., Li, S., Swanson, H. L., Dardick, W., & Tao, S. (2018). A meta-analysis on the relation between reading and working memory. *Psychol Bull*, *144*(1), 48-76. https://doi.org/10.1037/bul0000124

Peng, P., & Kievit, R. A. (2020). The Development of Academic Achievement and Cognitive Abilities: A Bidirectional Perspective. *Child Dev Perspect*, *14*(1), 15-20. https://doi.org/10.1111/cdep.12352

Pesce, C., Crova, C., Cereatti, L., Casella, R., & Bellucci, M. (2009). Physical activity and mental performance in preadolescents: Effects of acute exercise on free-recall memory. *Mental Health and Physical Activity*, *2*(1), 16-22. https://doi.org/https://doi.org/10.1016/j.mhpa.2009.02.001

Poitras, V. J., Gray, C. E., Borghese, M. M., Carson, V., Chaput, J. P., Janssen, I., Katzmarzyk, P. T., Pate, R. R., Connor Gorber, S., Kho, M. E., Sampson, M., & Tremblay, M. S. (2016). Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Appl Physiol Nutr Metab*, *41*(6 Suppl 3), S197-239. https://doi.org/10.1139/apnm-2015-0663

Poitras, V. J., Gray, C. E., Janssen, X., Aubert, S., Carson, V., Faulkner, G., Goldfield, G. S., Reilly, J. J., Sampson, M., & Tremblay, M. S. (2017). Systematic review of the relationships between sedentary behaviour and health indicators in the early years (0-4 years). *BMC Public Health*, *17*(Suppl 5), 868. https://doi.org/10.1186/s12889-017-4849-8

Resaland, G. K., Moe, V. F., Bartholomew, J. B., Andersen, L. B., McKay, H. A., Anderssen, S. A., & Aadland, E. (2018). Gender-specific effects of physical activity on children's academic performance: The Active Smarter Kids cluster randomized controlled trial. *Prev Med*, *106*, 171-176. https://doi.org/10.1016/j.ypmed.2017.10.034

Rollo, S., Antsygina, O., & Tremblay, M. S. (2020). The whole day matters: Understanding 24-hour movement guideline adherence and relationships with health indicators across the lifespan. *Journal of Sport and Health*

Science, *9*(6), 493-510. https://doi.org/https://doi.org/10.1016/j.jshs.2020.07.004

Ruiz, J. R., Ortega, F. B., Castillo, R., Martín-Matillas, M., Kwak, L., Vicente-Rodríguez, G., Noriega, J., Tercedor, P., Sjöström, M., & Moreno, L. A. (2010). Physical activity, fitness, weight status, and cognitive performance in adolescents. *J Pediatr*, *157*(6), 917-922.e911-915. https://doi.org/10.1016/j.jpeds.2010.06.026

Satterfield, B. C., & Killgore, W. D. S. (2019). Chapter 26 - Sleep loss, executive function, and decision-making. In M. A. Grandner (Ed.), *Sleep and Health* (pp. 339-358). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-815373-4.00026-5

Sharif, I., & Sargent, J. D. (2006). Association between television, movie, and video game exposure and school performance. *Pediatrics*, *118*(4), e1061-1070. https://doi.org/10.1542/peds.2005-2854

Sharif, I., Wills, T. A., & Sargent, J. D. (2010). Effect of visual media use on school performance: a prospective study. *J Adolesc Health*, *46*(1), 52-61. https://doi.org/10.1016/j.jadohealth.2009.05.012

Sternberg, R. J., Grigorenko, E. L., & Zhang, L.-f. (2008). Styles of Learning and Thinking Matter in Instruction and Assessment. *Perspectives on Psychological Science*, *3*(6), 486-506. https://doi.org/10.1111/j.1745-6924.2008.00095.x

Sternberg, R. J., Kaufman, J. C., & Grigorenko, E. L. (2008). *Applied Intelligence*. Cambridge University Press. https://doi.org/DOI: 10.1017/CBO9780511611445

Syväoja, H. J., Kantomaa, M. T., Ahonen, T., Hakonen, H., Kankaanpää, A., & Tammelin, T. H. (2013). Physical activity, sedentary behavior, and academic performance in Finnish children. *Med Sci Sports Exerc*, *45*(11), 2098-2104. https://doi.org/10.1249/MSS.0b013e318296d7b8

Tapia-Serrano, M. A., García-Hermoso, A., Sevil-Serrano, J., Sánchez-Oliva, D., & Sánchez-Miguel, P. A. (2022). Is adherence to 24-Hour Movement Guidelines associated with a higher academic achievement among adolescent males and females? *J Sci Med Sport*, *25*(2), 155-161. https://doi.org/10.1016/j.jsams.2021.09.005

Tarp, J., Domazet, S. L., Froberg, K., Hillman, C. H., Andersen, L. B., & Bugge, A. (2016). Effectiveness of a School-Based Physical Activity Intervention on Cognitive Performance in Danish Adolescents: LCoMotion-Learning, Cognition and Motion - A Cluster Randomized Controlled Trial. *PLoS One*, *11*(6), e0158087. https://doi.org/10.1371/journal.pone.0158087

Timmons, B. W., Leblanc, A. G., Carson, V., Connor Gorber, S., Dillman, C., Janssen, I., Kho, M. E., Spence, J. C., Stearns, J. A., & Tremblay, M. S. (2012). Systematic review of physical activity and health in the early years (aged 0-4 years) [Review]. *Appl Physiol Nutr Metab*, *37*(4), 773-792. https://doi.org/10.1139/h2012-070

Tremblay, M. S., Aubert, S., Barnes, J. D., Saunders, T. J., Carson, V., Latimer-Cheung, A. E., Chastin, S. F. M., Altenburg, T. M., & Chinapaw, M. J. M. (2017). Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act*, *14*(1), 75. https://doi.org/10.1186/s12966-017-0525-8

Tremblay, M. S., Aubert, S., Barnes, J. D., Saunders, T. J., Carson, V., Latimer-Cheung, A. E., Chastin, S. F. M., Altenburg, T. M., Chinapaw, M. J. M., Altenburg, T. M., Aminian, S., Arundell, L., Atkin, A. J., Aubert, S., Barnes, J., Barone Gibbs, B., Bassett-Gunter, R., Belanger, K., Biddle, S., . . . on behalf of, S. T. C. P. P. (2017). Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 75. https://doi.org/10.1186/s12966-017-0525-8

Tremblay, M. S., Chaput, J. P., Adamo, K. B., Aubert, S., Barnes, J. D., Choquette, L., Duggan, M., Faulkner, G., Goldfield, G. S., Gray, C. E., Gruber, R., Janson, K., Janssen, I., Janssen, X., Jaramillo Garcia, A., Kuzik, N., LeBlanc, C., MacLean, J., Okely, A. D., . . . Carson, V. (2017). Canadian 24-Hour Movement Guidelines for the Early Years (0-4 years): An Integration of Physical Activity, Sedentary Behaviour, and Sleep. *BMC Public Health*, *17*(Suppl 5), 874. https://doi.org/10.1186/s12889-017-4859-6

van der Maas, H. L., Dolan, C. V., Grasman, R. P., Wicherts, J. M., Huizenga, H. M., & Raijmakers, M. E. (2006). A dynamical model of general

intelligence: the positive manifold of intelligence by mutualism. *Psychol Rev*, *113*(4), 842-861. https://doi.org/10.1037/0033-295x.113.4.842

van Ekris, E., Altenburg, T. M., Singh, A. S., Proper, K. I., Heymans, M. W., & Chinapaw, M. J. (2016). An evidence-update on the prospective relationship between childhood sedentary behaviour and biomedical health indicators: a systematic review and meta-analysis. *Obes Rev*, *17*(9), 833-849. https://doi.org/10.1111/obr.12426

Vanhelst, J., Béghin, L., Duhamel, A., Manios, Y., Molnar, D., De Henauw, S., Moreno, L. A., Ortega, F. B., Sjöström, M., Widhalm, K., & Gottrand, F. (2016). Physical Activity Is Associated with Attention Capacity in Adolescents. *J Pediatr*, *168*, 126-131.e122. https://doi.org/10.1016/j.jpeds.2015.09.029

Vazou, S., & Smiley-Oyen, A. (2014). Moving and academic learning are not antagonists: acute effects on executive function and enjoyment. *J Sport Exerc Psychol*, *36*(5), 474-485. https://doi.org/10.1123/jsep.2014-0035

Wassenaar, T. M., Wheatley, C. M., Beale, N., Nichols, T., Salvan, P., Meaney, A., Atherton, K., Diaz-Ordaz, K., Dawes, H., & Johansen-Berg, H. (2021). The effect of a one-year vigorous physical activity intervention on fitness, cognitive performance and mental health in young adolescents: the Fit to Study cluster randomised controlled trial. *Int J Behav Nutr Phys Act*, *18*(1), 47. https://doi.org/10.1186/s12966-021-01113-y

Wickel, E. E. (2017). Sedentary Time, Physical Activity, and Executive Function in a Longitudinal Study of Youth. *J Phys Act Health*, *14*(3), 222-228. https://doi.org/10.1123/jpah.2016-0200

Wickel, E. E. (2017). Sedentary Time, Physical Activity, and Executive Function in a Longitudinal Study of Youth. *Journal of Physical Activity and Health*, *14*(3), 222-228. https://doi.org/10.1123/jpah.2016-0200

Wrulich, M., Brunner, M., Stadler, G., Schalke, D., Keller, U., & Martin, R. (2014). Forty years on: childhood intelligence predicts health in middle adulthood. *Health Psychol*, *33*(3), 292-296. https://doi.org/10.1037/a0030727