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European Master in Health and Physical Activity

Title of the Master Thesis

Physical activity and cognition in children in relation to academic performance

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Abstract

Background: The schools are demanding higher performance from their students and physical education is a subject that is easy to cut from the curriculum. As physical education steadily has declined since the 70s, the need to focus on the known benefits of physical activity in children is eminent. The aim of this paper is to look at the effects of physical activity and cognitive performance in school aged children and link is to the children's academic achievement.

Methods: A systematic search with pre-determined search terms was conducted using the electronic databases PubMed, SportDiscus and Web of Science searching for review studies on physical activity and cognitive function in a school based setting. The searched included school-aged children only, and only studies that included some form of physical activity intervention as well as a measure of cognitive function and academic achievement.

Results: Four review articles were included for review, two meta-analysis and two systematic reviews. The presented findings did not show a positive association between physical activity and academic performance. The studies report significant but weak relationship between physical activity and cognitive performance or a neutral association. None of the studies found negative effects of allocation academic time towards more physical activity during the school day.

Conclusion: The presented evidence cannot conclude in a positive relationship between physical activity and cognitive function. However given the positive outcome on children's health, there lies no apparent reason why physical activity should not be an important part of the school day in both recess and as activity breaks as well as normal physical education.

Keywords: COGNITION, EXECUTIVE FUNCTION, CHILDREN, PHYSICAL ACTIVITY, EXERCISE, ADOLESCENTS, ACADEMIC ACHIEVEMENT, INTELLIGENCE.

Table of contents

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Helle Nybø Waage

Abbreviations

5-HT	5-hydroxytryptamine aka Serotonin
ANS	Autonomic nervous system
APA	Aerobic physical activity
DLPFC	Dorsolateral prefrontal cortex
GPA	Grade point average
h.	Hour
HPA	Hypothalamic-pituitary-adrenal
Min.	Minutes
PA	Physical activity
PE	Physical education
RCT	Randomized control trials
SAS	Sympathoadrenal system
VO_{2max}	Maximum oxygen uptake

1. Introduction

A healthy mind in a healthy body is something we as humans aim for. The link between a physically active body and an intellectual mind was a well-known fact to the Ancient Greeks. Being overall healthy both in body and mind appears to be one of the key elements of having a good and happy life. Over the years scientists have enlightened us on the point that children as well as adults obtain numerous benefits from physical activity (PA). These advantages include improved cardiovascular function, metabolic function, improved fitness and better bone health (U.S department of health). Regardless of these known health benefits, many children worldwide fails meet PA recommendations even though the recommendation for children is only 60 minutes of moderate to vigorous physical activity daily (World Health Organization, 2011).

Physical activity in public schools has steadily declined since 1970 (Donnelly & Lambourne, 2011) and the number of obese and overweight children has increased drastically. Within Europe, Norwegian schools have some of the lowest allocated times set for physical education.

Scientists suggest that lack of physical activity might play an important role in the development of obesity. Ironically the schools in both the US and the rest of the western world appear to promote a sedentary lifestyle, where the children spend on average 6-8 hours a day in an academic institution (Donnelly & Lambourne, 2011).

Physical activity has long been suggested to have a positive effect on academic performance as it increases the blood circulation within the body and to the brain, as well as raising the levels of norepinephrine and endorphins. The effects of this might reduce stress, improve mood and possibly contributing to improve academic performance in children by providing a better learning environment (Taras, 2005). Although several studies indicate a positive outcome from physical activity in schools, there arrived some criticism in the 1990s from some parents claiming that physical education was harmful for the education and a waste of time and money (Shepard, 1997).

Other theories on why PA in schools became less popular came from anecdotal observations that told of over excited children in classes following PE, games or breaks with playing time. (Shepard, 1997) This overexcitement was believed to worsen classroom behaviour, concentration and in that manner reducing academic performance. (Shepard, 1997) This lead to an increase in studies to clarify if PE led to poorer concentration, but as the studies failed to show an impairment of academic performance following PA, the popularity of these kinds of studies sank (Tomporowski, 2003).

Most countries in the world have some sort of physical education in their national school system, and even though the health benefits from PA alone could justify this, campaigners for keeping and/or increasing PE are often met by arguments that PE is a waste of time, money and even harmful for academic process. A world health organization report from 2004 points out that PE is a threatened subject in all regions of the world (Hardman, 2004). Whereas economy is the most common reasons for these cuts, as PE lessons in general requires a higher cost than other subjects due to gym equipment and maintenance.

In regards to the known and suggested benefits of physical activity, I aim to show the importance of increasing the amount of physical activity in schools. Schools are a unique arena for studies and interventions on children and youth as they have the ability to reach almost 56 million youth's worldwide (U.S. Department of Health and Human Services, 2010). I will attempt to show that an increase in PA will not harm the children in regards to their academic performance, but that in fact in many cases more physical activity can show beneficial effects on the children.

1.1.1 Problem statement

In my dissertation I aim to look at school children. School is compulsory in most countries in the world for children and adolescents between the ages of 5 and 18. Children in this age group spend a large quantity of their day at school and they are therefore a group that is fairly easy to reach out to with interventions. I will be looking at potential relationships between physical activity and cognitive function and link it to children's academic performance.

1.1.2 Research question

1. Does more physical activity during the school day increase children's cognitive function?

2. Can the increase in cognitive function from this activity benefit children in relation to academic performance?

1.2 *Definition of terms*

1.2.1 Physical activity

Physical activity is defined as any bodily movement produced by skeletal muscles that result in energy expenditure (Caspersen, Powell & Christenson, 1985).
Exercise is a sub-set of physical activity that is planned, structured and repetitive and has as a final or an intermediate objective for the improvement or maintenance of physical fitness (Caspersen, *et* al. 1985). In this dissertation, the term exercise will be used in relation to regular or chronic physical activity rather than impulsive and acute bouts of physical activity unless otherwise specified. **Physical fitness** or fitness is a set of attributes that are either health- or skill-related, and can be measured by specific tests (Caspersen, *et* al. 1985). Most commonly talked about is cardiorespiratory fitness or aerobic fitness that is defined by the body's maximum oxygen uptake (VO_{2max}), (Caspersen, *et* al. 1985).The other components of physical fitness defined by Caspersen,

et al. (1985) is muscular endurance, muscular strength, body composition, and flexibility.

1.2.2 Cognition

Cognition originates from Latin and means "to know." Cognition as a concept can be seen as somewhat intangible and is often described as an umbrella term for aspects such as learning, reasoning, perception, intelligence, decision making, planning, information processing, executive function and attention (Zagrodnik, & Horvat, 2009). Cognition is most typically used to describe information processing and memory in humans (Davis & Lambourne, 2009). Cognition involves processes as attention, perception and problem solving. The cognitive processing includes both information processing and executive control (Davis & Lambourne, 2009). In relation to a student's ability to learn, cognition would refer to the student's capacity to learn through reasoning, perception, analysis, and judgement (Lees & Hopkins, 2013). In schools cognition is often measured through use of objective tests (Lees & Hopkins, 2013).

1.2.3 Executive function

Executive function is normally used when talking about various complex cognitive processes and sub processes. It is often used as an umbrella term to describe the cognitive processing required to co-ordinate sub processes in order to achieve a particular goal (Elliot, 2003). As the term suggests, executive function is like the brains administrator. Executive function deals with problem solving, modifying behaviour when new information is gathered, generating strategies, or when sequencing complex actions (Elliot, 2003). Executive function boils down to co-ordination, control and goal orientation as its main functions (Elliot, 2003).

1.2.4 Academic performance

Academic performance is a very broad term; in order to clarify it slightly I have chosen to divide academic performance into three main areas.

1. **Cognitive skills and attitudes** (e.g., attention, concentration, memory and verbal ability.)

2. **Academic behaviours** (e.g., conduct, attendance, time on task, and homework completion)
3. **Academic achievement** (e.g., standardized test scores, grades,) (U.S. Department of Health and Human Services; 2010).

2. Theory

When looking into the literature on exercise and cognition, the area has as a research field experienced an exponential growth over the last decade (Pesce, 2012). Pesce continues to suggest that the earliest studies on exercise and cognition were characterized by being too general when looking at the relationship between the two components. Exercise and cognition research have since then been grounded in theories of brain functioning and attention, and have been narrowed down to specific aspects of the exercise-cognition relationship (Pesce, 2012).

As the research shows trends towards being more specific it has become easier to identify the effects of physical exercise on cognition, both for acute and chronic exercise (Etnier & Chang, 2009, cited in Pesce, 2012). This research has also allowed the researchers to identify potential mediators and moderators acting on this relationship (Spirduso, Poon, & Chodzko-Zajko, 2008; Tomporowski, Lambourne & Okumura, 2011, in Pesce, 2012). The mediator works as a generating mechanism, through which physical exercise influences the cognitive functions, while the moderator is a variable that influences the strength and/or the direction of the exercise-cognition relationship (Pesce, 2012).

Acute and chronic exercises have both been widely used in interventions. It is however important to differ between the two, as they might induce different changes in the organism (Audiffren, 2009). As I have mentioned before, chronic exercise is something regular, rather than single bouts of exercise, and the effect is also different. In chronic exercise the physiological change arriving from it is more durable and can lead to anatomical changes in the brain structure, while the acute exercise is more transient and can lead to modulation of the activity in a neural network (Audiffren, 2009). Acute effects of exercise also differ from chronic by appearing quickly after the termination of the exercise and relatively quickly disappearing again (Audiffren, 2009).

Studies on aging humans have showed that endurance exercise can serve as a protector against cognitive decline (Ploughman, 2008). This protective mechanism is especially potent with respect to executive planning and working memory (Ploughman, 2008). Currently, there are many hypotheses working to explain the way exercise may affect cognitive performance. In the following part I will attempt to give an overview on the main hypotheses.

2.1 *Cognitive-energetic models*

Kahneman was the first to propose the cognitive-energetic model in 1974 in his book "Attention and Effort". Kahneman viewed the amount of resources available at any time as limited and dependent on the level of arousal (Kahneman 1973 cited in Audiffren 2009). The model proposes that the level of arousal is determined by (1) the demands imposed by the activities in which the organism engages in or prepares to engage in. (2) miscellaneous sources of arousal such as intensity of stimulations, psycho-stimulant effects of drugs, anxiety or acute effect of aerobic exercise (Audiffren 2009).

When trying to link Khaneman's model to the effects of exercise on cognition he brings up some important ideas. If exercise increases arousal levels, it also increases the amount of resources available to perform a connected cognitive task (Audiffren 2009). Processes that are resource limited are most likely improved by an arousing stressor, like acute exercise. Under-aroused participants in the rest or control condition are most likely to show improvements in performance in the aroused exercise state. In some experiments assessing the effects of exercise on cognition, the impairment in performance can be explained by the too high mental workload that is required by physical exercise (Audiffren 2009). Kahneman's model does however have one problem when tested, because of its uni-dimensional modelling of resources reservoir in which arousal and on-task effort are confounded (Audiffren 2009). This leads us over to Sanders model from 1983.

Sanders had a slightly different take on information processing and proposed a heuristic cognitive-energetic model of information processing (Sanders, 1981, 1983, 1998, cited in Audiffren 2009). In Sanders model arousal, activation and effort influence specific stages of information processing. According to Sanders model (cited in Audiffren 2009) the cognitive level is composed of four processing stages. The energetic level is composed by three energetic mechanisms that allocate processing resources and an evaluation level in which corresponds to an executive process. This executive process again manages processing resources.

The shift from a uni-dimensional conception of resources to a multidimensional perspective with three supply systems is the main differences between Kahneman's earlier model and Sanders' (Audiffren 2009). Linking Sanders model to acute aerobic exercise, we notice that the exercise might increase both arousal and activation mechanism and in that way modulate input and output processes. If both the cognitive task and the motor task require mental effort the exercise may influence the decisional process. This means that the decisional process might be slowed as the amount of effort needed to perform the cognitive task can be insufficient (Audiffren 2009).

2.2 *The reticular-activating hypofrontality (RAH) model of acute exercise*

According to the basic concept the RAH model the brain operates two largely independent cognitive systems to acquire and represent information. The **explicit** system is tied to conscious awareness, can be expressed verbally and is rule based. On the other hand, the **implicit** system is skilled or experience based, the content cannot be expressed verbally, but through task performance, and it is inaccessible to conscious awareness (Dietrich & Audiffren, 2011). As scientists make advances in cognitive neuroscience, they have begun to identify the circuits in the brain underlying the explicit system. Evidence from this research presents that the working memory buffer of the dorsolateral prefrontal cortex (DLPFC) holds the present content of consciousness, and the executive attentional network of the DLPFC is the mechanism to select content (Baddeley, 1996; Cowan 1995 in Dietrich & Audiffren 2011). This suggests that the explicit system is critically dependent on the pre frontal regions of the brain.

Animal research, brain-damaged patients and neuroimaging studies have shown that the two systems are different in both anatomy and function, and it is therefore indicated that they must be specialized in some way (Dietrich & Audiffren, 2011). The explicit system is understood to be the more sophisticated one, whereas the implicit seems to be primitive. The RAH model is based in three basic fundamental energetic principles in neuroscience;

1. The brain receives a continuous and limited supply of resources. The global cerebral metabolism is stable even though local changes in energy utilization occur.
2. Bodily motion is a bio computation of the highest order. The movement requires therefore substantial allocation of metabolic resources to the regions that control the movement. (I.e. motor, sensory, and autonomic.) The allocation of resources depends on two main factors, the quality of the muscle tissue involved in the motion, and the intensity of the motion.
3. Neural processing is competitive. Given the global cap on resources, local increases in the neural activity in some part of the brain must therefore be offset by associated decreases in others. Given the example of movement, the brain must shift metabolic resources, since the resources are limited, to the neural structures that sustain the movement. This leaves the brain with fewer resources in the regions that are computing functions that are not critically needed at the time (Dietrich & Audiffren, 2011).

In order to explain the psychological implications of the RAH model bases itself on three more fundamental principles; these are at the neurocognitive level.

4. Catecholamines and indolamines in the brain mediate arousal in humans and modulate information processing. Exercise is an arousing stressor and activates the brain monoamine systems mentioned above.
5. The brain operates on the two previous mentioned systems; implicit and explicit. The key argument here is the flexibility/efficiency tradeoff, which flows readily from an evolutionary analysis that considers the different formats each system uses for knowledge representation.
6. An overworked brain, from for example exercise or prolonged strenuous, full body motion will down-regulate in areas of the brain irrelevant to the motor task. This down-regulation works its way down the functional hierarchy starting with the most complex cognitive functions and down to the areas supporting basic functions. The first region to be affected would be the prefrontal cortex, making it less likely to be able to support sufficient activity to figure in phenomenology or any subsequent decision making process (Dietrich & Audiffren, 2011).

2.3 ***The neuroendocrinological explanation***

Cooper (1973) was the first to theorize a neuroendocrinological explanation for exercise-cognitive interaction (McMorris, 2009). Cooper claimed that there was a link between the catecholamines adrenaline and noradrenaline release into the bloodstream during exercise and increases in the availability of neurotransmitters in the brain (Cooper, 1973 cited in McMorris, 2009). Exercise would induce increases in the brain concentrations of noradrenaline and dopamine, and these would be available for use in cognitive tasks. Catecholamines however do not readily cross the blood-brain barrier, in fact only a small percentage can cross (Oldendorf, 1977; Cornford *et* al., 1983, cited in McMorris, 2009). This has lead scientists to argue that the action from the autonomic nervous system is the key in examining the interaction between exercise and brain catecholamines concentrations (McMorris, 2009).

From a clear theoretically view, the roles of noradrenaline and dopamine in reaction time and working memory tasks supports the hypothesis that exercise induced increases in the brain concentration of these neurotransmitters would result in an improvement of performance on such tasks (McMorris, 2009). It is a complex system that is being hypothesised for providing a neuroendocrinological explanation for an acute exercise-cognition interaction (McMorris, 2009). During exercise or just before, the hypothalamus triggers the synthesis of catecholamines in the SAS. Both dopamine and noradrenaline is released when the intensity of the exercise increases. Once the intensity reaches a certain threshold, adrenaline and noradrenaline is released into the blood.

Noradrenaline and adrenaline play important roles in the cardiorespiratory system and in the metabolism during exercise. The brain gets feedback from the ANS and this triggers further activity by the SAS and also the release of noradrenaline and dopamine into the noradrenergic and dopaminergic pathways in the brain (McMorris, 2009). These pathways again are important in the activation of cognitive and emotional regions of the brain. It is however to some extent simplistic to isolate this endocrinological process from other endocrinological going on in an individual (McMorris, 2009). The hypothalamus also triggers cortisol synthesis via the HPA, and during moderate exercise, the cortisol action helps modulate HPA activity. As the intensity or duration of exercise the arousal level also increases, giving greater activation of the limbic system. This comes at the expense of the cognitive centres in the brain, and the prefrontal cortex in particular. As these models are just hypotheses and catecholamine activity is very hard to measure, especially in humans, the author suggests measuring catecholamine of plasma concentrations of metabolites might be the way to go to test the model in future research (McMorris,2009).

Serotonin (5-hydroxytrypptamine) levels can also be put forward as a possible biological mechanism. Serotonin has a known association with exercise, depression and the expression of anger (Dishman *et* al., 2006), and in human adults aggression has been shown to correlate negatively with serotonergic activity in the CNS (central nervous system) (Coccaro, 1989 cited in Dishman *et* al., 2006).

Humans have a high density of serotonin receptors in the prefrontal cortex (Biver *et* al., 1996 cited in Dishman *et* al., 2006). Exercise has been shown to work as a stress buffer in studies performed on rats, by altering serotonin and noradrenalin brain systems (Greenwood *et* al., 2003 cited in Dishman *et* al., 2006). The executive function circuits of the brain are also rich in dopamine receptors and physical activity has been shown to enhance the brain dopamine synthesis (Sutoo and Akiyama, 1996 cited in Dishman *et* al., 2006).

2.4 *The executive function hypothesis*

There are several theories around indicating a link between physical activity and cognitive function. The executive function hypothesis presented by Kramer *et* al, (1999) & Hall, Smith & Keele (2001) brings up the idea that the benefits of exercise on cognition are specific to the process that requires cognitive control. As previous mentioned executive function has the overall control over cognitive processes. However, processes such as inhibition and planning are assumed to be enhanced by more exercise and fitness than tasks that do not necessitate effortful processing. Kramer *et* al, (1999), were the first to publish experimental evidence for the executive function hypothesis, doing a randomized study on older adults. Pointing out that there was a differential, age-related decline in cognitive processes, and the decline was largest in the frontal lobes and the executive functions connected to those areas. Sedentary individuals over the aged of 60 were randomly assigned to a six months long aerobic exercise or control group. The exercise consisted of 45 minutes brisk walking, three times a week for the intervention group, and toning and stretching for the control group (Kramer *et al*., 1999). Results from the study indicated that the exercise significantly improved performance on executive function tasks that depend on the prefrontal cortex circuitry.

Hall, Smith & Keele (2001) published a review where they made a distinction between the effects of exercise on executive vs. nonexecutive cognitive functions. The conclusion from this review was that aerobic exercise preferentially benefited executive function in older adults. Further on, Colcombe and Kramer (2003) ran a meta-analysis where they examined 18 experimental studies on sedentary older adults. The results showed that regular exercise resulted in cognitive benefits, where the strongest effect was found in tests for executive function that involved planning, inhibition and scheduling of mental processes. The conclusion of the results supported a causal relationship between exercise and cognitive function, with the strongest connection when the method of assessing tapped into executive function.

Imaging studies suggests that the prefrontal circuitry in the brain selectively is influenced by exercise (Colcombe *et* al., 2004; cited in Hillman, Ericson and Kramer, 2008). Evidence has been provided for exercise-induced neurogenesis in young adults using imaging studies and the loss of brain tissue has been associated with inactivity (Pereira *et* al., 2007 cited in Hillman, Ericson and Kramer, 2008). Another possible mechanism taken from studies conducted on animals suggests a more direct role of neural stimulation by exercise.

According to the neurotrophic stimulation hypothesis, the improvements in cognition are a result of neurological parameters such as growth in capillaries and increased capillary density in addition to an increase in synaptic connections (Churchill *et* al., 2002 cited in Davis & Lambourne, 2009).These animal studies show that aerobic training increases brain-derived neurotrophic factor and other growth factors, leading to an increase in capillary blood supply to the cortex and growth of new neurons and synapses. The outcome of this may result in better learning and performance.

Trudeau & Shephard (2008) claims that to their knowledge, mechanisms of enhanced learning and memory have never been explored in animals that is on a developmental stage that corresponds with school-aged children. They continue to hypothesize that because the brain has higher plasticity during childhood, the changes seen in older brains might have a larger magnitude in the brain of someone under development (Trudeau & Shephard, 2008).

2.5 *Summary*

The hypothetical framework for studies on physical activity and cognition is extensive, and the different contributors all have hypotheses that need further scientific research to back them up. In this section I have attempted to give a short overview over what I consider to be the main hypotheses on the effects of physical activity on cognitive outcomes, there are however many others out there.

In short, to summarize the different hypotheses: **The executive function hypothesis** - Exercise may increase oxygen saturation and angiogenesis in the areas of the brain that are crucial for task performance. **The catecholamines hypothesis** - Exercise may increase brain neurotransmitters, such as norepinephrine or serotonin, and in that facilitating information processing. **The neurotrophin hypothesis** - Exercise up-regulates neurotrophins that support the survival of neurons and the differentiation in the developing brain and dendritic branching and synaptic machinery in the brain of an adult (Ploughman, 2008).

Reticular-activating hypofrontality model of acute exercise (RAH) Cognitive performance is dependent on allocation of energetical resources through mental effort, and acute exercise influences the systems in the brain responsible for the allocation (Pesce, 2012). **Cognitive-energetic models** exercise might increase both arousal and activation mechanism and in that way modulate input and output processes. If both the cognitive task and the motor task require mental effort the exercise may influence the decisional process (Audiffren, 2009). **The neuroendocrinological model** suggests that there is an interaction between the SAS and HAP resulting in the secretion and synthesis of catecholamines, 5-HT and cortisol during exercise (McMorris, 2009).

3. Method

3.1 *Choice of method*

In order to answer my research questions,

1. Does more physical activity during the school day increase children's cognitive function?

2. Can the increase in cognitive function from this activity benefit children in relation to academic performance?

I have chosen to do a systematic literature research. There are several reasons for this. I could not do an empiric study of the effect on children's performance due to time limitations, as far as I believe, it should preferably been done in a timeframe far greater than what I dispose. The effect of physical activity on cognition is not necessarily an immediate effect, and it would also be interesting to investigate if the effect (if any) lasts over years. There is also an issue with funding when conducting large studies, and as there were no current studies going on that I could join in on, I saw this as an unlikely approach. When considering the lack of focus on physical active ways of learning, it is interesting to look at what have been done prior and where there is need for more research. The aim of the study is therefor to give a holistic overview on what has been done in the defined area of research, what conclusions has been made, and what methodological issues arise from the research.

3.2 *Inclusion criteria*

- Focus on children aged 5-19 (i.e. school aged)
- Review articles
- Published in the English language
- Publications with reliable and valid methodology
- Articles where both some sort of physical activity exposure and cognitive outcome have been measured.
- Publications with an experimental design (RCT's) or quasi experimental design
- School based interventions, recess, classroom based or physical education.
- Published in an academic/peer reviewed journal

3.3 *Exclusion criteria*

- Publications with an unclear method of measuring physical activity or cognition, or lacking one or the other.
- Publications where the primary focus was on children that have some form of physical or mental impairment.
- Publications outside school setting.
- Publications focusing on cardiorespiratory fitness or aerobic physical activity rather than physical activity in general.
- Publications focusing merely on children's mental health, children with learning difficulties or disabilities (e.g. Depression, anxiety, ADHD, dyslexia etc.)

Studies for this thesis were identified by searching through several electronic databases. Since the topic of interest touches into sport science and a more psychological aspect, the choice of databases to search were based on that to reach studies published in both areas. PubMed, Web of science® and SportDiscus™ in order to find studies relevant to the topic, the search was built up using pre-determined search terms that included both physical activity- and cognition related terms. In addition, I wanted to link the physical activities to academic performance, and terms related to this were added to the search. In order to get a large amount of information compared and reviewed I chose to limit my search to review studies. This gives me a comprehensive overview of the current literature relevant to my research question. I will not however be doing a meta-analysis in my review. In databases where filtering for review studies was not an filtering option I added "review" to the list of search terms in order to limit the search. The same was done to filter for children, thus adding child*, youth, and student to the search.

In addition to this, articles were also identified by reading through reference lists from the earlier identified articles and related citations. Since I aimed to look at review studies only, publications of newer date may not have been included in published meta-analysis or review studies yet and therefore not included in the results part of this dissertation. As there is a lot of interesting new research in this area going on, I have chosen to include some prospective studies in the discussion part of this thesis in order to find additional support or opposes to my hypothesis.

Publications with an experimental design are often believed to be the gold standard when trying to determine causality, but are often difficult to conduct, especially when dealing with exercise intervention studies. Quasi- experimental studies were therefore added to the inclusion criteria's. When doing studies on humans, it is almost impossible to make them believe that they are in an intervention group (i.e. exercise) when they are not and vice versa. Double blinding that is one way of reducing the risk of threats to the internal validity of a study, but as I said almost impossible when dealing with exercise intervention studies on humans, and thus the design of the study weakens (Thomas, Nelson & Silverman, 2011).

3.4 *Search terms*

3.4.1 Physical activity

- Exercise [MeSH Terms]
- Physical activity
- Physical education
- physical education and training [MeSH Terms]
- energy metabolism [MeSH Terms]
- Fitness
- Sport
- Sport participation
- Energy expenditure
- motor activity [MeSH Terms]

3.4.2 Academic related

- Academic achievement
- Academic performance

3.4.3 Cognitive related

- Cognitive function
- Executive function [MeSH Terms]
- Cognitive performance

3.5 *Search results*

Initially the search gave a total of 252 articles from the various databases. From there the articles where filtered for review articles only, and then filtered out to match the inclusion criteria's, excluding a total of 216 articles. After carefully reading abstracts and the methods part in the article if in doubt, screening out more articles and removing duplicates. I ended up with 4 review articles to include in this review.

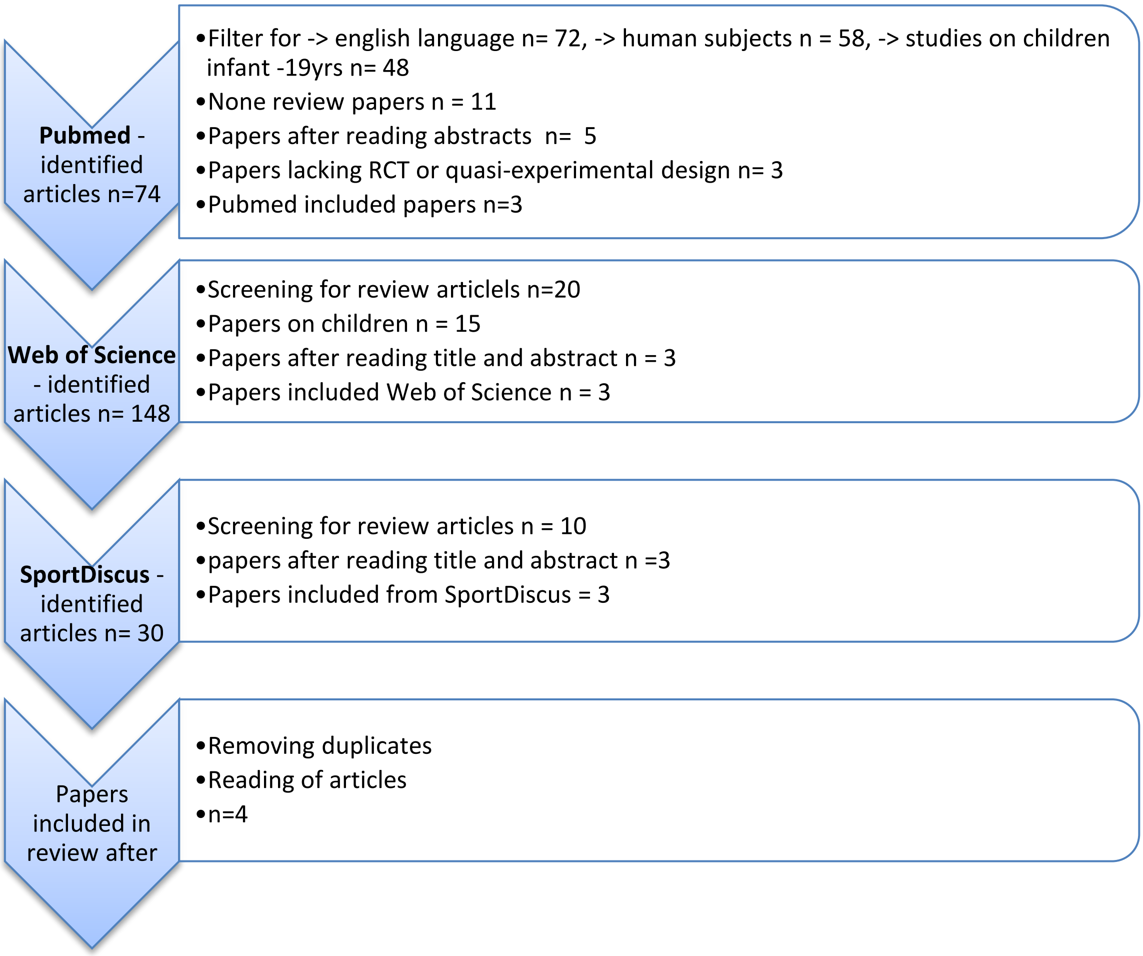

Figure 1 gives a general overview of the search process.

4. Results

Table 1-shows a summary of the review studies included is this thesis.

Author, date and years covered	**Type of review; number of studies (K)**	**Sample for current analyses**	**Exposure variables**	**Outcome measure**	**Types of research design**	**Main findings**	**Comments**
Fedewa, AL & Ahn, S 2011. 1947 - 2009	Meta-analysis K=59	3-18 Years	Resistance/circuit training, perceptual motor training, PE program, Aerobic, Combined, Strength, Total fitness, Development, flexibility, Cardio	Total achievement, Math achievement, Reading achievement, English/language art, Science achievement, GPA, Intellectual quotient, Other (educational development test, readiness test, etc.	Experimental, Quasi-experimental, Cross-sectional, Correlational data	Indication of a significant and positive effect on children's academic performance and cognitive outcomes with aerobic exercise having the largest effect.	Large number of studies with variable methodological strength, including cross-sectional and correlational data. I will be commenting on the experimental and quasi experimental studies.
Rasberry, C.N *et*.al. 2001. 1985-2008	systematic review K=50	5-18 years	Physical activity or exercise programs, Increased PE, brief physical activities in a classroom, after-school physical activity or exercise programs	cognitive skills and attitudes, academic behaviours, and academic achievement using one or more educational or behavioural outcomes (e.g., graduation or dropout rates, performance on standardized tests, academic grades/GPA, years of school completed, time on task, concentration or attentiveness in educational settings, attendance, disciplinary problems, school connectedness.	Experimental, Quasi-experimental, Descriptive	Results are suggesting PA to be either positively related to academic performance or a neutral relationship. Only 1,5% of the studies showed a negative association between the variables.	I will be commenting on the experimental and quasi experimental studies.

Keeley T.J.H. & Fox K.R (2009)	Systematic review K= 18	4- 18yrs	Mainly increased PE time in school	Academic achievement grades and standardised test score, Achievement tests, ACER arithmetic test and GAP reading test, Standardized exams.	Experimental, Quasi-experimental, Correlational data	Insufficient evidence to conclude that additional physical education time increases academic achievement; however there is no evidence that it is detrimental	I will be commenting on the experimental and quasi experimental studies.
Trudeau, F & Shephard, R.J 2008. 1966-2007	Systematic review K = 16	kindergarten - 16yrs.	Increase in physical activity, more PE, varied sport and activity programs.	Teacher ratings, achievement tests, overall academic achievement, Scores for reading and arithmetic, Classroom assessments and nationally standardized achievement scores	Quasi-experimental, Longitudinal	The results indicating that allocation up to an hour a day of curricular time to PA programs does not show negative effect on academic performance. Additional PE may result in GPA gain.	I will be commenting on the quasi experimental studies.

4.1 ***The review studies***

4.1.1 Fedewa,& Ahn, 2011

The first study (Fedewa,& Ahn, 2011.) included data from 59 studies altogether, whereas 39 were based on an experimental or quasi-experimental design. As the study included both included experimental data, and cross sectional- and correlational data the study was closely read to exclude the results of studies without a PA intervention. The focus in this dissertation is mainly on the causal relationship between PA and cognitive outcomes.

The 39 studies examined the effect of physical activity interventions on a cognitive outcome. The intervention focus varied from resistance/circuit training (k = 1) perceptual motor training (k = 10), regular PE (k=13), aerobic training (k = 15). In 13 of the 39 studies the PA was administered by the teacher (Fedewa,& Ahn, 2011). Indications from the post hoc tests showed that aerobic training had significantly larger mean differences on the cognitive outcomes in the children than perceptual motor training or PE. The scientists found no significant effects of the PA programs that focused on resistance training or combined training. The results also showed that small group interventions showed the largest effect on the cognitive outcomes, followed by medium sized groups (Fedewa,& Ahn, 2011).

It did not seem to matter who administered the PA program; the students appeared to gain benefits regardless of the person leading it. The frequency of the PA interventions might also be important to mention, and in Fedewa & Ahn's review the largest effect size (ES) was seen when the intervention was provided 3 times a week. The second largest effect size was seen in the interventions where PA was provided 2 times a week.

4.1.2 Rasberry *et* al, 2011

The next study included in this thesis is Rasberry *et* al, 2011. As the previous article, Rasberry also looked at both experimental data, and cross sectional- and correlational data. The results from the experimental data were split into the various settings of the intervention and will be presented under the following categories; School based PE studies, Recess studies, Classroom PA studies, and other school-related extracurricular PA.

Ten intervention studies considered school- based physical education studies, whereas six of them looked at how increased PE or level of PA intensity in PE classes affected academic performance, two examined improvement strategies for quality in PE classed, and the remaining two emphasised on the type of activity (i.e. aerobic exercise, coordinative exercise) and aspects of academic performance. Seven followed an experimental design, and the rest (n=3) used a quasi-experimental design. The studies assessed a wide range of cognitive outcomes, including cognitive skills, attitudes, academic behaviours and academic achievement, where most of the studies showed one or more positive associations. Six studies however, showed mixed conclusions where both positive and non-significant associations were displayed.

One of the studies (Dwyer *et* al, 1996 in Rasberry *et* al. 2011) compared a fitness group with 75min PA a day with a control group of 30-min periods of PE per week. They discovered no differences in the academic achievement between the two groups, even though the intervention group had less classroom-teaching time due to more PA.

Rasberry *et* al, (2011) presents six intervention studies where school recess was the setting for the intervention. The six studies take a closer look on the relationship between recess, and/or an increase in PA during recess, and cognitive outcomes. The studies were conducted in elementary school, including kindergarten children, and they all had an experimental or quasi-experimental design. In the data collection process, most used trained observers to access classroom and recess behaviour. Three of the studies showed all positive associations between more PA in the recesses and classroom behaviours. The other three presented positive or non-significant associations. The interventions by Pellegrini *et* al. (1995) presented in the review found lower attention in the students after long work periods without a break, and that the student’s attention was better after recess than before.

All nine classroom PA studies presented by Rasberry *et* al (2011) were intervention studies, and examined the relationship between classroom based PA and academic performance. The aim was to introduce short PA breaks (5-20 min) in a classroom setting affected cognitive skills, attitudes, academic behaviours and academic achievement. The interventions were conducted by trained teachers or other facilitators and were implemented daily or on a regular basis, mostly lasting for two to three months. There were three experimental design studies, one qualitative case study, and the rest used a quasi-experimental design. Similar to the studies on recess PA and the PE studies, the classroom PA studies showed overall positive outcomes or no association.

Four of the studies displayed all positive associations between classroom PA and classroom behaviours and academic achievement. As an example of this, Maeda and Randall (2003) is put forward by Rasberry *et* al, (2011) where it was demonstrated that 2nd grade students showed greater concentration and higher math fluency after a 5 minutes break of vigorous exercise 1 hour after lunch.

Four studies reported positive or non-significant associations where positive associations were found in for example spatial aptitude, reading skills and math skills, but no associations on indicators such as perception, reasoning, memory, verbal comprehension or emotional indicators. The last of the nine studies presented no relationship between an extra 15 min classroom based daily PA and standardized achievement tests, All in all, eight of the nine presented studies suggest that classroom based PA might have favourable associations with various indicators of cognitive functioning, academic behaviours and academic achievement, stressing that no negative associations were found.

4.1.3 Keeley & Fox, 2009

The third review by Keeley & Fox (2009) included 17 studies where 11 were cross-sectional correlation studies, 5 had a quasi-experimental design, and only one was a RCT. The five studies with a quasi-experimental design assessed the link between PA and academic achievement, the RCT looked at physical fitness and cognitive function. The 5 quasi-experimental studies were non randomized controlled trials, with duration from six months to five years.

The focus of the interventions was to sustain higher PA levels by increasing PE curriculum time. (Keeley & Fox, 2009)The increases in PE time varied from 27 min per week to 75 min per day. In all of the five studies, the increase in PA was not added on in addition to the normal curriculum, but was enforced at the expense of the normal curriculum. The control schools used in the studies continued their normal curriculum throughout the intervention period. The results for two of the studies displayed that an increase in school based PA time was not associated with changes in academic performance.

One study when compared to the control school, showed significantly smaller declines in four of eight measures of academic performance. One discovered an increase in mathematics performance, but no increase on English scores. The last of the studies showed a closing of a baseline difference in academic performance which was suggestive of a positive effect for higher levels of PA that is based in the curriculum. (Keeley & Fox, 2009). Although the five studies found no obvious dose response relationship among the degree of the increase in PA, or between the length of the intervention- and academic performance in schools, they failed to find evidence for a detrimental effect on children's academic performance followed by time allocated towards more PA at the expense of academic subjects.

The only RCT study included in Keeley & Fox's' (2009) review was one by Davis *et* al. (2007). As previous mentioned Davis studied the effect of physical fitness on children's cognitive performance. They used an aerobic fitness treadmill test and the CAS test (cognitive assessment system), and based their study on the PASS theory of cognitive functioning. The intervention subjects were divided into a low- and a high intensity based group, where the high dose group exercised for 40 min and the low dose group exercised for 20 min for 5 days a week in a total of 15 weeks. The results showed a significant difference from the control group on the Planning aspect of the CAS rest. The two intervention groups however did not differ significantly on the pre and post treadmill test, suggesting that the physical fitness gain was small and may not have been the factor making a difference on the children's' cognitive function. (Davis *et* al, 2007 in Keeley & Fox, 2009). This study however was conducted on overweight children, and can therefore not be used to generalize the claims of effect from PA to cognitive outcomes (Davis *et* al, 2007).

4.1.4 Trudeau & Shephard, 2008

The last and final study included in this review is Trudeau & Shephard (2008) and examined the link between PE, PA, school sports and academic performance. Like the reviews mentioned earlier, this review also examined longitudinal studies and cross-sectional studies in addition to the quasi-experimental studies I will be focusing on. Trudeau & Shephard (2008) did not identify and RCT, stating that RCTs' are not very practicable in a research setting such as a school milieu. Trudeau & Shephard (2008) reported 7 quasi-experimental studies where the main focus of intervention was to increase the amount of physical activity, mostly through increases in physical education throughout the school day or school week.

The results displayed much of what have been debated before; the overall results pointed towards a slight trend towards improved scores in some cases, while others reported no effect at all. An example of this is the SHAPE trial in South Australia where 500 students were exposed for a 1.25 hour a day fitness endurance program. When comparing with the control group, the scientists found that the students in the intervention group showed somewhat better arithmetic and reading grades, but the trends were not significant.

The researchers seem to agree on one matter however and that is that the time allocated away from the normal curriculum does not appear to affect the students negatively. These results indicate that even though the students spend overall less time studying traditionally, the efficiency of the learning might have been enhanced. (Trudeau & Shephard, 2008).

4.1.5 Summery

To summarize the findings in the review studies included in this section, the presented evidence cannot conclude that there is a positive relationship between increased physical activity in a school setting and cognitive performance. The findings points out that there are mostly weak associations or a neutral relationship between the two but the findings are mostly significant, though weak. The interventions with seemingly largest effect on cognitive outcomes are interventions that primarily focus on physical fitness and not physical activity in general (Fedewa,& Ahn, 2011). The four reviews included in this dissertation did appear to agree on one thing, when time is allocated from teaching time or academic learning and used for more physical activity, this does not seem to affect the students participating in the intervention to achieve poorer grades. The students in the intervention studies appear to have similar or better results in some measurements like mathematics, (Fedewa,& Ahn, 2011. and Rasberry *et* al, 2011.) then their control group peers.

4.1.6 Supplement

In addition to the studies mentioned above a very recent study by Verburgh, Königs *et* al (2014) have documented some very interesting results on physical exercise and executive function. This is a very new study and is to be featured in the June edition of the British Journal of Sport Medicine. As it did not appear in my initial search process, I will not present it as a part of my initial search results, but as a supplement to give more light on the topic on hand as I believe it to complement the results from my included review studies where they are lacking. I have therefore chosen to present the study here below.

Verburgh, Königs *et* al (2014) are the first to report systematic quantification of the effects of physical exercise on executive function across critical periods of the brains maturation dividing the studies into preadolescent children, adolescents and young adults. They made a distinction between the type of exercise; acute bouts or chronic exercise and what kind of executive function that was being measured. The article included 24 studies whereas 19 were acute and 5 were chronic.

Table 2- shows the study characteristics for the review by Verburgh, Königs et al, 2014

Age group	**N**	**Exercise type**	**Design**	**Executive function**
Preadolescent children				
	64	Chronic	RCT	Planning
	36	Chronic	RCT	Working memory
	74	Acute	RCT	Inhibition/interference
	61	Chronic	RCT	Planning
	62	Chronic	RCT	Planning
	20	Acute	Cross-over	Inhibition/interference
Adolecents				
	35	Acute	Cross-over	Inhibition/interference
	35	Acute	RCT	Inhibition/interference
	99	Acute	RCT	Inhibition/interference
Young adults				
	27	Chronic	RCT	Inhibition/interference
	18	Acute	Cross-over	Inhibition/interference
	19	Acute	Cross-over	Cognitive Flexibility
	36	Acute	Cross-over	Inhibition/interference
	20	Acute	Cross-over	Inhibition/interference
	12	Acute	Cross-over	Working memory
	12	Acute	Cross-over	Working memory
	12	Acute	Cross-over	Working memory
	12	Acute	Cross-over	Working memory
	22	Acute	RCT	Set-Shifting
	20	Acute	Cross-over	Inhibition/interference
	42	Acute	RCT	Planning
	76	Acute	Cross-over	Inhibition/interference
	10	Acute	Cross-over	Inhibition/interference
	12	Acute	Cross-over	Inhibition/interference

The results showed that acute physical exercise had an overall moderate positive effect on executive functions. When separating the results for age there was no difference, they all showed moderate positive effect. Looking at the different executive functions the 12 studies on physical exercise and inhibition/interference control showed a significant small-to-moderate positive effect size (Verburgh, Königs *et* al, 2014) The scientists indicated from these findings that acute exercise have similar effects on inhibition/interference control across all the age groups. Four of the studies on acute exercise reported on the effect on working memory, but in all cases the studies were conducted on young adults. The four studies showed no significant effect size.

Only five studies reported on effects of chronic exercise on executive functions. Across the age groups these studies showed a non-significant effect size. Four of the studies looked at planning performance and only in preadolescent children; there was no significant effect size.

5. Discussion

The main purpose of this thesis was to look at physical activity in general in a school/academic setting and see if it could increase the cognitive function in the children that participated in such an intervention. In addition, I wanted to see if this potential increase in cognitive function could benefit the children in relation to their academic performance.

Viewed in the light of the current research results, it seems like there is a weak connection between physical activity and cognitive function in children. When we link these results to academic achievement, the evidence presented in this thesis indicates that the increase in PA does not at least have a negative effect on children's academic performance following an exercise intervention. The main focus in this discussion is therefore to look at the research presented and try to give an broader understanding to what factors may play a role in trying to establish the link between PA and cognition and why these factors influence the potential outcome of the studies.

5.1 *Measures of physical activity*

Measuring the accurate level of physical activity in children can be very challenging, where there are several factors interfering. Depending on the size of the group, budget limitations, resources, time and equipment may interfere with the accuracy of the measurements. If the group in question is very large, it would seem beneficial to use questionnaires as a way of assessing the amount of physical activity. However, young children have a poor ability to recall activities, and have an activity pattern that differs from an adults' (Corder, Ekelund, Steele, Wareham & Brage (2008). The studies included in this review however had an experimental design, and the students themselves needed not recall their own activity level. One of the issued with the studies presented in this thesis would be how the intervention personnel made sure the students were keeping the intensity of the exercise if that was perceived as important for the cognitive outcome.

5.2 ***Measures of physical fitness***

As I have mentioned previously physical fitness is a set of functional capacities and capabilities like muscular strength, flexibility, and aerobic fitness. In regards to physical fitness in children these capabilities and capacities are partly determined by genetic factors, at what stage the child is on biological maturation and on the amount of PA the child undertakes (Keeley & Fox, 2009). To establish a child's physical fitness, a test battery made up by assessments of the various components is often used (Keeley & Fox, 2009).

Peak VO_{2max} is considered to the gold standard when measuring aerobic fitness (American College of sport medicine, 2013). The variable is typically expressed in relative terms ($mL * kg^{-1} * min^{-1}$) rather than absolute terms ($mL * min^{-1}$) this is normally done in order to compare individuals with different body weight (American College of sport medicine, 2013).

A majority of the studies performed were school based. In a large quantity of the studies, the children's aerobic capacity was measured during an ordinary *one mile run/walk* or similar field tests (Fedewa & Ahn 2011 & Keeley & Fox, 2009). This may not be a very valid way of measuring a child's capacity, even though it is an objective measure of aerobic capacity. Field tests are susceptible to confounding by motivational factors (Fox & Biddle, 1988 cited in Keeley & Fox, 2009). It is almost impossible to know for sure whether or not the child in question has exerted his or her maximum performance (Corder, *et*.al. 2008). The more validated Andersen test could be used instead, providing more accurate results and following the child's normal activity pattern with short bouts of activity better. This standardised test is fairly easy to perform and would give scientists a tool for comparing results should the test be used in several studies (Ahler, Bendiksen, Krustrup, Wedderkopp 2012). Children tend to have an activity pattern that differs from adults and should therefore be tested with methods more similar to their natural physical activity behaviour if a direct measure of aerobic capacity is problematic to perform (Corder, *et*.al. 2008).

5.3 ***Measures of academic achievement***

The numerous review studies showed a large number in ways to measure academic achievement. The measurement methods ranged from self-reporting of school grades, teacher ratings, achievement tests, overall academic achievement, scores for reading and arithmetic, classroom assessments and nationally standardized achievement scores various cognitive tests and combinations of the of different measures and scores. The studies did also have a large variability on what was actually tested. Some of the studies looked at total academic achievements including reading skills, math, history, language, science, art, world studies and IQ-tests and different cognitive tests. Other studies focused on a smaller range of skills like IQ-tests or various combinations of skills in different subjects (i.e. math, reading, English..,) or merely cognitive tests (Fedewa & Ahn(2011), (Rasberry *et*.al (2011) & Singh *et*.al (2012).

This large number of variations in both ways to measure the academic achievement and the way of reporting the results makes it difficult to establish the quality of the studies. Two of the review studies did run a meta-analysis where the effect size of the study was accounted for, but the other two did not. Although some of the studies reported to have used standardized tests and methods, there are very few of them that have used the same methods. This makes it very difficult to draw any conclusions from the numerous studies and even harder to compare one with the other in order to establish a certain cause-effect relationship between physical activity and academic achievement.

In order to be able to generalize the study findings towards all children, we need more reliable interventions in academic settings across the world. In addition to this, a child is quite likely to emulate their parents' values. These values might include both sports and academic achievement, meaning that a more capable or driven child may be more motivated to do well on both physical fitness tests and academic tests than children with behavioural or academically problems (Keeley & Fox, 2009).

5.4 ***Measures of cognitive outcome***

One of the main issues when it comes to establishing the relationship between physical activity and cognitive responses is that in a large number of the research the exercise researchers analyse the data without making a distinction between executive functions and other cognitive processes (Dietrich & Audiffren, 2011). Dietrich & Audiffren proposes that only a model that makes this distinction can be helpful when trying to establish why some cognitive functions are enhanced by exercise while other functions are impaired. This issue might help explaining why the various review studies presents data that is not unified and some find positive associations while others find no associations what so ever.

A recent article from Pirrie & Lodewyk (2012) for example found in their study that the only cognitive process affected by acute exercise was planning. As planning is associated with childrens ability to problem solve and to self-regulate their behaviour, it would consequently make sense for teachers to plan complex activities after PA (Pirrie & Lodewyk, 2012).

As I have mentioned before, the recent study from Verburgh, Königs *et* al (2014) is quite unique in their methods to analyse the study results based on both the age of the population and specifying what type of executive function that was measured. Their findings showed that there was a significant effect size found on the inhibition/interference control of executive function. Inhibitory control is very important in an everyday life as it is essential for the regulation of behaviour and emotions in social, academic and sport settings (Verburgh, Königs *et* al, 2014) More studies following that kind of design would be beneficial for moving forward in the exercise-cognition field because it would help to establish a more causal relationship between the variables, not just a correlational link.

5.5 ***Age and maturation***

One of the main problems in assessing various articles on children and adults are the methods used in gathering information. Children can be especially hard to work with both because they develop in different velocities and reach puberty in different ages (Rogol, Clark & and Roemmich, 2000). The disadvantage with this is that two children, both chronically age 11, might be on a totally different biological stage. Most interventions tend to divide their groups by chronological age, leading to a problem with reliability in the given population (Rogol, Clark & and Roemmich, (2000). Differences in children's maturation might play a mediation role especially in regards to neural, motor, cognitive or social development levels (Tomporowski, Davis, *et* al. 2007). According to Welsh *et* al. (1991) exercise interventions might affect different aspects of EF at different ages because of the differences in the age maturation of the pre- frontal cortex (Tomporowski, Davis, *et* al. 2008).

The change therefore in the EF may change and vary from age to age. Some abilities, like inhibition may develop primarily during the preschool years, while others, like planning and working memory continue to develop during the middle school years. In an exercise intervention on these components, improvement on inhibition might be seen in the pre-schoolers but not in the school aged children (Tomporowski, Davis *et* al. 2008).

5.6 ***Population characteristics***

Fedewa & Ahn (2011) pointed out that aerobic exercise might be more beneficial on cognitive functioning than other types of exercise. In a large number of the studies, the children's assessment of body composition was evaluated using the child's body mass index (BMI) in addition to other measurements. BMI is known to be a good tool on assessing large populations, but does not consider the child's general body composition (McArdle, Katch & Katch., 2010). Thus mistakenly assume children with for example large muscle mass to be overweight or obese. The overall assessment of physical fitness can therefore be inaccurate if it is based on assumption and inaccurate measures. Given that some researchers have presented results indicating that overweight and lower aerobic fitness is associated with lower cognitive performance, (Davis *et* al, 2007) it is important to use validated tools to measure children's body composition as well as their aerobic capacity. If we look to the U.S these kinds of findings might be especially important as it is estimated that nearly 1/3 of the childhood population is overweight. (Davis *et* al, 2007) An Italian study from 2013 supports the lower fit-lower performance claim and found in their research that higher fit children showed better results on inhibition, but the lower-fit children had more pronounced pre- to post-intervention improvements then the lean children in the intervention (Crova *et* al, 2014).

5.7 *Dose and intervention type*

Given the proposed hypotheses for the relationship between physical activity and cognitive outcomes, we can observe that research being conducted struggles to link the hypotheses to the actual interventions conducted. Although researchers have begun to investigate the effects of different kinds of exercise modes (not only aerobic) the evidence in both acute and chronic exercise research is still scarce (Pesce, 2012). In Fedewa & Ahn review (2011) it did not appear to matter who administered the intervention, but they found that aerobic exercise had a significantly larger mean difference on the cognitive outcomes than other forms of exercise intervention (Fedewa & Ahn, 2011). They also noted that the largest effect size was seen in the intervention where the participants exercised three times a week, followed by intervention with a twice a week exercise intervention. This might indicate that a more regular take to the interventions would be more beneficial for the subjects than more seldom ones.

Rasberry *et* al (2011) presented nine classroom based studies where the 5-20 min long activity breaks were used to break up the teaching lessons. Four of these studies showed all positive associations between classroom PA and classroom behaviours and academic achievement. One of the studies even showed better concentration and higher math fluency after a five min PA break. They also showed that students had a lower level of attention after long work sessions without breaks, and that the attention level increased after recess (Rasberry *et* al, 2011). Results like these might support some of the hypotheses on acute bouts of exercise on cognitive outcomes although a theoretical framework should be at the base of these kinds of studies in order to support causality.

In order to shed more light into the exercise-cognition relationship, Pesce proposes that the future research should focus on the role played by exercise intensity, duration, and frequency with renewed research focusing on qualitative nonphysical characteristics of exercise tasks (Pesce, 2012).

5.8 *Cause and effect*

Given the circumstances with large number of studies and large variability between methods and measurements, it may be hard to know how much exercise a child has to do to get an effect on cognition and academic achievement. A few researchers have examined the relationship between the amount of physical activity and the child's academic score and concluded that more physical activity produces higher scores (Fedewa & Ahn, 2011).

Furthermore the article in question here suggests that physical activity provided three times a week has the strongest effect on the cognitive outcomes and academic achievements in children. There are several proposed reasons for this, varying from minimizing fatigue and boredom to gaining higher levels of self-esteem and all the health related effects from doing physical activity on both body and mind (Fedewa & Ahn ,2011).

5.9 *Publication bias*

The scientific literature that is published may differ somewhat from the results of all research carried out. Researchers may choose not to publish studies with insignificant findings or the studies may not be accepted for publication. (Sutton, 2009) There is strong evidence suggesting that significant outcomes are more likely to be published or/and published more quickly than no significant ones. The Publication bias arises from these findings and is a factor to consider when trying to establish the validity of findings and when trying to establish new "truths" in science. (Sutton, 2009)

As seen from the research presented in this review, there are many studies reporting inconclusive, conflicting and weak evidence to support their hypothesis. One can therefore assume that there might be a number of studies conducted that have not seen the light of day. If might be questionable whether or not on should draw conclusions based on the published evidence on a certain topic. On the other hand, given the inconclusive results, the risk publication bias for the studies included in this review may be assumed to be very low. Even though the results of a study shows to be inconclusive, the research may still be important in establishing pathways that does not work, or for others to learn from previous made mistakes. In that way, future scientists can use this information in order to design enhanced interventions with improved methodology, which can help us come one step closer to a potential truth.

6. **Conclusion**

Given the current literature and its findings I would state that it is not possible to determine whether cognitive performance and academic achievement are improved by more physical activity. The present of cross-sectional evidence is weak, and though at hand, there are too many other possible and also plausible explanations for this relationship as discussed earlier. The studies analysing results from experimental or quasi experimental designs shows trends in the right direction and can provide information on what has been done before, and what future research should include.

The overall conclusion of the studies examined is that physical activities tend to have a small, but significant positive effect on children's cognitive function. When relating physical activity to academic performance it generally points in the direction that more physical activity in school does not affect the student's results negatively, but in many cases there is a positive relationship between the two. Given the results and the well-known positive effects of physical activity on children's health, I see no immediate reason for removing physical activities like physical education, physical activity breaks and recess physical activity from the schools. A child would gain many health benefits by maintaining a focus on physical activity throughout the school day, this without a negative effect on the child's cognitive function or academic performance.

6.1 ***Suggestions for future research***

There is a need for further research into the exercise-cognition field, given that the review studies included in this study is somewhat inconclusive. Pesce proposes as I have mentioned earlier that the future research should focus on the role played by exercise intensity, duration, and frequency with renewed research focusing on qualitative nonphysical characteristics of exercise tasks (Pesce, 2012). The very recent article from Verburgh, Königs *et* al, (2014) proposes that there should be a distinction in what kind of executive function the hypothesized effect will be on and that it would be beneficial to separate the intervention groups based on maturation. There should also in my opinion be more studies conducted focusing on breaching the gap between acute bouts of exercise interventions and interventions on chronic exercise. I feel that this would be beneficial as much of the present research on cognitive function is done with acute exercise as the intervention, but a lot of the health benefits children may experience from physical activity come from regular or chronic exercise. I think a combination of these newly proposed factors could make up a better experimental study than the ones presented here today, and maybe in the future we will be able to draw some substantial conclusions on children's physical activity and cognitive performance.

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List of tables

List of figures