Eur J Psychol Educ (2013) 28:945–962
DOI 10.1007/s10212-012-0148-z

The academic and psychological benefits of exercise in healthy children and adolescents

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Received: 16 November 2011 / Revised: 18 June 2012 / Accepted: 10 July 2012 /
Published online: 31 July 2012

Abstract This review examines the psychological benefits exercise is connected to in healthy children and adolescents. Studies on the effect of exercise on academic performance, self-esteem, emotions, and mood were examined. Academic performance is found to be maintained when normal academic classes are reduced and replaced by an increase in exercise, physical activity, or physical education. Exercise seems to have a positive effect on several aspects of cognition and self-esteem in healthy children and adolescents. A positive connection between exercise and emotions and moods in children is found in the few studies that have been conducted.

Keywords Adolescent · Child · Exercise · Physical activity · Psychological benefits · Academic performance · Education

The connection between a physically active body and an intellectual mind was an established part in the knowledge base of the ancient Greeks. Since then, science and research have changed how we view the world and many of the connections in it. The connection between a physically active body and an intellectual mind has however withstood these changes. Benefits of exercise have been shown in all age groups (Etnier et al. 1997) from early childhood (Alpert et al. 1990) to old age (Colcombe and Kramer 2003; Taylor et al. 2004). If someone were to wait until adulthood or old age before they adopted an active lifestyle, many benefits could still be obtained (Paffenbarger et al. 1993). Not all effects would however still be available (Hallal et al. 2006; Sallis et al. 1988), and those who are active in their childhood and adolescence are those who are the most likely to continue exercising and reaping the benefits throughout their lives (Hallal et al. 2006; Telama et al. 2005; Twisk et al. 2000). While the physiological benefits of exercise have been thoroughly examined, research on the psychological benefits of healthy children and adolescents has been sparse. The psychophysical changes in this age group have been the objective in some studies (Budde et al. 2010a,b,c).

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Research on the connection between exercise and academic effects, including connected psychological aspects such as cognition and self-esteem, became popular in the 1950s and 1960s in what was likely an attempt to justify exercise and physical education (PE) in schools from an academic standpoint (Sibley and Etnier 2003). This incentive disappeared when criticism towards PE was reduced in the 1970s, as it became widely accepted that PE was needed for its physical health benefits (Sibley and Etnier 2003). This acceptance did however start to fade in the 1990s with some parents even criticizing PE as harmful for the education and a waste of time and money (Shephard 1997). Another theory on the rise and fall in popularity of PE and exercise studies is that the incentive originated from anecdotal observations of overly excited children in classes following PE or breaks with games or playing. The overly excited children would then lack concentration and have worse behavior in class, leading to reduced academic performance. This led to studies with the intent of clarifying whether or not PE did in fact have this effect on children. As the studies failed to show any impairment to academic performance, the incentive for research was reduced and the popularity sank (Tomporowski 2003).

There are several difficulties in evaluating the possible benefits of exercise, the first being how do we define exercise. Several different definitions are being used, but the most commonly used seems to be Caspersen et al. (1985, p. 128) definition of exercise: "Exercise is a physical activity that is planned, structured, repetitive, and purposive in the sense that improvement or maintenance of one or more components of physical fitness is an objective," thereby clarifying it as a subset to the broader term of physical activity, which is defined as "any bodily movement produced by skeletal muscles that results in energy expenditure" (p. 126). This is however a very broad definition and includes a wide variety of activities performed at all frequencies, intensities and durations, which could reasonably be thought to have very different impacts on both physical and psychological factors. It would for example not be reasonable to expect to find the same benefits from recreational yoga as you would from professional sprinting. There are in other words "no single "exercise hypothesis" that can be tested experimentally" (Kirkcaldy and Shephard 1990, p. 166).

Determining the effects of exercise is difficult when some exercise habitually and frequently, while others only participate in the occasional session of exercise. Some enjoy 2-h relaxed walks, while others prefer an exhausting 10-min session at high intensity. These variances in how exercise is conducted lead to problems in studies examining the benefits of exercise as there could be threshold effects in terms of frequency, intensity, and duration of the exercise session. Choosing an appropriate experimental and control group can also be a challenge. Double-blind studies cannot be carried out since the subject will always know whether or not he or she is in the experimental or control group. This knowledge could create either positive expectations or demoralization (Kirkcaldy and Shephard 1990).

This review will examine whether exercise leads to benefits in academic performance and its underlying psychological factors in healthy children and adolescents. The psychological factors chosen for this review were cognition, self-esteem, emotions, and mood. The factors were selected based their connection to both academic performance (Tremblay et al. 2000) and exercise (Etnier et al. 1997; Sibley and Etnier 2003; Scully et al. 1998; Tremblay et al. 2000). This review will focus on the psychological benefits of healthy children and adolescents. For reviews on the alleviating effects of exercise on clinical diagnosis, see Stathopoulou et al. (2006) or Pope and Whiteley (2003) for effects of exercise on learning disabilities.

The studies were found through Boolean search of PsychINFO, ISI Web of Science, and Google Scholar. Qualitative studies, cross-sectional studies and studies of only physical benefits or effects were excluded. Studies were then chosen based on rigidity, choice of method, and type of benefits or effects measured. Studies of higher quality have been discussed in greater detail. We have also chosen to dedicate greater detail to studies with a unique method, choice of intervention or choice of participants. The studies in this review have been divided into which benefit of exercise they measured. The effects of exercise on academic performance will be presented first, followed by cognition, self-esteem, and finally emotions and moods. There is a strong connection between academic performance and cognition, but since academic performance is also influenced by several other factors [in addition to the factors examined in this review, among others, motivation, self-regulated learning (Pintrich and de Groot 1990), self-efficacy (Pajares 2003), and personality (O'Connor and Paunonen 2007)], and cognition includes several aspect that are not necessarily connected to academic performance we have chosen to discuss the benefits in terms of academic performance and cognition in separate sections. Some cross-sectional studies will be mentioned, but we have chosen to focus on short-term experiments and longitudinal studies in this review.

Academic performance

The relation between exercise and academic performance is of special concern, with most countries today having some sort of physical education required in their national school system (Hardman 2004). Although health benefits alone could justify physical education in schools, advocates for keeping or increasing physical education are often met by arguments that it is a waste of time and money or even harmful to the academic process (Armour and Jones 1998; DCMS/Strategy United 2002; Shephard 1997). While the majority of research published in English language journals is based on PE in the USA, Great Britain, and Australia, PE is considered to be threatened in all regions of the world in a 2004 report from the World Health Organization (Hardman 2004). Economy is the most common reason for not offering PE in schools today (Hardman 2004). With PE usually having higher costs than a normal academic subject for the school, due to additional cost such as gym maintenance and sports equipment, it is often the first subject to be reduced or cut when schools struggle with their budgets (Hardman 2004; Sibley and Etnier 2003). Other common reasons to why part of the child and adolescent population are not given PE in schools are cultural and religious reasons. Several countries, particularly in Africa and Asia, only provide PE for boys, or discourage girls to participate due to it not being accepted in their culture or religion (Hardman 2004). Free playing time during recess is even being cut in several American schools due to liability issues associated with the risks of someone being injured while at school (Donnelly and Coakley 2002).

Correlations among academic performance and exercise, athletic performance, participation in academic programs at school, and physical fitness has been found in cross-sectional studies dating all the way back to the 1930s (Shephard 1997). While a positive effect is often found in these studies, it is hard to determine the causality. It is likely that confounding variables such as intelligence, personality, genetic disposition, or teacher bias towards those with high performance in sports could be the reason for this effect, and not necessarily that the exercise or physical activity influenced academic performance (Shephard 1997).

Short-term experiments Academic performance is often measured by grades at the end of a term or a test after a certain amount of curriculum has been taught. With both of these, an exercise program that runs alongside the term or period is often preferred and the possibilities for short-term studies are few.

Hillman et al. (2009) (Table 2) studied how a single session of exercise affects academic performance through an academic achievement assessment (Wide Range Achievement Test, third edition). After a 20-min session of walking on a treadmill, the children performed significantly better in the academic achievement assessment compared to a resting session.

Longitudinal studies With academic performance often being measured in how a student performs on tests of the curriculum being taught during a certain period of time, longitudinal studies with an exercise program that runs alongside the period is an attractive way to measure possible benefits of exercise. The exercise program is often additional PE during normal school hours.

The earliest study was in 1950 in Vanves, France, where students at a selected school had their timetables modified for their last year of primary education. The school week was increased from 32 to 41.5 h, two half-hour breaks were introduced, academic instruction was limited to mornings and was reduced by 26 %, a wide range of required physical activities were introduced in the afternoons, and the students received regular vitamin supplements. Students were described calmer and more attentive, the number of average sick days was reduced, and academic results remained close to what was found in control classes despite the 26 % reduction of time spent in normal education classes (Hervet 1952; Shephard 1997). However, with so many different introductions and changes at the same time, it is difficult to conclude that exercise had an effect on academic performance. The Vanves study has been described as "an almost legendary study" (Sallis et al. 1999, p. 128). The status of "almost legendary" is partly due to the amount of attention the study has received and also from all the uncertainties surrounding it. The study has never received formal publication in an English-language journal, and the original French descriptions lack information about whether or not confounding variables, such as class size and socioeconomic status, was controlled for (Shephard 1997).

In, Trois Rivieres, Quebec, in the mid-1970, a large longitudinal study was conducted. Students in the first through sixth grade received more PE and spent less time on academic subjects. The results were compared with students at the same schools that preceded or followed the experiment (Sallis et al. 1999; Shephard 1997; Shephard et al. 1994). The students who received more PE had significantly higher grades than students that preceded and followed them in most subjects with grades in math being the most improved. The students did however score significantly lower in the categories English and "overall intelligence" on a province wide multiple-choice examination. This has been suggested to be due to the fact that students had a chance to practice on similar exams in classes before the actual exam, giving an advantage to the students with the most time spent in classrooms (Shephard 1997).

In 1978, the School Health, Academic Performance and Exercise (SHAPE) study was conducted in Adelaide, Australia, with 519 fifth grade students from seven schools (Dwyer et al. 1979). The students were divided into a fitness, skill, or control group and observed for 14 weeks. Both the skill and the fitness group had 15 min of PE in the early mornings and 60 min during normal class hours. The skill group spent most of the time on activities or sports that required a high amount of technique, while the fitness group spent most of the time on endurance activities and endurance sports. The skill and fitness group both performed significantly better than the control group on teacher rated classroom behavior. There were no significant differences in academic performance between the groups. A follow-up study 2 years later found that the classes that had implemented and kept the schedules from the fitness or skill group in the 2 years following the original study out-performed the control classes in math, reading, and teacher ratings of classroom behavior

(Dwyer et al. 1983). The study has been criticized for both the lack of standardized tests (Sallis et al. 1999) and possible bias from the teachers giving the ratings of classroom behavior (Shephard 1997).

The Sports, Play, and Active Recreation for Kids (SPARK) program was a 2-year program, in a suburb in Southern California from 1990 to 1991 (Sallis et al. 1999), with 1,538 students from the fourth and fifth grade. The students were divided into three conditions: a specialist condition, where PE was conducted by a certified physical education specialist; a trained teacher condition, where the research staff trained classroom teachers on how to implement the SPARK program in PE; and a control condition that would receive the usual PE program. The specialist and the trained teacher conditions both spent more time on PE and less on academic subjects per year (76 h in the specialist condition and 57 h in the trained teacher condition). A small advantage over control groups in academic performance was found, and while the advantage was small, the results reinforce previous findings that an increase in PE does not interfere or harm academic performance (Sallis et al. 1999).

Similar results were found in Canada, where the Action Schools! BC (AS! BC) program found no significant group differences between schools in the intervention and the control group, despite the control group having significantly higher scores before the intervention (Ahamed et al. 2007). Students from the fourth and fifth grade at schools in the intervention condition had an increase of 47 min of PE each week, while the schools in the control condition followed their normal schedule. Performance was measured through the Canadian Achievement Test.

A recent study of 214 sixth grade students from a public school in Michigan did not find any significant connection between introducing daily PE classes and academic performance (Coe et al. 2006). The children had 55 min of PE every weekday, while the students who were not part of the experiment had alternative exploratory classes such as arts or computer science. The lack of results from the PE could be due to average amount of vigorous or moderate activity only being 19 min per 55 min session (Coe et al. 2006), which could be beneath the threshold for how much exercise is needed before benefits are seen. The study also collected some cross-sectional data on exercise and found that the students that reported the highest amount of vigorous activity had significantly better grades than those reported a low amount.

Another Australian longitudinal study, the lifestyle of our kids project, ended in 2009. However, no publication has yet included the results from this study. A short report outlining the methods of the project has been published (Telford et al. 2009).

The general finding in studies of exercise and academic performance is that academic performance improves slightly or is maintained at the same level despite the reduced time spent in normal academic classes. With few or no adverse effects and a likely positive effect on academic performance or classroom efficiency, research today promotes the increase of exercise for children and shows that additional PE is a practical and possible way to accomplish this.

Cognition

Cognition is a broad term that covers many different aspects of mental functioning including thought processing, memory, attention, concentration, and creativity. Since cognitive processes are underlying every aspect of life, several different approaches to measuring and researching cognition exists. Research from a variety of disciplines, including developmental psychology, sports psychology, biopsychology, kinesiology, and cognitive neuroscience has contributed to our understanding of the role exercise plays in the development and functioning of cognition in children and adolescents. The effects of exercise and fitness in adults have been thoroughly examined, and several meta-analyses have been published. The general finding is that exercise has a small positive effect on cognition (Colcombe and Kramer 2003; Etnier et al. 1997) with the largest benefits found in executive-control processes (Colcombe and Kramer 2003). Sibley and Etnier (2003) conducted a meta-analysis of the cognitive effects of exercise in studies on all child populations. A significant positive connection was found between exercise and cognition. The authors concluded that this should not be a final conclusion to the topic, but rather an incentive to do further work in the field.

Short-term experiments Caterino and Polak (1999) studied the effect of 15 min of walking on concentration in an experiment with 177 children from the second, third, and fourth grade. Concentration was measured through the Woodcock–Johnson Test of Concentration. There was only found a significant effect in concentration in fourth graders, with no significant results in second and third graders, perhaps indicating that only some age groups benefit from exercise in terms of concentration (Caterino and Polak 1999). The short duration and low-intensity of the exercise and the small differences in age between the groups do make it hard to generalize these results. The differences in exercise intensity were investigated by Budde et al. (2010b) in an experiment with 60 ninth grade students. A working memory task (Letter Digit Span) was administered after a normal academic class and a 12-min session of exercise at a moderate or high intensity or resting control session. When the groups were divided into high and low performers (based on the working memory task administered after the normal academic class), a significant improvement was found in low performers, regardless of exercise intensity. There was no significant improvement in high performers. In addition, the study only found improvement in working memory after exercise at a moderate intensity, with no significant changes in the control and high intensity group.

In an experiment with 115 adolescents (aged 13–16), coordinative exercise was compared to endurance exercise (Budde et al. 2008). A d2-test, a test of concentration and attention, was conducted before and after a 10-min session of exercise. While both groups showed improvement from their pretest, the coordinate exercise group showed significantly higher d2-test scores. This could imply that coordinative exercise has a cognitive aspect, which further increases the benefits seen in other forms of exercise. Pesce et al. (2009) investigated the role of a cognitive component in exercise on immediate cognitive benefits from a single session of exercise. The participants were 52 students (aged 11–12) who were tested on three separate occasions in memory performance following aerobic circuit training, which included a cognitive component, team games, and a baseline session with no exercise. The children performed significantly better after both of the exercise sessions compared to the baseline and had the best performance in the team games session (Pesce et al. 2009). This could indicate that the cognitive requirements in cooperation and adopting your play and movement on the basis of your opponents could further increase the cognitive benefits of exercise.

A study with 35 healthy adolescents (aged 13–14) on stationary bikes (Stroth et al. 2009) found no effect of exercise in tests of executive control. A study of 69 overweight children (aged 7–11) on treadmills (Tomporowski et al. 2008) found no effect of exercise in visual task switching. The lack of effect found by Tomporowski et al. (2008) and Stroth et al. (2009) could be due to a threshold effect in terms of exercise duration. Tomporowski et al. (2008) had participants complete an exercise session of 23 min, while Stroth et al. (2009) used a 20-min session. Gabbard and Barton (1979) found a significant improvement on a math test in second grade children following 50 min of vigorous physical activity; however, this effect was not found after 20, 30, or 40 min. Contradictory to these results, Hillman et al. (2009) found that 20 min of treadmill walking had an effect on executive control in children using a similar test used in study of healthy adolescents on stationary bikes by Stroth et al. (2009).

To investigate if the positive cognitive effect from exercise with a cognitive component is from the cognitive stimuli alone, Ellemberg and St-Louis-Deschenes (2010) performed an experiment with 72 children (aged 7 and 10) divided into two groups, one group watched an age appropriate television show while exercising on a stationary bike, and the second group watched the same show without exercising. Each child was tested on a simple reaction time task and a choice response task immediately before and after a 30-min session of exercise or television watching. The exercise group outperformed the nonexercise group on the reaction time task.

The connection between exercise and cognitive benefits is not found in all studies. In addition to those already mentioned (Stroth et al. 2009; Tomporowski et al. 2008), Raviv and Low's (1990) experiment of 96 children (aged 11–12) found no difference in the quality and level of concentration after a PE class and a science class in children. Concentration was measured through the completion speed of a letter-cancellation test. The observed discrepancy could be related to the fact that the participation level in sport and physical activities have been rarely taken into consideration when analyzing the effects of acute exercise on cognition. This has shown to have an effect in university students (Budde et al. 2012).

Longitudinal studies A longitudinal study of 154 children from the fourth, fifth, and sixth grade studied the effects of 30 min of running three times a week on creativity and self-concept (Tuckman and Hinkle 1986). The students were separated into a running group and a control group. A significant difference was found between the groups in creativity measured by the Alternative Uses Test. There was however no significant differences between groups in terms of self-concept measured through the Piers–Harris Children's Self-Concept Scale. A following study with 85 students from the eighth grade with a similar running program also found an increase in creativity (Hinkle et al. 1993). The program consisted of 30-min running sessions that were preformed five times a week. Creativity was measured through the Torrance Test of Creative Thinking.

The general finding in studies of exercise and cognition is a small positive effect, concurring with meta-analysis on adult (Colcombe and Kramer 2003; Etnier et al. 1997) and child populations (Sibley and Etnier 2003). The effect is larger in exercise that requires a cognitive effort such as coordination or working with others.

Self-concept and self-esteem

While several different definitions exist, researchers seem to agree that self-concept is at least close to Rosenberg's (1979, p. 7) definition, where self-concept is the "totality of the individual's thoughts and feelings having reference to himself as an object." Self-esteem is often described as the discrepancy in how a person evaluates him-/herself (their self-image) and how they wish they were (their ideal self-image) (Sirgy 1982). A person with a self-image close to his or hers ideal self-image has a high self-esteem, while a person with a large degree of discrepancy between his or hers self-image and ideal self-image has a low self-esteem.

An early review of the psychological effects of exercise in the general population found that self-esteem was the only psychological aspect that was shown to benefit from exercise in existing literature at the time (Hughes 1984). This effect was however not clear as the participants in three of the four self-esteem studies examined were boys with low self-esteem (McGowan et al. 1974), youthful offenders (Hilyer et al. 1982), and alcoholics (Gary and Guthrie 1972). The fourth study, using college students, found that only those with low self-esteem benefitted from exercise (Hilyer and Mitchell 1979). The use of clinical or special populations in child and adolescent studies is common. This was the case for many of the studies included in an early meta-analysis of exercise and child development of self-esteem (Gruber 1986). The meta-analysis found a positive connection between exercise and self-esteem. Most of the studies published on self-esteem, self-image, and self-concept since then have used children and adolescents with self-esteem or behavior problems as participants (Basile et al. 1995; MacMahon and Gross 1988), but there have been some studies on healthy children and adolescents.

A cross-sectional study of 988 German students (Kirkcaldy et al. 2002) found that regular involvement in endurance sports or activities was connected to an improved self-image and better psychological well-being than their less active counterparts. The study did not include any measurement that was specifically designed to measure self-esteem, although the authors concluded that the favorable self-image could be generalized to an improvement in self-esteem. All measurements were done through self-report questionnaires, which included several socio-demographic control variables (i.e., gender, age, education, and family situation). While the control variables help clarify the connection between exercise and self-image or self-esteem, the cross-sectional nature of the study limits the possibilities for a causal conclusion. Since the concepts of self-concept and self-esteem are long-term concepts that are relatively stable over a long period, few have chosen to examine the immediate effects of a single exercise session in any population, and we have failed to find any that have used a healthy child or adolescent population.

Longitudinal studies The study with the youngest participants in this review is an 8-week longitudinal study with children aged 3–5 (Alpert et al. 1990). A sample consisting of 24 children were divided into a free play group and an aerobic exercise group. The exercise sessions were administrated on weekdays and lasted for 30 min (including 5 min of warming up and 5 min of cooling down). During the session, the children had their heart rates measured every 10 min. The children in the aerobic exercise group who had obtained the desired training heart rate of 160 beats per minute were awarded with a small sticker to place on their head. Those with lower heart rates were encouraged to increase the intensity of their activity. Self-esteem was measured through the Thomas Self-Concept Values Test, a 14-items scale with items such as happy, smart, strong, good looking, and other qualities related to self-concept or self-esteem. Each child was shown a picture of him-/herself and would then answer verbally to questions asked by a research assistant if the person in the picture was happy, smart, strong, and so on. After the 8-week program, the aerobic exercise group had a higher score on the Thomas Self-Concept Values Test compared with both their baseline results and the free play group. The aerobic exercise group also had better results tests of agility and decreases in heart rate. There were no significant changes in the free play group during the 8 weeks. Caution is necessary with regards to generalization of the results, as the sample is small and due to the children being at an age where they are likely to be very susceptible to bias from the research assistants during the verbal assessment of self-esteem.

A sample of 30 fifth and sixth grade children was divided into either a 7-week running program or a control condition (Percy et al. 1981). Self-esteem was measured with the

Coopersmith Self-Esteem Inventory before and after the period. Self-esteem had an increase in the running program condition.

A three-year longitudinal study was conducted in Sweden between 2000 and 2003, where a significant connection was found between physical self-esteem and exercise in girls and physical self-esteem and body mass index (BMI) in boys (Raustorp et al. 2006). Physical activity and fitness was measured through daily pedometer steps, BMI, and bioelectrical impedance (body fat percent). Self-esteem was measured through the Children and Youth Self-Perception Profile, a 36-item self-report questionnaire. In 2000, 871 children (aged 7–14), and 375 adolescents (15–18) participated in 2003. Of the children who participated in 2000, 97 also participated in 2003, allowing the authors to use a follow-up design on parts of the population. The authors concluded that physical self-esteem in girls and weight control leads to exercise and a healthy lifestyle. This is an interesting conclusion that exemplifies the causality problems of exercise.

Tendencies and inclinations towards physical activity, participation in organized physical activity, physical fitness, and self-esteem were assessed at ages 9, 11, and 13 in 197 non-Hispanic white American girls (Schmalz et al. 2007). Tendency and inclination towards physical activity were measured through the The Childrens's Physical Activity scale. Participation in organized physical activity was measured through a checklist of common organized activities. Physical fitness was measured through the Progressive Aerobic Cardiovascular Endurance Run (PACER). The PACER is a test where the children run laps at a progressively higher speed, and the test ends when the child cannot complete the lap within the set timeframe. A positive connection between physical activity and self-esteem was found. There was also a lagged effect of physical activity in terms of self-esteem, where physical activity at ages 9 and 11 predicted self-esteem at ages 11 and 13, even when controlled for covariates. This lagged effect was not seen the other way around, as self-esteem did not significantly predict future exercise. This could be interpreted as evidence towards that the main causal relationship between exercise or physical activity and self-esteem is that exercise or physical activity leads to a better self-esteem. While the longitudinal design of the study does provide a good measure of development in both individual participants and the sample, there are limitations due to the sample of only non-Hispanic white American female participants.

One possible explanation for why exercise or sports participation would increase self-esteem is the increase in skill that follows participation in a specific activity or sport. In a 10-week longitudinal study, 288 students aged 12–14 and 16–18 were divided into groups of field hockey (96 participants), athletics (96 participants divided into discuss throw (32 participants), long jump (32 participants), and sprinting (32 participants)) and a control group (96 participants) (Salokun 1994). Sports skill and self-esteem were measured prior and after the 10-week period. Both the field hockey and the athletics group had improvements in self-esteem and in sports skill. There was also a correlation between self-esteem and sports skill. The study concluded that the results support inclusion of success-oriented sports in the high school curriculums. Additional support for self-esteem benefits of skill acquiring during sports or exercise was found in a 12-day summer camp swimming program where 65 boys (aged 7–15) participated, where improvement in self-concept was found in boys who learned to swim (Koocher 1971). The 30 boys who knew how to swim before the start of the program spent the swimming classes swimming on their own. There was no change in the self-concept of the children who failed to learn how to swim, or the children who already knew how to swim, despite being the group that was the most physically active during the period. The children who failed to learn to swim did not have a negative change in self-concept. Self-concept was measured with the Index of Adjustments and Values modified for use with school-age children assessing the boys' description of themselves, their satisfaction with themselves, and their ideal self. Swimming ability was measured by whether or not the participant could swim 25 m unassisted. Since swimming ability was determined in this fashion, the improvement in swimming skills amount the boys who already knew how to swim was not recorded.

Not all studies have found a connection between exercise and self-esteem, self-image, or self-concept. In the previously mentioned study by Tuckman and Hinkle (1986), no improvement in self-concept measured though the Piers–Harris Children's Self-Concept Scale was found from an aerobic exercise program consisting of 30-min runs instead of normal PE. The aerobic exercise program was however found to have a positive effect on creativity measured though the Alternative Uses Test. It should be noted that while the running program might have been more exhausting than normal PE, it was replacing another form of exercise and not adding to it.

Emotion and mood

The benefits of exercise in terms of emotions and mood have been researched and discussed thoroughly in adults (Helmich et al. 2010) and in several child and adolescent populations such as children or adolescents with delinquent behavior (MacMahon and Gross 1988), youthful offenders (Hilyer et al. 1982), and various clinical diagnoses. The research on healthy children and adolescents is however sparse and is mostly limited to the protective factors exercise has towards depression. Studies that have only included measures of clinical diagnosis of depression or depression symptoms have not been included in this review. Only a few studies with other or additional measures than depression have been conducted.

While there is a lack of experiments and longitudinal studies on the effects of exercise on emotions and moods, some evidence of a connection has been found in cross-sectional studies. In a cross-sectional study with 5,061 16-year old British adolescents, it was found that exercise had a positive association with emotional well-being, even when social class and physical health were controlled for (Steptoe and Butler 1996). Emotional well-being was measured through a general health questionnaire, which is designed to measure a variety of physiological and psychological health aspects. The previously mentioned cross-sectional study by Kirkcaldy et al. (2002) also found this connection.

Longitudinal studies Norris et al. (1992) conducted both a cross-sectional study and a longitudinal study. In the cross-sectional study, 147 adolescents (age 13–17) completed self-reports of exercise, stress, and psychological well-being. Stress and psychological well-being were measured though a battery of tests consisting of the Life Events Questionnaire, the Seriousness of Illness Rating Scale, the Perceived Stress Scale, and the Multiple Affect Adjective Checklist. Exercise was measured through both "yes or no" questions on whether or not the participant exercised or played sports regularly and through how many hours the participant spent exercising per week. Exercise was found to have a negative correlation to both stress and depression. In the following study, 80 adolescents (mean age, 16.7) were divided into four groups: moderate intensity aerobic exercise, high intensity aerobic exercise, flexibility training, and a control group. The study used the same measurements for stress and psychological well-being as the cross-sectional study and lasted for 10 weeks. The groups met twice a week for 25–30 min of exercise. The high intensity aerobic exercise group had significantly lower scores on both depression and stress than the other three groups. No significant differences were found among the moderate intensity aerobic exercise group, the flexibility training group, and the control group.

Discussion

The research question for this review was, "What psychological benefits can exercise lead to in healthy children and adolescents?" Studies on the effect of exercise on academic performance, cognition, self-esteem, emotions, and mood were examined. Findings from each of these topics will be summarized and discussed separately followed by a general discussion on problems encountered in studying the effects of exercise.

Academic performance

There is not sufficient evidence to conclude that PE will increase academic performance. However, all studies in the review found that academic performance was maintained despite the reduced time spent in normal academic classes (Table 1). Caution should also be held when generalizing the results from these studies. While several used standardized tests as means of evaluation, most also relied of non-standardized measures such as grades, evaluations, and reports from the teachers (Table 1), increasing the possibilities of bias interfering with the results. A possible example of this could possibly be seen in the Trois Rivières study where advantages of exercise in grades were larger than in the standardized tests (Shephard 1997. During this study, 80 % of the teachers were positive towards the project, with the remaining 20 % being neutral towards it (Shephard 1997). In Trois Rivières, Vanves and SHAPE teachers had a daily 1-h break, while the students had PE, which could have led to the teachers feeling more refreshed and better prepared (Shephard 1997), which may have led the teachers to overevaluate both the program and the students' in-class behavior and performance.

Although there were weaknesses in the studies and the results did not find exercise to improve academic performance, there were very few indications of negative implications on academic performance, even when other traditional academic subjects were replaced. The general trend seemed to be a slight improvement in learning efficiency through an increase in PE. The physiological and psychological benefits unrelated to academic performance and the increased chance of continued exercising through life are aspects that might not be of great importance to academic institutions, but that would be a great bonus to the students.

Cognition

In the studies reviewed, cognition has been measured through creativity, concentration, attention, and memory. Benefits of exercise were found in both long-term studies where a certain amount of exercise is performed per week and in short-term experiments where cognition is measured shortly after a single session of exercise (Budde et al. 2010b; Caterino and Polak 1999). Exercise that is considered not to have cognitive demands, such as running and working out on a stationary bike, have been found to have cognitive effects when the exercise is performed both in a single session (Caterino and Polak 1999; Gabbard and Barton 1979; Hillman et al. 2009) and over an extended period (Hinkle et al. 1993; Tuckman and Hinkle 1986) (Table 2). Exercise that requires a cognitive aspect such as timing, balance, dexterity, strategy, and particularly team based games or sports that in addition require cooperation or adapting your play to opponents does seem to give the greatest cognitive benefits (Budde et al. 2008; Ellemberg and St-Louis-Deschenes 2010; Pesce et al. 2009).

Table 1 Summary of long-term studies on the effects of exercise on academic performance in healthy children and adolescents

Author(s)	*n*	Age	Intervention	Duration	Measurement	Results
Ahamed et al. (2007)	287	4–5 grade	47 min of extra PE per week.	16 months	Canadian Achievement Test (CAT-3)	Maintained the level of academic performance
Coe et al. (2006)	214	6th grade	55 minutes of PE every weekday.	One semester	Grades, Terra Nova Percentile	Maintained the level of academic performance
Dwyer et al. (1979)	519	5th grade	75 minutes of PE every day.	14 weeks	Grades	Maintained the level of academic performance
Hervet (1952)		Last year of primary education	8 hours of PE per weak.	1 year	Certificate of study test	Maintained the level of academic performance.
Shephard et al. (1994)	546	1–6th grade	5 hours of quality PE each week.	6-years	Grades, Province wide examination	Maintained the level of academic performance
Sallis et al. (1999)	1,538	4–5th grade	57-76 hours of additional of PE per year.	2 years	Metropolitan Achievement Test (MAT6 and MAT7)	Maintained the level of academic performance

Self-esteem

Self-esteem was in an early review (Hughes 1984) found to be the only psychological aspect that benefited from exercise in the literature at the time. This benefit was also found in children and adolescents in most studies in this review (Table 3). While the measurements of self-concept, self-esteem, and self-image used in the studies in this review are based upon similar understandings of the concepts, none of the experiments in this review have used the same index or scale. The terms and concepts are also used interchangeably with studies using scales which are meant for measuring self-concept, self-perception, and self-image in measurement of self-esteem (Alpert et al. 1990; Kirkcaldy et al. 2002; Raustorp et al. 2006). All of the studies in this review have measured self-esteem though questionnaires, or verbal administration of questionnaires to children who were too young to read. While modifications were made in many studies to better suit the questionnaires to children, additional methods such as structured interviews could in future studies provide a more in-depth understanding of children's self-esteem and how exercise affects it.

Emotions and mood

The benefits of exercise in terms of emotions and mood have been researched and discussed thoroughly in adults and in several clinical child and adolescent populations. The research on healthy children and adolescents is however sparse and is mostly limited to the protective factors exercise has towards depression and anxiety. Interestingly there seems to be an almost complete lack of studies on the relationship between exercise and positive emotions or positive moods in children and adolescents. While a positive trend is seen in terms of exercise benefiting emotional well-being, not enough evidence is available to make any conclusions.

Table 2 Summary of short-term studies on the effects of exercise on cognition in healthy children and adolescents

Author(s)	*n*	Age	Form of exercise	Benefit	Task	Results
Budde et al. (2010b)	60	9th grade	Running (12 min)	Working memory	Letter Digit Span (LDS)	Significant improvement. Most improvement in the low performers
Budde et al. (2008)	115	13–16	Coordinative exercise vs. normal sport lesson (10 min)	Attention and concentration	D2 test	Significant improvement. Most improvement in the coordinative exercise group
Caterino and Polak (1999)	177	2–4th grade	Walking (15 min)	Concentration	Woodcock–Johnson Test of Concentration	Significant improvement in concentration in 4th graders. No significant results in 2nd and 3rd graders
Ellemberg and St-Louis-Deschenes (2010)	72	7 and 10	Aerobic exercise (30 min)	Cognitive functioning	Simple reaction and choice response time task	Significant improvement in both tasks
Gabbard and Barton (1979)	106	2th grade	Relay activities (20–50 min)	Mental performance	Mathematical computing test	Significant improvement after 50 min of exercise. No significant results after 20, 30, or 40 min
Hillman et al. (2009)	20	9–10	Walking (20 min)	Academic achievement, inhibitory control	Modified flanker task, Wide Range Achievement Test 3	Significant improvement in response accuracy, larger P3 amplitude, and better performance on the academic achievement test following aerobic exercise

Table 2 (continued)

Author(s)	*n*	Age	Form of exercise	Benefit	Task	Results
Pesce et al. (2009)	52	11–12	Relay activities vs. team games in PE	Memory	Free-recall of a word list	Significant improvement. Most improvement in the team games group
Raviv and Low (1990)	96	11–12	Normal PE	Concentration	Letter-cancellation test	Same level of concentration after a PE and a science class
Stroth et al. 2009	35	13–14	Stationary biking (20 min)	Executive control	Combined go/no-go task with Eriksen flanker	No effect. General physical fitness, was positively correlated with cognitive processing
Tomporowski et al. (2008)	69	7–11	Walking (23 min)	Executive functioning	Visual task-switching test	No effect

Problems in studies of the effects of exercise

In research on the psychological benefits of exercise in children and adolescence, there are many difficulties in measurement. Exercise is a term that is clearly defined based on the physical activity pattern of an adult where the physical activity is done intentionally to improve or maintain physical form (Caspersen et al. 1985). This fits well with the modern adult life where moderate or intense physical activity often is only performed with this intention. It does however not fit well with a young child's life where a large part of the activity is through unregulated play, quickly shifting levels of activity, and probably with little thought of consequences in terms of physical shape. As children have a different natural way of performing physical activity than adults, perhaps different measurements and experiments should be developed to investigate possible benefits from exercise in children.

Finding the appropriate and optimal dosage of exercise is a problem in exercise studies. Most exercises studies have the experimental group exercise at one level of intensity for a set amount of time. A few of the studies in this review have included several dosages by varying intensity (Budde et al. 2010b; Norris et al. 1992) and duration (Gabbard and Barton 1979).

Compliance and choosing an appropriate control group are problems that have been mentioned in evaluating the benefits of exercise (Kirkcaldy and Shephard 1990). Both of these are less problematic in studies of children where often the exercise done through compulsory PE and control groups are often another class or grade from another school.

Future studies

Finding the appropriate and optimal dosage of exercise is a challenge and future studies should include several different levels of intensity and duration of exercise.

Table 3 Summary of long-term studies on the effects of exercise on self-esteem in healthy children and adolescents

Author(s)	*n*	Age/grade	Form of exercise	Length of program	Benefit measured	Measurement	Results
Alpert et al. (1990)	24	3–5	Aerobic exercise	8 weeks	Self-esteem	Thomas Self-Concept Values Test	Significant improvement in self-esteem
Koocher (1971)	65	7–15	Swimming classes	12 days	Self-esteem	Index of Adjustments and Values modified for use with school-age children.	Significant improvement in self-concept was found in boys who learned to swim
Percy et al. (1981)	30	5–6th grade	Running program	7 weeks	Self-Esteem	Coopersmith Self-Esteem Inventory	Significant improvement in self-esteem
Salokun (1994)	288	12–18	Field hockey, discuss throw, long jump and sprinting program	10 weeks	Self-esteem	Total Positive Self-concept	Significant improvement in self-esteem and in sports skill
Tuckman and Hinkle (1986)	154	4–6th grade	Running program instead of normal PE	12 weeks	Self-concept, creativity	Alternate uses test, Piers-Harris Children's Self-Concept Scale	No significant results in self-concept. Increased creativity

Not only to be able to design better experiments but also to be able to give recommendations to the general public on how they should exercise. PE is endangered and more research is needed to contribute to the knowledge on how it can benefit students and why it should remain in schools. More research is needed in all topics in this review, particularly in positive emotions were there seems to be a complete lack of research.

Conclusion

Academic performance is found to be maintained when normal academic classes are reduced and replaced by an increase of exercise, physical activity, or physical education. Exercise seems to have a positive effect on several aspects of cognition and self-esteem in healthy children and adolescents. A positive connection between exercise and emotions and moods in children is found in the few studies that have been conducted. Studies on the effects of exercise on positive emotions and positive mood of healthy children and adolescents are needed. The results in this review provide evidence for psychological benefits from exercise. The benefits can be experienced immediately and are therefore likely to be better incentives for children and adolescents to exercise than long-term effects of exercise such as reducing the chance of cardiovascular disease in the far future.

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