SMART MOVES!

Physical activity and cognitive performance in young adolescents

Vera van den Berg

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Chapter 1

General introduction

INTRODUCTION

In the Netherlands, children aged 4-12 years spend a significant amount of time at school. Dutch primary schools have an important task to support children in their cognitive-intellectual and social-emotional development, and the development of their creativity, cultural and physical skills (Education Council of the Netherlands, 2011; Government of the Netherlands, 1981). As such, schools play an important role in preparing children for and fostering their future (school) career (Education Council of the Netherlands, 2011; Ministry of Education, 2011).

Competence in language and mathematics/arithmetic is considered essential to acquire other knowledge and skills in life (Education Council of the Netherlands, 2011). Therefore, these subjects receive special attention in the core objectives of Dutch primary education (Dutch Inspectorate of Education, 2015; Education Council of the Netherlands, 2011). Moreover, schools are evaluated based on their pupil's performance levels, and therefore they are required to test and monitor children's progress in these subjects (Dutch Inspectorate of Education, 2015). This seems an important reason for schools to devote much of their curriculum time to language and mathematics/arithmetic, consequently reducing the time for other activities during the school day, such as physical activity (PA) (Centers for Disease Control and Prevention, 2010; Hardman & Green, 2011). It has, however, been suggested that PA can provide short- and long-term improvements in children's cognitive functions and academic performance (e.g. Howie & Pate, 2012; Singh, Uijtdewilligen, Twisk, van Mechelen, & Chinapaw, 2012; Verburgh, Konigs, Scherder, & Oosterlaan, 2014). In this respect, increasing the time for PA in the school curriculum may actually provide educational benefits and contribute to achieving school's core educational objectives.

Physical activity is defined as 'any bodily movement produced by skeletal muscles that results in energy expenditure' (Caspersen, Powell, & Christenson, 1985).

Exercise is a planned and structured form of physical activity (Caspersen et al., 1985). Single exercise bouts are expected to provoke an immediate physiological response, while repeated exercise has the purpose to improve or maintain physical fitness (Budde et al., 2016; Caspersen et al., 1985).

In this thesis, the results of different experimental studies examining the effects of exercise on children's cognitive performance will be described. This introduction continues with a definition of the cognitive functions as used in this thesis, followed by a short overview of the evidence on the effects of PA on cognitive performance in children. Thereafter, factors related to the implementation of school-based PA are addressed. The introduction ends with the aims and the outline of the chapters within this thesis.

Cognitive functions

Cognitive functions are known as mental processes that are important for processing information, acquiring knowledge and performing tasks. People use cognitive functions on a daily basis, enabling them to remind things, plan, reason and make decisions (Lezak, Howieson, Loring, Hannay, & Fischer, 2004). In this thesis, four cognitive functions will be used as primary outcome measures: 'selective attention', 'inhibition', 'working memory', and 'information processing speed'. These cognitive functions have been shown important for children to function well in school, as they are related to children's classroom behavior, learning efficiency and academic performance (e.g. Diamond, 2013; Rohde & Thompson, 2007; St Clair-Thompson & Gathercole, 2006; Stevens & Bavelier, 2012). A definition of each cognitive function can be found in the box below.

Selective attention is the ability to select and focus on relevant information, while simultaneously suppressing or ignoring irrelevant or distracting information (Jacob & Parkinson, 2015; Stevens & Bavelier, 2012). This cognitive function enables children to maintain their concentration by only paying attention to relevant aspects of a situation, task or problem (Jacob & Parkinson, 2015).

Inhibition is the ability to resist or override dominant or automatic responses, which enables children to resist a desire to do what seems most naturally (Diamond, 2013; Jacob & Parkinson, 2015; Miyake et al., 2000). By inhibiting responses children are (better) able to stay focused on academic tasks.

Working memory is the ability to temporarily maintain or store information and actively manipulate this information over a relatively short time period (Baddeley, 2003; Jacob & Parkinson, 2015). It enables children to remember information, while simultaneously being able to engage in other cognitive activities.

Information processing speed is the efficiency with which children can execute cognitive tasks and is associated with the efficiency of higher cognitive functions (Fry & Hale, 1996; Kail & Ferrer, 2007).

Physical activity and cognitive performance

It is well-known that PA is beneficial for children's physical, mental, social and emotional health. For example, it has been shown that regular participation in PA is favorable for children's cardiovascular fitness, motor skill development, and muscular and bone strength, and reduces risk factors for health problems such as obesity and cardiovascular disease (Janssen & LeBlanc, 2010; Poitras et al., 2016; Strong et al., 2005). Moreover, it has been shown that PA has positive effects on children's self-concept, pro-social behavior and well-being, and lowers symptoms of depression and anxiety (Biddle & Asare, 2011; Poitras et al., 2016; Spruit, Assink, van Vugt, van der Put, & Stams, 2016).

In past years, there has been increased attention for the effects of PA on children's cognitive functioning, both in research and in the popular media. While headlines such as "*physical activity makes children smarter*" or "*exercise breaks: a booster for children's concentration*" regularly appear in the popular media, these claims cannot yet be supported by scientific evidence.

Worldwide, studies examining the effects of PA on cognition are rapidly expanding. Several meta-analyses have concluded that *overall*, acute as well as long-term PA can have small, but positive effects on cognitive functions of children (e.g. Chang, Labban, Gapin, & Etnier, 2012; Ludyga, Gerber, Brand, Holsboer-Trachsler, & Puhse, 2016; Verburgh et al., 2014). However, there are still many inconsistencies between studies and many questions regarding the characteristics of effective PA programs remain unanswered. For example, little is known about what frequency, duration and type of PA can benefit cognitive functions (Donnelly et al., 2016; Verburgh et al., 2014). Also, little is known about how acute and long-term effects of PA on cognition relate to each other (Gearin & Fien, 2016; Verburgh et al., 2014). Moreover, the cognitive effects found in laboratory studies cannot immediately be translated into school practice, since several influential factors may come into play in daily school practice (Gearin & Fien, 2016; Janssen, Toussaint, van Mechelen, & Verhagen, 2014). For example, outcomes may differ when implementation rates turn out lower in the real life school setting compared to the controlled experimental setting, or when children do not reach intended intensity levels. This lack of knowledge hampers giving evidence-based and specific advice to schools about what kind of PA programs they should structurally implement in school in order to improve cognitive functions of children (Donnelly et al., 2016).

Acute studies focus on the short-term effects of physical activity on cognitive performance measured immediately or with a short delay after a single bout of PA.

Long-term studies examine the cognitive effects of physical activity programs with a duration of multiple weeks, months or years.

The experimental studies collected in this thesis examine the effects of exercise bouts in the school setting that are not integrated with academic content or activities. Several physiological mechanisms have been hypothesized to explain the potential cognitive effects induced by exercise. Acute effects are hypothesized to occur by an increased blood flow and supply of oxygen and glucose to the brain

(Ogoh & Ainslie, 2009), increased release of neurotrophic factors such as brain derived neurotrophic factors (Piepmeier & Etnier, 2015) and/or increased arousal levels, resulting in increases in neurotransmitters such as dopamine, serotonin and norepinephrine (McMorris, 2009). Long-term effects of exercise are hypothesized to occur as a result of increased physical fitness and changes in the brain, including the development of new blood vessels and neurons, changes in brain volume and improved efficiency of neural networks (see for reviews Cotman, Berchtold, & Christie, 2007; Huang, Larsen, Ried-Larsen, Moller, & Andersen, 2014; van Praag, 2008). The exact mechanisms need to be further examined, and are beyond the scope of this thesis.

To recapitulate, research in the field of 'PA-cognition' is rapidly expanding and insight in the characteristics of PA programs that can exert positive effects on cognitive performance is of great interest to school practice. Improving children's cognitive functions by PA may increase their learning efficiency and subsequently contribute to school's core educational goals (i.e. performance in language and mathematics/arithmetic). Moreover, given the earlier mentioned physical, mental and social-emotional benefits of PA, increasing the amount of PA in school can also contribute to multiple of children's developmental areas, thereby supporting the broad task of primary education.

School-based physical activity programs: implementation in school practice

Possible beneficial effects of PA on cognitive performance are regularly brought into play by researchers and local commercial parties to advocate more PA in school. However, many primary schools offer little to no structural PA opportunities besides their regular physical education classes and recess time (Hardman & Green, 2011; Slot-Heijs, Lucassen, & Reijgersberg, 2017). In line, it has been shown that 10 to 12 years old Dutch girls and boys spend respectively 68% and 65% of their time at school in sedentary activities, and only 3% (girls) and 4% (boys) of their school time in moderate-to-vigorous intensity PA (van Stralen et al., 2014).

Several school-based PA programs have been developed to increase children's PA levels (Naylor et al., 2015). However, the implementation of such programs appears very difficult in daily school practice, resulting in low adherence and little or no effects on children's PA levels (Dobbins, Husson, DeCorby, & LaRocca, 2013; Metcalf, Henley, & Wilkin, 2012). The main focus on academic performance and the associated sense of lack of time appear the main reason why teachers fail to adequately implement PA programs structurally in their daily school curriculum (Naylor et al., 2015). Moreover, it is unclear to what extent current PA programs fit the needs, interests and possibilities of school practice, since many programs are developed in a top-down manner, i.e. without involvement of school principals, teachers and children (Brunton et al., 2003; van Sluijs & Kriemler, 2016). An increasing number of researchers have advocated that for the development of PA programs that are feasible and sustainable in daily school practice, it is of utmost importance to involve school professionals and children in research projects (Glasgow & Emmons, 2007; van Sluijs & Kriemler, 2016; Webster, Russ, Vazou, Goh, & Erwin, 2015).

Aims of this thesis

The aims of this thesis are:

1) to examine the effects of acute and repeated exercise bouts on children's cognitive performance, and

2) to gain insight in the perspectives of school professionals and children with regard to additional PA in school.

The studies presented in the thesis have been conducted as part of the SMART MOVES! project. SMART MOVES! aimed to develop effective and feasible PA programs improving cognitive performance of children aged 10 to 14 years old.

Part I Acute effects of exercise on cognitive performance

The first part of this thesis is dedicated to the assessment of the acute effects of single exercise bouts on cognitive performance, measured immediately after exercise. In particular, characteristics of effective exercise bouts in terms of exercise type and duration are identified.

In **Chapter 2**, the acute effects of three different types of 12-minute classroom-based exercise bouts, i.e. aerobic, coordinative, and strength, on selective attention and information processing speed in 10 to 12 years old children are examined. In **Chapter 3**, the acute effects of exercise bouts with different duration, i.e. 10, 20, or 30 minutes, on selective attention and working memory of 10 to 13 years old children are examined.

Part II Physical activity in school practice: perspectives of school professionals and children

To gain insight in the feasibility of additional PA in primary school, the second part of this thesis focusses on the perspectives of primary school professionals and children in grades 5 and 6. In particular, their motivations, needs, preferences and ideas about (feasible) additional PA in school are explored.

In **Chapter 4,** the perspectives of school principals and teachers with regard to additional PA in school are explored. In **chapter 5**, primary schoolchildren's perspectives are central.

Part III Daily exercise breaks and cognitive performance

Based on the outcomes of the first and second part of this thesis, an exercise breaks program that closely meets the needs of school practice was composed. In the third part of this thesis, the effects of this exercise breaks program are evaluated.

In **Chapter 6**, the effects of a 9-week exercise breaks program consisting of a daily 10-minute Just Dance exercise break in the classroom are examined. The effects of the program on 9 to 12 years old children's selective attention, inhibition and memory performance, as well as aerobic fitness and PA levels are assessed.

This thesis concludes with a general discussion (**chapter 7**) in which the results of the different studies are summarized, integrated and discussed, with a focus on their implications for future research and school practice.

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Chapter 2

Physical activity in the school setting: cognitive performance is not affected by three different types of acute exercise

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Abstract

Recent studies indicate that a single bout of physical exercise can have immediate positive effects on cognitive performance of children and adolescents. However, the type of exercise that affects cognitive performance the most in young adolescents is not fully understood. Therefore, this controlled study examined the acute effects of three types of 12-minute classroom-based exercise sessions on information processing speed and selective attention. The three conditions consisted of aerobic, coordination and strength exercises respectively. In particular, this study focused on the feasibility and efficiency of introducing short bouts of exercise in the classroom. One hundred and ninety five students (5^{th} and 6^{th} grade; 10-13 years old) participated in a double baseline within-subjects design, with students acting as their own control. Exercise type was randomly assigned to each class and acted as between-subject factor. Before and immediately after both the control and the exercise session, students performed two cognitive tests that measured information processing speed (Letter Digit Substitution Test) and selective attention (d2 Test of Attention). The results revealed that exercising at low to moderate intensity does not have an effect on the cognitive parameters tested in young adolescents. Furthermore, there were no differential effects of exercise type. The results of this study are discussed in terms of the caution which should be taken when conducting exercise sessions in a classroom setting aimed at improving cognitive performance.

Introduction

Schools and teachers experience increased pressure to improve cognitive performance and scholastic achievement of their students (McMullen, Kulinna, & Cothran, 2014; Wilkins et al., 2003). This pressure is caused by the high demands that governments place on students' performance in language and mathematic subjects, which are used for the evaluation and funding of schools (Center for Education Policy, 2007; Dutch Inspectorate of Education, 2015).Consequently, the time allocated to academic subjects can result in reduced time for physical education and physical activity (PA) in the school curriculum (Wilkins et al., 2003; Centers for Disease Control and Prevention, 2010). Recent studies, however, showed that in addition to the well-known physical and mental health benefits (Biddle & Asare, 2011; Janssen & Leblanc, 2010), regular participation in PA seems to benefit cognitive functioning and scholastic achievement (see for a review Howie & Pate, 2012; Khan & Hillman, 2014; Singh, Uijtdewilligen, Twisk, van Mechelen, & Chinapaw, 2012).

In addition to the chronic effects of PA on cognitive performance, a single bout of physical exercise seems to have positive effects on performance in several cognitive tasks (see for a review Chang, Labban, Gapin, & Etnier, 2012; Tomporowski, Lambourne, & Okumura, 2011). For example, information processing speed (e.g. Cooper, Bandelow, Nute, Morris, & Nevill, 2012; Ellemberg & St-Louis-Deschênes, 2010) and selective attention (e.g. Janssen et al., 2014a; Tine & Butler, 2012) have been shown to improve immediately after a single exercise session. Information processing speed refers to the efficiency of executing cognitive tasks and is associated with cognitive performance (Kail & Ferrer, 2007). Selective attention is needed to 'select and focus on particular input for further processing, while simultaneously suppressing irrelevant or distracting information' (Stevens & Bavelier, 2012, p. 30). The above-mentioned cognitive functions play an important role in classroom behavior and learning processes and thereby contribute to scholastic achievement (Rohde & Thompson, 2007; Stevens & Bavelier, 2012). Therefore, conducting exercise sessions during the school day may yield immediate positive effects on learning efficiency in the classroom.

Several neurobiological mechanisms have been hypothesized to explain the acute effects of exercise on cognitive functioning: 1) increased blood flow to the brain thereby elevating oxygen uptake (Ogoh & Ainslie, 2009); 2) increases in neurotrophic factors, such as brain derived neurotrophic factor, growth hormone, and insulin-like growth factor-1 (Gregory et al., 2013; Piepmeier & Etnier, 2014); 3) increases in brain neurotransmitters, such as dopamine, norepinephrine, and serotonin, which results from an exercise-induced increase in arousal that involves the activation of the autonomic nervous system and hypothalamic-pituitary-adrenal axis (McMorris, Tomporowski, &

Audiffren, 2009; McMorris & Hale, 2014). According to the arousal theory, the exercise-induced arousal improves cognitive performance in an inverted U-shape fashion (Yerkes & Dodson, 1908).

Although there is emerging evidence of positive effects of acute exercise on cognition, the characteristics of exercise needed to improve cognitive functioning in children and adolescents remain largely unknown (Howie & Pate, 2012; Verburgh, Königs, Scherder, & Oosterlaan, 2014). A review of Chang et al. (2012) suggested that a minimum duration of 11 minutes is needed for obtaining relevant cognitive benefits. However, little is known regarding the *optimal type* of acute exercise that benefits cognition most. While the majority of studies among children and adolescents have focused on aerobic exercise, only few studies (e.g. Budde, Voelcker-Rehage, Pietraßyk-Kendziorra, Ribeiro, & Tidow, 2008; Gallotta et al., 2012; Gallotta et al., 2015) compared regular, repetitive aerobic exercises (e.g. walking, running) with more complex, cognitively demanding exercises (e.g. coordinative exercises). For example, Budde et al. (2008) found improved selective attention in adolescents (age 13-16 years) after both a 12-minute aerobic and coordinative exercise session, with highest improvements in the coordination group. Coordinative exercises are believed to improve selective attention by pre-activation of cognitive related neuronal networks (Budde et al., 2008). According to Budde and colleagues, there is an overlap in functional brain areas supporting motor functions and selective attention, such as the frontal lobes and the cerebellum. Higher motor demands, as in coordinative exercises, are suggested to require higher prefrontal cortex activity, thereby facilitating activation of neuronal networks responsible for attention performance (Budde et al., 2008). In contrast, Gallotta et al. (2012; 2015) found larger improvements in selective attention in 8 to 11 year old children after aerobic compared to coordinative exercise. Bailey and colleagues (2014) found no acute effects of 15 minutes coordination or aerobic exercises on selective attention in young adults (Bailey, Douglas, Wolff, & Bailey, 2014).

To our knowledge, no published studies report on the acute effect of strength exercise on cognitive performance in children and adolescents. However, studies in adults have shown positive effects of a single bout of strength exercises on selective attention (Chang & Etnier, 2009; Chang, Tsai, Huang, Wang & Chu, 2014; Alves et al., 2012) and information processing speed (Chang & Etnier, 2009; Chang et al., 2014).

The growing literature on the acute effects of exercise on cognition leads several researchers advocate the implementation of exercise sessions in schools (e.g. Drollette, Shishido, Pontifex, & Hillman, 2012; Hillman et al., 2009). However, most evidence of acute exercise effects on selective attention and information processing speed is derived from studies in laboratory settings (e.g.

Drollette et al., 2012; Ellemberg & St-Louis-Deschênes, 2010; Hillman et al., 2009). More studies in a school setting are needed in order to generalize these results into practice (Janssen, Toussaint, van Mechelen, & Verhagen, 2014b). Since there is only a limited number of studies in a school setting that examined exercise related effects on information processing speed and selective attention in young adolescents (e.g. Cooper et al., 2012; Cooper, Bandelow, Nute, Morris, & Nevill, 2013; Janssen et al., 2014a; Tine & Butler, 2012), this study will focus on 10-13 year olds.

Taken together, there is limited and inconclusive evidence regarding the differential effects of exercise types on cognitive functioning in children. In addition, there is a need for more studies in young adolescents conducted in a school setting. Therefore, the aims of this study were to examine 1) the acute effects of 12-minute classroom-based exercise sessions on cognitive tasks that measure information processing speed and selective attention in young adolescents aged 10-13 years; and 2) the moderating effects of type of exercise, i.e. aerobic, coordination or strength.

Given the inconsistencies in studies comparing the differential effects of exercise type on cognition, but mainly positive effects of each individual exercise type, we expect to find similar acute effects of different types of exercise on measures of information processing speed and selective attention in 10-13 year olds.

Materials and Methods

Recruitment and participants

A convenience sample of three regular public primary schools in The Netherlands participated in this study. In order to test classroom-based exercise sessions, all children enrolled in the 5th and/or 6th grade were eligible to participate. In total, eight classes participated, three grades 5 and five grades 6 divided over the three schools. The number of classes in each school varied from 1 to 5. All classes were invited and agreed to participate after receiving information on the nature and scope of the study. The principals of the three schools signed an informed consent for participation of all students in their grades 5 and 6. Upon principal agreement children and parents/legal guardians received information letters about the study and could withdraw their child from participation by signing and returning an objection form. Participation in this study was voluntary; children received a small incentive for their participation. The Ethics Committee of the Faculty of Human Movement Science of the VU University Amsterdam, The Netherlands concluded that our study does not fall within the scope of Medical Research Involving Human Subjects Act. They approved the study protocol and agreed with active informed consent by the school principal with parents having the option of opting their child out of the study.

Study design and procedure

The current study had a double baseline, mixed within- and between-subjects design. All students participated in one familiarization day and two experimental days: one exercise day and one control day, thereby acting as their own control. The exercise as well as the control day consisted of a pre- and post-test, by which we controlled for intra-individual differences in cognitive test performance across days. In order to minimize potential learning effects due to test repetition, we included a familiarization day and counterbalanced the order of the experimental days. During the familiarization day, students were acquainted with the test procedures and practiced the tests to make sure they clearly understood them. Furthermore, we controlled for potential learning effects by randomizing and counterbalancing the order of exercise day and control day across classes. By means of the counterbalanced design we were able to estimate effects of exercise more accurately. Three classes started with the control day in week 1 and exercise day in week 2, while five other classes started with the exercise day in week 1 and control day in week 2. Type of exercise acted as between-group factor. Each class was randomly assigned to one of three exercise types (see 'exercise session'). Three classes were assigned to the aerobic condition, three classes to the coordination condition and two classes to the strength condition. The experiment took place in the classroom and was procedurally the same for each class.

All classes were visited three times (see Figure 1). During the first visit the experimental protocol was explained and students were familiarized with the measurement procedures. The cognitive tests were introduced and practiced by the students. Height and weight were measured in a separate room outside the classroom. The subsequent visits consisted of the two experimental days, which were scheduled one week apart, at the same day of the week from 08:30 to 10:00 a.m.

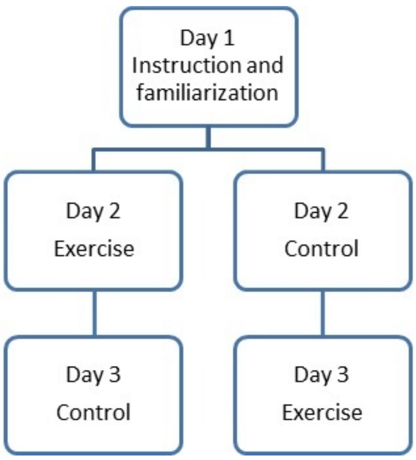

Figure 1. Overview study design.

Both experimental days followed a standardized routine, completed in the classroom setting (see Figure 2); 1) we informed the students about the daily procedure and asked them to fill in a short questionnaire about their bedtime, breakfast and transport to school; 2) students were fitted with a heart rate monitor and their resting heart rate (HR) was measured (exercise day) or students learned how they could measure their own heart rate at the wrist or neck (control day); 3) we asked to complete the pre-cognitive tests (T1), followed by the exercise or control session, each lasting 12 minutes; 4) immediately after ending of the session, administration of the post-cognitive tests (T2) took place.

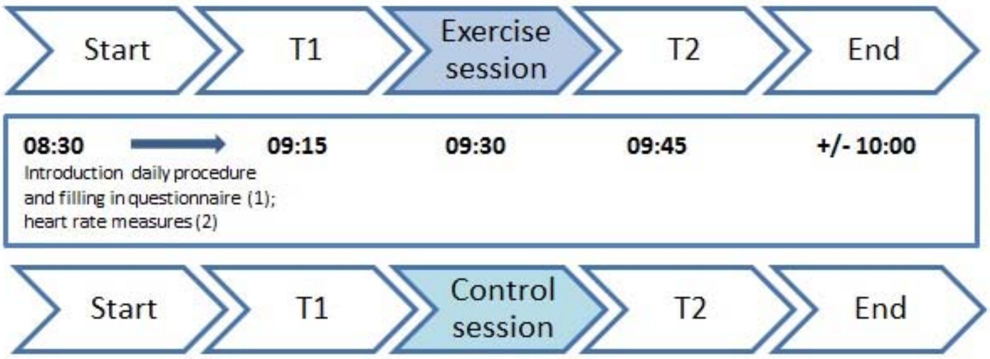

Figure 2. Experimental protocol during exercise day (above) and control day (below).

Bedtime, breakfast, and transport to school

In order to keep the circumstances in both experimental days similar, we asked students and their parents/legal guardians to try to keep bedtime, breakfast and transport to school approximately the same before each experimental day.

Exercise sessions

Together with two physical education teachers we developed three different types of exercise sessions. Each session lasted 12 minutes. The first 1 ½ minutes (warming-up) and last 30 seconds (cooling-down) were equal for all exercise types. The core of the sessions consisted either of 10 minutes aerobic, coordination or strength exercises. Exercises were intended to be of moderate intensity and easy to perform in the classroom behind students' desks.

The aerobic session consisted of various well-known, easy and repetitive movements. The coordination session consisted of more complex movements that stressed coordinative skills, including bilateral movements and movements in which the body mid line was crossed. The strength session consisted of dynamic and static body-weight exercises, adjusted to the age of the students (see Table 1).

In order to standardize the exercise sessions, a movie of each session was recorded beforehand. The movie was shown in the classroom and students were asked to follow and imitate the instructor in the movie. One researcher and three research assistants were present during the exercise sessions, to motivate and guide the students.

Table 1. Examples of exercises within each exercise type.

Aerobic exercises	**Coordination exercises**	**Strength exercises**
-Walking, marching, dribbling or jogging in place. -Jumping in place (pretending to jump rope, pretending to throw a ball in the basket). -Pretend to: swim freestyle, throw and kick a ball, riding on a hand-bike and ice skating.	-Dance steps with different directions and speed. -Walking in place and simultaneously touching the opposite ankle in front or behind the body. -Head, shoulders, knees and toes with different order and touching opposite body side. -Clapping hands under the legs, while standing straight and while rotating legs to the side.	-Squats ('bend your knees until you are almost sitting') -Abdominal exercises while sitting on chair (e.g. knee lifting, extending legs) and while standing (bending upper body aside; move knee and elbow towards each other). -Heel raise, shoulder side raise, and arm circles. -Dynamic and static bicep curls ('make your muscles as big as you can!').

Control session

In the control condition, students were seated during 12 minutes and listened to an educational lesson about exercise and movement. This lesson was always taught by the same research assistant and interaction with students was kept to a minimum. Students were allowed to ask a few questions during the last minute of the lesson.

Measures

Participant information

We assessed age and sex by self-report. Body weight and height were measured according to standardized protocols with the students wearing regular clothes without shoes. Body Mass Index (BMI) was calculated (weight(kg) / height(m)^2).

Heart rate

During the exercise session, students wore a heart rate monitor (Polar H7 Bluetooth) that was connected to the Polar Team App (Polar Electro Oy, Finland). Resting heart rate (HR rest) was measured after students sat still for five minutes. Heart rate during the exercise sessions was measured and stored in the Polar Team App. Mean HR during the exercise sessions was calculated (HR exercise). The formula '220 – age' was used to estimate maximum heart rate (HR max; American College of Sports Medicine [ACSM], 2013).

Intensity of the exercise sessions was calculated as percentage of HR max: (HR exercise/HR max)*100. Percentage of time spent in moderate to vigorous intensity zone (64-94% HR max; ACSM, 2013) was calculated for the 10 minutes aerobic, coordination and strength exercises.

Cognitive measures

Cognitive performance was measured with two neuropsychological tests, the d2 Test of Attention (Brickenkamp & Oosterveld, 2012) and the Letter Digit Substitution Test (van der Elst, van Boxtel, van Breukelen, & Jolles, 2006; van der Elst, Dekker, Hurks, & Jolles, 2012). Both paper-and-pencil tests were group-administered. Before each test, students were provided with standardized verbal and written instructions. During testing, the test leader gave instructions and kept track of time, while three research assistants each observed a group of students and took notes of disturbances (e.g. noise outside the classroom), deviant behavior (e.g. students ignoring test instructions), and practical problems (e.g. students having an empty pen).

Letter Digit Substitution Test (LDST)

The LDST is a substitution test that measures general information processing speed (van der Elst et al., 2012). It is an adaptation of earlier substitution tests, such as the Symbol Digit Modalities Test (Smith, 1982) and the Digit Symbol Substitution Test (Wechsler, 1981). The LDST requires students to match letter-number pairs according to a key, which is presented on top of the sheet. The key contains nine boxes with letters and associated numbers, between 1 and 9. Underneath the key, boxes of letters are shown with empty boxes below. Students were instructed to fill in the empty boxes with the appropriate numbers as fast and accurately as possible within 90 seconds. The number of correct substitutions made in 90 seconds was used as dependent variable. The test-retest reliability of the LDST has proven to be high in a large sample of adults ($r > .85$) (van der Elst, van Boxtel, van Breukelen, & Jolles, 2008). Furthermore, studies have shown that the LDST is sensitive to age, sex and education level in children and adolescents aged 8 to 15 years (Dekker, Krabbendam, Aben, de Groot, & Jolles, 2013; van der Elst et al., 2012). Four different versions of the LDST were administered during the four test moments. The order of test versions was equal for all students.

d2 Test of Attention

The d2 Test of Attention is a cancellation task that measures selective attention (Brickenkamp & Oosterveld, 2012). The test consists of one page with fourteen lines, each consisting of forty-seven letters 'd' and 'p'. Above and/or below each letter are one to four dashes displayed, either individually or in pairs. Students were instructed to mark as much letters 'd' with a total of two dashes ('d2') within each line, while ignoring all other characters. A 'd2' has either two dashes above, two dashes below or one dash above and one dash below the 'd'. Students were instructed to work from left to right, with a time limit of 20 seconds per line. After 20 seconds, the test leader gave a signal to continue with the next line. The total test lasted 4 minutes and 40 seconds.

Three different parameters can be calculated after completion of the d2 test. First, the total number of items processed, which is a measure of working speed. Second, the number of all errors relative to the total number of items processed, a measure of precision and thoroughness. Third, the number of correctly marked d2 characters minus the number of incorrectly marked characters, which is a measure of attention span and concentration ability. In this study, we used the latter as dependent variable. This value is, opposed to the other values, resistant to falsifications and therefore an objective measure of selective attention (Brickenkamp and Oosterveld, 2012). The test-retest reliability of the d2 test has been proven to be moderate to high in a population of 144 Dutch children, aged 10-13 years ($r = .79$ to $.83$) (Brickenkamp & Oosterveld, 2012).

Evaluation of the exercise sessions

To evaluate students' experience regarding the difficulty and enjoyment of the three exercise sessions, students were asked two questions: 1) How much did you like the exercise session? ('fun'); 2) How difficult was the exercise session? ('difficulty'). Answers were given on a five-point Likert scale, ranging from 1 'not at all' to 5 'very much'.

Statistical analysis

All statistical analyses were performed in SPSS version 20.0. One-way ANOVAs and Chi-square tests were conducted to compare student characteristics and HR data between the exercise types. Cognitive outcomes were analyzed using 2 x 2 x 3 mixed ANOVAs with time (T1, T2) and condition (control, exercise) as within-subject variables and exercise type (aerobic, coordination, strength) as between-subject variable. In order to control for session order (control-exercise versus exercise-control), this variable was included as additional between-factor in all analyses. Analyses were conducted separately for the LDST and d2 test. Post hoc comparisons (Bonferroni adjusted) were conducted in case of significant findings. Level of significance was set at $\alpha<0.05$.

Results

One hundred and ninety five students from eight classes of three primary schools in the Netherlands participated. Students were in 5th and 6th grade and their age ranged from 10 to 13 years. Two students´ parents returned the objection form and their children were therefore excluded from the study.

Eleven students were excluded from analyses due to absence at one or both experimental days. An additional number of four (LDST) and five (d2 test) students were excluded based on invalid test scores due to missing a part of the test (one student came in later, two students had an empty pen during the test) or ignoring test rules (students who did not follow the start/stop instructions). The final dataset consisted of 180 students in the LDST analysis and 179 students in the d2 test analysis.

Student characteristics

Demographics of the total group and for each exercise type group are shown in Table 2. Post hoc multiple comparisons showed higher mean age and height for the strength group. HR exercise, %HR max and percentage in moderate-to-vigorous intensity zone were significantly higher during the aerobic exercise session. Baseline test scores for the LDST and d2 test did not differ between exercise types.

Table 2. Characteristics of the total sample and three exercise types (means, standard deviations (SD), percentages).

	Total (n = 184)	**Aerobic (n = 66)**	**Coordination (n = 71)**	**Strength (n = 47)**
Age (years)	11.7 (0.7)	11.6 (0.7)	11.7 (0.8)	12.1 (0.5)*ac
Sex (boy/girl; %)	54 / 46	53 / 47	56 / 44	51 / 49
Height (cm)	154.6 (7.5)	152.8 (7.8)	154.3 (6.9)	157.4 (7.2)*a
Weight (kg)	44.1 (8.6)	43.1 (7.7)	43.6 (8.5)	46.3 (9.6)
BMI	18.4 (2.4)	18.5 (2.2)	18.2 (2.6)	18.5 (2.5)
HR exercise (beats/min)	120.1 (12.5)	127.0 (12.6)*cs	114.1 (10.6)	119.7 (9.9)*ac
%HR max	57.7 (6.0)	60.9 (6.0)*cs	54.8 (5.1)	57.6 (4.8)*ac
Moderate-to-vigorous zone (% of core 10 min)	24.4 (24.8)	39.5 (27.0)*cs	14.1 (17.3)	18.8 (20.9)
Familiarization day LDST	47.2 (8.9)	45.2 (8.7)	46.8 (8.5)	50.6 (8.8)
Baseline LDST	49.2 (8.7)	47.7 (8.7)	49.5 (8.8)	51.1 (8.5)

Familiarization day d2	142.1 (22.5)	141.3 (24.2)	139.8 (20.4)	146.5 (22.8)
Baseline d2	166.5 (26.0)	163.6 (26.3)	165.1 (25.2)	172.7 (26.2)
Perceived fun of exercise	3.9 (0.9)	3.6 (0.9)	4.0 (0.9)	3.9 (0.7)
Perceived difficulty of exercise	1.9 (1.0)	1.6 (0.8)	2.2 (1.1)	1.8 (0.9)

Note: Baseline LDST and d2 scores are pre-test scores at the first experimental day.
*a = significantly different from aerobic group (p<.05); *ac = significantly different from aerobic and coordination group (p<.05 and p<.001.). *cs = significantly different from coordination and strength group (p<.001 and p<.05).

Cognitive performance

Due to differences in age for exercise type, this variable was added as covariate in all analyses. After controlling for age and session order, there were no significant acute effects of exercise on information processing speed ($F(1, 174) = 0.71$, $p = .40$, $\eta_p^2 = 0.00$) and selective attention ($F(1, 172) = 0.91$, $p = .34$, $\eta_p^2 = 0.01$). Likewise, type of exercise did not moderate effects on information processing speed ($F(1,174) = 1.75$, $p = .18$, $\eta_p^2 = 0.02$) and selective attention ($F(1,172) = 0.60$, $p = .55$, $\eta_p^2 = 0.01$). Pre- and post-test scores showed similar patterns in the exercise and control day, and did not differ between exercise types (Table 3).

For both cognitive tasks, there was a significant interaction of session order. Independent of exercise or control day, information processing speed scores increased during day 1 and decreased during day 2. Selective attention scores improved significantly more during day 1 than during day 2.

Table 3. LDST and d2-test scores at T1 and T2 during control and exercise day for the total group and three exercise types, controlled for session order and age (means and standard errors of the means).

	Letter Digit Substitution Test							
	Total (n = 180)		**Aerobic (n = 65)**		**Coordination (n = 71)**		**Strength (n = 44)**	
	Control	Exercise	Control	Exercise	Control	Exercise	Control	Exercise
T1	51.7 (0.8)	51.7 (0.7)	49.5 (1.3)	49.8 (1.2)	51.4 (1.2)	50.5 (1.2)	54.3 (1.5)	54.7 (1.5)
T2	51.8 (0.6)	51.9 (0.7)	51.1 (1.1)	50.4 (1.1)	49.4 (1.0)	50.4 (1.1)	54.9 (1.3)	54.9 (1.3)
	d2-Test of Attention							
	Total (n = 179)		**Aerobic (n = 63)**		**Coordination (n = 69)**		**Strength (n = 47)**	
	Control	Exercise	Control	Exercise	Control	Exercise	Control	Exercise
T1	181.5 (2.5)	182.9 (2.3)	175.6 (4.2)	178.4 (3.9)	179.5 (4.0)	181.5 (3.7)	189.4 (4.8)	188.7 (4.4)
T2	200.4 (2.9)	203.2 (2.8)	194.9 (5.0)	199.1 (4.8)	199.2 (4.8)	200.9 (4.5)	207.1 (5.7)	209.5 (5.4)

Discussion

The purpose of the current study was to examine the acute effects of single classroom-based exercise sessions on information processing speed and selective attention, and differences in effects between three different exercise types (i.e. aerobic, coordination, strength).

Acute effects of exercise on cognition

There was no support for the notion that acute physical exercise improves cognitive performance, as there was no significant overall acute effect of 12 minutes exercise on a selective attention and information processing test in 10-13 year old children. There was neither a differential effect of one of the exercise types on students' cognitive performance.

The current results are partly in line with Hill and colleagues (2010), who found no significant main effect of 10 to 15 minutes classroom-based exercise on a digit-symbol coding task. However, a significant interaction in their analysis indicated that there was an acute effect of exercise for children who followed the exercise session in the second week of the counterbalanced experiment. In line with our current results, one laboratory study with a duration of 20 minutes (Stroth et al. 2009), and two school-based studies with exercises of 5 minutes (Kubesch et al., 2009) and 45 minutes (Pirrie & Lodewyk, 2012) neither found an acute effect of exercise on children's attention performance.

In contrast to our results, other published studies conducted in a school setting reported acute effects of 10 to 15 minutes aerobic exercise on information processing speed and selective attention in comparison to a control condition (e.g. Cooper et al., 2012; Cooper et al., 2013; Janssen et al., 2014a; Niemann et al., 2013; Tine & Butler, 2012). The inconsistencies in results of the aerobic exercise in the current and other studies may be due to differences in exercise intensity. The aerobic exercise session in the current study turned out to have low to moderate intensity for the average student in the classroom (mean: 61% HR max; 39.5% of time spent in moderate to vigorous intensity zone). In contrast, the positive result studies implemented aerobic exercises with moderate to vigorous intensity (mean HR: 172 and 169 beats/min in 11-13 year olds in Cooper et al., 2012 and 2013; 70-85% HR max in Niemann et al., 2013 and Tine & Butler, 2012; 2000-2999 and >3000 counts/minute, indicating moderate and vigorous intensity in Janssen et al., 2014a). According to the arousal theory, highest cognitive improvements are expected to occur at moderate intensity levels (McMorris & Hale, 2012). In this respect, the time spent in moderate to vigorous intensity within the aerobic exercise in the current study might have been insufficient to cause significant improvements in information processing speed and selective attention. This was supported by findings of a recent meta-analysis indicating effect sizes close to zero after a single bout of low intensity exercise in adults (McMorris & Hale, 2012). The necessity to exercise sufficient time at moderate intensity could have important implications for further research and implementation of exercise sessions in schools, since monitoring exercise intensity may not be feasible in a real-life school setting.

Another possible explanation for the inconsistency in results include the timing of the cognitive testing. In the current study, cognitive tests were conducted before and immediately after the exercise session. In contrast, in the studies of Janssen and colleagues (2014a) and Niemann and colleagues (2013) students attended academic classes before start of the experiment. In the studies of Cooper and colleagues (2012; 2013), the post-test was conducted 10, 45 and 60 minutes after ending of the exercise session. The influence of the timing of cognitive testing on cognitive outcomes in children is still unclear and needs further investigation (Hillman, Kamijo, & Scudder, 2011).

Further, there was no differential effects of exercise type on performance on the two cognitive tests. This is in line with a previous study of Bailey et al. (2014), who neither found acute, nor differential effects of 15 minutes aerobic and coordinative exercise on the same selective attention test (d2 test). However, this study differed with respect to age of the participants (young adults). Our findings are in contrast to an earlier study in adolescents, reporting higher improvements in selective attention after coordinative versus aerobic exercise (Budde et al., 2008). However, it is important to note that this study included no control group and was conducted in a selective population of elite athletes. The generalizability of the results to regular students is therefore questionable. Moreover, neither our, nor the studies of Gallotta and colleagues (2012; 2015) and Bailey and colleagues (2014) were able to replicate the findings of Budde and colleagues (2008). This might suggest that the role of exercise type may not be as prominent as suggested by Budde and colleagues (2008).

The current results are also inconsistent with the results of Gallotta and colleagues, who reported improved attention after both aerobic and coordinative exercise, with largest improvements after the aerobic exercise (Gallotta et al., 2012; Gallotta et al., 2015). Differences in results may be due to differences in age (8-11 year), duration (30 minutes within a physical education class of 50 minutes) and intensity of the exercises (mean HR: 146, moderate to vigorous intensity). However, it is worth mentioning that the improvement in attention was equal (Gallotta et al., 2012) and even larger (Gallotta et al., 2015) following a sedentary academic lesson as compared to the exercise conditions. Comparisons with studies on the acute effect of strength exercises on cognition in children and adolescents could not be made due to absence of studies in this age group.

The lack of effects in the current study may raise questions with regard to the generalizability of the results from lab-based studies into the classroom. The earlier, positive result studies in a school-setting conducted short exercise sessions outside the classroom (Budde et al., 2008; Cooper et al., 2012; Cooper et al., 2013; Niemann et al., 2013; Tine & Butler, 2012). In contrast, the current and other studies that reported no acute effects of exercise on attention and information processing speed (5 minute movement break in Kubesch et al., 2009; 10-15 minutes exercise within week 1 in Hill et al., 2010), implemented exercise sessions within the classroom. Although Kubesch and colleagues (2009) and Hill and colleagues (2010) did not report the intensity of their exercise sessions, the low to moderate intensity of the exercise sessions in our study indicate that it might be difficult to reach sufficient intensity when exercising in a classroom setting. Therefore, we recommend future studies to monitor and report on exercise intensity to gain more insight in the acute effects of exercise on cognitive performance.

Strengths and limitations

Strengths of the current study include the double baseline design with repeated measures. By means of a pre- and post-test design, we were able to control for intra-individual differences across measurement days. Another strength includes the standardized execution of the experiment in a classroom setting, by which we contribute to the generalization of outcomes from previous laboratory studies into the school setting.

Limitations include the measurement of exercise intensity in the strength group. Due to the nature of the exercises (i.e. body-weight exercises), intensity could not be determined by percentage of one-repetition maximum. However, the absence of weight load suggests low to moderate intensity strength exercises. The HR measured at rest turned out to be an inappropriate measure. Part of the children seemed not able to relax completely, possibly due to unfamiliarity with the experimental setting. For this reason, exercise intensity was determined based on an estimation of children's HR max, without controlling for individual differences in HR rest.

Despite the use of a double baseline, selective attention scores (d2 test) improved significantly more from pre- to post-test during the first experimental day compared to the second day, regardless of exercise or control session. The test-retest reliability of the d2 test has been found moderate to high over a 1 year period (Brickenkamp & Oosterveld, 2012), but it is questionable if this holds for short test-retest intervals and multiple test repetitions, as used in the current study. As these improvements seem to indicate a general learning effect, we recommend future studies to include a control condition other than exercise to be able to discriminate effects of exercise from a general learning effect.

Conclusion

In summary, the current results suggest that sessions of 12-minutes classroom-based exercise at low to moderate intensity have no acute effects on information processing speed and selective attention compared to a sedentary control condition in young adolescents. Likewise, no significant differential effects of aerobic, coordination or strength exercises were found. The execution of exercise sessions in the classroom seems feasible, but it might be difficult to reach sufficient intensity in order to gain cognitive benefits.

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Chapter 3

Exercise of varying durations: no acute effects on cognitive performance in adolescents

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Abstract

Participation in structured physical activity is assumed to have a positive effect on cognitive and academic performance. A single bout of moderate-to-vigorous exercise has been found to have a small acute positive effect on the cognitive performance of children and adolescents. However, the dose-response effects of exercise duration are largely unknown. Therefore, the current study examined the acute effects of moderate-to-vigorous exercise with a duration of either 10, 20, or 30 minutes on selective attention and working memory performance of young adolescents. One hundred and nineteen adolescents (11-14 years old) participated in a randomized, controlled crossover study. Adolescents were assigned to one of the three exercise durations, each paired with a sedentary control session of the same duration. Cognitive performance was measured before and immediately after the exercise and control condition. The Attention Network Test and n-back task were used to measure selective attention and working memory, respectively. There were no significant exercise effects on selective attention (i.e. alerting, orienting or executive control) or working memory performance measured immediately after the exercise bouts. Furthermore, there were no differential effects of exercise duration. In sum, acute exercise bouts with a duration of 10, 20, or 30 minutes did not improve, but neither deteriorate cognitive performance of young adolescents compared to a sedentary control condition.

Introduction

The maturation of the adolescent brain is guided by an interaction between genetic and environmental factors (Lenroot & Giedd, 2008; Rosenzweig, 2003). Among these factors, physical activity (PA) has been well studied, in particular because its potential beneficial effects on cognitive functioning and academic achievement. Two systematic reviews concluded that *overall*, single bouts of PA have small positive acute effects on cognitive performance of children and adolescents (Donnelly et al., 2016; Ludyga, Gerber, Brand, Holsboer-Trachsler, & Puhse, 2016). In addition, a recent meta-analysis concluded that PA can have acute positive effects on attention and inhibition in pre-adolescent children (de Greeff, Bosker, Oosterlaan, Visscher, & Hartman, 2018). Besides evidence on the acute effects, meta-analyses of longitudinal studies have shown that engaging in structured PA sessions can have a neutral or positive effect on cognitive functioning in children, and certainly does not harm children's performance (e.g. de Greeff et al., 2018; Li, O'Connor, O'Dwyer, & Orr, 2017; Watson, Timperio, Brown, Best, & Hesketh, 2017).

Despite the positive effects of PA on mental (Biddle & Asare, 2011) and physical health (Janssen & Leblanc, 2010), and its assumed effect on cognitive functioning, there is ample evidence that many children and adolescents do not meet PA guidelines (Health counsil of the Netherlands, 2017; WHO, 2010). Schools are seen as the most appropriate setting to enforce structural opportunities to increase PA levels in children and adolescents as they spend a substantial amount of their time at school (Webster, Russ, Vazou, Goh, & Erwin, 2015; WHO, 2010; WHO, 2014). However, time constraints are a frequently mentioned barrier that hinders implementation of PA in schools (e.g. Howie, Newman-Norlund, & Pate, 2014; McMullen, Kulinna, & Cothran, 2014; Naylor et al., 2015; Stylianou, Kulinna, & Naiman, 2015; van den Berg et al., 2017). Therefore, teachers have indicated that it would only be feasible to implement short PA bouts in the school curriculum, with a maximum of 5 (Howie et al., 2014) or 10 minutes per session (van den Berg et al., 2017).

Although studies have consistently shown that the intensity of acute PA needs to be of at least moderate-to-vigorous intensity to gain most cognitive benefits (McMorris & Hale, 2012; Peruyero, Zapata, Pastor, & Cervello, 2017), the optimal duration of acute PA is still unclear and needs further investigation (Donnelly et al., 2016; Janssen, Toussaint, van Mechelen, & Verhagen, 2014; Verburgh, Konigs, Scherder, & Oosterlaan, 2014). Previous studies have shown that acute exercise bouts with a duration of 30 or more minutes can improve children's and adolescent's performance in inhibition and shifting (Chen, Yan, Yin, Pan, & Chang, 2014; Ellemberg & St-Louis-Deschênes, 2010), working memory (Chen et al., 2014; Pontifex, Hillman, Fernhall, Thompson, & Valentini, 2009), selective attention (Gallotta et al., 2012), free-recall memory (Pesce, Crova, Cereatti, Casella, & Bellucci, 2009), planning (Pirrie & Lodewyk, 2012), and executive attention (Kubesh et al., 2009). However, studies by Pirrie and Lodewyk (2012, information processing and selective attention) and Kubesh and colleagues (2009, working memory and cognitive flexibility) reported no effects. The effects of a medium exercise duration (i.e. 20 minutes) on cognition are also inconclusive, with some studies showing improved performance in inhibitory control (Drollette et al., 2014; Drollette, Shishido, Pontifex, & Hillman, 2012; Hillman et al., 2009), comprehension (Hillman et al., 2009), and selective attention (depending on time of the day) (Altenburg, Chinapaw, & Singh, 2016), and others showing no effects on inhibitory control (Stroth et al., 2009), working memory (Drollette et al., 2012), and broad measures of executive functioning (Howie, Schatz, & Pate, 2015). Also, the effects of exercise of a shorter duration of 10 to 15 minutes are inconclusive: beneficial effects have been reported on selective attention (Budde, Voelcker-Rehage, Pietrabyk-Kendziorra, Ribeiro, & Tidow, 2008; Janssen, Chinapaw, et al., 2014; Niemann et al., 2013), working memory (depending on exercise intensity and performance level) (Budde et al., 2010), as well as on broad measures of executive functioning (Benzing, Heinks, Eggenberger, & Schmidt, 2016; Cooper et al., 2016; Cooper, Bandelow, Nute, Morris, & Nevill, 2012), while no effects on selective attention and information processing (van den Berg et al., 2016), visuo-spatial memory and general psychomotor speed (Cooper et al., 2016), sustained attention (Wilson, Olds, Lushington, Petkov, & Dollman, 2016), and executive functioning (Howie et al., 2015) have been reported. Studies examining the effects of 5-minute exercise sessions found no effects (Howie, Beets, & Pate, 2014; Howie et al., 2015; Kubesh et al., 2009). In sum, the evidence on the acute effects of relatively short, medium and long exercise bouts on cognitive performance is inconclusive and the differences in cognitive outcome measures across studies make it particularly difficult to compare the effects of exercise bouts with different durations with each other. Therefore, dose-response studies are needed to be able to elucidate the acute effects of exercise duration on cognitive performance.

To date, only few studies investigated the acute dose-response effects of exercise duration on cognitive performance in children and adolescents. Two studies of Howie and colleagues (Howie et al., 2014; Howie et al., 2015) investigated whether the cognitive performance of children (aged 9-12 years) differed after 5, 10, and 20 minutes of moderate-to-vigorous classroom-based exercise compared to 10 minutes of sedentary activities (i.e. listening to a lesson about exercise science). The authors reported higher math fluency scores after 10 and 20 minutes of exercise compared to the sedentary condition (Howie et al., 2015), and improved on-task behavior after 10 minutes, but not after 5 and 20 minutes of exercise (Howie et al., 2014). While these studies investigated the effect of different exercise durations, the authors conducted separate analyses and did not compare the effects of 5, 10 and 20 minutes exercise with each other. Recently, two studies in young male adults

(20 – 23 years old) examined the dose-response relation between exercise duration and cognitive performance on a Color-Word Stroop task (Chang et al., 2015; Tsukamoto et al., 2017). Chang and colleagues found that 20 minutes moderate intensity exercise on a cycle ergometer resulted in larger improvements in cognitive performance than 10 or 45 minutes of exercise (Chang et al., 2015). In contrast, Tsukamoto and colleagues reported no difference in the positive effects of 10, 20 or 40 minutes moderate intensity cycle ergometer exercise on cognitive performance (Tsukamoto et al., 2017).

In the current study, we examined the dose-response effects of exercise duration (10, 20 or 30 minutes) on selective attention and working memory of young adolescents (11-14 years). We conducted a randomized controlled cross-over study in the school setting and assessed effects on attention and working memory as these cognitive functions are associated with academic achievement (Stevens & Bavelier, 2012; van der Ven, van der Maas, Straatemeier, & Jansen, 2013). Selective attention is defined as 'the differential processing of simultaneous sources of information' (Johnston & Dark, 1986). In other words, it determines which stimuli are relevant and which are irrelevant and should be suppressed (Stevens & Bavelier, 2012). Working memory is a cognitive function with limited capacity that allows individuals to temporarily store and actively manipulate information over a brief period of time (Baddeley, 2003). Based on the results of earlier studies, we hypothesize that moderate-to-vigorous exercise bouts of different durations will have a neutral or positive acute effect on selective attention and working memory performance of young adolescents.

Method

Sample size calculation

An independent statistician performed a sample size calculation based on the effect size (partial eta-square = 0.12) of an earlier study using a similar research design and cognitive tasks (Drollette et al., 2012). A sample of approximately 62 adolescents was needed to detect within-subjects effects (i.e. exercise effects on cognition), and approximately 105 participants to detect within-between interaction effects (i.e. differential effects of exercise duration) with 80% power, 2-sided testing at $\alpha = .05$.

Participants

We invited a convenience sample of three elementary schools and one secondary school to participate with all apparently healthy adolescents attending the last grade of elementary school (11-12 years) or the first grade of secondary school (12-13 years). First, we provided detailed information on the study to the school staff. After obtaining their consent, we provided adolescents and their parents with written information about the procedure and the scope of the study. Written informed consent was obtained from a parent/caregiver, and adolescents who were 12 years or older. Adolescents with a confirmed medical condition that could affect memory or concentration (e.g. ADHD, epilepsy) were identified by the school staff and were not included in the statistical analyses. Adolescents received a small present for their participation after the study. The Medical Ethical Committee of the VU University Medical Center in Amsterdam, the Netherlands, concluded that the study does not fall within the scope of the Medical Research Involving Human Subjects Act and approved the study protocol [2014.363].

Design and randomization

We conducted a randomized controlled trial with a crossover design, including two within- and one between-subjects variables. The first within-subjects variable was 'intervention session': all adolescents performed one control and one exercise session of the same duration (i.e. either 10, 20 or 30 minutes), thereby acting as their own control. The second within-subjects variable was 'test': we conducted cognitive tests before (*pretest*) and after (*posttest*) the control and exercise session, to control for intra-individual differences in test performance. The between-subject variable was the 'duration' of the exercise/control session: 10, 20, or 30 minutes. The order of the control and exercise session was counterbalanced, i.e. half of the adolescents started with the control session, and the other half with the exercise session.

We applied a block-random selection procedure to determine duration (i.e. 10, 20 or 30 minutes) and sequence (i.e. order of exercise and control session) using two online software programs (http://www.randomizer.org/form.htm and http://www.graphpad.com/quickcalcs/randomize2/). We stratified by sex in the randomization procedure.

Procedure

We visited the schools on four separate occasions within a period of three weeks (see Figure 1). The first and the second visit were generally scheduled within the same week. The first visit consisted of a familiarization session in which adolescents received detailed information on the experiment and practiced with the two cognitive tasks (see cognitive measures). During the second visit, we assessed their maximum heart rate and fitness by means of a Shuttle Run test. The third and fourth visit consisted of the experimental days, which were scheduled one week apart at the same time of the day (between 08:00 – 11:45 a.m.). We asked the adolescents to keep their bedtime, breakfast and transport mode to school similar before each experimental day. We invited groups of four to six students to the testing location, which was a private area within the school. Each day had the same standardized routine: 1) all adolescents practiced with the two cognitive tasks and self-reported their sleep, breakfast, mode, and duration of transportation to school; 2) in the exercise session we measured height and weight of the adolescents and provided them with a Polar RS800cx heart rate monitor. After adolescents laid on their back comfortably for five minutes, with legs and arms positioned along the body, the resting heart rate was measured to calculate the heart rate zone corresponding to moderate-to-vigorous intensity (see section exercise bout); 3) adolescents performed two cognitive tasks on a laptop (pretest); 4) during the exercise session adolescents cycled for 10, 20 or 30 minutes, whereas during the control session they worked on educational materials (e.g. puzzles, questionnaires, worksheets) seated for either 10, 20 or 30 minutes; 5) adolescents performed the two cognitive tasks again (posttest) on the same laptop.

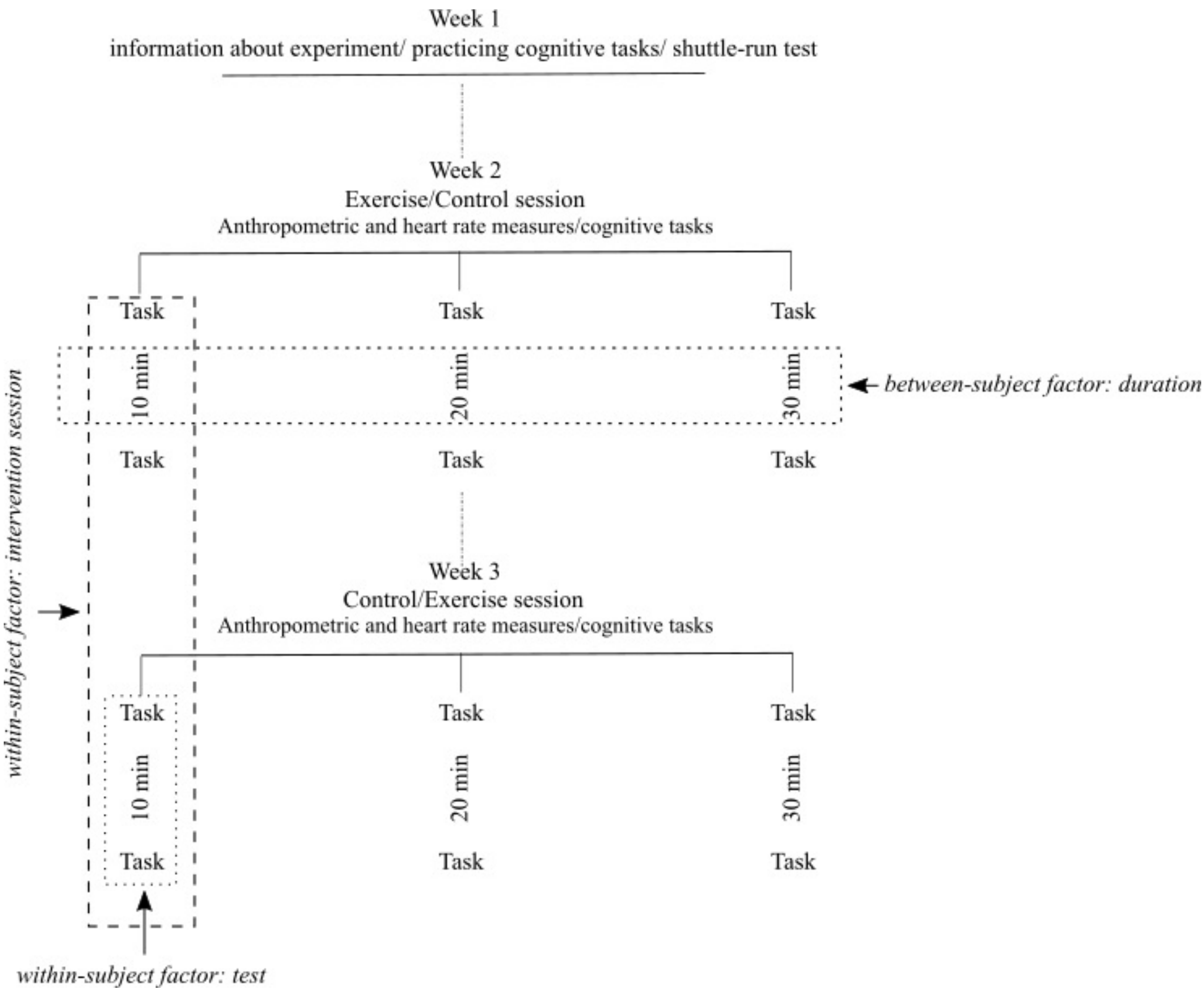

Figure 1. Schematic representation of the experimental design.

Exercise bout

The exercise bout followed a bicycle ergometer protocol. The adolescents biked at moderate-to-vigorous intensity for a duration of 10, 20, or 30 minutes. The first minute and a half served as warming-up (workload=0 kilopond (Kp)). After this period, the workload increased until adolescents biked within the predetermined boundaries of their moderate-to-vigorous intensity level. The maximum heart rate and resting heart rate were used to calculate the lower (40%) and upper (60%) boundary of the heart rate reserve, corresponding to a moderate-to-vigorous intensity level of exercise. The boundaries were calculated as follows: 40% =((maximal heart rate – resting heart rate) * (40/100) + resting heart rate); 60% = ((maximal heart rate – resting heart rate) * (60/100) + resting heart rate) (ACSM, 2010). Adolescents who did not reach the specified heart rate zone were excluded from the data analyses (i.e. if the mean exercise intensity was below 40% or above 60% of the heart rate reserve). To facilitate biking in a steady state manner, the number of flywheel revolutions per minute was matched to a metronome with 120-160 beats per minute. The last minute served as cooling down, in which the flywheel revolutions per minute were progressively reduced (workload= 0 Kp).

Measures and measurement instruments

Anthropometrics

Height (cm) and weight (kg) were measured in sport clothing using a Seca weighing scale (Seca Instruments, Frankfurt, Germany) and a Leicester Height Measure Mk II (Harlow Healthcare, UK). Body Mass Index (BMI) was calculated by dividing weight (kg) by height squared (m).

Shuttle run test

We administered a Shuttle Run test to assess the maximum heart rate and cardiovascular fitness (VO_2max) of the adolescents. All participants wore a Polar H7 heart rate monitor that was connected to the Polar Team App (Polar Electro Oy, Finland), in which the heart rate data was stored. The test was performed during a regular physical education lesson, under the supervision of the physical education teacher. All adolescents were familiar with this test and were encouraged by their teacher and the research team to exert maximum performance.

Due to the dimensions of the sports halls, students in the elementary schools performed an 18 meter instead of 20 meter Shuttle Run, while secondary school students performed the standard 20 meter test. The test had an initial running speed of 8.0 km/hour that progressively increased with 0.5 km/hour in 1 minute stages in the 20 meter test. This corresponded with an initial running speed of 7.2 km/hour increasing with 0.45 km/h in 1 minute stages in the 18 meter test. We recorded the highest completed stage with an accuracy of half a stage and calculated VO_2max (ml/kg/min) (Leger, Mercier, Gadour, & Lambert, 1988).

Cognitive measures

We used two computerized cognitive tasks: the Attention Network Test (ANT) and the n-back task. Both tasks have been shown to have optimal criterion validity, good statistical dependencies and adequate factorial structure, suggesting that these tasks are valid measures of cognitive performance in children (Forns et al., 2014). The tasks were programmed using E-Prime 1.2 software (Psychology Software Tools, Pittsburgh, PA), which was also used for stimulus generation and response registration. To minimize interference during the tasks, a maximum of two adolescents were seated at one working desk, facing each other supervised by a member of the research team. We asked them to work quietly and individually and to focus on their task the entire time. The order in which the cognitive tasks were performed was randomized and counterbalanced between participants (first ANT and then n-back, or vice versa).

Practice trials

During the familiarization session, the adolescents practiced 57 trials (nine trials with feedback) of the ANT and 150 trials (60 trials with feedback) of the n-back task. Given the complexity of the current n-back task, we incorporated a loop, which allowed them to repeat any part of the task (instructions or task blocks) until the task was fully understood. In addition, they made a few practice trials of both tasks at the start of each experimental day.

Attention Network Test

We used the short-version (Fan et al., 2007) of the ANT (Fan, McCandliss, Sommer, Raz, & Posner, 2002) to assess three attentional networks: alerting (i.e. achieving and maintaining an alert state), orienting (i.e. selection of information from sensory input), and conflict/executive control (i.e. resolving conflict among responses). The stimuli of this task were sets of five horizontal black arrows presented on a white background. The middle arrow pointing either to the left or to the right was the target, flanked by two lateral arrows on the left and the right. The flanker arrows pointed either in the same direction of the target arrow (congruent flanker condition: >>>>> or <<<<<) or in the opposite direction of the target arrow (incongruent flanker condition: >><>> or <<><<). We instructed the adolescents to respond as fast and as accurately as possible by pressing the left mouse button if the target arrow was pointing to the left and by pressing the right mouse button if the target arrow was pointing to the right. Adolescents were asked to focus on the fixation cross that was presented in the middle of the screen. A warning cue in the form of an asterisk sign (*) appeared in 66.7% of the trials for a duration of 200 ms in the center (‘center cue’ condition), or above or below the fixation cross (‘spatial cue’ condition), while being absent in the remaining trials (‘no cue’ condition). Details on the task parameters can be found elsewhere (Fan et al., 2007).

The total task lasted approximately 12 minutes and consisted of three blocks of 48 trials, with one minute breaks between the blocks. We calculated accuracy rates (proportion of correct responses) and mean reaction times of the correct responses for the three attentional networks by the following formulas: Alerting = (Score_no cue - Score_center cue); Orienting = (Score_center cue - Score_spatial cue); Conflict/executive control = (Score_incongruent - Score_congruent) (Fan et al., 2007). Responses with reaction times faster than 200 ms were considered as incorrect (Fan et al., 2007). For the alerting and orienting scores, a larger value for the difference in reaction time and a larger negative value for the difference in accuracy means better performance. For the conflict/executive control score, a smaller value for the difference in reaction time and a smaller negative value for the difference in accuracy means better performance. The task was downloaded from the website of the Sackler Institute for Developmental Psychobiology (www.sacklerinstitute.org/cornell/assays_and_tools/).

n-back task

We assessed working memory using a visual n-back task. After the task instructions, a continuous stream of letters (consonants displayed in 40 points Arial) was presented. The letters appeared one by one in the middle of the screen for a duration of 500 ms. The time between the stimuli varied randomly between 1000 and 2000 ms. The distance between the adolescent and the screen was approximately 65 cm. The visual angle of the stimuli was approximately 1.25°.

The task had three load conditions: the 0-back, 1-back and 2-back load. In the 0-back load, the target was the letter ‘X’. In the 1-back load, the target was any letter identical to the letter presented in the last trial preceding it. In the 2-back load, the target was any letter identical to the letter presented two trials preceding it. We asked the adolescents to respond as fast and as accurately as possible by manually pressing a “green button” for targets and a “red button” for non-targets. For half of the adolescents, the green and the red button corresponded, respectively, to the key 1 and 2 on the left side of the keyboard. For the other half, these buttons were reversed.

The total task contained three blocks of 60 trials each and lasted approximately ten minutes. Each block contained one load condition and the order of blocks was semi-randomized and counterbalanced between participants. Adolescents could differentiate the load of the block only through the instructions that were displayed on screen between the blocks. In each block, targets occurred randomly in approximately 37% of the trials. We calculated accuracy rates (proportion of correct responses) and mean reaction times of the correct responses for each load condition. Responses faster than 200 ms were considered as incorrect. Faster reaction times and higher accuracy rates indicate better working memory performance.

Data analysis

All analyses were performed in the SPSS version 22.0 (IBM Corp. Released 2013. Armonk, NY: IBM Corp.). We examined differences in demographic measures between the 10-, 20- and 30-minutes exercise groups by means of univariate ANOVA (see Table 1). For both cognitive tasks, reaction time and accuracy scores were separately analyzed by means of repeated measures (RM) ANOVAs, with intervention session (exercise versus control) and test (pretest and posttest) as within-subjects factors and duration (10, 20, and 30 minutes) as between-subjects factor. In addition, the factor load (0-, 1-, and 2-back) was entered as a within-subject factor for the analyses of the n-back task. Baseline reaction times for the n-back task and the ANT conflict/executive control score differed significantly between the exercise and control condition. Therefore, we included the pretest score as covariate in the respective RM ANOVA models. We report interactions between the factors intervention session, test, and duration in the Results section. Estimated effect sizes are reported using eta-squares (η^2). Statistical significance was set at $p<0.05$.

Adolescents with accuracy rates lower than chance level, indicating that they did not appropriately understood or followed the task instructions, were excluded from the respective analysis. For the n-back task, we only excluded adolescents with a lower accuracy rate than chance level in the 0-back and 1-back loads due to the difficulty of the 2-back load condition for which lower accuracy scores can be expected.

Between-tests timing

We aimed to assess the differential effect of exercise duration on cognitive performance. The groups did not only differ in terms of exercise duration, but also in terms of the timing between the pre- and posttest (i.e. between-tests timing). In order to exclude any possible influence of the between-tests timing on the effect of exercise on reaction time and accuracy, we additionally examined the interaction between test (pre- and posttest) and duration for each cognitive task.

Results

Participants

A total of 119 students participated. Data from 99 adolescents in the ANT and 92 adolescents in the n-back task were included in the statistical analyses (see Table 1). One adolescent achieved accuracy scores below chance level in the ANT and seven adolescents performed below chance level in the n-back task (0-back and 1-back). Data from 17 adolescents were incomplete (i.e. participated in only one test session (n = 15)) or data was lost due to technical problems (n =2, one in the ANT and one in the n-back task). Two adolescents were diagnosed with a medical condition and one adolescent exercised at a mean exercise intensity below 40% HRR.

Descriptive characteristics

Characteristics of the total sample and the subgroups according to exercise duration are presented in Table 1. Adolescents in the 10, 20 and 30 minutes duration had similar age, sex ratio, BMI, VO_2max, maximal HR, resting HR, 40% HRR and 60% HRR values. Adolescents in the 10 minutes exercise group had lower average HR scores within the moderate-to-vigorous intensity zone than those in the 20 minutes group but not the 30 minutes group, whereas average HR in the 20 and 30 minutes group was similar.

Table 1. Baseline characteristics of the total study sample, as well as each of the subgroups according to the duration of each intervention session (means and SD).

	Selective attention (ANT)								***Working memory (n-back task)***							
	Total sample		10 min		20 min		30 min		Total sample		10 min		20 min		30 min	
N (included/excluded)	99	20	34	8	30	8	35	4	92	27	30	12	28	10	34	5
Age (years) (included | excluded)	12.3(0.6)	12.6(0.6)	12.2(0.7)		12.4(0.7)		12.4(0.5)		12.3(0.6)	12.6(0.7)	12.3(0.6)		12.3(0.6)		12.3(0.5)	
Sex (n; male/female) (included | excluded)	47/52	10/10	17/17		13/17		17/18		42/50	16/11	14/16		12/16		16/18	
BMI[1] (kg/length^2)	17.9(2.5)		17.8(2.6)		17.5(1.9)		18.2(2.7)		17.7(2.5)		18.0(2.7)		17.4(1.9)		18.1(2.8)	
VO_2 max score[2] (ml/kg/min)	47.6(4.9)		47.7(4.8)		47.5(5.7)		47.7(4.4)		47.7(4.7)		47.4(4.8)		47.9(4.9)		47.8(4.5)	
Maximum HR (beats per minute)	207.0(8.2)		208.8(6.7)		206.4(9.0)		205.6(8.7)		206.9(8.3)		208.8(7.0)		206.7(8.8)		205.5(8.9)	
Resting HR (beats per minute)	73.3(9.8)		73.9(9.0)		74.7(8.1)		71.5(11.6)		73.5(9.4)		73.9(7.9)		75.3(7.7)		71.6(10.6)	
Average HR exercise (beats per minute)	134.6(7.6)		132.9(7.7)*		137.0(6.4)		134.8(8.1)		134.5(7.7)		131.8(7.9)*		137.2(6.5)		134.8(7.8)	
40% HRR (beats per minute)	126.7(7.7)		127.7(6.9)		127.4(7.2)		125.1(8.8)		126.8(7.6)		127.7(7.2)		127.9(6.8)		125.2(8.5)	
60% HRR (beats per minute)	153.4(7.3)		154.6(6.3)		153.7(7.5)		151.9(8.1)		153.4(7.3)		154.6(6.7)		154.1(7.1)		151.9(8.0)	

Note: Descriptives are rounded to the first decimal. ANT: [1]BMI values are based on 89 participant (10 min (31), 20 min (24) and 30 min (34)); [2] VO_2 max values are based on 93 participants (10 min (33), 20 min (29) and 30 min (31)); n-back: [1] BMI values are based on 83 participant (10 min (27), 20 min (23) and 30 min (33));)); [2] VO_2 max values are based on 85 participants (10 min (29), 20 min (27) and 30 min (29)). *Significant group difference in average HR during exercise, HR in the 10 min group is lower than HR in the 20 min.

Cognitive performance

ANT

For all three attentional networks of the ANT, accuracy rates were not significantly different between the exercise and control condition, or between the 10-, 20-, and 30-minutes exercise groups. Likewise, reaction time was not significantly different between the exercise and control condition for alerting and orienting, nor for conflict/executive control after controlling for pretest score. We found no differences in reaction time performance between the 10-, 20-, or 30-minutes exercise groups. Pre- and posttest scores and F-statistics of the RM ANOVA models can be found in Table 2 and 3, respectively. There were no interactions between the factors test and duration, indicating that the results were not influenced by the time between the tests.

Table 2. ANT data: pre- and posttest scores in the control and exercise condition (means, standard errors and 95% confidence intervals).

Reaction time (ms)						
	Alerting		Orienting		Conflict/Executive control	
	Control	Exercise	Control	Exercise	Control	Exercise
Pretest	19.0 (2.8) [13.5;24.5]	20.4 (2.4) [15.6;25.2]	63.2 (2.9) [57.3;69.1]	59.9 (2.5) [54.9;64.9]	78.3 (3.3) [71.7; 84.9]	86.8 (2.9) [81.1;92.6]
Posttest	22.3 (2.8) [16.8;27.7]	23.0 (2.6) [17.7;28.2]	57.4 (3.1) [51.3;63.6]	60.4 (2.9) [54.7;66.1]	72.0 (3.3) [65.5;78.5]	70.1 (2.8) [64.6;75.6]
Accuracy (%)						
	Alerting		Orienting		Conflict/Executive control	
	Control	Exercise	Control	Exercise	Control	Exercise
Pretest	1.1 (0.6) [-0.1;2.2]	1.6 (0.4) [0.8;2.5]	-2.2 (0.5) [-3.2;-1.1]	-1.9 (0.5) [-2.9;-0.9]	-7.7 (0.9) [-9.5;-5.9]	-7.8 (0.9) [-9.5;-6.0]
Posttest	1.1 (0.6) [0.0;2.2]	1.7 (0.7) [0.3;3.0]	-2.0 (0.5) [-3.0;-1.1]	-3.2 (0.5) [-4.2;-2.3]	-8.3 (0.7) [-9.8;-6.9]	-7.5 (0.9) [-9.2;-5.7]

Table 3: F-statistics of the RM ANOVA model for the ANT data (reaction time and accuracy).

ANT	**Reaction time**			**Accuracy**		
RM ANOVA: factor interactions	Statistics			Statistics		
	F (df1,df2)	p	η^2	F (df1,df2)	p	η^2
Alerting						
Intervention session*test	0.023 (1,96)	0.880	0.000	0.000 (1,96)	0.987	0.000
Intervention session*test*duration	0.133 (2,96)	0.876	0.003	0.090 (2,96)	0.914	0.002
Orienting						
Intervention session*test	1.892 (1,96)	0.172	0.019	2.586 (1,96)	0.111	0.026
Intervention session*test*duration	0.155 (2,96)	0.856	0.003	0.777 (2,96)	0.463	0.016
Conflict/Executive control						
Intervention session*test	0.616 (1,96)	0.434	0.007	1.397 (1,96)	0.240	0.014
Intervention session*test*duration	0.463 (2,96)	0.631	0.010	0.247 (2,96)	0.782	0.005

n-back

For accuracy, we found no significant differences between the exercise and control condition or between the 10-, 20-, or 30-minutes exercise groups. Likewise, after controlling for pretest scores, there were no significant differences between the exercise and control condition for reaction time performance, nor between the 10-, 20-, and 30-minutes exercise groups. Pre- and posttest scores and F-statistics of the RM ANOVA can be found in Table 4 and 5. In line with the ANT data, we observed no significant between-test time differences.

Table 4. n-back data: pre- and posttest scores in the control and exercise session (means, standard errors and 95% confidence intervals).

	Reaction time (ms)		**Accuracy (%)**	
	Control	Exercise	Control	Exercise
Pretest	501.9 (8.4) [485.3;518.5]	495.6 (7.5) [480.7;510.5]	86.3 (0.8) [84.8;87.8]	85.7 (0.8) [84.2;87.3]
Posttest	497.0 (8.0) [481.1;512.8]	501.4 (8.3) [484.8;517.9]	84.7 (0.9) [82.8;86.5]	84.9 (0.8) [83.2;86.6]

Table 5: F-statistics of the RM ANOVA model for the n-back data (reaction time and accuracy).

n-back	**Reaction time**			**Accuracy**		
RM ANOVA: factor interactions	Statistics			Statistics		
	F (df1,df2)	p	η^2	F (df1,df2)	p	η^2
Intervention session*test	2.478 (1,89)	0.119	0.028	1.398 (1,89)	0.240	0.015
Intervention session*test*duration	2.205 (2,89)	0.116	0.048	0.749 (2,89)	0.476	0.017
Intervention session*test*load	0.627 (2,178)	0.536	0.007	0.888 (2,178)	0.413	0.010
Intervention session*test*load*duration	1.037 (4,178)	0.390	0.023	0.969 (4,178)	0.426	0.021

Discussion

This study investigated the acute effects of 10, 20 and 30 minutes of moderate-to-vigorous intensity exercise on selective attention and working memory performance in 11-14 years old adolescents. In addition, we explored possible dose-response effects of exercise duration on cognitive performance. We found no acute effects of exercise on selective attention and working memory performance and no differential effects of exercise duration, measured immediately after the exercise bouts.

Our results are in line with some earlier studies that neither found acute effects on selective attention after long (45 minutes; Pirrie & Lodewyk, 2012), medium (20 minutes; Stroth et al., 2009) or short (12 minutes; van den Berg et al., 2016) bouts of exercise. Other studies, however, did report positive effects on selective attention performance. For example, Janssen et al. (2014), Budde et al. (2008), Niemann et al. (2013) and Gallotta et al. (2012) reported acute effects of single exercise bouts on selective attention in children and adolescents. A difference between above-mentioned studies and our study was the administration of a paper-and-pencil task (d2 test of attention) versus a computerized Flanker task. However, the use of a different cognitive task might not fully explain the differences in the results, as our findings are also inconsistent with the results of studies that used comparable computerized Flanker tasks. The studies that assessed the acute effects of exercise with comparable Flanker tasks reported positive effects on children's and adolescent's reaction time (Chen et al., 2014; Kubesh et al., 2009) and accuracy scores (Drollette et al., 2012; Hillman et al., 2009). In contrast to our study, in which cognitive performance was measured immediately after the cessation of exercise, cognitive performance in the studies of Kubesch et al. (2009), Chen et al. (2014), Hillman et al. (2009), Drollette et al. (2012) and Niemann et al. (2013) was measured with a delay of approximately 5 to 38 minutes after the exercise session ended. All of the before mentioned studies reported positive effects of the exercise bouts on selective attention. Chang et al. (2012) reported in their meta-analysis that acute exercise effects on cognition are largest when cognitive tests are assessed 11 to 20 minutes after the exercise bout (Chang, Labban, Gapin, & Etnier, 2012). Although we found no acute effects of exercise, it might be that exercise related effects on cognitive performance exist, but only become detectable some time after cessation of the exercise bout. The timing of the cognitive task administration is therefore an important factor to consider in future 'exercise-cognition' research. We recommend future research to gain more insight in the timing of the posttest measurements, for example by comparing children's cognitive performance immediately as well as with a delay after a single exercise bout. In addition, it would be interesting to include multiple follow-up measures or to compare effects of different posttest timings (e.g. after 10, 45, and 60 minutes) to see how long potential exercise-related effects remain. This type of research has however a considerable participant burden reducing the feasibility in the school setting. Another potential reason for the differences in results might be the differences with regard to the control conditions. For example, Hillman et al. (2009) and Drollette et al. (2012) used passive control conditions, i.e. seated rest in which children performed no activities, whereas the children in the control condition in our study were working on school-related tasks, i.e. more cognitively engaging activities. It has been hypothesized that performing any cognitive activities during the control condition, such as watching an educational video or reading a book, may cause acute effects in cognitive performance which may be absent in case of a completely passive control condition in which children are not allowed to do anything (Best, 2010). In this respect, there could have been too little contrast between the exercise and control condition in our study to detect subtle exercise related effects. Future research with various sedentary control conditions is needed to further explore this issue. Lastly, inconsistencies in results between our and other studies might be attributed to differences in the age of the participants, i.e. 11 to 14 years old adolescents in our study versus 8 to 11 years old children in the studies of Chen et al. (2014), Drollette et al. (2012), Gallotta et al. (2012), Hillman et al. (2009) and Janssen et al. (2014). In this respect, a recent meta-analysis found the largest effects of acute aerobic exercise bouts on reaction time measures of executive functioning in preadolescent children (6 to 12 years), as compared to older adolescents (13 to 19 years) (Ludyga et al., 2016).

Working memory performance was neither affected by exercise bouts of 10, 20 or 30 minutes, which is in line with previous studies that used a similar n-back task (Drollette et al., 2012; Soga, Shishido, & Nagatomi, 2015), as well as studies that used a Sternberg task (S. B. Cooper, Bandelow, Nute, Morris, & Nevill, 2013) or a mixed dot task (Kubesh et al., 2009). In contrast to our results, a study of Chen et al. (2014) found faster reaction times after exercising compared to the control session on a n-back task (Chen et al., 2014). In their study, only the 2-back load of the n-back was used and their stimuli remained on screen for a considerably longer time than in our study (i.e. 2000 ms versus 500 ms). Hence, the n-back version we used in our study could be considered as more difficult due to a shorter memory trace. The difficulty of the n-back version we used in the current study could have contributed to the fact we were not able to detect the subtle effects of exercise on working memory performance. There were also differences in age and exercise activities (8 to 11 years old children and group-based running exercises in Chen et al., 2014), but not in the sample size tested (N = 92 in our study and N= 98 in Chen et al., 2014). The n-back task is often used to train cognitive performance, as it engages multiple executive functions at once which allows little room for employing automatic processes or task-specific strategies to optimally perform this task (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008). In retrospect, the n-back task is highly susceptible to intra-individual differences and might not be the best choice to investigate the subtle effects of exercise on performance.

Another purpose of our study was to assess the possible dose-response effects of 10, 20 and 30 minutes of moderate-to- vigorous intensity exercise on cognitive performance. As we found no acute effects of any exercise duration, we cannot make statements on a “longer duration – better performance” type of function between exercise and cognitive performance. This is in line with the study of Howie and colleagues who found no improvement in executive functioning after exercise bouts of either 5, 10 or 20 minutes (Howie et al., 2015). In contrast, they did report higher math fluency scores after 10 and 20 minutes of exercise compared to a 10-minute sedentary control condition (Howie et al., 2015). However, the math fluency test measures other domains of cognitive/academic performance and is therefore difficult to compare with our findings. Although we recruited approximately 15% more participants than needed based on the sample size calculation (n = 105 to detect differential effects of exercise duration), the final number of adolescents included in the data analyses was 92 in the n-back task and 99 in the ANT analyses. However, given the small effect sizes and large p-values that we found ($\eta 2 = 0.002$ to 0.017 and $p = 0.463$ to 0.914), we expect that the lack of significant effects is not due to lack of power. We measured cognitive performance immediately before and after our 10-, 20-, and 30-minutes condition. Although we found no differences related to the time between pre- and posttest across the three conditions, further research on dose-response effects should consider to use comparable time frames between testing (e.g. group A: sitting for 20 minutes followed by 10 minutes of exercise, group B: sitting for 10 minutes followed by 20 minutes of exercise, and group C: exercising for 30 minutes).

Although we found no positive acute effects of exercise on selective attention and working memory measured immediately after the exercise bouts, adolescent's performance did not deteriorate after exercising for 10, 20 or 30 minutes compared to working on school related tasks. This is in line with the (sub)conclusions of several recently published systematic reviews and meta-analyses on the acute effects of exercise on cognition in children and adolescents (e.g. Daly-Smith et al., 2018; de Greeff et al., 2018; Donnelly et al., 2016; Li et al., 2017)). Hence, implementing single exercise bouts of moderate-to-vigorous intensity throughout the school day does not seem to harm cognitive performance, and may help to increase the overall physical activity levels of children and adolescents (Bassett et al., 2013; WHO, 2011). The relevance of implementing exercise bouts for academic achievement in the long term needs further study. Therefore, we recommend researchers to investigate whether the longer term implementation of single exercise bouts may result in improved cognitive and academic performance of children and adolescents. Repeated exercise bouts may also increase enjoyment of school lessons and thereby improve cognitive and academic performance.

Conclusion

In summary, acute moderate-to-vigorous exercise bouts with a duration of 10, 20, and 30 minutes did not improve nor deteriorate selective attention and working memory performance of young adolescents immediately after exercising, compared to a control condition in which they worked on school-related tasks. We found no differential effects of exercise bouts of relatively long, medium, and short duration.

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Chapter 4

"It's a battle… you want to do it, but how will you get it done?": Teachers' and principals' perceptions of implementing additional physical activity in school for academic performance

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Abstract

School is an ideal setting to promote and increase physical activity (PA) in children. However, implementation of school-based PA programmes seems difficult, in particular due to schools' focus on academic performance and a lack of involvement of school staff in program development. The potential cognitive and academic benefits of PA might increase chances of successful implementation. Therefore, the aim of this qualitative study was: (1) to explore the perceptions of teachers and principals with regard to implementation of additional PA aimed at improving cognitive and academic performance, and (2) to identify characteristics of PA programmes that according to them are feasible in daily school practice. Twenty-six face-to-face semi-structured interviews were conducted with primary school teachers (grades 5 and 6) and principals in the Netherlands, and analysed using inductive content analysis**.** Teachers and principals expressed their willingness to implement additional PA if it benefits learning. Time constraints appeared to be a major barrier, and strongly influenced participants' perceptions of feasible PA programmes. Teachers and principals emphasised that additional PA needs to be short, executed in the classroom, and provided in "ready-to-use" materials, i.e. that require no or little preparation time (e.g. a movie clip). Future research is needed to strengthen the evidence on the effects of PA for academic purposes, and should examine the forms of PA that are both effective as well as feasible in the school setting.

Introduction

Schools are considered an ideal setting for the promotion of a healthy life style among children, such as regular physical activity (PA) (Webster, Russ, Vazou, Goh, & Erwin, 2015). It is well-known that regular participation in PA is beneficial for children's physical and mental health (Biddle & Asare, 2011; Janssen & Leblanc, 2010). Recent studies also suggest that participation in PA can result in immediate as well as longer-term improvements of children's cognitive and academic performance (Chang, Labban, Gapin, & Etnier, 2012; Singh, Uijtdewilligen, Twisk, van Mechelen, & Chinapaw, 2012). Many school-based programmes have been developed with the aim to increase PA levels of children and adolescents (Naylor et al., 2015). However, adequate implementation of PA programmes in schools has been shown to be very difficult, resulting in low adherence rates and little or no effects on increasing children's PA levels (Naylor et al., 2015; van Sluijs, McMinn, & Griffin, 2007).

Studies on the effectiveness of PA interventions are increasingly accompanied by process evaluation studies to gain insight into the feasibility of the intervention, and barriers and facilitators of the implementation process (van Sluijs & Kriemler, 2016). A recent comprehensive review concluded that a lack of time is the most prevalent barrier for school staff hindering the implementation of school-based PA interventions (Naylor et al., 2015). Due to high pressures of academic performance and reaching educational targets as formulated by the government, schools mostly focus on teaching academic core subjects such as mathematics, language, and reading (Dutch Inspectorate of Education, 2015; Center for Education Policy, 2007). Consequently, activities that are not directly related to these subjects, such as PA, are often eliminated (Christian et al., 2015; Parks, Solmon, & Lee, 2007). Other important barriers include an unsupportive school climate (e.g. lack of principal support and monitoring), and low teachers' motivation and readiness to change (Naylor et al., 2015; Webster et al., 2015).

Although process evaluation studies provide valuable information to adapt interventions developed by health professionals, school professionals are rarely involved in the development of school-based PA programmes (Christian et al., 2015; van Sluijs & Kriemler, 2016; Webster et al., 2015). As a result, many programmes do not align with school professionals' needs, and appear to be unfeasible in daily school practice (Christian et al., 2015; Glasgow & Emmons, 2007). Consequently, programmes are often not implemented as intended, which complicates the interpretation of the effectiveness of these programmes (Naylor et al., 2015; van Sluijs et al., 2007). Therefore, it is important to involve teachers and principals before or during early intervention development (Christian et al., 2015; McMullen, Martin, Jones, & Murtagh, 2016; Stylianou, Kulinna, & Naiman, 2015; van Sluijs &

Kriemler, 2016; Webster et al., 2015). Besides, there is a need for input from a variety of teachers and principals, including those who are least motivated and not yet involved in implementation of PA programmes (McMullen et al., 2016; Webster et al., 2015). While teachers are designated to deliver PA programmes, principals have a significant role in supporting the implementation, as they are involved in establishment of school policy and school-wide supervision (Christian et al., 2015; Todd et al., 2015). Therefore, both groups play an important role when it comes to the development of school-based PA interventions.

In particular, we lack knowledge on teachers' and principals' perceptions of feasible PA programmes in schools with regard to how often, how long, and in which setting (e.g. classroom, playground, physical education, recess) PA can be implemented (Webster et al., 2015). Some previous process evaluation studies reported that teachers prefer classroom-based PA that is enjoyable for students, short in duration and easy to manage, with some teachers preferring PA related to academic content (Howie, Newman-Norlund, & Pate, 2014; McMullen, Kulinna, & Cothran, 2014; Stylianou et al., 2015). More insight is also needed in what, according to teachers, are the most appropriate types of PA for students in the highest grades of primary school (Stylianou et al., 2015).

Previous school-based PA interventions have mainly focused on promotion of children's health. However, several studies reported that not all teachers and principals consider health promotion their responsibility (Cothran, Kulinna, & Garn, 2010; Stylianou et al., 2015; Todd et al., 2015). A recent review reported small, but positive effects of PA on several cognitive and academic outcomes of children and adolescents (Donnelly et al., 2016), which may better align with teachers and principals' needs. To date, however, little is known about the perceptions of teachers and principals to implement PA aimed at enhancing cognitive and academic performance rather than health. Only few studies explored the perceptions of school staff with regard to implementation of PA interventions with the purpose to improve academic performance, or to improve both health and academic outcomes (Gately, Curtis, & Hardaker, 2013; Macdonald, Abbott, lisahunter, Hay, & McCuaig, 2013; McMullen et al., 2016; Stylianou et al., 2015). The majority of teachers in these studies was positive about the use of the PA programmes, since they experienced learning benefits for their students (Macdonald et al., 2013; McMullen et al., 2016; Stylianou et al., 2015). In a study of Gately and colleagues, teachers perceived the use of the PA programme as a loss of time (Gately et al., 2013). The generalisability of these studies is limited due to a small number of participating schools and respondents. Besides, each study evaluated the use of one specific PA intervention, e.g. 60 minutes additional physical activity per day (Macdonald et al., 2013), movement integration in academic subjects (Gately et al., 2013; McMullen et al., 2016; Stylianou et al., 2015) or PA sessions in the classroom (Stylianou et al., 2015).

To our knowledge, there are currently no published results of studies that focus on how teachers and principals, in general, perceive the use of PA in school to improve children's cognitive and academic performance. Therefore, in the current qualitative study we (1) explored the perceptions of teachers and principals with regard to implementation of additional PA in school aimed at improvement of cognitive and academic performance of 10 to 13 years old students in grades 5 and 6 of primary education in the Netherlands; and (2) identified characteristics of PA programmes that, according to school staff, are feasible and sustainable in daily school practice.

Materials and Methods

Study Design

The current study has a qualitative research design with an inductive approach; we identified themes from the data, which allowed us to gather information from teachers and principals' perspectives (Ryan & Bernard, 2016). We conducted semi-structured interviews, which are widely used in qualitative research and form an appropriate method to provide in-depth knowledge on the views, experiences, opinions and beliefs of participants (Rubin & Rubin, 2005).

Recruitment of Participants and Ethics

A purposive sampling method was used to recruit participants (Creswell, 2014). Selection criteria included: (1) schools in urban, suburban and rural areas in different regions across The Netherlands; (2) classroom teachers in grades 5 and/or 6 in primary education, or school principals in primary education, and (3) schools that currently do not implement school-wide PA interventions in addition to their regular physical education classes.

Teachers and principals of 53 regular primary schools were approached by email and follow-up phone calls to participate. We emphasized in our recruitment email that teachers and principals who are enthusiastic as well as those who are sceptical on the subject "PA and academic performance" were welcome to participate in our study. Twenty schools (38%) did not respond. Nineteen schools (36%) were not able to participate due to busy school schedules (n = 8), an overwhelming number of requests to participate in research projects (n = 3), already participating in other research projects (n = 1), no interest in the research topic (n = 1), or without specific reason (n = 6). Fourteen schools (26%) agreed to participate in the study with either their principal(s), their teacher(s), or both.

All participants received written information of the purpose and procedure of the study and signed informed consent prior to participation. The Medical Ethical Committee of the VU University Medical Center Amsterdam concluded that the study does not fall within the scope of the Medical Research Involving Human Subjects Act, and approved the study protocol (2014.363).

Interview Guide

Two interview guides (teacher and principal version) were developed following the recommendations of Creswell (2014). The interview started with a number of short questions regarding background variables of the participants, followed by two opening questions aimed at introducing the subject and building a working relationship with the interviewer. Thereafter, the core questions were addressed (see Appendix A). Probes and follow-up questions were used to encourage participants to talk, provide examples and elaborate on their ideas and opinions (Rubin & Rubin, 2005).

We developed a protocol and organized a training day to make sure that the interview guides were applied equally by our four interviewers. The interview guides were pilot tested in two preliminary interviews and evaluated with the interviewers. Based on the results of the pilot testing, the order of the questions was slightly adapted.

Data Collection

The four trained interviewers conducted 26 semi-structured interviews in Dutch concurrently between April and July 2015. At each school, one or two principals and/or one to four teachers were interviewed individually. The interviewers visited participants at their school, where the interviews were held in a quiet, private setting. Before the start of the interview, information on the aim of the study, the duration of the interview, and anonymity and confidentiality was provided. The importance of participants' own opinions, experiences and ideas was emphasized.

All interviews were audio- or video-recorded and transcribed afterwards by two interviewers and Vera van den Berg. The duration of the interviews ranged from 9–35 minutes (mean 20 minutes) for teachers and 17 to 26 minutes (mean 19 minutes) for principals. The raw data consisted of 70 transcript pages from the principal interviews and 90 pages from the teacher interviews (Times New Roman, size 12, single spaced).

Data Analysis

The data analysis started after the data collection. Inductive qualitative content analysis was used to systematically identify and extract categories and themes from the data (Cho & Lee, 2014; Schreier, 2012). Three core steps of qualitative content analysis were followed: (1) selecting the unit of analysis and open coding; (2) creating categories; and (3) establishing themes (Cho & Lee, 2014; Elo et al., 2014). The analysis consisted of an iterative process, with all data processed in Microsoft Word and Excel by Vera van den Berg and Rosanne Salimi. The data of the teacher and principal interviews were analysed separately. Figure 1 shows an overview of the data analysis process.

In step 1 transcripts were read repeatedly, relevant text fragments were selected, and preliminary codes were allocated. Codes were supported by short phrases of the content of the text fragments, and coded transcripts were checked and revised repeatedly in order to make sure that identified codes were corroborated across the interviews (Elo et al., 2014). A short summary of each interview was written. In step 2, categories were created by grouping text fragments with similar codes. During this phase, categories were reorganized and refined until final categories were established (Cho & Lee, 2014). In step 3, themes and subthemes were identified by grouping related categories. Interview transcripts were reread, systematic comparisons were made across the data, and overviews were created to reflect on the themes arising from the interviews.

For example, categories "small classroom size", "many students in the classroom", and "full schedules of the external sports hall", were grouped together under the subtheme "space constraints", and theme "barriers".

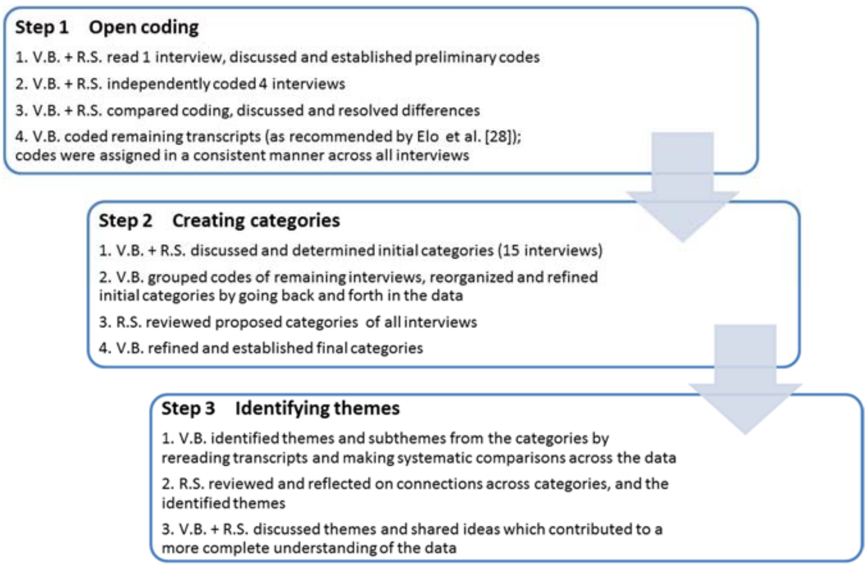

Figure 1. Overview of the data analysis process. Note: V.B.: Vera van den Berg; R.S.: Rosanne Salimi.

Results

Participants

In total, 15 fifth and sixth-grade teachers and 11 principals of the 14 schools participated. Schools were located in urban (n = 8), suburban (n = 2), and rural (n = 4) areas across the Netherlands. Teachers had a mean age of 41 years (range 25–61); principals were on average 48 years old (range 34–59). Work experience ranged from 1–37 years (mean 13.4) and 1–30 years (mean 11) in teachers and principals, respectively. Of the participants, 80% were female.

Interviews

Although data saturation was reached after analysis of approximately three quarter of the interviews, we analysed all interviews. One interview with a principal was excluded, since the interviewer used the teacher version instead of the principal version of the interview guide.

The results of the interviews were organized around four key themes: attitude towards PA, barriers towards additional PA, characteristics of feasible PA programmes, and requirements for implementation of PA programmes in school. The findings were supported by quotations from the interviews, translated from Dutch into English. Figure 2 shows an overview of the themes and subthemes.

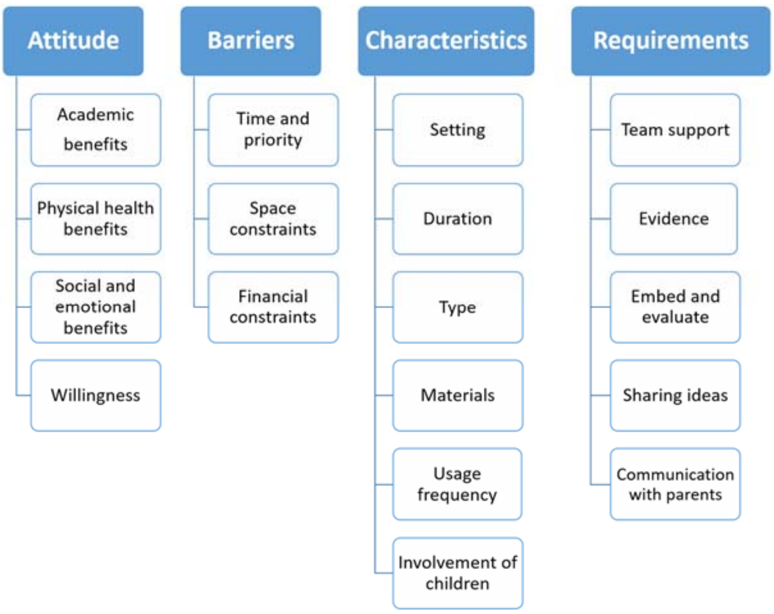

Figure 2. Themes and subthemes resulting from the data analysis.

Attitude towards PA

All teachers and principals showed a positive attitude towards PA, and gave several reasons why they believed PA is important for their students.

Academic benefits. The most common belief of all participants was that PA positively influences children's ability to learn. Teachers indicated from experience that the majority of children need to move in order to release their energy and to recover attention. For example, teacher #10 noticed "Even if you just do a little bit of exercise, because a lot of children really need it, after that you can start up your attention span again".

Physical health benefits. Almost all teachers and principals mentioned the importance of PA for physical health, and some (four teachers and seven principals) believed that "if you've got a healthy body, you perform better cognitively" (teacher #3). However, some participants argued that their "core business is getting children to learn" (principal #7).

Social and emotional benefits. A group of five teachers and five principals also observed the benefits of PA for children's social skills and self-confidence. "They learn to function in a group, to collaborate, learn to deal with losing… But also to be in the limelight if you happen to be good at basketball and maybe can't learn very easily, you notice that a child gets a kick out of it" (principal #4).

Willingness. Overall, teachers and principals were positive towards implementation of additional PA in school. However, they mentioned that their willingness depended on the perceived needs of children to move and the efficiency for learning. Teacher #7 mentioned for example: "If it isn't showing any results, I say stop doing it and leave them sitting". In addition, the willingness was restricted to certain forms of PA (see section 3.2.3). Both groups discussed that willingness may vary across colleagues, because "some people don't see the use of it very much" (teacher #1).

Barriers towards additional PA

Nearly all teachers and principals indicated a gap between their intention and actual implementation of additional PA, which they related to time constraints (major barrier), lack of financial support, and space constraints.

Time and priority. All teachers and principals emphasized a lack of time as a major barrier hindering implementation of PA programmes, and this topic recurred repeatedly throughout all interviews. The perceived lack of time was related to high demands of the government and parents on academic performance, competing priorities, and full school schedules. Teachers expressed that they feel overwhelmed by several responsibilities on top of teaching, like administrative tasks. Overall, it appeared that, according to teachers and principals, implementation of additional PA currently has no priority in school. “Sometimes you’re trapped between the everyday rush, inspection reports, entrance exams, and the things that have to be done… The question is, whether that’s possible, and whether it’s desirable in our system, our school system in the Netherlands… because you’re judged on how good your arithmetic and spelling results are” (teacher #5).

Space constraints. According to the principals, implementation of additional PA in form of additional physical education classes is hindered by the available space. Principal #5 mentioned for example: “Then you have to go to the gym or the sports hall. And you have to take the timetable into account, because other schools also use the same facilities”. Concerns with regard to limited space in the classroom for PA were reported by one third of the teachers: “Make allowances for the fact that the space available—you can see that here—is often limited” (teacher #15).

Financial constraints. A lack of financial support from the government was mentioned by more than half of the principals and a small group of teachers. This barrier was related to hiring a physical education teacher or professional education of classroom teachers, and playground or sport facilities. “We won’t be getting an extra PE teacher, which is a real shame. It would be great, but you need more money from the government. It would be really good if you had money to redesign your playground more effectively” (principal #10).

Characteristics of feasible PA programmes

Teachers and principals’ ideas of feasible forms of PA followed logically from the perceived barriers. The vast majority of participants emphasized that additional physical education classes are not feasible in school. In general, teachers provided more concrete ideas than principals.

Setting. In terms of feasibility and relative to the time barrier, teachers reported that PA programmes need to be implemented by teachers themselves in their classroom. Teacher #2 mentioned: “If you have to go to another location all the time, it just won’t work. You’re stuck with the time factor... If I start doing things here in the corridor, the other classes won’t be very happy”. In addition, being active with the whole class was considered important for supervision and safety reasons. “If they start moving around in small groups for example, someone has to be around, otherwise it’s irresponsible” (teacher #7).

Duration. All teachers and principals agreed that additional PA needs to be of short duration. Teacher #4 said for example: “You can find 5 or 10 minutes somewhere during the school day”. According to both groups, a feasible duration varies between 1 to 5, up to a maximum of 10 minutes.

Type. Most teachers (n = 13) and principals (n = 7) considered PA breaks within or between academic lessons feasible. Several teachers suggested to use dance, movement clips, movement games or exercises around the table, such as jumping and running in place. Some teachers mentioned that there are short movement games available, with which they already had positive experiences. Another suggested type of PA was integration of PA with academic subjects (5 teachers and 5 principals). A recurrent example was exercising while performing math sums. Teacher #2 explained: “That’s a way of calculating that focuses on automation, it’s about movement, so every time you do something, you jump”. However, some participants thought it would be difficult to use such methods in the highest grades of primary education (10–12 year olds). A small group of two teachers and four principals also mentioned other forms of being active while learning. For example, games with alternately sitting and standing, or walking to corners of the classroom when answering questions. Furthermore, some teachers (n = 4) and the majority of principals (n = 7) saw opportunities to increase PA levels outside learning hours. They discussed the possibility of stimulating PA during recess, since not all children are physically active during recess time. They suggested to let children choose from activities, or by giving them cards with PA exercises, and providing more playground facilities. Also, PA interventions after school hours were mentioned by six principals. “I also know that there are out-of-school situations where sports instructors are hired to get children to exercise. It would be very interesting to see if we could make it accessible for all children… to create a kind of extended school day” (principal #1).

Materials. Almost all teachers and principals reported that it is important that PA interventions “don’t cost too much time to prepare” (teacher #9). They recommended materials that are ready to use, for example on the digital screen, in a booklet, or in a card box.

Usage frequency. The majority of teachers (n = 11) reported that they would implement PA spontaneously/incidentally, when children lost their attention, while a small group (i.e. 3 teachers) preferred structural implementation.

Involvement of children. A quarter of all teachers and several principals pointed out the importance of involving the children when designing PA programmes. They emphasized that PA must be varied, fun, challenging, and appropriate for the age group, which could best be explained by the children themselves. Several teachers reported that “up until the second last year at school (grade 5), things are just fine, it’s easy to make it fun… but in the final year (grade 6), they think it’s more important that it’s cool” (teacher #15).

Requirements for implementation of additional PA in school

Teachers and principals addressed several prerequisites for successful implementation and sustainability of PA programmes in school.

Team support. Everyone emphasized that school-wide team support is essential when trying to implement additional PA in school. Teacher #5 said for example: “We’re fantastic at imagining all kinds of complications ... which is why I say you have to make a statement as a team that you want this. That’s the most important thing”. And after the decision has been made “it’s important to make clear agreements with each other” (principal #6).

Evidence. To establish team support, both groups reported the importance of a clear rationale, supported by evidence about the usefulness of PA for cognition/academic performance. Participants emphasized that providing this knowledge is especially important to gain support from colleagues who are less familiar or willing to use PA. In this respect, principal #1 said: “If a teacher is not convinced it’s going to help and that it’s practical, it doesn’t matter how many programmes you set up, nothing much will change. Even if you say it’s been agreed within the school and we’re going to do it”.

Embed and evaluate. Teachers and principals discussed the importance of structurally incorporating PA programmes in the school schedule, such that teachers are aware that they need to implement it. For example, teacher #11 mentioned: “Regular set periods during the week would be great. That you think to yourself, oh yeah, that’s still to come”. In addition, several principals reported that PA programmes must be part of the school policy in order to successfully integrate it in school. Both teachers and principals discussed the importance of regular evaluation within the team to prevent relapse. The majority recommended an internal PA-commission or coordinator responsible for the implementation. Teacher #8 explained: “You can say that everyone takes care of it themselves, but they coordinate it, or propose ideas, or monitor it. Because we all have so much to do that if nobody specifically reminds you, it just doesn’t happen”. The one(s) responsible should, according to teachers and principals, place the topic on the agenda, monitor the implementation, and motivate, inspire and coach teachers.

Sharing ideas. Teachers and principals both indicated that no extensive instruction or course for teachers is needed when implementing short forms of PA in the classroom. A single workshop can be helpful to get ideas, but thereafter, team members need to share and exchange ideas, tips and tricks. A part of teachers and principals who had a physical education teacher in their school, suggested that he/she could take on a supporting role herein.

Communication with parents. Half of the principals stressed the importance of informing parents when deciding to implement additional PA in school. Principal 7 explained: "You need to communicate properly about why you make the choices you make and what effect they have".

Discussion

In this study, we aimed to explore the perceptions of teachers and principals with regard to the implementation of PA interventions aimed at improving cognitive and academic performance, and identify characteristics of feasible school-based PA programmes. Our results add new information to the existing literature that has mainly focused on the perceptions of school staff towards the implementation of PA programmes with the purpose of health promotion. The main findings will be discussed in light of the current evidence on the effects of PA for cognitive and academic performance, and can be used in the development of future school-based PA interventions.

Perceptions of teachers and principals

In line with earlier process evaluation studies, teachers and principals in our study had positive attitudes towards PA, attributed to academic, health, and social-emotional benefits for their students (Cothran et al., 2010; Howie et al., 2014; Brown & Elliott, 2015; McMullen et al., 2016; Stylianou et al., 2015). Similar to Brown and Elliot (2015), our participants particularly mentioned the benefits of PA for learning (i.e. increasing attention), which was a major argument in their expressed willingness to implement additional PA in school. These results are in line with previous studies on health promotion-based programmes suggesting that such programmes need to be complementary to the school curriculum and supportive for learning (Christian et al., 2015; Todd et al., 2015). As the willingness of school staff can affect the success of interventions in schools (McMullen et al., 2016; Zimmerman, 2016), the potential cognitive and academic benefits of PA may facilitate the implementation of school-based PA programmes.

Despite the expressed willingness, our participants emphasized similar barriers as found in previous studies that evaluated the implementation of PA interventions focusing on health outcomes, with a lack of time as the most prominent barrier (Cothran et al., 2010; Gately et al., 2013; Howie et al., 2014; Langille & Rodgers, 2010; Stylianou et al., 2015). Therefore, we conclude that the perceptions of our participants with regard to the potential benefits of PA for cognitive and academic performance do not outweigh the perceived time barrier in schools. The accountability of reaching academic targets, that are subject to governmental assessments, seems to determine schools' priorities and heavily influence teachers' and principals' perceptions of the feasibility of school-based PA programmes. Therefore, in order to prioritize and increase the time that can be devoted to PA programmes in schools, future research should gather insight in possibilities to adapt policies at governmental levels (Brown & Elliott, 2015).

Participants' feeling of a lack of time due to pressures on academic performance seemed contrary to their expressed willingness to use PA to improve learning, as the latter suggests that PA can help improve academic performance. Our results suggest that teachers and principals perceive PA as a tool that can be used to restore attention in the short-term, rather than a structural intervention that supports them in improving academic performance in terms of students' grades. The majority of the teachers mentioned that they would implement PA only at times when students needed a break from learning, for example when they lost their focus. This aligns with the literature on the acute effects of PA for cognitive performance, which suggest that PA breaks can provide immediate improvements in for example attention and on-task behaviour (Chang et al., 2012; Janssen, Toussaint, Van Mechelen, & Verhagen, 2014).

None of our participants related PA to students' grades or referred to scientific evidence when talking about the academic benefits of PA. This could suggest that the current level of evidence does not convince school staff of the long-term effects of structural PA interventions on cognitive and academic performance (Donnelly et al., 2016; Kvalo, Bru, Bronnick, & Dyrstad, 2017), or that they are not aware of the results of scientific research, which is often the case in school practice (Dekker, Lee, Howard-Jones, & Jolles, 2012). Summarizing the most recent reviews, we can conclude that, although small effects of PA on academic performance are reported, there are still many inconsistencies and obscurities in the literature, complicating communication of clear recommendations to policy makers for school practice (Donnelly et al., 2016; Gearin & Fien, 2016; Li, O'Connor, O'Dwyer, & Orr, 2017).

Teachers and principals stressed that evidence on the benefits of PA for cognitive and academic performance is needed to gain team support, which they considered crucial when attempting to implement additional PA in school. Participants furthermore reported that the implementation process needs to be organized within the school, under the supervision of an internal PA coordinator or PA commission, which is in line with earlier studies (Christian et al., 2015; Langille & Rodgers, 2010). Despite convincing evidence of the academic benefits of PA, the overwhelming evidence on health benefits may justify integration of theory on the academic as well as health benefits of PA in teacher training programmes.

The perceptions of the teachers and principals in our study were often similar, although there were some differences that align with their different roles. In general, teachers focused mostly on practical issues that they face in their daily routines (e.g. the use of PA as a means to restore children's attention spans, lack of time, usage frequency), while principals also expanded on organizational barriers such as a lack of financial support and restricted availability of space. Additionally, establishment of policy and communication with parents were important to principals. Earlier studies suggest that principals, besides initiating the implementation, have an essential role in supervising and supporting the implementation process (Brown & Elliott, 2015; Stylianou et al., 2015). However, the participants in our study recommended to assign the supervision of PA implementation to a "PA coordinator(s)", which is not necessarily the principal. In the Netherlands it is common that teachers fulfil the role of "coordinator", as shown by the presence of several "coordinators" in schools (e.g. arithmetic coordinator, information and communications technology (ICT) coordinator, English coordinator). Furthermore, several principals reported the importance of integrating additional PA in the school policy. In line with an earlier study (Langille & Rodgers, 2010), our findings indicate that this is not only the decision of the principal, but it rather needs to be a shared decision of all school staff members.

Feasible school-based PA interventions

Due to the perceived time barrier, and financial and space constraints, teachers and principals indicated that additional PA moments in the school-setting are most feasible when implemented in the classroom, carried out by the classroom teacher. In line with earlier studies, teachers and principals suggested that PA programmes need to be short and easy to implement (McMullen et al., 2014; Webster et al., 2015). More specifically, they recommended PA programmes that are "ready-to-use", i.e. providing materials that require little or no preparation time from the teacher. For example: PA breaks presented in a book, from which teachers can choose one to perform with their students, or PA breaks in digital formats, such as movie clips that can be started on the computer. According to teachers and principals PA must be limited to 1–5 minutes, up to a maximum of 10 minutes. In this respect, it must be noted that only two studies examined the acute effects of five-minute PA breaks, but found no improvements in cognitive performance (executive functioning and attention) (Howie, Schatz, & Pate, 2015; Kubesh et al., 2009). In contrast to studies which used standardized tests to measure cognitive performance, teachers have repeatedly reported to observe improvements in attention after short periods of PA in their classroom (Cothran et al., 2010; Howie et al., 2014; McMullen et al., 2014; McMullen et al., 2016; Stylianou et al., 2015), which was also mentioned by some teachers in the current study. Therefore, it is important that future research includes a measure of teachers' experiences in addition to standardized performance tasks when evaluating cognitive effects of short PA interventions. This could result in stronger and more practice-based evidence for PA related effects in the school setting.

Although teachers in the study of McMullen and colleagues (2014) preferred PA to be connected to academic content, teachers and principals in our study saw most opportunities in PA breaks during or between academic lessons, followed by PA integrated with academic content. In line with Stylianou and colleagues (2015), this indicates that teachers see PA as a break from learning to restore attention rather than a way to learn. However, it could also indicate that our teachers are not familiar with integrating PA with academic content in higher grades, as supported by their concerns for the appropriateness of this type of PA in grades 5 and 6.

Furthermore, teachers and principals discussed that PA programmes must be fun, varied, challenging and age-appropriate; factors that have been found previously as facilitators of PA engagement in children and adolescents (Howie et al., 2014; Martins, Marques, Sarmento, & Carreiro da Costa, 2015; van Sluijs & Kriemler, 2016). As indicated by several of the teachers in this study, we recommend to involve 5th and 6th grade students in the development of PA programmes in order to explore what fun, varied and challenging PA programmes look like according to them.

Lastly, many principals looked for opportunities to implement additional PA outside academic learning hours, for example during recess and after school. This finding is not surprising, considering their role, and again reflect the competing priorities within the school curriculum.

Recommendations for research and practice

Looking at the current line of research, we established a gap between the forms of PA that teachers and principals consider most feasible in school (i.e. classroom-based PA, ≤ 10 minutes), and the forms of PA that have been examined and proved effective in research studies (i.e. acute PA with a minimum duration of 10 minutes (Janssen et al., 2014), and chronic PA interventions with durations of 15 minutes or longer per session (Donnelly et al., 2016). Therefore, we recommend future research to investigate the cognitive and academic effects of forms of PA programmes that are, according to teachers and principals, feasible in school. In particular, studies should focus on very short PA breaks in the classroom (≤ 5 minutes), and examine the acute as well as long-term effects of repeated use of short PA breaks in the classroom. Our findings also confirm the importance of involving school staff in the development of school-based PA interventions, in order to develop interventions that are more likely to be implemented successfully in daily school practice (van Sluijs & Kriemler, 2016). Furthermore, we recommend research on health promotion-based PA interventions to include additional measures of cognitive and academic performance, as we revealed that these outcomes are important for teachers' and principals' willingness to implement PA programmes in school. In addition, this would help to form a better picture of the evidence base of PA for cognitive and academic performance, which is needed to inform policy makers and school professionals, hence increasing the chance of successful PA implementation in schools.

Our findings have also implications for school practice. As the perceived lack of time is a major issue in schools, this needs to be taken into account when aiming to implement additional PA in school. Therefore, we recommend principals and teachers to look for opportunities to implement PA in the classroom, since this requires relatively little time, finances and space (e.g. there is no need for hiring additional staff and/or PA facilities, like a sports hall). We also suggest schools to discuss strategies to lower the perceived time barrier, and look for ways to prioritize the use of PA in school. Herein, the potential benefits of PA for learning could be central. Decisions should be made by both principal and teachers, as team support seems essential for successful and sustainable implementation. We recommend enthusiastic teachers to take a leading role in the promotion of PA in school. Principals can support these teachers and encourage them to take a role as "PA coordinator". We also recommend principals to provide/organize a workshop on the background and practical use of PA in the classroom. In particular, we suggest to discuss the cognitive and academic benefits of PA perceived by teachers, as well as the current scientific evidence. In this respect, it is important to note that although the scientific evidence needs to be strengthened, we can safely conclude that additional time spent on PA will not negatively influence cognitive and academic performance (Donnelly et al., 2016). This may stimulate teachers to spend more time on implementing PA in their classroom. Lastly, we recommend teachers to exchange ideas and experiences with each other, and set up regular follow-up meetings, which might promote PA as part of their daily school routines.

Strengths and limitations

A strength of our study was that data saturation was achieved, and that we consulted participants from several regions across the Netherlands. Other strengths were the inclusion of the audit trail and the interview guides, which provided transparency and ensured trustworthiness of our study, thereby enabling replication. Also, we provided new information that could be used by researchers in future studies on school-based PA interventions, as well as ideas and suggestions that could be used by schools that are looking for ways to implement additional PA in school. A limitation was that we faced a group of fairly motivated teachers and principals, despite the attempt to recruit and include teachers and principals that were also sceptical on the topic. This was supported by the response rate of 26%, and limited the generalisability of the results to less motivated teachers and principals. However, even in this group of participants, several barriers were apparent that would also be applicable to less motivated school staff. Moreover, our findings may not be generalisable to teachers and principals in other countries with different school systems and cultures. Another limitation was that due to time constraints and short availability of interviewers, we could not start data analysis during the data collection period. Therefore, we were not able to adjust questions during the course of the study, which could have provided us with more in-depth information into some aspects of the topic.

Conclusion

In summary, the 5th and 6th grade teachers and primary school principals who participated in the current study had positive attitudes towards PA. They expressed their willingness to implement additional PA in school, in which the academic benefits was an important argument. However, teachers and principals highlighted similar barriers as found in studies on implementation of health promotion-based PA interventions, with time constraints as the most important barrier. Our participants emphasized that feasible PA programmes should be short (i.e. few minutes), provided in "ready-to-use" materials, and be executed in the classroom by the classroom teacher. According to our participants, PA could be best used as break at moments that attention spans decline. Future research on the effects of such PA programmes on cognitive and academic performance is needed to provide policy makers and school staff with clear information on its benefits for school practice. Furthermore, we recommend schools to look for opportunities to implement PA in the classroom, and discuss strategies to lower time barriers and prioritize PA in school.

Appendix A

Table A1. Interview guides.

Subgroup	Interview Questions
Teachers	**Initial Question**
	Do you include some form of physical activity during your lessons? If so, what are your experiences? If not, can you say why not?
	Core Questions
	1. What do you think of the idea of introducing additional physical activity at school to improve cognitive performance and academic performance? 2a. What possibilities do you see in general for additional physical activity at school? 2b. If so, with what goal would you introduce additional physical activity? Does it make any difference to you whether this is introduced to improve health or to improve cognitive skills or academic performance? 3. What possibilities can you see for introducing physical activity during or in between your lessons in the classroom? 4. What, in your opinion, is the best way to provide additional physical activity at school? 5. What, in your opinion, is required to make a success of introducing additional physical activity in the school setting? And what is required to make this a permanent component of the curriculum? 6. What, in your opinion, are the most important points to consider when implementing additional physical activity in the school setting?
Principals	**Initial Question**
	What is the vision and policy of the school with respect to physical activity? In what way is attention focused on physical activity in the school curriculum? Is some form of physical activity implemented by the teachers in their lessons?
	Core Questions
	1. What do you think of the idea of introducing additional physical activity at school to improve cognitive performance and academic performance? 2a. In your opinion, what possibilities are there for introducing additional physical activity in the school curriculum? 2b. If so, with what goal would you introduce additional physical activity? Does it make any difference to you whether this is introduced to improve health or to improve cognitive skills or academic performance? 3. In your opinion, what is the best way to embed additional physical activity in the school curriculum? How do you envisage this in practice? 4. In your opinion, who is the most suitable person to provide additional periods of physical activity? 5. What, in your opinion, is required to make a success of introducing additional physical activity in the school setting? And what is required to make this a permanent component of the curriculum? 6. What, in your opinion, are the most important points to consider when implementing additional physical activity in the school setting?

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Chapter 5

Untapped Resources: 10- to 13-Year-Old Primary Schoolchildren's Views on Additional Physical Activity in the School Setting: A Focus Group Study

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Abstract

Schools are considered ideal venues to promote physical activity (PA) in children. However, a knowledge gap exists on how to adequately integrate PA into the school day and in particular, on the preferences of children regarding additional PA in school. Therefore, the aim of our qualitative study was to gain comprehensive insight into 10–13-year-old primary schoolchildren’s perspectives on how to increase PA in the school setting. We conducted nine focus groups (32 girls and 20 boys) with children attending the final two grades of primary school in the Netherlands. We used inductive thematic analysis to analyze the data. The results showed that children were enthusiastic about additional PA in school. Children suggested various ways to increase PA, including more time for PA in the existing curriculum, e.g. physical education (PE), recess, and occasional activities, such as field trips or sports days; school playground adaptation; improving the content of PE; and implementing short PA breaks and physically active academic lessons. Children emphasized variation and being given a voice in their PA participation as a prerequisite to keep PA enjoyable and interesting in the long term. Finally, children mentioned the role of the teacher and making efforts to accommodate all children and their different preferences as important. Children have concrete ideas, acknowledging the challenges that accompany integrating additional PA in school. We therefore recommend actively involving children in efforts to increase school-based PA and to make “additional PA in school” a shared project of teachers and students.

Introduction

Although the numerous physical and mental health benefits of physical activity (PA) for children are scientifically well-documented (Biddle & Asare, 2011; Janssen & Leblanc, 2010), many children worldwide continue to fall short of meeting the recommended minimum of 60 minutes of moderate-to-vigorous physical activity (MVPA) per day (WHO, 2010; Hallal et al., 2012; Verloigne et al., 2012). Self-reported PA data for children from 39 countries show that only 23% of 11-year-olds and 19% of 13-year-olds currently meet this guideline (WHO, 2017). These low levels of PA become even more pressing since time spent on MVPA typically further declines from primary to secondary education (Nader, Bradley, Houts, McRitchie, & O'Brien, 2008; Ortega et al., 2013). Moreover, it has been shown that a decrease in PA goes hand in hand with a decrease in motivation to keep participating in PA for children in the late years of primary school (Ntoumanis, Barkoukis, & Thøgersen-Ntoumani, 2009; Xiang, McBride, & Guan, 2004).

Because of their potential to reach many children, schools have been widely recognized as an ideal setting to contribute to raising children's PA levels (Pate et al., 2006). To this end, schools have been the nexus of the implementation of a variety of curricular and extra-curricular PA interventions, ranging from spending more time on physical education (PE), school sports, and PA in recess, to integrating movement into classroom time (e.g. classroom-based activity breaks during or in between lessons or physically active academic lessons) (Webster, Russ, Vazou, Goh, & Erwin, 2015).

However, several systematic reviews concluded that school-based PA interventions often have only limited or short-term effects on children's overall PA levels (Dobbins, Husson, DeCorby, & LaRocca, 2013; Metcalf, Henley, & Wilkin, 2012). A possible explanation for this finding is that the evaluated interventions are commonly developed with limited involvement of school staff and children and may therefore be insufficiently tailored to their specific circumstances, needs, and wishes (Brunton et al., 2003; Jacquez, Vaughn, & Wagner, 2013; van Sluijs & Kriemler, 2016). This could result in the development of inappropriate interventions resulting in sub-optimal implementation of and participation in these interventions, limiting their effectiveness (Craig et al., 2008; Naylor et al., 2015; van Sluijs & Kriemler, 2016). In order to ensure that school-based PA interventions will succeed in daily school practice, they need to be relevant to local school contexts and appropriate for and attractive to the intended users (i.e. children and school staff) (Craig et al., 2008; Hawkins et al., 2017; Jacquez et al., 2013; van Sluijs & Kriemler, 2016; Wight, Wimbush, Jepson, & Doi, 2016). A recent systematic review concluded that involving students in the development and implementation of school-based health activities has positive effects on students' motivation and attitude towards the activities, health-related outcomes, and social interactions, as well as the school's culture, climate, rules, and policies (Griebler, Rojatz, Simovska, & Forster, 2017). Moreover, an earlier systematic review by Jacquez and colleagues (2013) has shown that involving children and adolescents in research projects can lead to increased quality of research and higher chances of translating research outcomes into action in daily practice (Jacquez et al., 2013).

In the past few years, several qualitative studies have investigated the perspectives of teachers and school administrators regarding primary school-based PA interventions (e.g. Christian et al., 2015; Todd et al., 2015; van den Berg et al., 2017; Webster et al., 2017). These studies provided valuable information on facilitators and barriers, mostly regarding the organization and execution of PA. However, children are the ones who are expected to actually participate in the intervention, and it is very likely that their perspectives differ from the views of adult school staff.

Thus far, several qualitative studies investigating children's preferences regarding PA have been conducted, focusing on PA promotion in general (i.e. not specifically in the school setting). These studies identified a range of promising PA intervention components that were important according to primary school-aged children, such as providing new and fun activities, the use of technology, using rewards and incentives to encourage participation in PA, and providing opportunities to be active with friends (Carlin, Murphy, & Gallagher, 2015; Jago et al., 2009; Kirby, Levin, & Inchley, 2013; Mulvihill, Rivers, & Aggleton, 2000; Noonan, Boddy, Fairclough, & Knowles, 2016; Rees et al., 2006). Furthermore, a review of qualitative studies found that children prefer to choose their own physical activities and that a range of activities should be offered based on their preferences (Brunton et al., 2003). In addition, to encourage PA in 13- and 14-year-olds, adolescents recommended providing them with opportunities to try new activities, using role models to deliver the intervention, and adding rewards and elements of competition to PA interventions (Corder, Schiff, Kesten, & van Sluijs, 2015). Although some of the results of the above-mentioned studies could be applied to PA interventions in schools, more specific and comprehensive insight is needed regarding PA promotion in the school setting. Accordingly, Carlin and colleagues (2015) emphasized that there is a gap in knowledge on how to maximize the potential of the school day in making children more active (Carlin et al., 2015).

There is currently a lack of qualitative studies that focus specifically on PA opportunities in the primary school setting, and in particular involving the critical age group of 10–13 years, where, as mentioned above, PA tends to decline (Nader et al., 2008; Ortega et al., 2013). Moreover, the qualitative studies investigating additional PA opportunities that have been conducted in the primary school setting often have a narrow focus, determined in advance by the researchers, such as (barriers to) PA promotion in recess (e.g. Pawlowski, Tjornhoj-Thomsen, Schipperijn, & Troelsen, 2014; Stanley, Boshoff, & Dollman, 2012; Watson, Eliott, & Mehta, 2015), or adapting the school physical environment (e.g. Hyndman, 2016; Hyndman, 2017; Willenberg et al., 2010)). For example, a focus group study of Hyndman (2016) investigated what kind of school PA facilities 10–13-year-old children find appealing (e.g. a variety of recreational, sporting, and adventure facilities). However, this study was limited to features of the physical environment and did not consider other ways of enhancing school-based PA. As previous studies focused on certain predefined aspects of the school day, it remains unclear how exactly PA opportunities can be increased within the broader primary school setting according to children. In particular, knowledge is lacking on what kind of activities would be appealing to children, as well as what they need to successfully engage in school-based PA. Therefore, a comprehensive investigation of children's thoughts and ideas concerning PA promotion within the primary school setting is required.

Additionally, the sustainability of PA interventions remains a major challenge (Hatfield & Chomitz, 2015; Kriemler et al., 2011). There is currently little known about how to keep children under the age of 13 motivated to being active in the longer run (Pannekoek, Piek, & Hagger, 2013). For example, it has been shown that a major prerequisite for children's engagement in activities is "having fun" (Brunton et al., 2003; Humbert et al., 2008; van Sluijs & Kriemler, 2016). Yet, we know little about what kind of PA programs result in sustained enjoyment instead of just momentary fun (van Sluijs & Kriemler, 2016). In this respect, Agans and colleagues pose that it is key to create contexts that support "positive movement experiences" for all children (Agans, Säfvenbom, Davis, Bowers, & Lerner, 2013). Early positive experiences with PA for children (i.e. focusing purely on enjoyment rather than increasing performance, and with a good "fit" between the context of PA and an individual's skill level and preferences) result in a higher likelihood of continued PA participation in later life (Agans et al., 2013). Therefore, it is imperative to investigate what PA characteristics contribute to positive movement experiences, for whom, when, and under what circumstances.

In sum, for the development of attractive and effective PA interventions in primary school, more knowledge of the perspectives, needs, and wishes of children is needed. To the best of our knowledge, no qualitative studies have explicitly and comprehensively explored the multi-faceted ideas of 10–13-year-old children regarding increasing PA in the primary school setting. Therefore, the aim of our study was to: 1) explore 10–13-year-old primary schoolchildren's perspectives on incorporating additional PA into the school day, in particular what practical ideas children have to be more physically active in school and what they think is important to successfully implement these ideas; and 2) to investigate children's views on how to keep the proposed activities and ideas interesting and fun for a longer period of time. The results of this study can inform both research and practice regarding the development and implementation of future PA interventions aimed at 10–13-year-old children.

Materials and Methods

Study design

We conducted a qualitative study, employing focus group interviews with 10–13-year-old children in the last two years of primary school in the Netherlands, i.e. in grades 5, 6, or combined 5/6. Focus groups are an effective method to explore the ideas and perspectives of children (Gibson, 2007; Vaughn, Schumm, & Sinagub, 1996). By interviewing children in a group setting at school, we aimed to create a familiar and safe peer environment, encouraging the children to share their ideas and thoughts (Greene & Hogan, 2013; Vaughn et al., 1996), acknowledging them as experts (Heary & Hennessy, 2002), and reducing the power imbalance that may exist between children and the (adult) researchers (Morgan, Gibbs, Maxwell, & Britten, 2002).

PA in the Dutch primary school system

In the Netherlands, children aged 4 to 12 attend primary school (2 years of pre-school followed by grades 1 to 6). On average, children participate in an hour and a half of PE per week. There are no legal provisions issued by the government on the amount of PE that should be provided, but the guideline of the Ministry of Education, Culture and Science prescribes at least two to three lessons of PE per week. PE should either be taught by classroom teachers with a qualification for PE, or a PE specialist. Schools are free to choose their own recess hours, e.g. a short break in the morning and a longer one for lunch break, or two breaks of the same length (Government of the Netherlands, 2018a). Furthermore, schools receive a budget issued by the government that they can spend at their discretion on facilities or personnel, such as a PE teacher (Government of the Netherlands, 2018b). In addition to the regular PA curriculum, there are some national/municipal initiatives (e.g. Healthy Schools, Jump-In, PLAYgrounds, Young People on Healthy Weight (JOGG)) that promote extra physical activity in schools, e.g. by providing PA interventions, school (playground) adaptations, or external coaches who organize PA activities during recess or after school hours.

Recruitment of participants

We used a purposive sampling method (Creswell, 2014) to recruit participants for our study. We approached 45 regular primary schools via email and follow-up phone calls, both from the network of the research group and schools that had not been approached before. Schools were located in both urban and rural areas across the Netherlands. To prevent children's ideas being influenced by earlier implemented PA programs and/or initiatives that promote PA in school (e.g. Healthy Schools, Jump-In, PLAYgrounds, JOGG), only schools that did not structurally provide such additional PA programs were eligible to participate in our study. Nineteen schools did not respond (42%), and twenty-two schools (49%) declined to participate due to a lack of time (*n* = 9), an overload of research requests (*n* = 3), or without a specific reason (*n* = 10). Four schools (9%) agreed to participate.

After a school decided to participate, children in grades 5, 6, and 5/6, and their parents and/or caregivers received an information letter including information on the aim and procedures of the study, and an informed consent form. In order to include perspectives of children with different PA levels in each focus group, we asked parents to fill out a short questionnaire. The questionnaire contained three questions on their child's PA behavior: 1) sports participation: yes/no; 2) hours of sports participation per week; and 3) hours spent in other PA per week, such as outdoor play and active gaming. We used this information to compose the focus groups (see below). For participation in the focus groups, at least one parent/caregiver and children older than twelve had to sign informed consent. Children received a small present (e.g. a key cord) for their participation afterwards. The Medical Ethical Committee of the VU University Medical Center Amsterdam approved the study protocol (2014.363).

Focus group composition

Group sizes of four to eight children allow for a manageable, active discussion, and have been recommended in focus group research with children (Horner, 2000; Kennedy, Kools, & Krueger, 2001). In addition, single-sex focus groups are often recommended as boys and girls may have different attitudes, interests, and viewpoints (Greene & Hogan, 2013; Heary & Hennessy, 2002), which could cause participants to feel uncomfortable to express their ideas in the presence of the opposite sex (Greene & Hogan, 2013). Therefore, we selected six boys and six girls in each class to participate in separate focus groups. All children that returned signed informed consent forms were eligible to participate. To include the perspectives of children with different PA levels, we randomly selected two children that scored relatively low, moderate, and high on PA behavior, as reported by their parents in the questionnaire (see above). In some classes only four to eight children returned the informed consent form, in which case they were all selected for participation.

Focus group guide

The focus group interview guide can be found in Table 1. It was developed following the suggestions of Krueger and Casey (Krueger & Casey, 2009), and consisted of semi-structured, open-ended questions combined with a task-based activity. To introduce the subject and to establish a relationship between the children and researchers, we started the focus group with two warm-up questions. To aid the generation of PA ideas, for main question two in the interview guide we applied a task-based activity in which we asked children to write down each idea on an individual sticky note (see Table 1). Afterwards, the children clustered their ideas in groups on a poster and discussed them with the group. By using this method we assured that all children had time to think about their answers without being influenced by others, and that all children had equal opportunities to express their ideas (Punch, 2002). Probes and follow-up questions were used throughout the focus group to facilitate the discussion (Elo et al., 2014). We ended the focus group with a summary and asked the children if the poster with their ideas was complete or if they had anything more to add.

We developed a protocol and pilot-tested the focus group guide with a group of six boys and a group of six girls from a school that was not included in this study. Based on the feedback of the children and our own experiences, we adapted some instructions and the order of the two warm-up questions. The pilot confirmed that all questions could be answered within 45 to 60 minutes, which is an optimal duration when conducting focus groups with 10–14-year-olds (Vaughn et al., 1996).

Table 1. Semi-structured focus group discussion guide.

Question number	Focus group question
Warm-up question 1	What do you think we mean by “physical activity”?
Warm-up question 2	What kind of physical activity do you currently do in school?
Question 1	Let’s say you start being more physically active in the classroom or in school, how would you feel about that?
Question 2*	If you could tell the school your ideas about how to be more physically active during the school day, what would you say?
Question 3	What do you need to be more physically active in school?
Question 4	What if the school decided to let you be more physically active throughout the entire year. How could we make sure physical activity keeps being fun and interesting?

*Including a task-based activity, i.e. writing individual ideas on sticky notes.

Data collection

Five focus groups with boys and five focus groups with girls were conducted by two interviewers, i.e. Vera van den Berg (V.B.) and a research assistant. Both completed several courses on interviewing techniques during their educational programs, were trained in using the focus group guide, and practiced their moderator skills during the pilot focus groups. V.B. is experienced in working with groups of children and supervised the research assistant during the data collection. The researcher and the research assistant acted alternately as the group moderator who facilitated and encouraged the discussion, and as the observer taking notes.

The focus groups were conducted at the schools of the children in a quiet and private room. For descriptive purposes, we asked the children to report their date of birth. We explained the procedures of the focus group, such as the duration, the use of audio equipment, and confidentiality/privacy. All children were encouraged to express their ideas and opinions. We emphasized that there were no wrong answers and that they were the experts on their preferences with regard to PA in the school setting.

The focus groups were audio-recorded and transcribed verbatim by V.B. and the research assistant. The average duration of the focus group was 46 minutes (range 35 to 50 minutes) for the boys, and 50 minutes (range 36 to 65 minutes) for girls. Raw data consisted of 312 pages of transcript (Calibri, 11, single spaced).

Data analysis

The data analysis started after data collection was finished. The data was coded and analyzed using the qualitative data analysis software program ATLAS.ti version 7 (ATLAS.ti GmbH, Berlin, Germany). For the data analysis we followed the six steps of inductive thematic analysis of Braun and Clarke (2006), and we used the checklist for qualitative reporting of interviews and focus groups as proposed by Tong, Sainsbury, & Craig (2007) to report the data. Thematic analysis as proposed by Braun and Clarke is a widely-used method for qualitative analysis for systematically identifying, analyzing, and reporting patterns (themes) within data (see audit trail in Table 2). To make sure children were unhindered by researchers' previous notions about what might or might not be important in PA interventions, in our study we chose a "bottom-up" inductive approach without an a priori theoretical framework to guide and/or influence children's answers (Pope, Ziebland, & Mays, 2000). As thematic analysis is not theoretically bounded, it is a suitable choice of method when using an inductive approach. Based on the recommendations of Elo and colleagues (2014), one researcher (Eline E. Vos (E.V.)) coded the transcripts, and a second researcher (V.B.) checked all codes and complemented the files. E.V. and V.B. discussed all steps and outcomes in each phase of the data analysis process until they reached consensus. In case of disagreements and uncertainties, a senior member (Amika S. Singh (A.S.) or Mai J. M. Chinapaw (M.C.)) was consulted. We analyzed the data of boys and girls separately until data saturation was reached, i.e. that no new ideas were expressed for each of the groups, indicating that analyzing additional data would not substantially alter the initial categories that were generated (Given, 2008).

Table 2. Audit trail of the data analysis, following the steps of Braun and Clarke (2006).

Step	Description	Examples
1. Familiarizing yourself with the data	• V.B. and research assistant transcribed focus group data verbatim. • E.V. and V.B. read all transcripts and discussed initial ideas and interesting features.	• Initial interesting features: Children seemed to have many ideas regarding PE, active games, recess activities, and activities outside the school building.
2. Generating initial codes	• E.V. and V.B. open coded two transcripts independently, selecting relevant text fragments, and ascribing initial codes. After each transcript, E.V. and V.B. compared their work and discussed until consensus was reached. • E.V. coded the remaining transcripts. Each time E.V. had coded either one or two transcripts, V.B. checked the manuscript(s) and supplemented relevant text fragments and assigned codes. Discrepancies were discussed until consensus was reached. This process was repeated until E.V. and V.B. concluded that coding the transcript yielded no significant new codes in relation to the previously coded transcripts. This was the case after coding four focus groups with boys and five focus groups with girls.	• Initial code examples: "PA barrier: weather", "PA facilitator: teacher", "Resources: playing equipment", and '"PA motivation: health". • The coders discussed whether the text fragment "*I would like to play more sports in school*" should be coded as "Need to be more active" or "Need for more PE". • The coders discussed whether children meant the same thing when they indicated that they prefer more "Workshops" or "Clinics".
3. Searching for themes	• E.V. re-read all coded data, comparing the coded extracts to the assigned code names. Similar codes were grouped together into initial (sub)categories. The collated text fragments of (sub)categories were read and re-read	• The codes "Doing the same activities" and "Alternate location of PA" were grouped together in the subtheme "Variation" and theme

	to identify potential overarching themes.	"Characteristics of additional PA".
4. Reviewing themes	• E.V. formulated a preliminary map of the main (sub)themes and how they related to each other. The coherence and distinctness of the themes and subcategories were first discussed and revised together with V.B., and subsequently within the larger research team (E.V., V.B., A.S., and M.C.).	• Initial themes that were identified: "Children's motivations", "Characteristics of additional PA", "Influences on enjoyable PA" (Choice, Personal preferences, Inclusion, and Supervision), "External barriers and facilitators".
5. Defining and naming themes	• Going back and forth between all data, E.V. refined the content of each (sub)theme, collated significant quotes and wrote a first draft of the results. • E.V. and V.B. reflected on the first draft of the results in detail until consensus about clear definitions of the (sub)themes was reached.	• The theme "Characteristics of additional PA" was revised into "Additional PA according to children" with subthemes "Variation", "Location", etc. • Some of the subthemes were revised into a main theme; for example, subtheme "Inclusion" was revised into main theme: "Taking into account the differences between children" with subthemes "Perceived differences" and "Overcoming differences".
6. Producing the report	• E.V. refined and completed the report of the data analysis with input from V.B., A.S., M.C., and R.G.	

Note: E.V.: Eline Vos; V.B.: Vera van den Berg; A.S.: Amika Singh; M.C.: Mai Chin A Paw; R.G.: Renate de Groot; PE: physical education; PA: physical activity.

Results

Participant characteristics

Four primary schools agreed to participate; two located in urban areas and two in rural areas. Data of 52 children (32 girls from five focus groups and 20 boys from four focus groups) were included in the data analysis. Three focus groups were held with children in grade 5, two with children in a combined grade 5/6, and four with children in grade 6. Five of the focus groups consisted of six girls or boys, one of eight girls, one of four boys, and two of five boys. The mean age of the children was 11.7 years (SD = 0.6), ranging from 10 to 13 years. Eleven children were considered relatively high-active by their parents, 16 children medium-active, and 16 children relatively low-active. Data on activity-levels of the other 9 children were not provided. Overall, the data analysis revealed that themes were quite similar for girls and boys. Therefore, we present the data as a whole and highlight some cases in which the opinions of girls and boys differed.

Focus group results

We identified six key themes: 1) children's motivations for participating in additional PA, 2) children's ideas and perspectives on incorporating additional PA in school, 3) giving children a voice in additional PA participation, 4) the role of the teacher in providing additional PA, 5) taking into account the differences between children in relation to PA participation, and 6) external barriers and facilitators of PA according to children. Figure 1 shows an overview of the themes and subthemes.

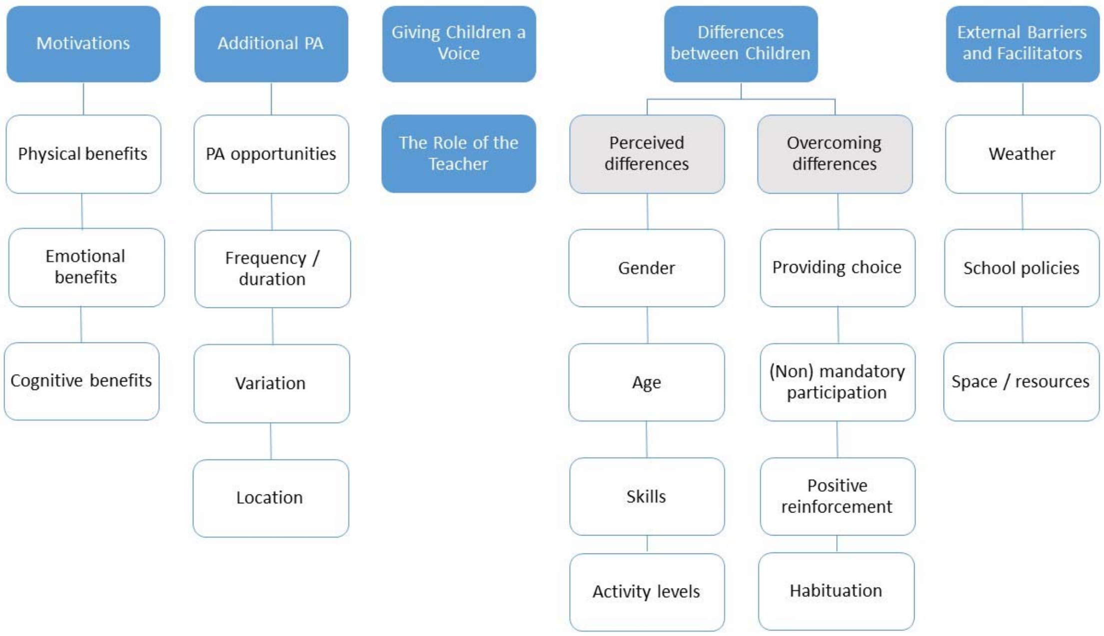

Figure 1. Overview of themes and subthemes resulting from the analysis. PA: physical activity.

1. Children's motivations for participating in additional PA

Generally, children displayed a positive attitude towards additional PA during the school day, stating that it would be "fun" or even "super fun" to be more physically active in school. They also mentioned being dissatisfied with the current amount of PA provided, for example, "*A little more [PE] would be nice*" (girl#7, Focus group (FG) 4). A few children expressed mixed feelings, stating that, "*I think we're doing enough physical activity in school already*" (girl#2, FG2), or that it would depend on the type of extra PA provided. One boy explained that he did not like PA per se, but that he preferred PA over working on school tasks.

The children mentioned three important reasons for additional PA in school. First, in all focus groups, children discussed the importance of PA for achieving *physical health benefits.* Most children acknowledged that PA is good "*for your body, to stay healthy*" (boy#1, FG5), in particular with regard to physical fitness, maintaining a healthy body weight and strengthening the muscles. Second, children discussed the *emotional benefits* of PA. In the majority of focus groups, children reported that being active is fun and can make you feel better: "*I feel happier and have more energy*" (girl#3, FG9). Likewise, they mentioned that PA can be used as a stress reliever after a test. Lastly, in all but three focus groups, children believed that PA could possibly lead to *cognitive benefits,* i.e. improving their ability to focus and/or learn in school: "*You can concentrate better, so it might also help to improve your grades*" (girl#5, FG6). Relatedly, children expressed the need to regularly alternate time spent on academic learning with time being physically active. Children explained that they get distracted, bored, or restless with pent-up energy after long periods of uninterrupted sitting and working on school tasks: "*Then, for example, you have arithmetic, languages, and spelling right after each other, and then you get a little impatient and you really want to move"* (boy#2, FG5). They believed that PA could serve as a break and recharge opportunity: "*You get re-energized*" (girl#5, FG6), which helps them to stay motivated and focused during lessons. However, one girl also stated that being active works in a counterproductive manner and distracts her from work.

2. Children's ideas and perspectives on incorporating additional PA in school

Children had many ideas on how to incorporate additional PA in school, concerning: 1) different PA opportunities, 2) frequency and duration, 3) variation, and 4) location of PA.

*Different opportunities for additional PA**:*** Children saw opportunities to increase PA time in different parts of the curriculum: during classroom time, recess, physical education (PE), and occasional (outdoor) school activities. In addition, children proposed other ideas, such as the establishment of a child PA committee and possibilities to cut back on academic lesson time in favor of PA. In Table 3, we present all ideas generated by the children, including descriptions and examples.

Frequency and duration of PA: Children did not agree on how long and how often they would like to engage in additional PA opportunities. Concerning the implementation of regular PA breaks, most children agreed on keeping them short, i.e. up to ten minutes. Additionally, in five focus groups children underlined that not too much time should be spent on additional PA, since there has to be enough time left to do school work: “*Yeah because the work still needs to get done*” (girl#2, FG2).

Variation: The majority of children emphasized that providing variation is an effective way to make (additional) PA fun, while it also keeps them motivated to participate in PA throughout the school year. Children suggested implementing variation in different ways. First of all, repeating the same activities too often was deemed boring and could negatively impact participation: “*I don’t like tennis or badminton very much and if we have to do that five weeks in a row, I won’t really put much effort in taking part*” (girl#1, FG8). Children discussed the idea of alternating different activities (e.g. tennis one day, soccer the other), and activity types (e.g. collaboration games, ball games, and performing gymnastics exercises). In addition, some children indicated that they would enjoy trying out new activities regularly, for example alternating PE classes with workshops or clinics where they are taught a new sport. Second, children highlighted the importance of regularly replacing and/or expanding the supply of playing equipment in PE and at recess, both because of wear and tear and because “*after a while, it feels like old news*” (boy#4, FG7). Providing variation by purchasing new playing materials and improving the playground facilities (see Table 3) was an important factor for children to facilitate activity during recess throughout the year.

Location: In addition to opportunities for PA in the school building, a reoccurring theme was that children enjoy having activities outside. In all focus groups children came up with one or more suggestions for additional PA outside of the school building, ranging from extending existing “outdoor” time (additional recess and field trips) to moving regular indoor activities outdoors (executing PA breaks in the playground, playing a game in the nearby park).

3. Giving children a voice in additional PA participation

Children indicated that they valued having a voice in their PA participation as they emphasized that they would like to have the opportunity to choose the kind of PA that they themselves prefer. For example, one boy said, “*I like it when we get to choose activities ourselves*” (boy#5, FG5). According to the children, this could either be achieved by presenting them a range of options to choose from or by letting them think up their own games or activity program, such as preparing a PE class or, in the case of girls, preparing an academic lesson involving PA. Also, girls specifically mentioned that doing self-invented activities can prevent PA from becoming boring in the long run. However, children also expressed concerns about the school being receptive to their ideas, “*Yeah, but the school always has the last word anyway, no matter what we think*” (boy#1, FG1).

Children also discussed some drawbacks of freedom of choice as some found it difficult to come up with activities themselves. For example, one boy did not prefer so-called "free" PE lessons in which children get to choose their own activities: "*I don't like that because then I won't know what to do*" (boy#5, FG7). Moreover, it might actually hamper variation: "*If you're allowed to choose every time, then I think people will choose the same thing over and over*" (boy#1, FG7). In this respect, two girls suggested providing a box of cards with different games and activities to choose from, which could, for example, be used during recess. Furthermore, some children felt that teachers and supervisors could stimulate them being active by helping them think up fun activities and games.

4. The role of the teacher in providing additional PA

Although some children thought that they would not need much guidance from teachers in executing their ideas for additional PA, others deemed supervision necessary to ensure that PA is safe and enjoyable, in particular to prevent rough play and arguments, and to make sure everyone knows and abides by the rules. According to the children, teachers and supervisors should actively and enthusiastically encourage them to engage in PA: #8: "*Yeah, the teacher should encourage you a little bit, so you won't just sit on the sidelines and do nothing".* #7: *"Yeah, like the teacher should say 'come on, you can do it'*" (girl#8 and #7, FG4). In some cases, children thought it could be motivating when the teacher joins the activities; however, this depended strongly on whether the teacher is considered "fun." Children were clear that teachers who are considered grumpy or too strict should not join.

It appeared that the priority given to PA depends strongly on the teacher. Many children mentioned that they have regular PA breaks or extra recess time with certain teachers, but not with others: "*With teacher X, we get to move around every once in a while, but never with teacher Y.*" (girl#6, FG10), or "*Teacher X is more into gardening and being physically active, while teacher Y focuses more on teaching the subjects*" (boy#3, FG5). One boy reported that in his class, children who are behind on schoolwork occasionally have to finish their work at the cost of recess time. In other cases, earlier PA routines implemented by teachers seem to have been forgotten along the way: #6: "*Yes and then we made up these little dances".* #4: *"Yeah we used to do that every other lesson".* #6*: "Right, but now the teacher kind of…also because we've had the holidays…she kind of forgot about it*" (girls #6 and #4, FG10).

5. Taking into account the differences between children in relation to PA participation

Perceived differences in preferences between children: Children perceived several differences between children that may influence participation in school-based PA. First, several children mentioned *gender differences*. For example, one boy observed that girls always tend to choose dancing activities (such as Just Dance ™), which, according to him, demotivates boys to be physically active: "*Then we're not enjoying it, and instead we'll sit down and not move at all*" (boy#2, FG5). Another boy believed that girls generally prefer talking over being physically active during recess. Both boys and girls mentioned that boys tend to play more roughly, which may be off-putting for girls who want to join.

Second, children mentioned *age differences.* For example, boys in one focus group perceived the school sports day as "boring" and "not challenging" because they had to do the same activities as the younger children. In addition, several children indicated that children in the lower grades get allotted more recess/playing time, and that the playground equipment is not sufficiently tailored to older children: "*Nowadays, all the sports equipment is made for small children*" (girl#1, FG9).

Third, children perceived that *differences in skill levels* also influence PA participation, as occurs to this girl when talking about making PE more challenging, "*Yeah, [PE] could be more challenging, but it shouldn't be made too difficult because some children might not be able to keep up*" (girl#5, FG6).

Lastly, some children observed differences between *active and non-active* children, "*Some people just prefer sitting on their chair*" (boy#3, FG1).

Overcoming the differences between children in relation to PA participation: Children discussed that due to above-mentioned differences, it may be difficult to satisfy everyone when it comes to additional PA in school. Although some children did not necessarily experience this as a problem—"*Yeah but there will always be something that somebody doesn't like*" (girl#5, FG2)—many others emphasized the importance of "*keeping it fun for everybody*" (girl#3, FG2). In most focus groups, children discussed efforts that should be made to make sure that all children (want to) participate. Without necessarily agreeing on one best option, they proposed several potential strategies to take into account children's different needs and preferences.

First of all, according to most children, participation can be encouraged by either *allowing children to choose* their own activities, or to choose from a range of options which increases the chance of everyone finding something that fits their interest. In this respect, some children suggested organizing separate activities and/or providing different equipment for girls and boys and for children with diverse skill levels (see also "Providing different difficulty levels in PE" in Table 3). To ensure a fair selection process, children proposed to let everyone take turns in choosing PA, rotate activities often, and/or to decide on activities by voting or drawing lots.

Second, a couple of children suggested *making participation mandatory* for all children, regardless of them actually liking the activities. Some even proposed a penalty for non-participation such as staying after school. However, many others preferred to always have the possibility to opt-out because they did not feel that participating is fun if you do not like the activities, which might lead to half-hearted participation at best, and at worst to an unsafe PA environment: "*I would only let children do it who enjoy [participating in PA] because if some of them don't enjoy it they might ruin it for the others*" (girl#2, FG8).

A third line of thinking in some focus groups with girls concerned employing *positive reinforcement.* Girls suggested that children or teachers could try to encourage hesitant children to join in games during recess or offer them a reward as an incentive to participate: "*Maybe they can be allowed to do something else afterwards, like drawing*" (girl#6, FG4). In one focus group, boys indicated that it would be important that teachers provide a rationale for (additional) PA: #4: "*Well, teachers should stimulate [PA] more and also explain the purpose of it […] because some children ask themselves, why are we doing this?*". #1: "*Yeah, why should you be active?*" (boys#4 and #1, FG3). Finally, a few girls pointed at the benefits of *habituation*: "*No you should just let him participate and in the end he might learn to like it because he's done it so often*" (girl#5, FG6). Therefore, they considered it important that children are willing try out new activities that are chosen by others.

6. External barriers and facilitators of PA according to children

Lastly, children mentioned several external barriers and facilitators that may influence the implementation of (additional) PA in school.

Weather: The weather was mentioned as an important determinant of (additional) PA time. One boy indicated that they are often kept inside during recess when it rains: "*Usually when it rains we don't go outside but stay in and watch a video or film or something*" (boy#5, FG7). Another girl remarked that the school sports day had recently been cancelled twice due to bad weather. As a solution, two boys proposed to catch up lost recess time later, and to buy adequate outdoor boots for everyone. Conversely, children mentioned that when the weather is good, they sometimes get extra PA time outdoors, such as playing games in the nearby park.

Current school policies: Children also gave examples of school policies that impede being active in school. For instance, they mentioned that some areas that offer opportunities to be physically active, such as the bushes, the lawn, and access to equipment in the shed, are restricted to them. In one focus group (FG7) children mentioned that they do not have recess on Wednesday since they already have PE that day.

Lack of space and resources: Children recognized and discussed that carrying out some of their ideas for extra PA would require considerable planning and organization because of limited space and resources in the school. Therefore, they suggested to keep group sizes manageable, implement activity timetables (e.g. a rotation system to use the Wii gaming console), and build multi-functional exercise facilities, such as a soccer field that serves as an ice-skating rink in winter.

Costs: The children were also very conscious of the monetary costs connected to their PA ideas, and therefore designated some ideas as not feasible in advance, e.g. weekly school outings that cost money or buying gaming consoles for everyone. As a solution to financial barriers, children suggested organizing a charity run or fundraising activity to raise money, for example, to buy new playground equipment or materials.

Table 3. Primary schoolchildren’s suggestions for integrating additional physical activity (PA) in school.

	Mentioned in Focus Group*	**Description**	**Examples**
Classroom time:			
PA breaks	B1, G2, B3, G4, B5, G6, B7, G8, G9	Short PA breaks (up to ten minutes) in between tasks, usually involving a game component. Either in the classroom itself or in/around the school property	Various games that require moving (relay, hide and seek, Twister ™); dancing breaks, (e.g. Just Dance ™); short exercise activities (e.g. plank exercise, jumping jacks, squads, running around your chair, running a lap around the school)
Technology-based PA breaks	B1, B3, B5, G6, G8	PA games involving technology	Active gaming (Nintendo Wii ™); Virtual reality games (Oculus Rift ™)
Incorporating PA in academic lessons	G4, G6, G9	Movement integration (1) related to, or (2) unrelated to the content of the academic lesson	(1) Having to run to the right answer of addition problems in math lesson; answering language or math questions while tackling an obstacle course; (2) using bicycle desks
Physical Education:			
Extra PE time	B1, G2, B3, G4, B5, G6, B7, G8, G9	Increasing frequency and/or duration of PE	Children had differing opinions on how often or how long PE should be taught
Staying active in PE:			
Playing music in PE	G8	Playing music helps you be more active as you automatically start moving to the music in between exercises.	“*When you have to wait in line you can see everyone moving a little to the music*” (girl#2)
Providing different PA levels	B3, G4, G6	Providing or increasing different levels of PA to accommodate children who prefer (1) more challenge and/or (2) more intensive activities	(1) Challenging activities, such as athletics, gymnastics jumps, obstacle course or rope climbing; (2) activities or sports that make you tired such as running or cardio
Increasing effective PE time	B1, G2, B5, G6, G9	Increasing the time children are actually physically active in PE	Limiting waiting time in between exercises and time spent on travelling, changing clothes, setting up, and putting away equipment; providing short alternative activities if you have to wait for a longer period of time (e.g. during a Dutch variant of softball)
Recess:			
Extra recess	B1, G2, B3, G4, B5, G6, B7, G8, G9	Increasing frequency and/or duration of recess	Children had differing opinions on how often or how long extra recess should be implemented

Improving the playground	G4, B5, G6, B7, G8, G9	Making physical changes to the playground and area around the school to encourage more (active) playing	Updating or installing new playground equipment, such as trampolines, table tennis table, adventure/obstacle course, climbing frame, soccer field, water slide, swing set, indoor playground
Occasional activities:			
Extra school sports days	G4, B5, G6, B7	Increasing frequency of school sports days, where children play different kinds of sports and games for the entire or a part of the day	Different games and sport activities (new and familiar), obstacle course, discus throw, long-jump
Extra clinics/workshops	B1, B3, G4, B5, G6, G9	Increasing frequency of inviting a sports expert to teach children new skills/sports in addition to PE	(Rescue) swimming, street dance, hip hop, baseball, learning new/unfamiliar sports
Extra stage performances	B5, G6, G9	Increasing frequency of stage performances where children prepare an act and perform it in front of all children	Different acts, such as drama, singing, and dancing
Extra active field trips	B1, B3, G4, G6, B7, G9	Increasing frequency of active field trips	Going to the beach or to the park, camp, cycling, paintball, indoor playground, laser gaming, swimming, climbing, amusement park
Using bicycle as transportation	B3, G8, G9	Using bicycles more often or as standard mode of transportation to and from field trips	Cycling to the beach, the swimming pool, the park or to camp
Other:			
PA committee	B1	Establishing a child PA committee that organizes fun and interesting activities for the children in school	Preparing PE class or physical activity for classmates and/or children in other grades
Cutting back on academic lesson time	B1, G9	Cutting back on academic lesson time to spend more time on PA	Letting out school early to do PA on Fridays; shortening lessons to provide more time for activity breaks; giving children one free period per day to do a physical activity of their own choice

G = focus group with girls; B = focus group with boys.

Discussion

To the best of our knowledge, this is the first study that comprehensively explored the views and needs of 10–13-year-old children to increase PA opportunities in the broader primary school setting. Children provided various ideas for additional PA and discussed important factors that need to be taken into account when developing feasible, enjoyable, and sustainable school-based PA programs. In line with the socio-ecological model (Mehtälä, Sääkslahti, Inkinen, & Poskiparta, 2014), children in our study mentioned factors related to opportunities to be physically active in school on multiple levels (i.e. individual level, social level, physical environment, and school policy level). We will discuss the main findings of our study with a focus on their novelty and their implications for research and school practice.

Motivations for additional PA in school

Despite the fact that children with different activity levels participated in each focus group, almost all children in our study were enthusiastic about additional PA in school, which is in line with earlier research showing that many children and young people generally enjoy participating in PA (Allender, Cowburn, & Foster, 2006), and want to be more active (Corder, Atkin, Ekelund, & van Sluijs, 2013). Reasons for this appeal are similar to findings of other studies: children considered PA important because it is fun, provides enjoyment and/or feelings of happiness (Allender et al., 2006; Brunton et al., 2003; Mackintosh, Knowles, Ridgers, & Fairclough, 2011; Rees et al., 2006; Strauss, Rodzilsky, Burack, & Colin, 2001), and because it helps to stay fit and healthy (Brunton et al., 2003; Mackintosh et al., 2011; Rees et al., 2006). A novel finding of our study, expanding on the existing literature, was the importance of the perceived cognitive benefits of PA, specifically in the school setting. Children indicated that PA helps them to increase their motivation and focus, which was, according to them, particularly important given the long and uninterrupted bouts of sitting and/or working on school tasks during a school day. Children’s expressed motivations for and needs to be physically active during school time reflect the importance and relevance of increasing PA opportunities in primary schools. In line with our findings, teachers have also reported that children have a need to move regularly during the school day to restore and increase their attention (Stylianou, Kulinna, & Naiman, 2015; van den Berg et al., 2017). Moreover, these perceived “cognitive” benefits have been shown a key argument in teachers’ willingness to implement additional PA in school (Christian et al., 2015; Todd et al., 2015; van den Berg et al., 2017).

To date, however, recommendations to increase school-based PA have often targeted increasing knowledge on the long-term health benefits of PA (Brunton et al., 2003). It might be that in schools, strategies focusing on the “here and now” benefits of PA, such as enjoyment, increased attention, and a good atmosphere in the classroom, may connect better to children’s and teachers’ day-to-day experiences and motivations and therefore be a more promising avenue to integrate more PA in schools. In this respect we must note that the scientific evidence for the effects of PA on cognitive outcomes, as measured by objective and standardized measurement instruments, is still inconclusive (Daly-Smith et al., 2018; Singh et al., 2018). On the other hand, two recent systematic reviews found that PA breaks can improve children’s classroom behaviour (Daly-Smith et al., 2018) and school engagement (Owen et al., 2016), which seem more closely related to the PA benefits that teachers and children experience. To gain more insight in these “practice-based” effects of PA, we recommend including children’s and teachers’ experiences as additional outcome measures in future research on school-based PA interventions.

Although almost all children acknowledged the importance of PA and showed a positive attitude towards additional PA in school, there appeared to be a gap between “willing” and “having the opportunity” to participate in (additional) PA in school. In line with the findings of a systematic review of Morton et al (2016) focusing on adolescents (Morton, Atkin, Corder, Suhrcke, & van Sluijs, 2016), children in our study specifically mentioned the importance of factors on the social level, i.e. teacher support, to address this gap. For example, children indicated that they noticed vast differences between teachers with respect to what PA they offer, or their willingness to implement extra PA. Therefore, teachers’ priorities and affinities with PA seem to have a strong influence on whether or not children engage in (additional) PA at school. Thus, our results suggest that an important step to create more opportunities for children to be active in school is to overcome barriers at a teacher level. However, teachers’ priorities are likely shaped by organizational and policy level factors. It is, for example, well known that teachers feel time constraints due to an overcrowded academic curriculum and pressures to reach academic targets (Clarke, Fletcher, Lancashire, Pallan, & Adab, 2013; Corder et al., 2015; Hatfield & Chomitz, 2015; van den Berg et al., 2017). While increasing children’s academic performance is an important core goal of school and a responsibility of teachers, the current focus on academic performance subsequently reduces the willingness to increase time for PA during school hours. Our results indicate that these pressures also extend to the children. In more than half of the focus groups, children emphasized that not too much time should be spent on additional PA at cost of time for school tasks. However, compelling evidence shows that spending additional time on PA at the cost of time for learning has no adverse effects on children’s academic performance (Li, O'Connor, O'Dwyer, & Orr, 2017; Singh et al., 2018; Watson, Timperio, Brown, Best, & Hesketh, 2017). Therefore, we recommend informing policy makers, schools, teachers, and children about these findings in order to address and take away their concerns and to create more support for additional PA in schools. Furthermore, these insights might stimulate schools to adapt some of the policies that are clearly within their realm of control, such as not withholding recess, to give room for more PA.

Sustainable participation in PA

Children mentioned several factors that are, according to them, important to stay motivated to participate in PA. We will now highlight the major themes that emerged. Children stressed the importance of involving them and giving them voices when it comes to additional PA in school. Children particularly recognized motivational benefits of student participation in relation to durable PA interventions, as they indicated that involving them in choosing and inventing activities will motivate them to sustain in PA participation in the long run. This finding can be explained using the self-determination theory, which postulates that three basic psychological needs (i.e. competence, autonomy, and relatedness) need to be fulfilled in order to have children intrinsically motivated to engage and sustain in a health behaviour such as PA (Pannekoek et al., 2013; Ryan, 2007). Within this theory, the need for autonomy is a particularly important factor to attain high levels of intrinsic motivation (Pannekoek et al., 2013). However, our study also revealed that children questioned whether the school would actually be open to implementing their ideas, which indicates that it is currently not common to involve children in choosing and designing school-based activities.

On the other hand, children also indicated a need for guidance in their PA choices as they suggested that teachers can help them in choosing or designing PA activities. This aligns with the finding that, to successfully implement educational innovations and school health promotion programs, co-creation with all stakeholders is recommended, leading to increased ownership of the intervention in both students and teachers (Castelijns, Vermeulen, & Kools, 2013; Griebler et al., 2017; Morton et al., 2017). Moreover, teacher support and encouragement appeared important to keep children participating in school-based PA over time.

Our results indicate that 10- to 13-year-old children are very capable of inventing solutions to perceived barriers (e.g. sharing equipment, fundraising to collect money, using timetables, catch up on lost PA time). Hence, it seems of considerable value to involve children actively and make “additional PA in school” a shared project of teachers and children. One specific way in which to increase student participation in school-based PA could be establishing a child-PA-committee, as suggested by some boys in our study. Lastly, children considered variation not only important to make PA enjoyable (see Section 4.3), but also considered it a major factor in keeping them interested in participating in additional PA in the long run. In particular, they highlighted the importance of variation in terms of (types of) activities and PA equipment, which indicates that it is important to adapt and change school-based PA programmes regularly.

General PA promotion versus school-based PA

In line with earlier research on PA promotion in general (i.e. not specifically in the school setting), children in our study reported several factors that are important to make school-based PA enjoyable, such as variation (Carlin et al., 2015; Humbert et al., 2008; Hyndman, 2016; Mackintosh et al., 2011; Martins, Marques, Sarmento, & Carreiro da Costa, 2015), choice in PA activities (Corder et al., 2015; Hyndman, 2016; Mackintosh et al., 2011; Pannekoek et al., 2013; Rees et al., 2006), providing encouragement (Clarke et al., 2013; Martins et al., 2015) and new activities (Carlin et al., 2015; Corder et al., 2015), supervision of teachers (Humbert et al., 2008; Hyndman, Telford, Finch, & Benson, 2012), and using technology (Carlin et al., 2015; Hyndman, 2016). In contrast to earlier studies (Morton et al., 2016), children in our study did not emphasize the importance of competitive elements in PA, which might be due to differences in age of the participants (preadolescents in our study versus adolescents in Reference (Morton et al., 2016) or the setting of PA. Also, being physically active with friends has previously been reported by children as an important factor to make PA fun (Carlin et al., 2015; Corder et al., 2015; Martins et al., 2015), but was not emphasized by the children in our study. This contrast between our and previous studies might be explained by the different settings of PA promotion, i.e. in school versus PA in general. Similar to earlier studies, children's perceived barriers towards school-based PA included bad weather (Martins et al., 2015; Stanley et al., 2012) and lack of time to fully utilize PE (Kirby et al., 2013; Rees et al., 2006). Furthermore, in line with teachers and principals (Brown & Elliott, 2015; van den Berg et al., 2017), the current school policies, lack of space and resources, and financial constraints were also recognized by the children as barriers towards school-based PA. Overall, we can conclude that most facilitating factors and barriers in general PA promotion also apply to PA promotion specifically in the school setting. Expanding on the existing literature on general PA promotion, our study provides a comprehensive and concrete overview of children's voices with regard to preferred and enjoyable PA opportunities in school (see Table 3). This overview is of great value for future research and practice, as it can be used as a basis for developing school-based PA programmes that are appropriate for and attractive to 10-to-13-years old children.

Feasible opportunities for additional PA

Many of the children's suggestions centered around expanding time of the existing PA curriculum, such as increasing the duration and frequency of PE, recess, and occasional activities (e.g. sports day, school outings). These findings confirm the results of earlier studies and reflect the need of children to be more physically active during school time (Clarke et al., 2013; Hyndman, 2016; Robertson-Wilson, Lévesque, & Richard, 2009). However, if we look at the myriad of barriers that schools currently experience, these forms of additional PA are difficult to realize in daily school practice due to time constraints and the financial and material resources that are needed, e.g. hiring PA professionals, acquiring new (technological) play equipment, and adapting playground facilities (Clarke et al., 2013; Hatfield & Chomitz, 2015). This was also recognized by children in our study, whom, for example, worried about too little time remaining to finish school work. In the Netherlands, schools are accountable for reaching academic targets set by the government (Dutch Inspectorate of Education, 2015), and receive a budget from the government that can be used at the school's discretion to hire staff and for maintenance of the school building (Government of the Netherlands, 2018b). In this sense, schools have some flexibility in deciding to spend (part of these) resources on facilitating more PA. However, to realize substantial extensions of the current PA curriculum, considerable investments and shifts in priorities of the school board or even the political level (such as installing legal provisions prescribing a minimum amount of PE in schools) seem necessary (Brown & Elliott, 2015).

Additionally, children had various ideas for additional PA in school that seem relatively easy to realize in daily school practice. For instance, children indicated that more effective PA time could be achieved during current PE lessons, for example by playing music to stimulate movement during waiting times, by providing short activities in between exercises/games, or by providing exercises with different intensity levels for children that need more of a challenge. Likewise, providing children with activities during recess could also stimulate them to be (more) physically active. These suggestions all appear within the control of a (PE) teacher to realize and can therefore be relatively easily implemented. In the case of the Netherlands, PE is often taught by classroom teachers instead of PE specialists, which could potentially hamper the delivery of quality PE (Decorby, Halas, Dixon, Wintrup, & Janzen, 2005). Investing in a physical education specialist or PE support for generalist instructors therefore seems prudent.

Another suggested form of feasible additional PA was PA in the classroom, either in the form of short exercise breaks (suggested in all focus groups) or physically active academic lessons (only suggested by girls). Children preferred to have the exercise breaks in between lessons, which aligns with their need to regularly alternate working on school tasks with being active. Children's suggestions for classroom-based PA are in line with forms of PA that teachers and principals consider most feasible in school, i.e. short exercise breaks of 5 to 10 minutes (Howie, Newman-Norlund, & Pate, 2014; van den Berg et al., 2017) or active academic lessons (McMullen, Martin, Jones, & Murtagh, 2016). Both PE-related interventions and interventions that involved activity breaks have been proven to be an effective way to increase children's PA in the school setting (Salmon, Booth, Phongsavan, Murphy, & Timperio, 2007). Finally, in line with the findings of Hyndman (2016), children often suggested PA in the form of games or PA that included a game component. Earlier intervention research on recess activities shows that providing a game-based curriculum (Chin & Ludwig, 2014; Larson, Brusseau, Chase, Heinemann, & Hannon, 2014) and game equipment (Verstraete, Cardon, de Clercq, & de Bourdeaudhuij, 2006) can successfully increase children's overall PA levels. Playing games and incorporating "game" features or equipment within exercise bouts might therefore be an effective way to increase PA in children.

Tailored PA programs

Also, worthwhile reporting is the apparent contradiction between children's need for "tailored PA" and "including everyone in PA." On the one hand, children indicated the importance of taking into account their individual needs and preferences, while on the other hand they emphasized that efforts must be made to make sure that all children can participate in additional PA in school. Related to the first, earlier studies have repeatedly recommended developing individually tailored PA programs (Brunton et al., 2003; Carlin et al., 2015; Corder et al., 2013; Hatfield & Chomitz, 2015; Humbert et al., 2008). However, these recommendations are rarely followed-up since the development of such PA programs is very difficult due to considerable heterogeneity in school populations and corresponding logistical challenges (Corder et al., 2013; Hatfield & Chomitz, 2015). Hence, most PA programs are still of a "one size fits all" type. Our results indicate that it is important to find a middle way in this paradox i.e. finding solutions to meet individual preferences within a group setting.

Although children emphasized the importance of taking into account individual preferences, another new finding of this study is that they also indicated that it is fine to perform PA activities that they consider less fun, as long as everyone's preferences are represented once in a while. As such, it seems important for future research to invest more in active engagement/participation of children when developing PA programs (Castelijns et al., 2013; Morton et al., 2017; van Sluijs & Kriemler, 2016). It is important that children can discuss the content of the PA program and find compromises when preferences differ. Co-creation of PA promotion programs become more prevalent (Morton et al., 2017) and future effectiveness trials should be conducted to gain insight regarding whether co-created PA promotion programs are more effective in improving physical activity and subsequently health and school-related outcomes.

Strengths and limitations

Our study has several strengths. First, we used children's views as the starting point and children were not restricted by researchers' preconceived notions, resulting in an in-depth and comprehensive exploration of children's perceptions of additional PA in the primary school setting. Second, we included a task-based activity, resulting in a broad representation of different viewpoints and opinions. Third, we included schools in both regional and urban areas of the Netherlands, and made efforts to include children with different PA levels in each focus group to avoid selection bias. Fourth, by including our interview guide and an extensive audit trail, we provide trustworthiness and transparency in the data collection and analysis process.

Our study also has some limitations. First, due to the nature of qualitative research, our findings may have limited generalizability, for example, to other school systems and to children with other cultural backgrounds (most children were of Dutch origin). Moreover, we have to keep in mind that each school has its own context, which influences children's ideas regarding PA opportunities in their particular school. Second, although we included children with different activity levels, it is possible that more children who were already enthusiastic about PA signed up to participate. A third potential limitation is that we started the data analysis after data collection was concluded, which prevented ad hoc adjustments to the interview protocol. However, we pilot-tested the interview guide beforehand. Fourth, one focus group included eight girls and was difficult to moderate. This could have inhibited some girls to express their opinions. Lastly, we aimed to collaborate with two interns of an external institution, but unfortunately, we noticed that they did not follow the interview protocol. Therefore, we decided not to use data from these two focus groups. Although the interns wrote their internship report on this data, we could not fully avoid research waste. Nevertheless, we reached saturation with the available focus groups.

Conclusion

In general, primary schoolchildren who participated in this focus group study would welcome additional PA opportunities in school and expressed a desire to be more physically active during the school day. Schools and researchers should capitalize on this enthusiasm when developing PA programs, while the child-perceived beneficial practice-based effects of additional PA, such as restored attention in the classroom, warrant further investigation. Children in this study suggested various ways to increase PA in school, of which finding ways to improve effective PE time and providing short activity breaks in between lessons seem relatively easy to implement in daily school practice. Future research could provide further insight into whether including the child-identified suggestions are indeed effective in structurally raising their PA levels. Furthermore, children perceived choice and variation as important for keeping the PA options attractive in the long term and identified teachers as both a key barrier and facilitator of PA participation. We therefore recommend actively involving children in efforts to increase school-based PA and to make “additional PA in school” a shared project of teachers and students. Overall, our study provides a comprehensive overview of children’s voices regarding additional PA in school, which could be used to inform the development of future PA interventions aimed at increasing the activity levels of children in primary school. To ensure relevance to local contexts, it is important that these strategies include the involvement of children, teachers, and other key stakeholders.

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Chapter 6

Improving cognitive performance of 9 to 12 years old children: Just dance? A Randomized Controlled Trial

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Abstract

Exercise is assumed to have positive effects on children's cognitive performance. However, given the inconclusive evidence for the long-term effects of exercise, it is difficult to advice schools on what specific exercise programs can improve children's cognitive performance. In particular, little is known about the effects of small exercise programs that may be feasible in daily school practice. Therefore, we assessed the effects of a 9-weeks program consisting of daily exercise breaks on children's cognitive performance, aerobic fitness and physical activity levels. We conducted a cluster-randomized controlled trial in 21 classes of eight Dutch primary schools. A total of 512 children aged 9 – 12 years participated. The exercise intervention had a duration of 9 weeks and consisted of a daily 10-minute classroom-based exercise break of moderate to vigorous intensity. Before and after the intervention, we used four cognitive tasks (i.e. the Attention Network Test, Stroop test, d2 test of attention and Fluency task) to measure children's cognitive performance in domains of selective attention, inhibition and memory retrieval. In addition, we measured aerobic fitness with a Shuttle Run test and physical activity during school hours by accelerometers. We analyzed data using mixed models, adjusting for baseline scores, class and school. After 9 weeks, there were no intervention effects on children's cognitive performance or aerobic fitness. Children in the intervention group spent 2.9 minutes more of their school hours in moderate to vigorous physical activity as compared to the children in the control group. In conclusion, daily 10-minute exercise breaks in the classroom did not improve, nor deteriorate cognitive performance in children. The exercise breaks had no effect on children's fitness, and resulted in 2.9 minutes more time spent in moderate to vigorous physical activity during school hours. Daily exercise breaks can be implemented in the classroom to promote children's physical activity during school time, without adverse effect on their cognitive performance.

Introduction

The assumed positive relationship between exercise and cognitive performance is widely used to advocate in favor of increasing exercise opportunities in schools (e.g. Erwin, Fedewa, Beighle, & Ahn, 2012; Savina, Garrity, Kenny, & Doerr, 2016; Webster, Russ, Vazou, Goh, & Erwin, 2015). In particular, since cognitive performance in domains such as selective attention, inhibition, working memory and cognitive flexibility, has been shown to be important for children's academic performance (Jacob & Parkinson, 2015; Stevens & Bavelier, 2012). However, recent systematic reviews and meta-analyses have shown that the evidence for the long-term effects of structured exercise programs on children's cognitive performance is inconclusive; some studies report positive effects, while others report no effects (see for reviews (Donnelly et al., 2016; Li, O'Connor, O'Dwyer, & Orr, 2017; Singh et al., 2018; Watson, Timperio, Brown, Best, & Hesketh, 2017). Nevertheless, it can be concluded that increasing the time spent on exercise in school at the cost of academic lessons does not negatively impact children's cognitive performance (Donnelly et al., 2016; Singh et al., 2018).

Recently, an international expert panel indicated that there is a need for more well-designed, randomized controlled trials to gain better insight in the causal effects of exercise on cognition (Singh et al., 2018). In addition, the experts highlighted the importance of elucidating the characteristics of exercise interventions that may improve cognitive performance. Due to substantial heterogeneity in interventions (e.g. duration, frequency, content), it is difficult to advise schools on the optimal form of exercise interventions to improve children's cognitive performance (Donnelly et al., 2016; Singh et al., 2018; Watson et al., 2017).

The vast majority of studies that examined the long-term effects of exercise on cognitive performance of children have implemented extensive exercise interventions with durations of 30 to 60 minutes per session, mostly delivered three to five times a week (Alvarez-Bueno et al., 2017; Donnelly et al., 2016; Singh et al., 2018). However, it seems unlikely that such time-consuming programs will be implemented on a large scale in real-life daily school practice. Several qualitative studies have reported that time constraints are perceived as a major barrier that limit the opportunities for physical activity and exercise in schools (Dinkel, Schaffer, Snyder, & Lee, 2017; Howie, Newman-Norlund, & Pate, 2014; McMullen, Kulinna, & Cothran, 2014; Stylianou, Kulinna, & Naiman, 2015; van den Berg et al., 2017). In addition, teachers indicate that it would only be feasible to implement short exercise bouts with a maximum duration of 5 to 10 minutes (Howie et al., 2014; van den Berg et al., 2017).

Previous studies have focused on the *acute,* or immediate, effects of relatively short exercise bouts on cognitive performance, such as attention, inhibition and working memory (e.g. Howie, Schatz, & Pate, 2015; Niemann et al., 2013; van den Berg et al., 2016). Several systematic reviews and meta-analyses concluded that *overall*, single moderate to vigorous exercise bouts with a minimum duration of 10 minutes can have small to moderate acute positive effects on children's classroom behavior (i.e. time-on-task) (Daly-Smith et al., 2018; Watson et al., 2017), selective attention (Chang, Labban, Gapin, & Etnier, 2012; de Greeff, Bosker, Oosterlaan, Visscher, & Hartman, 2018; Janssen, Toussaint, van Mechelen, & Verhagen, 2014), and executive functioning (Chang et al., 2012; Donnelly et al., 2016; Ludyga, Gerber, Brand, Holsboer-Trachsler, & Puhse, 2016; Verburgh, Konigs, Scherder, & Oosterlaan, 2014). However, it is still unclear whether these acute effects accumulate over time, i.e. if implementing short exercise bouts on a regular basis can improve children's cognitive performance after weeks or months.

Several potential mechanisms underlying the effects of exercise on cognition have been discussed in the literature. For example, acute effects of exercise have been related to increased blood flow (Ogoh & Ainslie, 2009), increased release of neurotrophic factors, such as brain derived neurotropic factor (BDNF) and insulin-like growth factor-1 (Piepmeier & Etnier, 2015), increased arousal levels (Terry McMorris & Hale, 2015), and increased activity in certain brain areas (Budde, Voelcker-Rehage, Pietrabyk-Kendziorra, Ribeiro, & Tidow, 2008). Mechanisms of chronic exercise effects include increased availability of growth factors (e.g. BDNF), development of new blood vessels and neurons, changes in brain volume, increased efficiency of neural networks, and increased physical fitness (see for reviews Fernandes, Arida, & Gomez-Pinilla, 2017; Hillman, 2008; Huang, Larsen, Ried-Larsen, Moller, & Andersen, 2014). In addition, chronic exercise is suggested to improve self-control, which is important for self-regulation and functioning of higher cognitive functions (Audiffren & André, 2015). Some of the above-mentioned mechanisms may explain cumulative effects of acute exercise. For example, acute exercise-induced elevations of BDNF have been shown to be augmented by repeated exercise, resulting in increased resting levels of BDNF important for cognitive improvements and brain changes (see for a review Huang et al., 2014). Furthermore, several acute and long-term studies have shown that cognitively demanding exercise (e.g. coordinative exercise, team games) can improve cognitive performance to a higher extent than mere repetitive aerobic exercise (e.g. Budde et al., 2008; Koutsandreou, Wegner, Niemann, & Budde, 2016; Schmidt, Benzing, & Kamer, 2016), likely due to the inherent motor and cognitive demands (Best, 2010; Tomporowski, McCullick, Pendleton, & Pesce, 2015). Acute cognitively demanding exercise requires high cognitive effort due to exercise complexity and changing circumstances, which may provide long-term improvement of self-control capacities and cognitive functioning (Audiffren & André, 2015; Best, 2010). This type of exercise could also result in higher intervention compliance, since challenge and variety seem important for children's exercise motivation (e.g. Martins, Marques, Sarmento, & Carreiro da Costa, 2015).

To the best of our knowledge, no previous studies investigated the long-term effects of short exercise breaks (i.e. 10 minutes) in the classroom on cognitive performance of preadolescents (aged 9 to 12 years). Costigan and colleagues (2016) examined the effects of two 8-week interventions, in which 8- to 10-minute exercise bouts consisting of 1) high intensity aerobic exercises or 2) high intensity combined aerobic and strength exercises were implemented three times per week in 14 to 16 years old adolescents. The exercise bouts were implemented once a week during recess and twice a week as part of the regular physical education (PE) classes. The authors found no significant differences in executive functioning between the intervention groups and the control group that followed the regular PE classes (Costigan, Eather, Plotnikoff, Hillman, & Lubans, 2016). Little contrast in the amount of additional exercise in the three groups and the absence of measures to compare adolescent's physical activity levels limit conclusions about the exercise related effects on cognitive performance. Furthermore, the authors indicated that the relatively small sample (N = 65) from one secondary school limits the generalizability of their results (Costigan et al., 2016).

To fill this gap, we conducted a cluster randomized controlled (RCT) trial to investigate the effects of a 9-week exercise break program on cognitive performance of 9 to 12 years old Dutch primary school children. The intervention consisted of one daily, classroom-based 10-minute exercise break in which children were asked to mimic dance movements (i.e. aerobic exercise with coordinative and cognitive demands). The intervention was implemented within the school curriculum, as it has been shown that curricular exercise programs can result in stronger effects on cognition compared to programs that are implemented outside school hours (Alvarez-Bueno et al., 2017). Moreover, Dutch teachers have indicated that classroom-based physical activity is most feasible in daily school practice (van den Berg et al., 2017).

We examined the effects of the intervention on selective attention, inhibition, and semantic memory retrieval, since these cognitive domains are associated with children's academic performance (Rosario Rueda, Checa, & Rothbart, 2010; Stevens & Bavelier, 2012). As secondary outcomes, we measured children's aerobic fitness and their physical activity levels during school hours. Given the earlier reported *acute* effects of short exercise bouts, we hypothesized that implementing a daily exercise break will have a positive effect on children's cognitive performance after nine weeks.

Methods

Sample size calculation

We used G*power 3.1.9.2 (Faul, Erdfelder, Lang, & Buchner, 2007) to calculate the required sample size. In line with earlier studies and meta-analytic findings, we expected to find a small to medium effect of our exercise intervention on children's cognitive performance (e.g. Costigan et al., 2016; Schmidt, Jager, Egger, Roebers, & Conzelmann, 2015; Vazou, Pesce, Lakes, & Smiley-Oyen, 2016). The sample size calculation revealed that we needed to include a total of 404 participants (N = 202 per group) to detect a small to medium effect (f = 0.18) of the intervention on children's cognitive performance, with a power of 95% (2-sided testing at $\alpha = 0.05$).

Recruitment of participants

We approached a convenience sample of regular primary schools from the network of our research group by email and personal contact. Twenty-three schools across the Netherlands received an information letter and were asked to respond if they were interested to participate. We included schools that were willing to participate with a minimum of two classes. For feasibility reasons, we decided to stop the inclusion after eight schools agreed to participate. Two schools declined due to busy school schedules and one school was excluded since they had only one class available. Twelve schools did not respond, but were neither followed-up since we reached the required sample size with schools that responded to our first invitation.

All children in grades 5 and 6 (N = 549) were invited to participate. Children and their parents/caregivers received an information letter about the study, including an informed consent form. In consultation with the schools it was decided that all children participated in the intervention/control program as part of the regular school curriculum. Permission of at least one parent/caregiver and children of 12 years and older was required to participate in the measurements. We received informed consent of 512 children (93%), who were included in the study. The study was approved by the Medical Ethical Committee of the VU University Medical Center Amsterdam [2014.363].

Study design, randomization and blinding

We conducted a cluster RCT. An independent statistician randomly assigned the participating classes to the intervention (N = 11) or control group (N = 10). Randomization was performed in R using block randomization with blocks of size 2. The randomization was stratified by school and grade for the schools in which multiple classes of the same grade took part. Randomization for the remaining schools was done by randomly assigning the 5th grade to one of the two conditions (with the 6th

grade automatically receiving the alternative). This procedure ensured that in each school there were both control and intervention classes and that number of control and intervention classes was balanced between the two grades. The randomization took place after the pretest measurements to ensure that all children, teachers and researchers were blinded. Two members of the research team remained blinded the entire experiment and acted as test administrators at the posttest measurements.

Procedure

Before the experiment, we trained the research team to conduct the measurements following a standardized protocol. We visited each class six times (see Figure 1). The first visit consisted of a familiarization session in which we introduced the study and explained all measurement procedures. Children received detailed instructions about four cognitive tasks and practiced all tasks to make sure they understood them well. Furthermore, children filled out a demographics questionnaire and we measured their baseline height, weight, and fitness. During the second visit, we conducted the baseline measurements (pretest) in which the cognitive tasks and a questionnaire were administered. We randomly assigned the children in each class to group A and B, stratified by gender (10 to 15 children per group, depending on class size). Group A started in the classroom where two paper-and-pencil cognitive tasks and the questionnaire were administered, while group B started in a separate room where two computerized cognitive tasks were administered on laptops. Halfway the test session, the groups switched rooms and continued with the other half of the measurements. In one school (N = 2 classes) there was no private room available, so we administered the paper-and-pencil tasks with the entire class, and divided the classroom in two testing areas for the laptop tasks and questionnaire. The week after the baseline measures, the classes started with the 9-week intervention/control program. The third and fourth visit were scheduled during the intervention period to: 1) hand out accelerometers in a subgroup of children, and 2) measure the exercise intensity of one exercise break in the intervention classes. After the intervention period, we conducted the post-intervention measurements (fifth visit: posttest), which were identical to the pretest and scheduled at the same day of the week and time of the day. To avoid contamination of the effects by possible acute exercise effects, we instructed all teachers not to perform an exercise break on the measurements days. During the sixth visit we measured children's fitness again. After the experiment, all children received a small symbolic present for their participation.

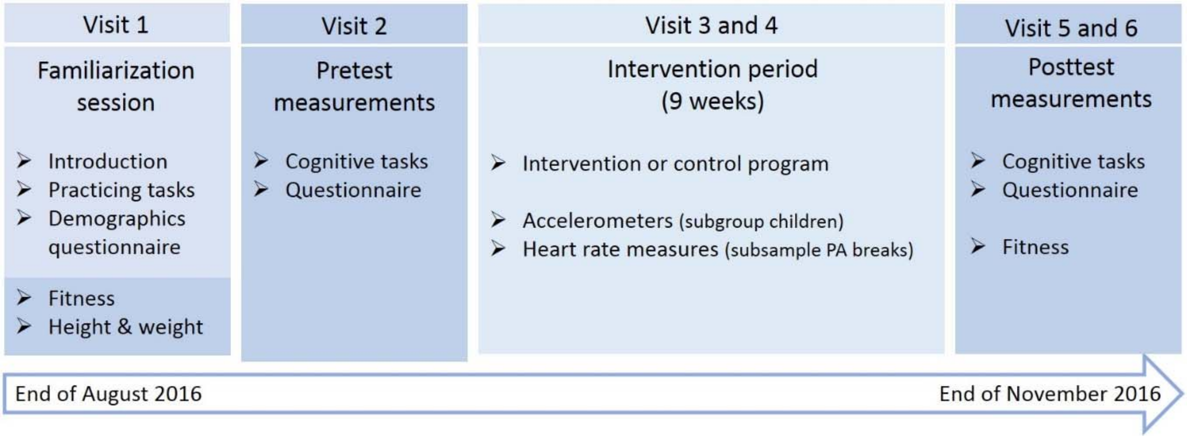

Figure 1. Overview and timeline of the study.

Intervention program

The intervention lasted 9 weeks and consisted of one moderate to vigorous intensity exercise break per school day. The intervention duration was chosen for feasibility reasons. A period of 9 weeks best fitted the school's year schedules and was relatively short, by which we aimed to keep compliance high during the entire intervention period.

Each exercise break lasted approximately 10 minutes and consisted of three 'Just Dance' videos (Ubisoft, free available via YouTube). In the videos, a figure performs a dance which the children are asked to mimic. Our choice for Just Dance videos and the exercise duration of 10 minutes was based on the acute exercise literature combined with the preferences of Dutch teachers and children in the upper grades of primary school. The exercise literature indicates that moderate-to-vigorous exercise bouts need to have a duration of at least 10 minutes to exert acute cognitive improvements (Daly-Smith et al., 2018; Howie, Beets, & Pate, 2014; Howie et al., 2015). Teachers have indicated that they prefer additional PA in school to be classroom-based, easy to implement (i.e. requiring little preparation time) and up to a maximum of 10 minutes (van den Berg et al., 2017). Accordingly, many teachers in the Netherlands already use Just Dance in the classroom setting. A recent study of our group revealed that one of the ideas of children to increase PA in school, that matched the preferences of teachers, is to implement short exercise breaks during classroom time, for example Just Dance (van den Berg, Vos, De Groot, Singh, & Chinapaw, 2018). Teachers received an instruction sheet with a password to access the exercise breaks via a secured webpage. The exercise breaks were performed in the classroom and we asked teachers to make sure that all children kept moving. The exercise break program was performed in addition to the regular physical education classes.

The exercise breaks were selected based on a pilot study, in which we tested 83 Just Dance videos once (100%) or twice (67%) in 31 grades 5 and 6 of fourteen primary schools (unpublished data). Children (N = 766) wore heart rate monitors to determine the mean exercise intensity of each video and we asked them to rate the videos on being fun and difficult, respectively. In addition, we observed the feasibility of performing the dances in the classroom. The pilot resulted in the selection of 55 suitable videos that were used to compose 45 different exercise breaks used in the current study. To ensure variety in the program, each exercise break consisted of a unique combination of three videos. Each video returned two or three times during the 9 weeks period, each time combined with two other videos.

Control program

The control program consisted of nine educational lessons, lasting 10 to 15 minutes, one for each week of the experiment. The lessons were unrelated to the core school curriculum. We composed the lessons using information and educational videos on topics related to the body, exercise and/or sports for 9 to 12 year olds (free available online; see for example: NTR, 2012) Teachers received an instruction card including a password to access a secured webpage with the instructions, videos, worksheets and answers for each lesson. During the experiment, children in the control group followed the regular physical education classes.

Measures and measurement instruments

Demographics and anthropometrics

Children self-reported their birth date, gender and sports participation. The questions on sports participation were derived from the ENERGY-child questionnaire, showing good to excellent test-retest reliability (ICC's: 0.68 to 1.00) and moderate to excellent construct validity (ICC's: 0.51 to 1.00) (Singh et al., 2011). The Dutch version of the Harter's Self Perception Profile for Children was administered to measure children's perceived competence in five domains (scholastic, social, athletic, physical appearance, behavioral conduct) and their perceived global self-worth (Veerman, Straathof, Treffers, Van den Bergh, & ten Brink, 1997). This questionnaire has been shown to have sufficient construct validity and good test-retest reliability (ICC's ≥ 0.84) in 8 to 14 years old Dutch children (Egberink & Vermeulen, 2018a; Muris, Meesters, & Fijen, 2003). Parents self-reported their highest completed educational level, which was used as a proxy measure of socio-economic status.

We asked teachers to provide standardized test scores of the children on reading comprehension, orthography and arithmetic. Scores were obtained from the standardized and norm-referenced CITO test battery (Hollenberg & van der Lubbe, 2017), which most schools in the Netherlands administer twice a year to assess and track children's academic performance. After the experiment, teachers provided information on children with special educational needs (e.g. ADHD, autism spectrum disorders, learning disorders).

We measured children's body height (cm) and weight (kg) in sport clothes without shoes, using a Leicester Height Measure Mk II (Harlow Healthcare, UK) and a Seca weighting scale (Seca Instruments, Frankfurt, Germany). The Body Mass Index (BMI) of each child was calculated with the formula: (weight (kg) / height (m)^2).

Intervention integrity

Each class received a calendar-poster that was attached to the classroom wall and remained visible during the intervention. We asked teachers and children to put a sticker on the poster each time they performed an exercise break (intervention group) or an educational lesson (control group). The poster served as a reminder to implement the program, as well as a measure of intervention integrity. We calculated the percentage of exercise breaks that were conducted, with 45 exercise breaks equaling 100% implementation. Halfway the intervention, we asked teachers to report potential implementation problems. In case of problems, we gave advice and encouraged teachers to implement as many exercise breaks or educational lessons as possible.

Exercise break intensity

We assessed the intensity of a subsample of exercise breaks by monitoring heart rate (11 exercise breaks; one per intervention class). All children were fitted with a Polar H7 Bluetooth heart rate monitor that was connected to the Polar Team App (Polar Electro Oy, Finland) in which the mean heart rate of each child was stored. Exercise intensity was calculated as percentage of the maximum heart rate: (mean heart rate/maximum heart rate)*100. The maximum heart rate was measured during the Shuttle Run test (see section aerobic fitness).

Primary outcomes: cognitive performance

We measured cognitive performance with two paper-and-pencil tasks, i.e. the d2 Test of Attention and the Fluency Task, and two computerized tasks, i.e. the Stroop Color-Word task and Attention Network Task (ANT) using E-prime 1.2 Software (Psychology Software Tools, Pittsburgh, PA). During the pre- and posttest, children received standardized verbal and written instructions and made a few practice trials (d2 test, Stroop, ANT). Two trained and blinded test instructors gave task instructions for all tests and kept track of time in case of the d2 test and Fluency task. During the tests, two to three members of the research team each supervised a small group of children and made notes. We instructed the children to work quietly, individually, and as fast and accurately as possible. The order in which the tests were administered was counterbalanced and randomized, stratified by gender, grade and intervention/control group. The order of tests was identical during the pre- and posttest and each child made all tests on the same laptop.

d2 test of attention

The d2 test was used to measure selective attention (Brickenkamp & Oosterveld, 2012).The construct validity of the d2 test has been rated as sufficient (Egberink & Vermeulen, 2018c). The reliability has been rated as good, with moderate to high test-retest reliability in 10-13 years old Dutch children (r = 0.79 to 0.83) (Brickenkamp & Oosterveld, 2012; Egberink & Vermeulen, 2018c).

The d2 test consists of one page with fourteen lines, each consisting of 47 characters ‘d’ and ‘p’ with one to four dashes displayed above and/or below. We instructed the children to mark as much letters ‘d’ with a total of two dashes (‘d2’) as possible, while ignoring the other characters. They had to work from the left to the right, with a time limit of 20 seconds per line. The test instructor gave a signal when to continue with the next line. The total test lasted 4 minutes and 40 seconds.

We used the concentration performance (i.e. number of correctly marked d2’s minus the number of incorrectly marked characters) as dependent variable, since this is an objective measure of selective attention (Brickenkamp & Oosterveld, 2012).

Fluency task

We used a paper-and-pencil version of the Verbal Fluency task (Mulder, Dekker, & Dekker, 2006) to measure semantic memory retrieval performance. The validity and reliability of the Verbal Fluency task has been shown sufficient in children and adolescents (Egberink & Vermeulen, 2018b; Korkman, Kirk, & Kemp, 1998).

Children were instructed to write down as many words as possible in the category ‘animals’ within 60 seconds. The total number of correct words was used as dependent variable.

Attention Network Task (ANT)

We used the short version of the ANT to assess the efficiency of three attentional networks: alerting (i.e. achieving and maintaining an alert state), orienting (i.e. selection of information from sensory input) and executive control (i.e. resolving conflict among responses) (Fan et al., 2007; Fan, McCandliss, Sommer, Raz, & Posner, 2002). Several studies have recommended the use of the ANT in children, as it has been shown a valid instrument to measure their attentional performance (Forns et al., 2014; Rueda et al., 2004). The task was downloaded from the website of the Sackler Institute for Developmental Psychobiology (Psychobiology).

Sets of five horizontal black arrows pointing to the right or left were presented on a white 15-inch laptop screen. Children were instructed to identify the direction of the middle arrow (the 'target'), by pressing the right mouse button for the right direction and the left mouse button for the left direction. The central target was 'flanked' by two lateral arrows on the left and on the right, pointing either in the same direction (congruent; >>>>> or <<<<<) or in the opposite direction (incongruent; >><>> or <<><<). A fixation cross remained visible in the middle of the screen during the task. In two-third of the trials, a warning cue (*) was presented for 200 ms either above or below (spatial cue) or at the place of the fixation cross (center cue) before the stimuli appeared. The total task lasted approximately 12 minutes and contained three blocks of 48 trials, with one-minute breaks in between.

We calculated the mean reaction time (correct responses only) and accuracy (proportion of correct responses) by the formulas of Fan et al. (2007): Alerting effect = (SCORE no cue – SCORE center cue); Orienting effect = (SCORE center cue - SCORE spatial cue); Conflict effect (executive control) = (SCORE incongruent - SCORE congruent). Larger reaction time scores indicate better alerting and orienting performance, while a smaller value indicates better conflict performance. For accuracy, a larger value indicates better alerting performance, a larger negative value better orienting performance, and a smaller negative value better conflict performance. Reaction times faster than 200 ms were considered as incorrect and excluded from the data analysis (Fan et al., 2007).

Stroop Color-Word task

We used a computerized Stroop Color-Word task to assess children's inhibitory performance. Computerized versions of the Stroop have been shown to have moderate to good test-retest reliability in children ($r = 0.50$ to 0.80) (Penner et al., 2012).

During the task, a color-word (the Dutch word for BLUE, GREEN or RED) was presented on a 15-inch white laptop screen. In the congruent conditions, the color-word was displayed in a similar text color as the meaning of the word (e.g. the word BLUE displayed in a blue text color). In the incongruent conditions, the text color differed from the meaning of the color-word (e.g. GREEN written in a red text color). Children were instructed to press the button '1', '2' or '3' at the left side of the key board that corresponded to the text color of the color-word. A fixation cross was presented for 1000ms, followed by the color-word that was presented for 2500ms. After a child responded, the color-word disappeared. The inter stimuli interval was 4000ms. The answer options, 1 = GREEN, 2 = BLUE, 3 = RED, remained visible at the bottom of the screen. The task consisted of 105 trials and lasted approximately 9 minutes.

We calculated the interference score as dependent variable by subtracting the scores of the incongruent from the congruent conditions for both reaction time (correct responses only) and accuracy rates. A smaller interference score indicates better inhibition.

Secondary outcomes

Aerobic fitness

We conducted a Shuttle Run test to assess children's aerobic fitness (Léger, Mercier, Gadoury, & Lambert, 1988). Due to the limited dimensions of the sports halls, all children performed the test over a distance of 18 meters instead of 20 meters. The highest completed stage was recorded with an accuracy of a half stage and was used to estimate children's VO_2max (Léger et al., 1988). All children were familiar with the test and were encouraged by the research team to exert maximum performance. Children wore heart rate monitors (Polar H7, Polar Team App) to determine their maximum heart rate.

Physical activity levels

We measured children's PA during the intervention period with GT3x ActiGraph accelerometers (de Vries et al., 2009). In each class, we randomly selected a subgroup of 11 to 19 children that were asked to wear the device during waking hours for seven consecutive days, including the weekend (mean of 15 children per class; total n = 330). We gave children verbal instructions on how to wear the device and provided them and their parents/caregivers with an information sheet including a web-link to an online instruction video. ActiLife 6.13.3 software (ActiGraph, LCC.) was used to initialize the accelerometers and for processing the data (epoch = 15 seconds).

We calculated children's PA levels during school hours only. We included children in the data analysis when they wore the accelerometer at least four week days (Yildirim et al., 2011). We created a time filter for each school to extract only the exact school hours for analysis (e.g. 08:30 a.m. to 15:00 p.m.). Recess time was included in the analyses, because this is part of a regular school day for both intervention and control group. Non-wear time was defined as having 20 minutes consecutive zero's (Yildirim et al., 2011). We used the cut points of Evenson (Evenson, Catellier, Gill, Ondrak, & McMurray, 2008) to estimate the time spent in sedentary (0-100 cpm), light (101-2295 cpm), moderate (2296-4011 cpm) and vigorous intensity activity (>4012 cpm), which have been shown to most accurately classify PA intensity levels in children and adolescents (Trost, Loprinzi, Moore, & Pfeiffer, 2011).

Data analysis

We performed all statistical analyses in SPSS version 22.0 (IBM SPSS Statistics). Independent t-tests and Chi-square tests were used to compare baseline values of the control and intervention group. To test the effect of the intervention, we conducted a separate mixed-model analysis for each cognitive outcome and for aerobic fitness (VO_2max). The mixed-model included the cognitive outcome or VO_2max as dependent variable and group (i.e. control or intervention) as fixed factor. Class and school were included as random intercepts. Covariates were the pretest score on the dependent variable, age and/or arithmetic performance. The latter two were included because of group differences at baseline and their expected relationship with the dependent variables. Differences in PA levels between the intervention and control group were also analyzed by mixed-models, with group as fixed factor, class and school as random intercepts, and total wear time as covariate. The level of significance was set at $\alpha < .05$.

We used an intention-to-treat approach, including all children that participated in the study in the data analyses. However, children with a missing pre- or posttest score of the dependent variables or with a missing score on a covariate, were excluded from the respective analysis. In addition, children who did not fully understand or follow the test instructions (i.e. having accuracy rates below chance level (<50%) in the ANT or Stroop task, or indicated by a note of the researchers) were excluded from the respective analysis.

Results

Study population and descriptive characteristics

A total of 510 children between 9 and 12 years old completed the trial (n = 2 lost to follow-up). The number of children included in the data analyses ranged from 448 to 467, depending on the outcome variable (Figure 2). A flow diagram including the numbers and reasons for exclusion can be found in Figure 2. In addition to common reasons for exclusion (e.g. absence during the pre- or posttest, missing arithmetic score), we excluded 13 children from the d2 test analysis due to a technical mistake in the test administration by one of the test instructors.

Baseline characteristics of the control and intervention group were similar, except for age and arithmetic performance (see Table 1). There were no significant differences between the groups in pretest scores on any of the outcome variables.

Table 1. Descriptive characteristics (means and standard deviations) and group differences.

	Control group (n = 249)	**Intervention group (n = 263)**	**p-value**
Age (years)	10.9 (0.7)	10.8 (0.6)	.01*
Special educational needs (%)	13	19	.06
Sex (%, boys/girls)	53 / 47	54 / 46	.79
Parental educational level (%)	(n = 228)	(n = 244)	.25
-low	0	0.8	
-low to medium	3.6	1.9	
-medium	24.9	28.9	
-high	63.1	61.2	
Height (cm)	(n = 244)	(n = 259)	
	148.7 (7.2)	147.5 (7.6)	.06
Weight (kg)	(n = 238)	(n = 258)	
	38.4 (6.9)	37.7 (7.3)	.26
BMI	(n = 238)	(n = 258)	
	17.3 (2.3)	17.2 (2.3)	.78
Academic performance	(n = 242/244/238)	(n = 255/258/258)	
-reading comprehension	42.6 (15.1)	40.7 (16.2)	.17
-orthography	140.2 (7.4)	140.1 (7.0)	.88
-arithmetic	102.1 (14.7)	98.0 (13.9)	.00*
Sports participation (hours per	(n = 244)	(n = 258)	
week)	3.4 (2.0)	3.3 (1.9)	.78
Self-competence	(n = 236/237)	(n = 255/257)	
-scholastic	17.3 (3.8)	16.9 (3.5)	.22
-social	19.1 (3.5)	18.8 (3.4)	.36
-athletic	19.1 (3.5)	18.9 (3.4)	.53
-physical appearance	20.0 (3.7)	19.9 (3.8)	.98
-behavioral conduct	18.3 (3.0)	18.3 (2.9)	.79
-self-worth	20.7 (3.1)	20.5 (3.6)	.46
VO2max, pretest (ml/kg/min)	(n = 236)	(n = 253)	
	48.1 (5.0)	48.0 (5.0)	.84
d2 test, pretest	(n = 237)	(n = 258)	
	133.9 (22.9)	132.1 (22.2)	.38
Fluency, pretest	(n = 240)	(n = 258)	
	10.7 (3.3)	10.8 (3.3)	.80
Stroop interference, pretest	(n = 236)	(n = 254)	
-reaction time (ms)	46.2 (69.2)	41.1 (80.2)	.45
-accuracy (%)	-1.0 (5.4)	-1.7 (5.2)	.14
ANT pretest, reaction time (ms)	(n = 236)	(n = 253)	
-Alerting	25.6 (37.3)	24.6 (35.5)	.78
-Orienting	58.0 (36.5)	61.1 (39.6)	.37

-Conflict	108.4 (45.4)	105.3 (41.5)	.43
ANT pretest, accuracy (%)	(n = 236)	(n = 253)	
-Alerting	0.7 (5.1)	0.8 (4.9)	.80
-Orienting	-1.5 (4.3)	-1.3 (4.7)	.70
-Conflict	-5.3 (5.0)	-5.9 (5.8)	.27

*significant group-difference, p<.05.

Intervention integrity and exercise break intensity

The median of implemented exercise breaks was 89%, which corresponds to 4.4 exercise breaks per week during the 9-week intervention (range: 49% to 98% across classes). The mean exercise intensity of the subsample of tested exercise breaks was 60% (SD 8.5) of the maximum heart rate.

Intervention effects: cognitive performance and fitness

We found no significant differences between the intervention and control group in any of the cognitive outcomes, after controlling for pretest score, age, arithmetic performance, class and school. Children in both groups showed similar patterns of change from pre- to posttest. Thus, the exercise intervention did not improve cognitive performance of the children as compared to the control group. We found no intervention effect on aerobic fitness either. An overview of the mean scores, regression coefficients, 95% confidence intervals, and p-values can be found in Table 2.

PA levels

A total of 312 children (95%) had valid wear time and were included in the data analysis. Children in the intervention group spent on average significantly more minutes of their school hours in moderate PA (1.7 minutes) and moderate to vigorous PA (MVPA; 2.9 minutes) per day as compared the control group, adjusted for total wear time, class and school (see Table 3).

Table 2. Test performance (means, standard errors and [95% confidence intervals]) and statistics of the mixed model analyses for cognitive performance and fitness.

Dependent variable (posttest)	Control group	Intervention group	Regression coefficient (SE)	95% confidence interval	p
d2 test (n = 448)	151.2 (0.86) [149.5;152.9]	152.5 (0.80) [151.0;154.1]	1.3 (1.5)	-1.9 – 4.4	.42
Fluency (n = 467)	11.9 (0.17) [11.6;12.2]	11.7 (0.16) [11.4;12.0]	-0.2 (0.2)	-0.7 - 0.2	.33
Stroop interference, reaction time (ms) (n = 461)	41.1 (4.4) [32.6;49.7]	33.4 (4.2) [25.2;41.6]	-7.7 (6.0)	-19.6 – 4.1	.20

Stroop interference, accuracy (%) (n = 461)	-1.8 (0.4) [-2.5;-1.1]	-1.3 (0.3) [-2.0;-0.6]	0.5 (0.5)	-0.5 – 1.5	.29
ANT alerting, reaction time (ms) (n = 459)	23.5 (2.0) [19.6;27.4]	23.5 (1.9) [19.7;27.2]	0.0 (2.8)	-5.4 – 5.4	.99
ANT orienting, reaction time (ms) (n = 459)	61.6 (2.1) [57.5;65.6]	61.5 (2.0) [57.6;65.4]	1.9 (3.3)	-4.5 – 8.3	.57
ANT conflict, reaction time (ms) (n = 459)	95.6 (2.3) [91.1;100.1]	92.3 (2.2) [88.0;96.7]	-3.9 (3.7)	-11.1 – 3.4	.29
ANT alerting, accuracy (%) (n = 459)	1.0 (0.3) [0.4;1.7]	1.2 (0.3) [0.5;1.8]	0.1 (0.5)	-0.8 – 1.0	.85
ANT orienting, accuracy (%) (n = 459)	-1.5 (0.3) [-2.2; -0.9]	-1.4 (0.3) [-2.0; -0.7]	0.1 (0.5)	-0.8 – 1.1	.77
ANT conflict, accuracy (%) (n = 459)	-6.4 (0.4) [-7.1;-5.7]	-5.9 (0.3) [-6.6; -5.2]	0.6 (0.5)	-0.4 – 1.6	.24
VO2max (ml/kg/min) (n = 448)	48.8 (0.2) [48.4;49.2]	48.9 (0.2) [48.5;49.3]	0.1 (0.3)	-0.6 – 0.7	.77

Table 3. Physical activity levels during school hours (means, standard deviations, [95% confidence intervals]) and statistics of the mixed-model analyses.

	Control (n = 144)	**Intervention (n = 168)**	**Regression coefficient**	**95% confidence interval**	**p**
Sedentary (minutes/day)	228.9 (2.0) [225.1;232.8]	224.6 (1.8) [221.0;228.2]	-2.6 (4.3)	-11.9 – 6.7	.56
Light PA (minutes/day)	98.2 (1.6) [95.0; 101.4]	99.4 (1.5) [96.5;102.4]	-0.3 (3.5)	-7.9 -7.4	.95
Moderate PA (minutes/day)	12.6 (0.4) [11.8; 13.3]	14.4 (0.3) [13.7;15.1]	1.7 (0.7)	-0.3 – 3.2	.02*
Vigorous PA (minutes/day)	8.1 (0.4) [7.3;8.8]	9.3 (0.3) [8.7;10.0]	1.2 (0.7)	-0.2 – 2.6	.09
MVPA (minutes/day)	20.6 (0.7) [19.3;22.0]	23.8 (0.6) [22.5;25.0]	2.9 (1.3)	0.2 - 5.6	.04*

*significant, p<.05; PA = physical activity; MVPA = moderate to vigorous physical activity. Note: PA levels include the exercise break time in the intervention group.

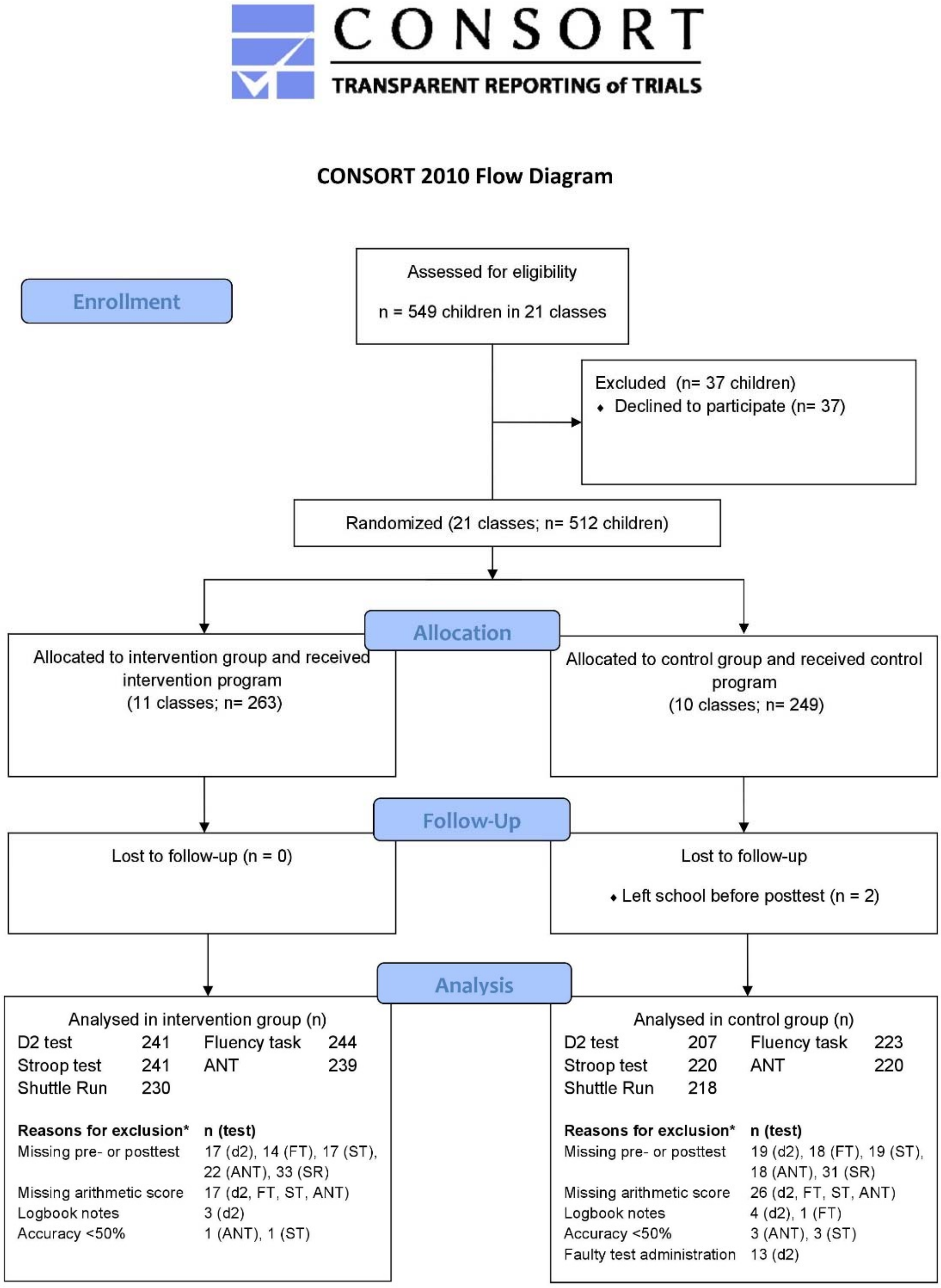

Figure 2. CONSORT flow diagram: progress of participants through the trial.

Note: *Children can be excluded for one or more reasons; e.g. a child with a missing arithmetic score can also have a missing pretest score. Abbreviations: d2 = d2 test; FT = Fluency task; ST = Stroop test; ANT = Attention Network Test; SR = Shuttle Run test.

Discussion

Daily exercise breaks did not improve nor harm children's selective attention, inhibition and semantic memory retrieval performance as compared to the control group. Likewise, there were no effects on children's aerobic fitness. Children that followed the intervention spent about 3 minutes more of their school hours in moderate to vigorous PA per day than the children in the control group.

Our results are in line with the study of Costigan and colleagues (2016) who assessed the effect of two 8-week exercise interventions, consisting of short exercise bouts that were implemented three times a week, on executive functioning in adolescents. Although there were several differences between our study and the study of Costigan and colleagues, such as the sample size (512 versus 65), setting in which the exercise bouts were implemented (classroom versus during recess and PE), exercise intensity (moderate versus high) and age of the participants (9 to 12 years versus 14 to 16 years), there were also similarities. In both studies, the exercise intervention lasted approximately two months and consisted of bouts of approximately 10 minutes. Our findings do not confirm our hypothesis that acute effects of short exercise bouts on cognition accumulate over time. It is possible that exercise sessions of longer duration are needed to have beneficial effects on cognitive outcomes. In this respect, Ludyga and colleagues, who evaluated an 8-week school-based exercise program in which children performed a daily 20-minute exercise bout, reported improvements in working memory (Ludyga, Gerber, Kamijo, Brand, & Puhse, 2018) and inhibition (Ludyga, Gerber, Herrmann, Brand, & Pühse, 2018). Furthermore, a longer intervention period than 9 weeks might be needed to find effects of 10-minute exercise bouts.

We also found no effects on children's aerobic fitness, which may be explained by our minimal exercise intervention. This finding is in line with several systematic reviews reporting that school-based exercise interventions with long durations and high frequencies are needed to improve children's aerobic fitness (e.g. Braaksma et al., 2018; Dobbins, Husson, DeCorby, & LaRocca, 2013; Kriemler et al., 2011). Another reason for the lack of cognitive effects might be due to the coordinative requirements of our exercise breaks. Our exercise breaks may have been (too) difficult for the children, thus limiting the time they were active at moderate-to-vigorous intensity, which has been suggested to be important to exert cognitive effects (Chang et al., 2012; McMorris & Hale, 2012). Furthermore, high difficulty levels might have led to substantial cognitive demands/effort during the exercise breaks, depleting children's cognitive resources and hindering improvements in cognition after exercise. This claim finds support in some earlier acute studies that reported no effects of classroom-based cognitive demanding exercise bouts on selective attention (van den Berg et al., 2016), updating and inhibition (Egger, Conzelmann, & Schmidt, 2018; Jäger, Schmidt, Conzelmann, & Roebers, 2015), and even negative effects on shifting (Egger et al., 2018) as compared to low cognitive demanding aerobic exercise in children and young adolescents. In contrast, recent meta-analyses reported positive chronic effects of cognitively demanding exercise programs (e.g. Alvarez-Bueno et al., 2017; de Greeff et al., 2018). Therefore, we recommend future research to examine how exactly the effects of acute and chronic cognitively demanding exercise relate to each other. Furthermore, research is needed to gain more insight in the optimal dose of the cognitive demands, taking into account children's motor- and cognitive development, and exercise characteristics such as difficulty, duration and intensity (Egger et al., 2018; Pesce et al., 2013).

Although the exercise breaks in our study did not result in improvements in cognitive domains of attention, inhibition and memory retrieval, it might be that short exercise bouts contribute to improved academic performance (e.g. maths or language scores) in the long-term via increasing children's learning efficiency and academic engagement (e.g. improved classroom behavior, motivation) in the lessons following the exercise bouts (Owen et al., 2016). Long-term effects of exercise interventions with a relatively short bout duration on academic performance in children are inconsistent. A recent study of Fedewa and colleagues (2018) reported small improvements in reading performance of 8 to 11 year olds who participated in two 5-minute aerobic exercise breaks per day for a period of nine months as compared to children who performed two 5-minute exercise bouts in which academic content was integrated (Fedewa, Fettrow, Erwin, Ahn, & Farook, 2018). On the other hand, Ahamed and colleagues (2007) found that implementing a daily 15-minute classroom-based exercise break for 16 months did not improve academic performance in children aged 9 to 11 years (Ahamed et al., 2007). Given the inconsistent findings, more insights need to be gained on the relevance of implementing short exercise breaks for academic purposes. Therefore, we recommend researchers to 1) combine acute as well as long-term measures; 2) include cognitive- as well as academic outcomes; and 3) include an inactive control group.

Our results further revealed that children who participated in the exercise breaks spent 2.9 minutes more of their school hours in MVPA per day compared to children in the control group. Our findings are in line with an earlier study that found that implementing three 5-minute classroom-based exercise breaks per day, increased schoolchildren's MVPA levels (Drummy et al., 2016). Hence, these results suggest that implementing short exercise breaks in the classroom are one promising way to promote PA in children. The additional time spent in MVPA during school hours in our study, however, does not equal the length of the exercise breaks, i.e. 10 minutes MVPA per day. This might be due to an underestimation of MVPA during dance movements using accelerometers (van Ekris, personal communication). On the other hand, it could be that children were not (moderate to vigorously) active the entire exercise break. In this respect, our heart rate data showed that the mean intensity of the exercise breaks was at the lower boundary of MVPA (i.e. 60% HR max), indicating that it may be difficult to reach or sustain moderate to vigorous intensity levels in a classroom setting. The low exercise intensity could also be a reason for not finding improvements in cognitive performance (McMorris & Hale, 2012).

Our results have several implications for practice and future research. First, it is important to be aware of the apparent gap between research and practice. Although we found no effects of daily exercise breaks on children's cognitive performance, teachers have indicated that they experience improved classroom behavior and performance when using short exercise breaks in the classroom throughout the school year (e.g. Carlson et al., 2015). Therefore, it might be important to consider using more ecological valid measurement instruments, such as systematic observations, teacher logs and/or tasks that mimic curricular activities as a more appropriate representation of classroom-related performance (Khan & Hillman, 2014). In addition, measures of academic engagement and enjoyment of academic lessons can provide important additional information as these factors may have a role in the relationship of exercise and cognitive/academic performance (Owen et al., 2016). Second, the number of exercise breaks implemented in our study was relatively high (median of 4.4 per week), suggesting that 10-minute exercise breaks in the classroom are feasible to implement in school practice. However, the controlled setting and reminders during the experiment (i.e. poster-calendar, email contact and visits by the researchers) have likely influenced these outcomes. Future studies should therefore evaluate the feasibility of the long-term implementation of short exercise breaks in real-life school practice. Third, it is important to notice that children's cognitive performance did not deteriorate either. We can therefore conclude that implementing exercise breaks on a daily basis, instead of devoting this time to academic tasks, has no adverse effect on children's cognitive performance. Lastly, an increase of 3 minutes MVPA induced by the exercise breaks is small. However, implementing short exercise breaks can be a relatively feasible and easy manner to start increasing PA opportunities in school. In order to increase minutes of MVPA during a school day, we recommend to complement exercise breaks in the classroom with other short and feasible exercise interventions in school, e.g. during recess or integrated in academic lessons. Furthermore, PA is suggested to have beneficial effects for mental health (e.g. depression), well-being, mood, self-esteem, motivation and social connectedness (Biddle, Ciaccioni, Thomas, & Vergeer, 2018; Lubans et al., 2016). However, the effects of short exercise bouts on before mentioned outcomes is still unknown (Poitras et al., 2016). Therefore, we recommend including these outcome measures in future research on the effects of short exercise bouts. As such, we can gain deeper insight in the benefits of short exercise bouts on several domains important to children's (academic) development, and thereby strengthening the relevance of short exercise bouts in school.

Our study has several strengths, such as the randomized controlled design, substantial sample size, blinded test administrators, use of objective measurement instruments, high compliance and a high implementation rate. Though, our study had also some limitations. Our population consisted of children of parents with a relatively high educational level, which limits the generalizability of the results. In addition, we have no baseline accelerometer-based measure of PA. However, the intervention and control classes were equally distributed within each school, i.e. representing a similar population, and did not differ on important descriptive characteristics, such as sports participation, aerobic fitness and parental educational level. Another limitation is that we did not assess children's PA behavior outside school hours. It could be that exercise breaks influenced children's PA behavior outside school, for example if children liked the Just Dance videos they could have decided to perform them during leisure time as well. Lastly, for practical reasons we used a paper-and-pencil version of the verbal fluency task which adds a motor component to the task. Therefore, the test outcomes also depend on writing speed and the length of the chosen words. In addition, we used a computerized Stroop task which measures interference effects to a somewhat lower extent than interference effects measured by the original oral version of the Stroop task (Penner et al., 2012).

Conclusion

In sum, we found that implementing a daily 10-minute exercise break for a period of 9 weeks in the classroom had no effects on cognitive performance and aerobic fitness of 9 to 12-year old children. The exercise breaks brought about 3 minutes more MVPA during school hours. Therefore we conclude that schools can implement the seemingly feasible daily exercise breaks in the classroom to promote PA in children without adverse effects on their cognitive performance.

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Chapter 7

General discussion

GENERAL DISCUSSION

The purpose of the research presented in this thesis was 1) to examine the effects of acute and repeated exercise bouts on cognitive performance of children, and 2) gaining insight in the perspectives of school professionals and children about additional PA in school. In the general discussion the results of the different studies will be summarized, integrated and debated in light of their implications for future research and daily school practice. The discussion concludes with a general conclusion.

Summary of main findings

Part I Acute effects of exercise on cognitive performance

In chapter 2 and 3, the acute effects of single exercise bouts on cognitive performance were investigated in two randomized controlled cross-over studies. Both experimental studies found no acute effects of exercise on information processing speed (chapter 2), selective attention (chapter 2 and 3) and working memory (chapter 3) of 10 to 14 years old children. The two studies also intended to gain insight in the characteristics of potentially effective exercise bouts in terms of *type* and *duration*. The findings in chapter 2 showed that none of the three 12-minute exercise types, i.e. aerobic, coordinative or strength, resulted in cognitive improvements and that there were no differential effects of exercise type. In chapter 3, no differential effects of exercise bouts of different *durations*, i.e. 10, 20 or 30 minutes, on children's cognitive performance were found. The results of both studies also showed that single exercise bouts of different types and durations did not deteriorate children's cognitive performance.

Part II School-based physical activity: perspectives of school professionals and children

In Chapter 4 and 5 two qualitative studies are described in which the motivations, needs, preferences, and ideas of principals, teachers and children regarding additional PA in the final two grades of primary school were explored. Semi-structured interviews with principals and teachers, and focus groups with children were conducted. The results of the studies revealed that principals and teachers (chapter 4), as well as children (chapter 5) were enthusiastic about additional PA in school and reported several perceived benefits of PA, including physical, social-emotional and cognitive (e.g. increased attention and focus in the classroom). However, teachers' willingness of implementing PA during school time depended on the learning benefits and form of PA. Time constraints appeared a major barrier for principals and teachers to structurally implement PA in school. They indicated that a feasible PA program should be short (1 to 5, up to maximum 10 minutes), 'ready-to-use' (i.e. requiring little or no preparation), and suitable to be executed in the classroom (chapter 4). Children had numerous ideas to increase PA in school, including more time for

PA in the existing curriculum (e.g. physical education, recess, occasional activities), improving the content of physical education lessons, implementing short PA breaks and physically active academic lessons, and adapting the school playground. In line with teachers and principals, some children emphasized that time for additional PA must not be at the cost of time to work on academic tasks (chapter 5). Children as well as principals and teachers emphasized that 'variation' is an important factor to make and keep PA enjoyable. Moreover, children indicated that it is important to give them a voice in PA participation and that individual preferences of children should be taken into account. Principals and teachers emphasized that it is important to have support of the entire school team, including principal and all teachers, when aiming to implement additional PA in school (chapter 4). Children also indicated that the teacher has an important role in the success of implementation of additional PA in school. Lastly, several principals and teachers suggested to appoint a 'PA coordinator' responsible for the implementation and evaluation of PA in school (chapter 4), while some children suggested to install a 'child PA committee' (chapter 5).

Part III Daily exercise breaks and cognitive performance

The experimental studies in part I (chapter 2 and 3) found no acute effects of single exercise bouts on cognitive performance. Therefore, in chapter 6 the potential accumulating effects of repeated single exercise bouts on cognitive performance were examined in a large-scale cluster randomized controlled trial. Factors addressed by school professionals and children (chapter 4 and 5) were used as the basis to compose a 9-weeks exercise breaks program consisting of a daily 10-minute 'Just Dance' exercise break in the classroom. Chapter 6 showed that the exercise breaks program did not result in significant improvements in selective attention, inhibition and memory retrieval performance of 9 to 12 years old children in the two latest grades of primary school, nor in deteriorations in their performance after 9 weeks. In addition, the exercise breaks program did not improve children's physical fitness. Children participating in the exercise breaks spent on average 3 minutes per day more in moderate-to-vigorous PA during school hours compared to the children that did not follow the exercise breaks program.

Effects of PA on cognitive performance

The results of the three experimental studies reported in this thesis are in line with outcomes of recent systematic reviews and meta-analyses showing no convincing evidence for acute and long-term effects of PA on children's cognitive performance (e.g. Daly-Smith et al., 2018; Gunnell et al., 2018; Singh et al., 2018; Watson, Timperio, Brown, Best, & Hesketh, 2017). The results of the studies described in this thesis also illustrate that children's cognitive performance does not deteriorate after single or repeated use of exercise bouts. In other words, the results indicate that exercise bouts do not work as a 'booster' for children's cognitive performance, but neither do they have adverse effects on preadolescent children's cognitive performance.

However, in contrast to above-mentioned findings, several meta-analyses have concluded that PA can have positive acute and long-term effects on different subdomains of cognitive performance (e.g. Alvarez-Bueno et al., 2017; de Greeff, Bosker, Oosterlaan, Visscher, & Hartman, 2018; Ludyga, Gerber, Brand, Holsboer-Trachsler, & Puhse, 2016). Moreover, in the qualitative studies in this thesis as well as in earlier studies (e.g. Brown & Elliott, 2015; Carlson et al., 2015; McMullen, Martin, Jones, & Murtagh, 2016), principals, teachers and children have reported to experience positive effects of PA on cognitive performance in terms of children's improved attention and classroom behavior. Potential reasons for finding no effects on cognitive performance in this thesis, and for differences between *evidence-based* and perceived *practice-based* effects will be discussed to gain more insight in factors that can be addressed in future research.

Characteristics of PA

One of the aims of part I of this thesis was to gain insight in characteristics of effective PA bouts. The experimental studies in this thesis provided no evidence for cognitive improvements, nor cognitive declines after exercise bouts of different types and durations.

Intensity

A first potential reason for finding no effects may be related to the relatively low exercise intensity levels reached by the children during the implemented exercise bouts. When looking at the hypothesized mechanisms of exercise on cognition, at least moderate-to-vigorous intensity seems necessary to exert effects on cognitive performance (McMorris & Hale, 2012). In this thesis, the average exercise intensity of the exercise bouts turned out to be light-to-moderate (chapter 2: 55 to 61% of the maximum heart rate; chapter 6: 60% of the maximum heart rate) or was at the lower bound of moderate-to-vigorous intensity (chapter 3: 64 to 66% of the maximum heart rate). In this respect, the results are in line with several systematic reviews that conclude that light intensity PA results in little to no effects on cognitive performance (e.g. Chang, Labban, Gapin, & Etnier, 2012). In two of the experimental studies (chapter 2 and 6), classroom-based exercise bouts were implemented. Apparently, moderate-to-vigorous exercise intensities are difficult to reach when exercising in the classroom. In contrast, a recent review reported that some studies implementing light intensity cognitively engaging PA bouts in the classroom resulted in positive effects on learning outcomes of young children (Mavilidi et al., 2018). In this respect, the intensity may not be decisive in combination with certain types of PA. It is recommended for future research to gain more insight in the role that exercise intensity plays in exerting PA-related cognitive effects, particularly since the exercise intensity may also influence the feasibility of implementing PA in the school setting. This point will be further discussed later in this chapter.

Type of PA

Traditionally, 'PA-cognition' research has focused on the effects of repetitive, aerobic exercise bouts (e.g. walking, running, biking). In the past years, several researchers have suggested that more complex forms of PA, consisting of cognitively engaging exercises (e.g. with coordinative requirements, changing task circumstances, cognitive elements, team games), may result in larger cognitive improvement compared to the non-cognitively engaging, repetitive forms of PA (Pesce, 2012; Tomporowski, McCullick, Pendleton, & Pesce, 2015). Cognitively engaging types of PA may be effective at lower intensity and shorter duration (Mavilidi et al., 2018; Xue, Yang, & Huang, 2019). It has been suggested that the combined motor and cognitive demands of this type of PA activate brain regions that also play a role in cognitive processes, subsequently improving cognitive performance (e.g. Best, 2010; Budde, Voelcker-Rehage, Pietrabyk-Kendziorra, Ribeiro, & Tidow, 2008). In the long-term, the cognitive engagement in PA is expected to improve self-control capacities and higher order cognitive functions (e.g. Audiffren & André, 2015; Diamond & Ling, 2016), and/or can increase cognitive performance via social-emotional pathways (e.g. joy, self-confidence, social belonging; Diamond, 2015).

The studies described in this thesis do not support the notion that cognitively engaging PA leads to (more) cognitive improvements. The results of chapter 2 showed no differences in effects of acute coordinative exercise as compared to repetitive aerobic or strength exercises. The results of chapter 6 – in which children participated repeatedly in cognitively engaging exercises (i.e. mimicking dance movements) - showed no improvements in cognitive performance either. It could be that the cognitively engaging exercise bouts in the studies described in this thesis lacked the optimal difficulty level, e.g. were too easy or too difficult (Pesce et al., 2013). Moreover, it could be that effects of exercise bouts used as a break from learning (as in the studies described in this thesis) differ from effects of cognitively engaging PA bouts that are integrated with learning tasks.

Duration

Another potential reason for the lack of effects of the interventions evaluated in this thesis could be that the duration of the exercise sessions (chapter 2: 12 minutes; chapter 3: 10, 20 or 30 minutes; chapter 6: 10 minutes), the duration of the exercise break intervention (chapter 6: 9 weeks) or the frequency of implementing exercise bouts (chapter 2 and 3: once per day; chapter 6: approximately

4.5 exercise bouts per week) was too low. In this respect, studies assessing effects of exercise interventions with a similar duration (8 weeks), but with longer session duration (20 minutes instead of 10 minutes) have reported positive effects on children's inhibition performance (Ludyga, Gerber, Herrmann, Brand, & Pühse, 2018). In addition, it could be that short, 10-minute exercise bouts need to be implemented over longer periods, such as months or years, to sort structural long-term cognitive effects. However, it could also be that exercise bouts of short duration are simply ineffective to increase cognitive performance. Future research on the effects of short exercise bouts is needed to give a decisive answer on this question. Moreover, more frequent exercise bouts may be needed for (longer lasting) effects on selective attention (Altenburg, Chinapaw, & Singh, 2016). Insight in the minimal duration and frequency of PA is necessary, as it will have major consequences for the feasibility of implementing PA in daily school practice (see below).

Lastly, it is possible that the combination of duration, intensity and type of the exercise bouts of the studies described in this thesis was not optimal for improving children's cognitive performance. To understand the role of all above-mentioned characteristics, researchers should invest more in examining 1) the underlying mechanisms of different types of acute as well as long-term PA (Singh et al., 2018), and 2) the optimal combination of intensity, duration, type and frequency of PA bouts. This information is strongly needed to understand under which circumstances PA is or is not beneficial for cognitive performance, and will provide relevant information to inform daily school practice about the use of PA to improve children's cognitive performance. Moreover, it would be useful to gain more insight in effects of less structured PA forms, such as participation in playground activities, transport to school or outdoor play during leisure time on children's cognitive outcomes. Supposing that cognitively engaging PA, regardless of its intensity and duration, contribute to cognitive performance in the long-term, then the playground could for example be adapted or specific recess activities could be provided to children. These PA forms would require no academic lesson time, which might increase the feasibility in school.

Methodological considerations

In addition to the characteristics of PA that were assessed in the studies described in this thesis, some methodological factors are noteworthy to discuss.

Cognitive subdomains

In this thesis, acute as well as repeated exercise bouts exerted no effects on any of the measured cognitive outcomes, i.e. information processing speed, selective attention, working memory, memory retrieval and inhibition. In other words, there were no effects of exercise bouts on different cognitive subdomains. Several recent systematic reviews and meta-analyses (Alvarez-Bueno et al., 2017; Daly-Smith et al., 2018; de Greeff et al., 2018; Ludyga et al., 2016; Watson et al., 2017; Xue et al., 2019) that examined whether effects of PA depend on the cognitive subdomain measured, showed inconsistent results. As such, the results presented in this thesis are in line with some findings, but not with others. For example, de Greeff and colleagues (2018) reported in their meta-analysis beneficial acute and long-term effects of PA on children's attention, while Daly-Smith and colleagues (2018) and Watson and colleagues (2017) reported no effects. Acute and long-term effects of PA have been found for working memory performance (acute: Ludyga et al., 2016; long-term: Alvarez-Bueno et al., 2017; de Greeff et al., 2018), while other meta-analyses did not report such effects (acute: de Greeff et al., 2018; long-term: Xue et al., 2019). Likewise, for inhibition, some of the review studies reported positive effects of PA (acute: de Greeff et al., 2018; Ludyga et al., 2016; long-term: Alvarez-Bueno et al., 2017; Xue et al., 2019), while others did not (acute: Watson et al., 2017; long-term: de Greeff et al., 2018). Lastly, Alvarez-Bueno and colleagues (2017) reported improvements in non-executive functions (e.g. processing speed), while Daly-Smith and colleagues (2018) did not.

Inconsistencies in outcomes of above-mentioned literature reviews and meta-analyses may be caused by several factors, such as differences in study design (systematic review versus meta-analysis), inclusion criteria and between-study heterogeneity (e.g. measurement instruments, characteristics of PA programs) of the included studies, methodological quality assessment of the included studies, or differences in age groups. Therefore, with regard to certain aspects, more homogeneity is needed in future research. Researchers can for example start with using (the same) quality assessment tools in literature studies, to ensure that conclusions about the effects of PA on different cognitive outcomes are based on (the same) 'high quality' studies. Moreover, it would be useful to have a selection of reliable and valid measurement instruments, such that researchers in this field can report on outcomes based on the same instruments. Lastly, the popular media and researchers often emphasize or solely report the positive effects found within studies, which could easily be accepted as truth by school practice and other stakeholders. Researchers should therefore take a little reluctance, and clearly communicate the inconsistencies in the current evidence-base.

Measurement instruments

To examine PA effects on cognitive performance neuropsychological tests are commonly used. Although the reported test-retest reliability of these instruments is often sufficient or good (e.g. Brickenkamp & Oosterveld, 2012; Penner et al., 2012), the acute experimental studies in this thesis revealed that there are strong learning effects when repeating tests multiple times over a short time period, even after practicing the tests thoroughly before the start of the experiments. Therefore, it is important to pay attention to the design of studies in order to control for these learning effects. To minimize the influence of learning effects on the outcomes, the acute experimental studies described in this thesis used within-subjects, cross-over designs in which exercise and control conditions were counterbalanced (i.e. half of the group starting with the exercise condition and the other half with the control condition). Furthermore, in all three experimental studies, control conditions were included in which the children did not participate in PA. In contrast, some earlier studies reporting positive effects of acute PA on cognitive performance compared two different PA conditions with each other, without a no-PA control condition (e.g. Budde et al., 2008; Lambrick, Stoner, Grigg, & Faulkner, 2016), or without contrasting the outcomes of the PA conditions with the control condition (e.g. Gallotta et al., 2012). Likewise, many studies that examined the long-term effects of PA on cognitive performance compared two PA programs, without a no PA control condition (Singh et al., 2018). When comparing the effects of two PA conditions without control condition, it is difficult to conclude whether cognitive improvements are truly caused by PA or rather reflect a learning effect that is caused by test repetition. Therefore, it is strongly recommended for future research to include no PA control conditions when using cognitive tasks in both acute and long-term studies.

Although neuropsychological tests are considered valid measures of cognitive functioning, these tests are traditionally developed to detect deficiencies in cognitive processes in order to distinguish clinical from healthy populations (Lezak, Howieson, Loring, Hannay, & Fischer, 2004). One may question to what extent these tests are able to detect the cognitive benefits that teachers, principals and children have reported to perceive in daily school practice. Therefore, it is recommended for future research to add other measurement instruments, such as systematic observations, teacher logs and tasks that measure progress in learning activities (Mavilidi et al., 2018; Singh et al., 2018; Watson et al., 2017). These instruments may provide more ecological valid measures as compared to the currently used neuropsychological tests. Some earlier studies have used systematic observations scales to measure children’s on-task behavior, such as (adapted versions of) the Behavioral Observation of Students in Schools (Shapiro, 2004). These studies - in contrast to studies using neuropsychological tests- consistently showed positive effects of PA on children’s on-task behavior (see for a review Daly-Smith et al., 2018; Watson et al., 2017), and may better reflect the cognitive benefits that principals, teachers and children experience in practice (e.g. increased attention for school tasks). Using ecological valid measurement instruments in future research is in particular important since principals and teachers have indicated that evidence for effects of PA on learning outcomes are important to gain team support for additional PA in school (chapter 4).

Timing of cognitive measurements

Another point of discussion is the timing of the cognitive measures in the experimental studies. The acute effects of exercise bouts in part I of this thesis were measured immediately after ending the exercise bouts. On the one hand, this timing provides insight in the immediate effects of exercise bouts used as 'breaks' within or in between lessons. This is relevant for school practice, as teachers have indicated that they want to use PA to restore children's attention in the classroom (chapter 4). However, measuring cognitive performance immediately after the exercise bouts could also be considered a limitation of the studies. First, some earlier studies have reported that acute effects of PA on cognitive performance are largest when measured with a delay after ending the exercise bouts (e.g. Chang et al., 2012) which we may have missed by measuring immediately after the exercise bouts. If delayed effects exist it is relevant to examine when such effects occur and how long these effects remain. The reason for not including delayed measures in this thesis, was the feasibility of conducting the experimental studies in daily school practice. The experiments had to be scheduled around fixed break times and there was only limited amount of time available.

Moderators

Outcomes of the studies in this thesis were evaluated in a general sample of school children attending mainstream primary schools in the Netherlands. However, it could be that only certain subgroups of children benefit from PA, while others not or to a lower extent. Some meta-analyses have shown that PA leads to higher cognitive improvements in children with higher body mass index (Xue et al., 2019) and children with lower physical fitness (Chang et al., 2012). However, other meta-analyses showed no differences for children with higher body mass index (Alvarez-Bueno et al., 2017), or lower physical fitness (Ludyga et al., 2016). The majority of children participating in the studies in this thesis had a healthy BMI and were relatively fit. Further research is needed into the moderating effect of body mass index and physical fitness in the 'PA-cognition' relationship (Singh et al., 2018).

In addition, more insight is needed in the cognitive benefits of PA for subgroups of children with, for example, attention deficit hyperactivity disorder (ADHD), as these children often attend regular primary schools in the Netherlands. A large group of teachers experience the presence of children with developmental/behavioral disorders in the regular classroom as a heavy load, which also puts a burden on the other children in the classroom (Smeets et al., 2013). Therefore, more PA during school hours might be promising to improve classroom behavior for specific subgroups of children. Recent systematic reviews concluded that PA has positive effects on cognitive performance of children with ADHD, both in the short and long term (e.g. Grassmann, Alves, Santos-Galduroz, &

Galduroz, 2017; Suarez-Manzano, Ruiz-Ariza, De La Torre-Cruz, & Martinez-Lopez, 2018). However, more research is needed since only few studies – often of low methodological quality - were included in these reviews. Lastly, it would be useful to further examine whether PA related effects differ for children with low versus high baseline cognitive/academic performance and in different age groups.

Additional PA in school: research and practice

In part II of this thesis, principals, teachers and children were involved with the aim to increase knowledge about the feasibility of additional PA in school, and their motivations, preferences and needs. Based on the findings, it can be concluded that on several points there is currently a *gap* between science and practice. Below, these gaps will be discussed together with recommendations for future research.

Adherence in controlled trials versus daily school practice

In part III of this thesis, an exercise breaks program was implemented by classroom teachers during a randomized controlled trial. Children performed a daily 10-minute exercise break in which they participated in the dance game 'Just Dance' (Ubisoft). The Just Dance movies were shown on the digital screen and children were asked to mimic dance movements performed by characters in the movies. During the trial, researchers provided teachers with several reminders to implement the exercise breaks, such as a poster in the classroom to keep track on the daily exercise breaks and reminders via email. The adherence to the exercise breaks program turned out to be high for most of the teachers, i.e. they implemented approximately 4.5 of the 5 exercise breaks per week. This may indicate that relatively short, 10-minute exercise breaks are feasible to implement on a daily basis in primary school. However, there was also a teacher who implemented the exercise breaks only 2 to 2.5 times per week. Therefore, to gain more insight in the implementation of the exercise breaks program in real life daily school practice, a process evaluation study was conducted (not reported in this thesis). During the process evaluation, amongst other aspects, the degree of implementation was assessed. The results showed that only 19% of the teachers actually implemented the exercise breaks on a regular basis. More specifically, teachers implemented only one to three instead of five exercise breaks per week, and the exercise bout duration often decreased from 10 to 3 minutes (unpublished data). Thus, even a seemingly feasible PA program, fitting the preferences of teachers and children (i.e. short, 'ready-to-use', classroom-based and with a maximum of 10 minutes), turned out to have low feasibility outside a controlled research setting. In line with earlier process evaluations (see for a review Naylor et al., 2015) and also addressed by principals and teachers in this thesis (chapter 4), time constraints due to academic pressures appeared the main reason for the low implementation rates. The perceived time constraints should be taken seriously, and researchers, principals and teachers should discuss this barrier together in order to find solutions. Furthermore, only one 'Just Dance' exercise breaks program was composed, which likely does not perfectly match each individual teacher's preferences. Therefore, future PA programs should be developed in co-creation with a teacher and his/her particular class such that it can be personalized, thereby increasing ownership and the chance of successful implementation.

Other relevant outcome measures

The findings of this thesis (i.e. no effects of exercise bouts on cognitive performance) will probably not convince teachers to implement additional PA in school, since they indicated that it is important to them that there is evidence that PA results in cognitive/academic improvements (chapter 4). The effects of PA on academic performance were beyond the scope of this thesis, but are generally in line with the evidence of effects on cognitive performance, i.e. weak and inconclusive (Donnelly et al., 2016; Singh et al., 2018). Therefore, it is important to reflect on other outcome measures that may be relevant to school practice.

Principals, teachers and children participating in the qualitative studies of this thesis mentioned, in addition to cognitive benefits, several benefits of PA that they considered important. First, physical benefits such as increased physical fitness and health were mentioned. However, some principals and teachers considered children's health not a core task of education (chapter 4; Stylianou, Kulinna, & Naiman, 2015; Todd et al., 2015). Other benefits relevant to principals, teachers and children included social and emotional outcomes, such as improved mood, social skills and self-confidence/esteem. These benefits can be very relevant to school practice, as they align with the task of education to support children's cognitive-intellectual as well as social-emotional development (Education Council of the Netherlands, 2011; Government of the Netherlands, 1981). Although there are careful indications that PA can have positive effects on above-mentioned outcomes, more research is needed on the effects of relatively short PA bouts in school settings (Biddle, Ciaccioni, Thomas, & Vergeer, 2018; Poitras et al., 2016). Lastly, children indicated that PA is important to alternate prolonged periods of uninterrupted sitting and working on school tasks, which they considered often 'boring'. According to them, PA bouts can be used to recharge, and provide enjoyment and renewed motivation to work on school task. This finding is particularly important given the sedentary nature of current school systems, and should be taken seriously by researchers as well as principals and teachers. Some earlier studies have reported positive effects of different types of short PA bouts on children's enjoyment and motivation (e.g. Mavilidi, Okely, Chandler, & Paas, 2016; Vazou & Smiley-Oyen, 2014). In addition, a separate study of the SMART MOVES! project (not reported in this thesis), found that 10 to 11 years old children enjoyed short physically active lessons, in which a mathematics lesson program was combined with juggling, significantly more than children who followed the same mathematics lesson program sedentary. Increased enjoyment and motivation may also be beneficial for children's cognitive and academic outcomes, but the exact mediating role of these factors in the 'PA-cognition' relationship warrants further research (Owen et al., 2016).

In sum, besides cognitive performance PA may benefit several other outcome measures relevant to school practice - such as self-esteem, mood, enjoyment and motivation – that need further examination.

Evidence-based 'requirements' versus feasibility in school

As described earlier in this discussion, the classroom-based exercise bouts may have been ineffective due to their low intensity, duration and frequency. However, moderate-to-vigorous exercise intensity seems difficult to reach in a classroom setting. Therefore, it might be necessary to perform PA bouts outside the classroom to reach a sufficient intensity to improve cognitive performance. Earlier studies implementing PA bouts outside the classroom setting showed that children reached moderate-to-vigorous intensity levels and improved their cognitive performance (e.g. Janssen et al., 2014; Niemann et al., 2013). Moreover, it could be that only structural PA programs of relatively long exercise bouts and intervention duration are effective to improve children's cognitive and academic performance (Singh et al., 2018). These research findings are in contrast to what principals and teachers consider feasible: PA bouts of short duration and implemented in the classroom setting 'when needed' (i.e. not structurally, but only when attention spans decline). Therefore, considerable changes in school culture, school policies and on higher governmental levels are needed to bring intensive and structural PA programs into the school setting. Considering the current school systems and perceived academic pressure on reaching core educational goals, this seems difficult to realize. Therefore, it is recommended to first expand research on the effects of different types of small and feasible PA programs on multiple ecological valid outcome measures (as described before).

Participation of school professionals and children in educational innovations

The results of this thesis emphasize the importance of including school professionals and children in research. Teachers seem to have a decisive role in the success of additional PA, since they decide whether additional PA will be implemented in the classroom (chapter 4 and chapter 5). Children in the highest two grades of primary school appeared very capable in providing ideas for additional PA in school, in which they also considered what is realistic and feasible. Although principals and teachers indicated that it is important to involve children in the choice of PA (chapter 4), children questioned if the school would actually make use of their ideas (chapter 5). Therefore, future research should consult principals, teachers and children together, such that they can discuss their preferences and reach agreements about the types of PA that are both feasible and enjoyable. As such, researchers can develop PA programs that closely meet the needs and wishes of all target groups, which is particularly important for the success of school-based PA (Jacquez, Vaughn, & Wagner, 2013; van Sluijs & Kriemler, 2016). As the participants in the studies described in this thesis were quite enthusiastic about additional PA, it is also recommended to include principals, teachers and children who have less affinity with PA, for example children with low motor skills or who are anxious or feel uncomfortable to be physically active in a classroom setting with their peers. Besides discussing the content of PA, principals, teachers and children can also be consulted to decide on the choice of outcome measures in research, which will make results more relevant to school practice.

Implications of the results: advice to school practice

There is still insufficient evidence to provide schools and teachers with specific advice about the usefulness of PA to improve children's cognitive performance. However, schools can already start with implementing additional PA in school, since the results of this thesis also indicate that single and repeated exercise bouts do not harm children's cognitive performance. In other words, principals and teachers should not be afraid that spending more time on PA will be at the cost of children's cognitive performance, both in the short and the longer term. Moreover, the fact that principals, teachers and children have reported that many children have a need to move during school time (e.g. to release energy, alternate school tasks), combined with the reported perceived practice-based benefits for children's attention, mood and school motivation (chapter 4 and 5; Carlson et al., 2015; McMullen et al., 2016; Stylianou et al., 2015), could be reason enough to start implementing additional PA in school. In addition, the fact that children indicate that they enjoy PA and would be happy to participate in additional PA in school, is important to utilize as starting point for increasing PA participation and an active lifestyle. Thus, principals and teachers who are willing to implement additional PA in school are highly encouraged to do so. Some suggestions that may be helpful for schools that consider to start implementing additional PA are provided below.

Look for feasible and suitable PA opportunities

To increase the chance of successful and sustainable additional PA in school, it is important to find forms of PA that 1) teachers consider feasible and that fit their needs and possibilities, and 2) match the preferences of children. Table 3 in chapter 5 of this thesis provides several concrete ideas of 10 to 12 years old children to increase PA in school, which can be used by teachers and children to make a choice for the PA activities that best match the preferences of their class. Of course, these ideas can be adapted or expanded with the ideas of other children, preferably the ones in the class/school concerned. Moreover, different PA activities can be alternated to ensure variety. Some of the ideas proposed by children in this thesis are easily accessible and will not be at the cost of time for academic tasks, which may be of particular interest for teachers who experience high time pressure. For example, increasing time being active in PE lessons (e.g. by lowering waiting times), or creating opportunities to increase PA participation during recess (e.g. by providing materials, games, adaptations of the playground). Another option for teachers who do not want to 'lose' academic time is integrating PA within academic instructions and/or tasks. A number of Dutch educational methods that integrate PA with academic tasks are available, of which most can be purchased. A benefit of these programs is that they are 'ready-to-use' and could therefore be implemented in school with little preparation. However, it is important for schools to check if these programs fit the preferences of teachers and children, particularly when using them structurally and over the long-term.

PA committee

The results of this thesis emphasize the importance of having someone responsible for the implementation of additional PA in school, otherwise it is likely that it will quickly dilute. One option could be installing a 'PA committee' including teachers and children that are responsible for additional PA in school. This PA committee can take the form of a working group, in which a small group of children representing the students in school, and one or two teachers representing the school team. Herein, it is important that both groups listen to each other and have equal decision power. In regularly scheduled meetings the PA committee can make an inventory of wishes and preferences, choose or select existing PA opportunities and/or explore and make a plan to develop new activities. Based on the chosen form of PA, the PA committee can have an active role in organizing PA activities, supporting and reminding teachers to implement PA, and evaluating the implementation process. In this process, it is important that the PA committee keeps in mind that 'variation' is a keyword in successful and sustainable additional PA. Thus, PA activities should continuously be adapted and varied. It would be relevant to appoint one of the teachers as 'PA coordinator', who communicates ideas and requirements to the school principal, such that changes on the organizational level can also be made. Student participation in a PA committee is not only relevant to increase the chance of successful additional PA, but may also result in positive effects on student-teacher and student-student interactions and relationships, and the school culture/climate (Griebler, Rojatz, Simovska, & Forster, 2017; Mager & Nowak, 2012). As such, it may also provide additional benefits for daily school practice.

The physical education teacher

Within this thesis, the voice of PE teachers is lacking as they were not included in the qualitative studies. Only few of the participating classroom teachers indicated that the PE teacher could fulfil a role when it comes to additional PA in school, which could be due to the fact that in most schools there was no PE teacher or he/she was only part-time available. However, when recruiting schools for the experimental studies in this thesis, all of the PE teachers were very interested and enthusiastic about additional PA in school and the potential effects on cognitive performance. Therefore, schools that are willing to implement additional PA and that have a PE teacher available, are strongly encouraged to involve him/her. The PE teacher can for example take a role in: 1) developing easy-to-implement PA activities based on the preferences of teachers and children in his/her school; 2) motivating and supporting teachers to implement additional PA, e.g. by providing them tips and tricks; 3) organizing and executing additional PA activities outside the classroom setting, e.g. during recess; 4) providing classroom teachers who give PE lessons with ideas, e.g. how to increase the time being active during PE; 5) ensuring the quality of additional PA. The PE teacher could fulfil this role preferably in collaboration with the above-mentioned PA committee. Collaboration between PE teacher and classroom teachers is required, as both may – considering their educational background - have other underlying goals/intentions with additional PA in school. Discussing the goals of PA implementation is an important first step to be able to choose appropriate PA activities. For example, some teachers may prefer to implement PA as a break from learning, while others to integrate PA within their academic lessons. Both forms of PA will have a different content. PE teachers and classroom teachers can also look for activities that combine acquisition and/or improvement of motor skills with learning and/or rehearsing academic content, which may contribute to educational goals in domains of physical education, as well as for example language or mathematics/arithmetic.

Final remarks

It is important to realize that above-mentioned suggestions require considerable motivation and effort from classroom-teachers, since additional PA in school is mostly not part of their school policy and daily curricular routines. Therefore, in the majority of schools it will likely be very difficult and have little priority to increase PA opportunities. The results of this thesis do not justify a plea for changing school policies or adapting educational targets on governmental levels. However, it remains important to be aware of the other benefits that PA can have for children's development and health. As such, it is important to encourage schools to offer PA opportunities during school time. Honesty and reluctance is needed in using statements like "*physical activity makes children smarter*" or "*exercise breaks: a booster for children's concentration*", as a means to convince schools of implementing additional PA. It would be more appropriate to describe the multiple evidence-based benefits of PA supplemented by perceived practice-based benefits, which can together be linked to the broad task of primary education, i.e. supporting children in various domains of their development.

OVERALL CONCLUSION

The studies in this thesis found that acute exercise bouts of different types and durations did not improve, nor deteriorate children's cognitive performance. Likewise, 9-weeks of daily short 'Just Dance' exercise breaks in the classroom did not improve, nor deteriorate children's cognitive performance. Principals, teachers and children were generally enthusiastic about additional PA in school, recognized the need for PA and reported multiple benefits, including perceived cognitive improvements. Future research is needed to be able to give a decisive answer regarding the effectiveness of PA for cognitive performance. However, enthusiastic primary school principals and teachers that are willing to implement additional PA in school are encouraged to do so. In this process, it is important to make additional PA a shared project of teachers and children in order to increase the chances of successful and sustainable implementation of PA in school.

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Summary

SUMMARY

Schools have an important task to support children in their cognitive-intellectual and social-emotional development, preparing them for their future (school) career. Academic subjects such as language and mathematics/arithmetic receive particular attention in school. Therefore, much of school's curriculum time is spent on these subjects, which subsequently limit the time for other activities during the school day, such as physical activity (PA). However, PA may provide short- and long-term improvements in children's cognitive and academic performance, which can be of interest for school practice.

Although the benefits of PA for children's physical and mental health are widely described in the literature, research on the effects of PA for cognitive performance is upcoming. The current evidence base shows several inconsistencies between studies and many questions regarding what frequency, duration and type of PA may benefit children's cognitive performance are still unclear. Gaining more insight in the effects of PA on cognitive performance is important to be able to give explicit advice to schools on the implementation of additional PA in school.

Structural implementation of school-based PA programs in daily school practice is challenging. The current focus on performance in language and mathematics/arithmetic subjects and the associated lack of time appears a major barrier for teachers hindering implementation. Moreover, most evaluated PA programs are developed by researchers, and little is known about the needs, interests and preferences of primary school principals, teachers and children when it comes to additional PA in school. More insight in their perspectives is needed to be able to develop PA programs that are feasible and sustainable in daily school practice.

Therefore, the aims of this thesis are 1) to examine the effects of acute and repeated exercise bouts on children's cognitive performance; and 2) to gain insight in the perspectives of primary school principals, teachers and 10 to 13 years old children with regard to additional PA in school.

Part I Acute effects of exercise on cognitive performance

The first part of this thesis is dedicated to the assessment of the acute effects of single exercise bouts on cognitive performance, measured immediately after exercise. In particular, characteristics of effective exercise bouts in terms of exercise *type* and *duration* are identified.

The randomized controlled cross-over study described in **chapter 2** examines the acute effects of three different types of 12-minute classroom-based exercise bouts on selective attention and

information processing speed in 10 to 13 years old children. One hundred and ninety five children from eight classes participated in a 12-minute exercise session, either consisting of aerobic, coordinative or strength exercises, and a 12-minute sedentary control session, thereby acting as their own controls. The exercise and control condition were scheduled one week apart and the order of sessions was counterbalanced across classes. Children performed two paper-and-pencil cognitive tasks before as well as immediately after both the exercise and control condition, measuring information processing speed and selective attention. None of the three 12-minute exercise bout types, i.e. aerobic, coordinative or strength, resulted in cognitive improvements, and there were no differential effects of exercise type. The exercise bouts did not deteriorate children's cognitive performance.

The randomized controlled cross-over study described in **chapter 3** examines the acute effects of exercise bouts with different duration on selective attention and working memory in 11 to 14 years old children. One hundred and nineteen children participated in an exercise bout of either 10-, 20-, or 30-minutes, and a sedentary control session of similar duration, thereby acting as their own controls. The order of exercise and control condition was counterbalanced and sessions were scheduled one week apart. Two computerized cognitive tasks that measured children's selective attention and working memory performance were administered before and immediately after the exercise and control conditions. There were no acute effects of exercise and no differential effects of exercise duration, i.e. 10, 20 or 30 minutes, on children's cognitive performance. Single exercise bouts of different duration did not deteriorate children's cognitive performance.

Part II Physical activity in school practice: perspectives of school professionals and children

The second part of this thesis focusses on the perspectives of primary school professionals and children in grades 5 and 6. In particular, their motivations, needs, preferences and ideas about (feasible) additional PA in school are explored.

The qualitative study described in **chapter 4** explores the perspectives of school principals and teachers with regard to additional PA in school. Twenty-six school professionals (11 principals and 15 teachers working in the highest two grades of primary school) participated in individual, semi-structured interviews. Principals and teachers expressed their willingness to implement additional PA if it can benefit children's learning. Time constraints appeared a major barrier to structurally implement additional PA in school, and strongly influenced principals and teachers perceptions of feasible PA programs. They indicated that additional PA in school needs to be short (1 to 5, up to maximum 10 minutes), executed in the classroom and provided in 'ready-to-use' materials (i.e.

requiring no or little preparation time). Variation in activities, support of the entire school team and a 'PA coordinator' responsible for the implementation and evaluation were mentioned as important factors for the success of additional PA in school.

The qualitative study reported in **chapter 5** aims to provide insight in 10 to 13 years old primary schoolchildren's perspectives on how to increase PA in school. Thirty-two girls and twenty boys participated in nine semi-structured focus groups. Children were generally enthusiastic about additional PA in school, reported physical, emotional and cognitive benefits and emphasized the need to alternate time working on school tasks with time being physically active. Children had numerous ideas to increase PA in school, including allocating more time for PA in the existing curriculum (e.g. physical education, recess, occasional activities such as field trips or sports days), improving the content of physical education lessons, implementing short PA breaks and physically active academic lessons, and adapting the school playground. According to the children variation and being given a voice in their PA participation are important prerequisites for enjoyable and sustainable PA in school. Moreover, children indicated that it is important to take individual preferences of children into account and make efforts to accommodate all of them. Lastly, children indicated that the teacher has an important role in additional PA in school. Children also suggested to install a 'child PA committee' responsible for the organization and implementation of additional PA in school.

Part III Daily exercise breaks and cognitive performance

Based on the outcomes of the first and second part of this thesis, an exercise breaks program that closely meets the earlier identified needs of school practice was composed. The 9-week program consisted of a daily 10-minute 'Just Dance' exercise break in the classroom.

The cluster randomized controlled trail described in **chapter 6** examines the effects of the exercise breaks program on 9 to 12 years old children's selective attention, inhibition and memory performance, as well as their aerobic fitness and PA levels. Five hundred and twelve children from 21 classes of eight primary schools participated. Half of the classes were assigned to the exercise breaks program and the other half followed a control program. Before and after the 9-week intervention period, children performed four cognitive tasks in domains of selective attention, inhibition and memory retrieval. In addition, a shuttle run test was performed to assess children's aerobic fitness. A subgroup of 330 children from the intervention as well as control classes wore an accelerometer for one week during the intervention period. The exercise breaks program did not result in significant improvements, nor in deteriorations in children's cognitive performance and aerobic fitness. Children in the exercise breaks program group spent on average three additional minutes of moderate-to-vigorous PA per day during school hours compared to the children in the control group.

Implications of the results

In chapter 7 the findings and methodological challenges are critically discussed, and advice to school practice is given based on the results of this thesis.

It could be that PA has no cognitive benefits among healthy primary school children. However, reasons for finding no effects on cognitive performance could also be due to inadequate intensity, type and duration of the exercise bouts, inadequate measurement instruments or timing of cognitive measurements. Moreover, PA may only have relevant beneficial cognitive effects in specific subgroups of children. In future studies, researchers should pay attention to multiple school-relevant outcome measures, the feasibility of research-based PA programs in school and the involvement of school professionals and children in research.

There is still insufficient evidence to provide schools with specific advice about the usefulness of PA to improve children's cognitive performance. However, it can be concluded that spending additional time on PA does not result in adverse effects on children's cognitive performance. Given the multiple health benefits of PA and the child- and teacher perceived benefits for children's attention, mood and school motivation, principals and teachers are encouraged to implement PA as part of the school day. In this process, it is important to make additional PA a shared project of teachers and children. Suggestions to increase the chances of successful and sustainable implementation of additional PA in school are provided, such as choosing feasible and suitable PA opportunities, installing a PA committee and, if possible, increasing involvement of the physical education teacher.

Conclusion

The studies in this thesis found that acute exercise bouts of different types and durations did not improve, nor deteriorate children's cognitive performance. Likewise, 9-weeks of daily short 'Just Dance' exercise breaks in the classroom did not improve, nor deteriorate children's cognitive performance. Principals, teachers and children were generally enthusiastic about additional PA in school, recognized the need for PA and reported multiple benefits, including perceived cognitive improvements. Future research is needed for a decisive answer regarding the effectiveness of PA for cognitive performance.