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The effects of sit-stand desks on cognitive performance of primary school children

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Abstract

A popular solution to the rising problem of sedentary behaviour are sit-stand desks. Studies at schools indicate that this can be an effective method to reduce sitting time of school-age children. However, a hardly studied, though important question about this topic is: does the use of sit-stand desks influence children's cognitive and academic performance? Based on previous findings about the effect of exercise on executive functions that involves similar mechanisms, we expected that it does, in a positive way. We investigated this in a pre-/ post-test control group design with two fifth-grade classes (36 children in total). One group received sit-stand desks, while the other remained with their normal desks. Executive functions were measured with the N-back, Wisconsin Card Sorting, Tower of London and the Fish Flanker task. Standardized skill scores of CITO are used to compare school performances. RM ANOVAs showed no positive effects of sit-stand desks on indicators of executive functions, academic performance and sit-and stand percentages. Therefore, an important outcome of this research is that implementing sit-stand desks with no clear usage instructions seems not enough to let children actually use them. Explorative correlations did show some positive relations between standing, high intensity activity and academic performance. Another positive finding is that implementing sit-stand desks does not seem to negatively influence children's executive functions and academic performance. More longitudinal experimental research involving sit-stand desks with emphasizing on using them seems needed to get a clearer insight on the influences of the use of sit-stand desks on cognitive and academic performance of children.

Keywords: Sit-stand desks, primary school children, cognitive performance, executive functions, academic performance, experimental research.

Introduction

The risks of sedentary behaviour and having too little exercise are broadly discussed topics these days, especially when it comes to health problems. Studies have shown that sitting time is positively correlated with an increased risk of obesity, cardiovascular diseases and diabetes (Healy et al., 2008; de Rezende, Rodrigues Lopes, Matsudo & Luiz, 2014; Dunstan, Thorp & Healy, 2011). Therefore, more and more solutions to this problem are provided. These solutions are especially focused on people with the highest risk of long periods of sedentary behaviour with too little exercise, such as office workers. One of these most popular solutions is the implementation of sit-stand desks at office workplaces. A randomized control study with 19 different offices (317 workers in total) showed a positive effect of the implementation of sit-stand desks on the reduction of sitting time and a decrease in body fat percentage (Danquah et al., 2016).

However, office workers are not the only population that tends to sit many and long periods of time. Given the fact that regular classrooms at schools are filled with chairs, long bouts of sedentary behaviour are also present in school-age children. Therefore, recently, attempts to reduce sedentary behaviour have been introduced in schools. Studies on the implementation of sit-stand desks at school also indicate that this can be an effective method to reduce sitting time of school-age children (Minges et al., 2016). However, a hardly studied, yet important question about this topic is: does the use of these sit-stand desks influence the children's cognitive and academic performance? This is what we investigate in this study.

Sit-stand desks and cognitive performance

Several researches on the health risks of sedentary behaviour and possible interventions pertaining to cardiovascular and physical health has already been done. However, little is known about the effect of sedentary behaviour in relation to cognitive performance. Research that has been done is more focused on the type of sedentary behaviour (watching television vs reading a book) in relation to cognitive performance (Guyot et al., 2012; Carson et al., 2015; Feliz-Nobrega, Hillman, Cirera & Puig-Ribera, 2017), rather than on the amount of sedentary behaviour and its effect on cognitive functions. However, this is an important issue for both work and academic settings, because of the societal value of cognitive performance. If sit-stand desks can decrease sedentary behaviour, that is a good thing, but if sit-stand desks can also increase cognitive performance that would be even better. Also, even if sit-stand desks will not increase cognitive performance, it is of high importance to investigate if they at least do not lead to a decrease of cognitive performance.

Some research has recently been done on the effect of sitting and standing on cognitive performance. Bantoft et al. (2016) performed a counterbalanced study to differentiate the effects of sitting, standing, and walking while working on tasks that involve working memory, selective and sustained attention and information-processing speed in young adults. The results showed that there was no significant difference between these three positions/activities. Another study by Schraefel and Andersen (2012) on the effect of positioning while working on executive functioning also showed no significant difference between a standing and seated position in young men. However, both studies described above investigated the direct effect of standing on cognitive performance and not the effect of sit-stand desks after a longer period of use. Moreover, a systematic review and meta-analysis by Neuhaus et al. (2014), which included studies with adults performing administrative tasks, concluded that activity-permissive workstations, including sit-stand desks, are effective in reducing sedentary time, without a decrease of work performance. In addition, Sherry, Pearson and Clemes (2016) concluded in their systematic review that there are no negative outcomes of sit-stand desks in school classrooms on learning related outcomes like fatigue, concentration and classroom behaviour. Nonetheless, the latter two studies described above did not study the effect on cognitive and academic performance, but the effect on work performance and classroom behaviour. Thus far, most studies on the effect of sit-stand desks on cognitive performance involved adults, not children; and studies involving children using sit-stand desks at school did not study the effects on cognitive performance. Hence, the effect of the use of sit-stand desks in school classrooms on cognitive and academic performance is still inconclusive.

Exercise and cognitive performance

More in-depth research has been done on the effect of exercise on cognitive performance. For example, the review study and meta-analysis by Sibley and Etnier (2003) evaluated several studies on the effect of both chronic and acute exercise on cognitive functions of school-age children aged four to eighteen years old. The cognitive functions that were tested are in the categories: perceptual skills, intelligence quotient, achievement, verbal tests, mathematic tests, memory, developmental level and academic readiness. For all categories, except memory, positive effects of exercise on cognitive functions were found. The effect size reported in this meta-analysis was larger than in an earlier and comparable meta-analysis by Etnier et al. (1997), who focused besides children also on adults and older people until 90 years old. This larger effect size in the meta-analysis from studies solely focusing on children, suggests that physical exercise could perhaps be most effective for cognitive performance of children. A longitudinal pre-test/post-test control group design study about the effects of a football exercise program on executive functions of children between 8 and 10 years old showed a positive effect of the program on working memory, attention, planning and inhibition (Alesi, Bianco, Luppina, Palma & Pepi, 2016). Moreover, the study of Ishiara, Sugasawa, Matsuda and Mizuno (2016) showed that longer durations of non-physical activities were negatively correlated with inhibitory control and working memory of 6-12-year-old children, indicating that more physical activities are associated with better executive functions. Hillman, Erickson and Kramer (2008) support this finding by evaluating multiple studies that investigated the effect of physical activity on executive functions for both children and adults. Based on the results of those studies they concluded that physical activity, and especially aerobic exercise, improves executive functions and cognitive health through the lifespan. Another study of Hillman et al. (2014) compared a group of children (8-9 years old) that participated in a 9-months fitness program with a control group, to assess the effect of physical activity on cognitive flexibility. Cognitive flexibility was measured with a colour-shape switch task. They found a positive effect of the fitness program on cognitive flexibility.

The relationship between exercise and cognitive performance is associated with changes in arousal. With a moderate level of exercise, an intermediate level of arousal is achieved, which in turn leads to an optimal cognitive performance level (Brisswalter, Collardeau & René, 2002). Ebara et al. (2008) used a low frequency/ high frequency ratio of heart rate variability to measure differences in the level of arousal of their participants (with ages between 20 and 64 years old) while standing and sitting. In addition, they investigated the difference in work performance of the participants while standing and sitting. They found a steadily high physiological arousal in the standing condition and a decline in arousal in the sitting condition. A difference was also found in work performance: this remained steady in the stand condition and declined in the sitting condition, indicating a relationship between the level of arousal and work performance. Based on these findings, it seems that physical exercise and standing have important mechanisms in common that could lead to an improvement of cognitive performance.

Physical fitness and cognitive performance

Next to the explanatory mechanism involving the level of arousal, there is another mechanism involving physical fitness that may play an important role in cognitive performance. Physical fitness seems to enhance cognitive performance in both adults and children (Hillman et al. 2008). Several studies investigated a link between a child's overall physical fitness and cognitive functioning. Haapala et al. (2015) showed strong positive correlations between a child's overall physical performance and moderate body fat percentage on the one hand and executive functions and academic performance on the other.

Additionally, the studies of Scudder et al. (2014) and Chaddock et al. (2010) compared higher and lower aerobically fit primary school children on their performances on tasks that measured executive functions, including inhibition, attention and working memory. They found better performance on these tasks in higher fit children. Hillman, Kramer, Belopolsky and Smith (2016) compared four healthy groups: older sedentary adults (M = 66), older active adults (M = 63), younger sedentary adults and younger active adults (M = 19 and 19) to investigate the relationship between physical activeness and task switching performance for both younger and older adults. They observed a better performance of task switching of the active group compared to the sedentary group, for both older and younger adults. Higher levels of physical fitness seem to facilitate greater cortical efficiency, i.e., a need of less cognitive resources, than lower levels of physical fitness (Hogan et al., 2013). The use of sit-stand desks seems effective in reducing body fat percentage in office workers (Danquah et al., 2017) and increases caloric expenditure in elementary school children (Benden, Blake, Wendel & Huber, 2011). If one's overall physical fitness is related to cognitive performance and the use of sit-stand desks is related to an improvement of one's physical fitness, it would make sense if chronic use of sit-stand desks is also related to cognitive performance. In this case, the sit-stand desks would serve as a mediator between physical fitness and cognitive performance.

Executive functions and academic performance

In addition to the question if sit-stand desks could influence cognitive performance, another important question when it comes to changing a school environment is: does it affect the school performances of children? To answer this question, it is necessary to first explain the relation between executive functions and academic performance. The review study of Tomporowski, Davis, Miller and Naglieri (2008) concluded that exercise facilitates executive functions (comprising of scheduling, inhibition, planning and working memory) and school performance of children. Moreover, there is a correlation between executive functions and academic performance, as shown by the study of St Clair-Thompson and Gathercole (2006) showed. They found a link between working memory and performance on English and mathematics courses and a link between inhibition and performance on English, mathematics and science courses in 11 to 12-year-old children. Alloway and Alloway´s (2010) study confirms this link. In addition, Blair and Diamond (2008) suggest in their paper about preventing school failure that skills as cognitive flexibility and inhibitory control are important components of school success. They found that working memory capacity has strong links to learning outcomes and is a valid predictor for academic success during the early years of a child. Further, the study of Sikora, Haley, Edwards and Butler (2002) suggests that the executive function 'planning' is correlated with mathematic skills. Therefore, if sit-stand desks can improve executive functions of children, there are strong arguments to suggest that this would also improve their performances at school.

Current study

The current problem of sedentary behaviour, the lack of sufficient evidence about the effect of sit-stand desks on cognitive performance, the positive effect that exercise seems to have on executive functions and the link with academic performance of children has led to the following research question: *Does the use of sit-stand desks at primary schools have a positive effect on executive functions and school performance of children?* The following hypotheses to examine this research question were drafted: 1) The use of sit-stand desks has a positive effect on executive functions; 2) The use of sit-stand desks has a positive effect on school performance and 3) Indicators of executive functions are correlated with school performance.

A pre-test/post-test control group design study with two fifth-grade classes from the same primary school was carried out to test these hypotheses. In this experiment, it was tested if the children in the class with sit-stand desks outperformed the children in the class with normal sit-desks on four different tasks that measured executive functions. The executive functions that were measured by these tasks are working memory, task switching, planning and inhibition. Working memory was tested with the N-back task (NBT; Jaeggi et al., 2003), task switching with the Wisconsin Card sorting task (WCST; Berg, 1948), planning with the Tower of London task (TOL; Berg & Byrd, 2002) and (response) inhibition with the Fish Flanker task (FFT; Christ, Kester, Bodner & Miles, 2011). Better performance of the children on the tasks in the sit-stand desk condition compared to the children in the normal desk condition, controlling for the pre-test (baseline condition) would mean that the first hypothesis could be supported. In addition to the hypotheses that were drafted, the expectations were that the children performed better on the congruent trials than the incongruent trials of the FF. This was expected because of the conflicting effect of the incongruent trials: the fishes that look the other way cause bias for a different response (Rueda, Posner, Rothbart & Davis-Stober, 2004). For the NBT it was expected that the children performed better on the 1-back than the 2-back and better on the 2-back than the 3-back, because of the difference in difficulty and load of working memory. Furthermore, a higher skill score on grammar, math and reading of the children in the sit-stand desk condition, comparing to the children in the normal desk condition, controlling for the pre-test would mean that the second hypothesis could be supported. At last, a correlation between the outcomes of the tasks and the school skill scores would mean that the third hypothesis could be supported. Collectively, these relations would give an indication for the possible influence that the usage of sit-stand desks has on cognitive and academic performance of children and could either provide support for or discourage implementing sit-stand desks in primary schools.

Method

Design

The experimental design was a single-blind pre-test/ post-test controlled trial. Two fifth-grade school-classes (5C and 5D) from the Lorentzschool participated, which were randomly assigned to the experimental or the control group. The sit-stand desks have been implemented in class 5D, which is the experimental group. The other class, 5C, is the control group, which continued using regular sit desks. The between-subjects factor was group (experimental and control) and the within-subjects factor was time (pre- and post-test). In other words, both groups did the cognitive tasks before and after the sit-stand desks were implemented. Those outcomes, together with the standardized skill scores before and after the sit-stand desks implementation, were compared. This allowed us to control for a possible learning effect. The order in which the children performed the tasks was counterbalanced, so for every child it was randomly decided in which order they performed the tasks, but the order was the same in the pre-and the post-test.

Sit-stand desks

The sit-stand desks were developed by Presikhaaf, which is a company that supplies school furniture (Schoolmeubelen, n.d.). Presikhaaf is a part of Ahrend, a company that is specialized in supplying office furniture (Ahrend, n.d.). These desks are of the same size and dimensions as the regular sit desks at the Lorentzschool. They can be manually adjusted from the sitting to standing mode and vice versa. The desks have been implemented in the first week of May 2017.

Independent variables

The independent variables of the study are the desk type (group), with two levels: sit-stand desks (experimental, class 5D) and sit desks (control, class 5C). This is a categorical variable. The second independent variable is time, which has also two levels: pre-and post-test. This variable is also on a nominal, categorical level.

Dependent variables

Each task measures different dependent variables. For the NBT there are two × three dependent variables; the percentages of correct responses (CR), for level 1, 2 and 3 and the mean reaction time to correct responses in milliseconds (RT), also for level 1, 2 and 3 (Jaeggi et al., 2003). Those are on the interval level of measurement. The WCST measures four dependent variables; the number of completed categories (CC), number of perseverative errors (PE), number of non-perseverative errors (NPE) and total trials (TT) (Barceló and Knight, 2002; Bowden et al., 1998; Greve, 1993;1999; 2002). Those are also all on the interval level of measurement.

For the TOL there are three dependent variables, which are the total move score (TMS), the total correct score (TCS) and the mean solution time in milliseconds (ST) (Culbertson & Zillmer, 2001; Berg & Byrd, 2002). Those are also on the interval level of measurement.

The FFT measures two × two dependent variables; the mean reaction time in milliseconds of congruent (RTc), and incongruent trials (RTi), and percentage error of congruent (PEc) and incongruent trials (PEi) (Christ, Kester, Bodner & Miles, 2011). Those are also all on interval level.

For measuring school performance, there are four dependent variables, which are the math, technical reading, comprehensive reading and grammar standardized skill scores of the children. Those are all on the ordinal level of measurement. The skill scores are measured by the student follow system of CITO (Cito, n.d.).

Participants

The participants in this study are 36 children of the public primary school of the

Lorentzschool in Leiden in the fifth grade of the Dutch system, with the age between eight and ten years old. The children were in two different classes, 18 children in each class have participated. That is 36 in total. There was an equal distribution of girls and boys in the control group (9 of each). In the experimental group, there were 10 girls and 8 boys (56 and 44% respectively). The mean age in both groups was 9 years. The principal of the Lorentzschool selected those two classes, in consultation with the teachers. A coin flip determined which class was the experimental and which class was the control group. Children who were in the experimental group and did not want to participate, still received and could use the sit-stand desks, but have not been involved in any testing. The criteria to participate in this study were being a child between the ages of 8-10 years old, following regular primary education in grade 5 of the Dutch system, with a signed informed consent form to participate in this study. See appendix A for this informed consent form. Both parents/ caregivers and children were asked to sign this form. All participants were physically able to stand without serious health problems. There was no compensation for the children or parents/ caregivers. However, the children, principal and teachers received a small gift from Leyden Academy, as an appreciation of their help and participation: Leyden Academy will organise some guest lessons/ lectures on health and environment for all grade 5 groups.

This study is approved by the Committee Ethics Psychology (CEP) of Leiden university and the Central Committee on Research Involving Human Subjects (CCMO, NL60159.000) in The Hague, Netherlands.

Procedure

The pre-test for both the experimental and control group took place in the first and second week of May 2017. The post-test for both groups took place one month after the implementation of the sit-stand desks, which were the last two weeks of June 2017. The test place was the Lorentzschool in Leiden. The tasks were performed in separate rooms and were conducted during school time, i.e., between 8:30AM and 3PM.

The parents were informed about the study during an information session at the Lorentzschool, where everything was explained about implementing the sit-stand desks and the exact kind of tasks the children would perform and how long this would take. The parents could ask all their questions regarding the study, and could sign for informed consent afterwards.

During the experiment, the children were taken out of the class one by one. Unique eight-character codes were randomly assigned to participants. For every task they performed, they were instructed to fill in this code. Instructions for tasks were presented on the screen. A researcher supervised with every task to make sure the children knew what to do and to act in case there were technical problems. This was also communicated to the children, together with the fact that they could ask the researcher anything about the tasks. Taken together, the tasks took up to an hour to complete. The procedure and instructions were the same across groups and pre-and post-tests. Because this study is part of a longitudinal study, the debriefing will take place at the end of the entire study, which will be four years after the first measurement.

Apparatus and software

The psychological software tool Inquisit was used to perceive, run and adjust all tasks. All task instructions were translated to Dutch, and the letters of the N-back task were replaced with pictures, to make it child friendly. All tasks have been piloted with a child that was also in grade 5 of the Lorentzschool, but in a different, non-tested class. The statistical program Statistical Package for the Social Sciences (SPSS) was used to analyse the data. The hardware that was used to work with these software programs, are laptop and computer devices using Windows 8.

Tasks

N-back task. The NBT measures working memory capacity. The NBT that was used consists of 198 trials in total; 63 for the first, 66 for the second and 69 for the third level. Eight pictures of different drawings of animals and non-animate objects (for example a scissor or umbrella) were randomly and consecutive presented on the screen. In the first level, the participant was instructed to press the letter A on the keyboard, when the picture was the same as the picture exactly before it (1-back). See figure 1 for an example of the 1-back level. In the second level, the participant was instructed to press the letter A when the picture was the same as two pictures before it (2-back). In the third level, the participant was instructed to press the letter A, when the picture was the same as three pictures before it (3-back). Every level has 12 practice trials, which could be repeated. Dependent on how often the participants repeat the practice levels, the whole task takes approximately 15 minutes to finish (Jaeggi et al., 2003).

Figure 1. Example of 1-back trial.

Wisconsin Card Sorting task. The executive function that was tested by the WCST is task switching, which is the ability to switch between competing rules based on feedback (Eling, Derckx & Maes, 2008). The WCST consists of four cards with geometric figures. Above those four cards a different figure appears with every trial. There are maximal 128 trials in this version, depending on the number of errors someone is making consecutively (Berg, 1948). The participants were instructed to sort this card with the matching card underneath, by using their mouse. The card had to be sorted based on a match on the currently relevant dimension. The relevant dimension varied between three different dimensions; colour, shape or number of the figures. Figure 2 gives an example of a trial and the different dimensions. The subjects were required to find the correct classification by learning through trial and feedback. Every time the subject had found the correct rule they needed to maintain this sorting classification until the rule changes after four correct matches. They could notice this change, because suddenly sorting the card based on the former sorting dimension would most likely not lead to the correct response, and thus participants would receive the feedback 'wrong'. The former sorting dimension should now be ignored and the subject should continue matching cards on the new sorting dimension, until the rule changes again. This demands flexible shifting between the different sorting sets.

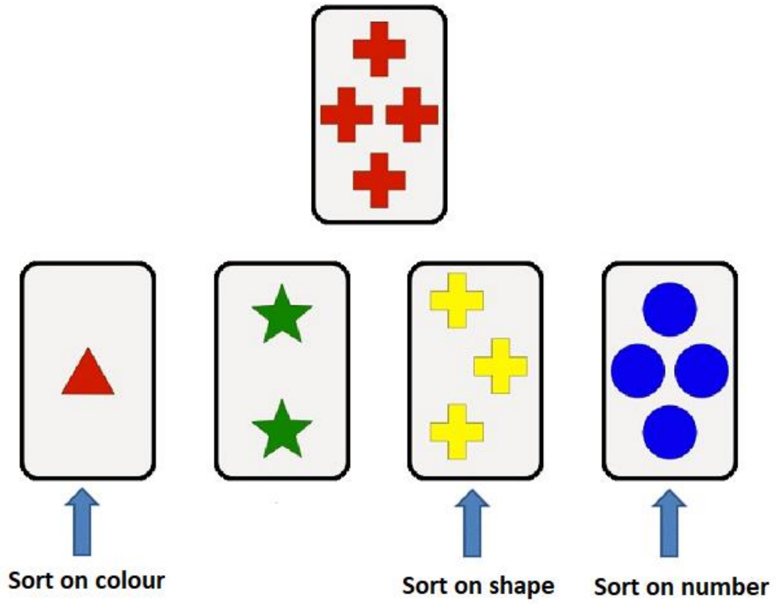


Figure 2. Example of a WCST trial with the different sorting dimensions.

Tower of London task. The TOL is used to measure planning (Luciana & Nelson, 1997). The task consists of two pictures with both three coloured balls (blue, red and green) that are placed on three vertical pins of different heights. The one picture is called the 'Goal State' and the other picture is called the 'Work Space'. This means that the 'Goal State' is the example for the participant, so the set-up of these balls is the goal of the assignment. The 'Work Space' picture is the space where the participant can move the balls to this same set-up as the balls in the 'Goal State', by using their mouse. In every trial, there were different goal states that they needed to achieve. There are three restrictions for this: a) the balls should be moved one by one; b) the balls cannot be placed outside the pins and c) a maximum of three balls can be placed on the longest pin, a maximum of two on the middle pin and a maximum of one on the shortest pin (Gonzalez Marin, Bouwmeester & Boonstra, 2010). In the right angle of the screen, the number of moves that the participant should make to go to the Goal State, was presented. Figure 3 depicts an example trial.

The total task existed of 12 trials, of which 2 goal states required 2 moves, 2 required 3 moves, 4 required 4 moves and 4 required 5 moves. At first there was one practice trial that required 2 moves. The primary score is the total move score (TMS). This is the number of moves the subject makes to reach the goal state beyond the minimum number of moves to reach the goal state summed over all problems. This means that if a subject solved three problems that could all be solved in five moves, solved them all in eight moves, the total move score is 3 (amount of problems) X 3 (moves that went beyond the minimum number of moves). Therefore, a low total move score stands for good planning. The second important score is the total correct score (TCS). This is the total number of problems which are solved in the minimum number of moves (Culbertson & Zillmer, 2001). The last important score is the mean solution time. This is the mean time in milliseconds it takes for the participant to solve a problem. Or in other words, the time it takes to go from the Work Space to the Goal State in the number of moves that are allowed (Berg & Byrd, 2002).

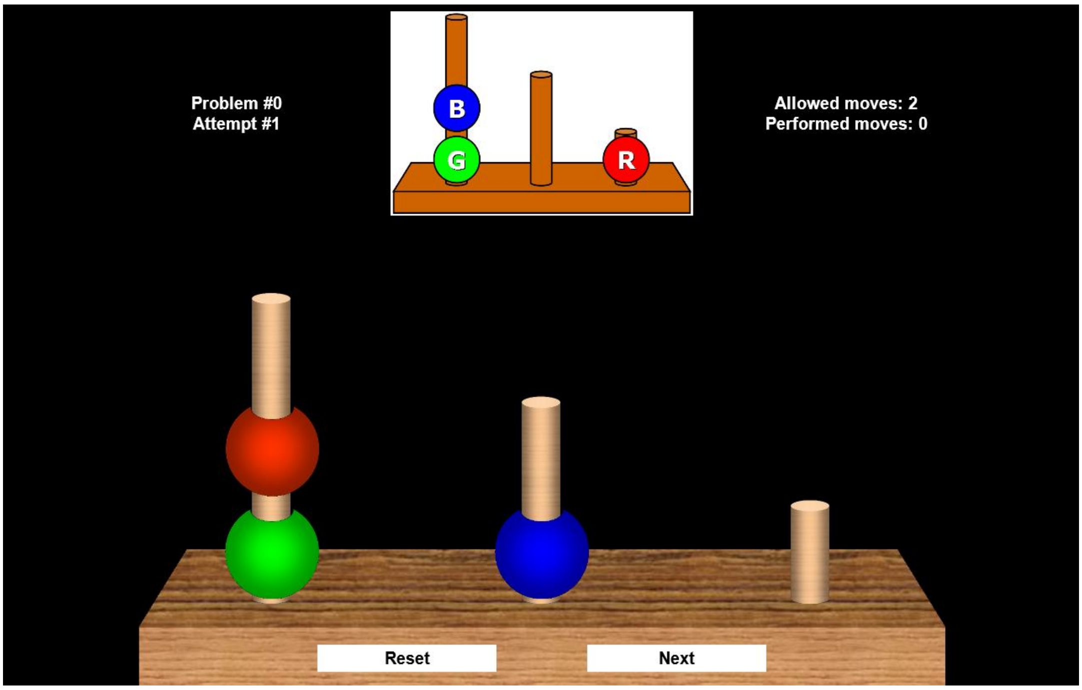


Figure 3. Example of a TOL trial, with the Goal State at the top and the Work Space at the bottom of the screen.

Flanker Fish task. The FFT measures response inhibition (McDermott, Pérez-Edgar & Fox, 2007). The task consists of 5 equally sized fishes in each trial. The participants were instructed to focus on the direction of the fish in the centre and to pay no attention to the other four flanking fishes. Moreover, the participants were instructed to press the left arrow on their keyboard when the centre fish that appears on the screen faces to the left and press the right arrow when the centre fish that appears on the screen faces to the right. The other four fishes, in other words the 'flanking fishes' all pointed in the same direction as the central fish (congruent) or they all pointed in the opposite direction (incongruent trial). Figure 4 shows an example of an incongruent trial. There were 120 trials in total with equally often congruent and incongruent trials. The participants started with 20 congruent and 20 both congruent and incongruent practice trials (Christ, Kester, Bodner & Miles, 2011). The whole task takes approximately 8 minutes to finish.

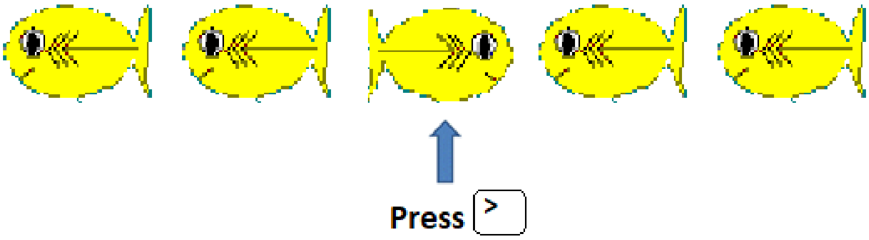


Figure 4. Example of a FF incongruent trial.

School performance measurements

Besides the cognitive tasks, the standardized skill-scores of math, technical reading, comprehensive reading, and grammar were compared for both the experimental and the control group and for the pre-and post-test of both groups. This way it could be measured if the sit-stand desks influenced school performance of the children.

Physiological and activity measurements

BMI, weight, physical fitness and body composition of the children have been measured in both the pre-and post-test. The body composition measures were the fat and muscle percentages of the children. Those variables were measured with a bio-impedance Omron BF 511 (Bosy-Westphal et al., 2008). The physical fitness of the children was measured with the Shuttle run test (Léger, Mercier, Gadoury & Lambert, 1988).

Next to this, the percentages of time the children spent sitting, standing, running, walking and cycling in school time during the pre-and post-test period were measured with an Activ8 monitor (Activ8all, 2017). The running together with the cycling activity data were classified as high intensity activity and the walking and standing activity together as light activity. This monitor was placed on the right upper leg of every child who participated and had permission from his/ her parents on a first day of the school week (Monday). After 5 days (by the end of the school week; i.e. Friday), it was removed again. The placing and removing of the monitors was done by a female researcher for the girls and by a male researcher for the boys. This way we could check if the sit-stand desks influenced the sit and stand time, which gave an indication about the use of the stand-function of the tables. Furthermore, we could check if the sit-stand desks influenced the activity level of the children. These data give information about the question if the children of the experimental group, so who had the sit-stand desks, used the stand function of the tables.

Analysis

The data that were collected in Inquisit were first transferred to Microsoft Excel and subsequently to SPSS, for computation into variables. The main analyses that were conducted were repeated measures analyses of variance (RM ANOVAs). This choice was based on the design of the study, which involved two time points and two within factors. Another reason to use RM ANOVAs is the robustness of this test against violations of the normality assumption. Before starting with the analyses, we checked for violations of the assumptions of RM ANOVAs. Even though RM ANOVAs are known as robust against violations of normality, we still checked for this assumption, because our relatively small sample size could affect this robustness (Field, 2008). The Shapiro-Wilk test of normality, histograms and QQ-plots were inspected to check for the assumption of normality. Next to this, the box plots and QQ-plots of the variables were inspected to find significant outliers and the data file was inspected on missing data. In addition to the general assumptions, we checked if the assumption of sphericity is violated for the variables which had more than one within factor, so for the NBT and the FF. The changes on the outcomes of the pre-test and post-test between the two groups were assessed with an interaction analysis of time x group. Profile plots were used to inspect those differences. Additionally, planned comparison t-tests were performed to explore the effect of time per group as follow up on these possible interaction effects. In addition to RM ANOVAs, Pearson correlation coefficients were used for the correlations between school performance and executive functions conducted on the difference scores. A Bootstrap confidence interval is added to the correlations in case of non-normality and/ or outliers (Field, 2012).

Computing variables. The scores of the children for every level (1, 2 and 3- back) in the NBT on the CR and RT were combined to separate (dependent) variables. A high score of CR and a low score of RT indicates good performance on working memory. The scores of the children for every trial in the WCST for the CC, PE, NPE and TT are combined to four separate variables. A high score on the CC and a low score on the PE and NPE indicates good task switching. The scores of the children for every trial in the TOL for the TMS, TCS and ST are combined to three separate variables. A low score on the TMS and ST and a high score on the TCS indicates good planning and behavioural inhibition. The scores of the children for every trial in the FFT for the RT and PE of the congruent and incongruent trials are combined to separate variables. A low score on the RT and PE indicates good inhibitory control.

All data of the skill-scores of the children on math, grammar, comprehensive and technical reading are combined to four separate variables. The same is for BMI, weight, fat percentage, shuttle run test and the sitting, standing, walking, running and cycling percentages. Additionally, the standing and walking percentages are combined to one variable (light intensity activity) and the running and cycling percentages are combined to one variable (high intensity activity).

Testing hypotheses. First, RM ANOVAs were conducted to check if the data confirms the expectations about congruency of the FFT and the levels of difficulty of the NBT. A main effect of congruency on RT and PE of the FFT and a main effect of N-back level on CR and RT would confirm those expectations. Values with an alpha of < 0.05 are reported as significant effects for all statistical tests. To test the first hypothesis: *The use of sit-stand desks has a positive effect on executive functions*, RM ANOVAs were conducted on all scores of the cognitive tasks. An extra within factor was added for the NBT which was the n-back level (1, 2 and 3 back) and for the FFT, which was congruency (congruent vs incongruent trials). A significant interaction effect between group and time on the scores of the tasks indicates an effect of sit-stand desks on executive functions. To test the second hypothesis: *The use of sit-stand desks has a positive effect on school performance*, RM ANOVAs were conducted on the outcomes of the math, grammar, technical and comprehensive reading skill-scores. A significant interaction effect between group and time on the math, writing, technical and comprehensive reading skill-scores indicates an effect of the sit-stand desks on school performance. To test the third hypothesis: *Executive functions indicate directions correlated with school performance,* Pearson R correlations were conducted between the difference scores (post – pre-test) of the math, grammar and reading skill-scores and the difference scores of the cognitive tasks. Only the variables which indicate that a learning effect took place were included to limit the chance of hazard correlations. This means that all skill scores and indicators of executive functions with a main effect of time with a F value < 1.5 were excluded. Significant correlations between the math, grammar, technical and comprehensive reading skill-scores and indicators of executive functions indicate that the hypothesis can be accepted. Correlation coefficients with an absolute value of 0.3 of more are reported. However, only correlations above 0.5 should be interpreted as strong correlations (Field, 2008).

Furthermore, RM ANOVAs were conducted to test if the sit-stand desks influenced the BMI, weight, physical fitness, body composition, sit-stand and high and light activity of the children. A significant interaction effect between group and time on the BMI, weight, physical fitness, body composition, sit-stand activity, high or light activity indicate that sit-stand desks influence children's physiology and activity.

When RM ANOVAs showed that the sit-stand desks did not influence children's physiology and activity, additional correlations were conducted between the difference scores of BMI, weight, physical fitness, body composition, sit-stand, high and light activity and difference scores of the cognitive tasks. This serves as an explorative analysis as alternative for the RM ANOVA's. Again, all indicators of executive functions with a main effect of time with a F value < 1.5 were excluded. This way we could still investigate the relationship between fitness and executive functions.

Results

No participants were excluded from data analysis. Only one participant was not present during the post-test of the cognitive tasks, which led to missing data on all tasks. Two participants were not tested during the pre-test to measure their weight, BMI, fat and muscle percentage, which led to missing data on their body composition. Moreover, two participants were not present during the pre-and post-test of the shuttle run test and three others not during the pre-or post-test, which led to missing data of physical fitness. There is also missing data of five participants on the activity tracker data of the pre-and/ or post-test, because some children took their monitor off, lost it or did not want to wear it anymore during the post-test. The variables on the different cognitive tasks, body composition measurements, physical fitness and activity data were analysed separately. This way we made sure we used all data we had available and no information was lost because of the list-wise deletion in the RM ANOVAs.

Some outliers were detected in a number of variables. However, excluding them did not lead to significant differences on the outcomes. This, together with the relatively small sample sizes of the two groups led to the decision not to exclude those outliers in the final analyses.

For some variables, the data were not normally distributed. Of these variables, most had right skewed data. However, given the robustness of RM ANOVA, we decided to analyse the data with this method of analysis. For the sake of exploration, we also tried transforming the data with square root, cube root and log transformations. However, this still did not lead to normal distributions of the data. Furthermore, we considered but could not find a useful non-parametric method with similar qualities to RM ANOVAs for the analyses.

Given all shortcomings and considerations provided above, the results should be carefully interpreted. This could lead to inaccurate test statistics and p-values and the presented outcomes may therefore be over- or underestimated (Field, 2012). Lastly, the assumption of sphericity has not been violated for any of the relevant variables. Therefore, the sphericity-assumed *p*-value is always reported.

In the analyses of correlations, a bootstrap confidence interval is added because of the small sample size in combination with present outliers (Field, 2012). The same is the case for the additional correlation analyses between the difference scores of indicators of EF and the difference scores of the activity data.

N-back task

As expected, the overall (experimental and control group taken together) RTs differed significantly on the N-back levels, $F(2, 33) = 23.361$, $p < 0.001$, $\eta^2 = 0.414$. Bonferroni post-hoc tests showed a significantly lower RT with a working memory load of N=1 (M = 737 and M = 704), than with a working memory load of N=2 (M = 905 and M = 875) and N=3 (M = 906 and M = 900), all *p*'s < 0.001. Moreover, the overall CRs differed significantly on the N-back levels, $F(2, 33) = 105.\ 355$, $p < 0.001$, $\eta^2 = 0.761$. Post-hoc tests showed a significantly higher CR with a working memory load of N=1 (M = 89.6% and M = 87.6%), than with a working memory load of N=2 (M = 77.9% and M = 75.5%). Furthermore, the CR is significantly higher with a working memory load of N=2 than with N=3 (M = 67.0% and M = 71.1%), all *p*'s < 0.001. Figure 5 shows this main effect of the N-back level on RT (5A) and CR (5B). Furthermore, there were no overall significant differences on the RT and CR in time, from pre-to post-test, all *p*'s > 0.5. In other words, considering performance on all N-back levels and both groups together, the children had no significantly more or less CR and had no longer or shorter RT on the post-test compared to the pre-test. This means that no learning effects occurred. The analyses showed an interaction effect between N-back level and time on the CR, $F(2, 66) = 4.684$, $p = 0.013$, $\eta^2 = 0.124$. This means that the trending of the CR differs between the N-back levels over time from pre-to post-test. Bonferroni post-hoc tests showed a significantly decrease on the CR with N=3 over time from pre- to post-test, compared to the CR with N=1 from pre-to post-test, $p = 0.013$. Furthermore, there was a significantly decrease on the CR with N=3 over time from pre-to post-test, compared to the CR with N=2 from pre-to post-test, $p = 0.034$. Figure 6 depicts this interaction effect.

However, there were no interaction effects between group and time on the RT and CR, all *p*'s > 0.32. This means that there were no significant differences between the experimental and control group on the RT and CR over time, from pre- to post-test. Table 1 gives an overview of all mean scores. In sum, there were no significant differences between the experimental and control group on performance of the NBT over time from pre-test to post-test.

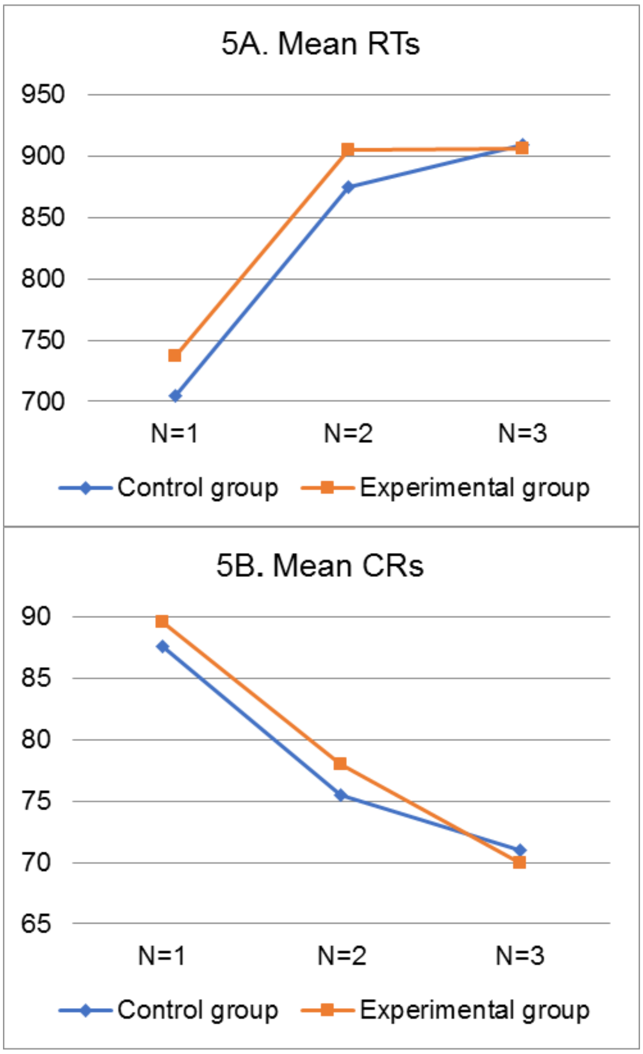


Figure 5. Main effects of N-back level on the RT and CR in the NBT.

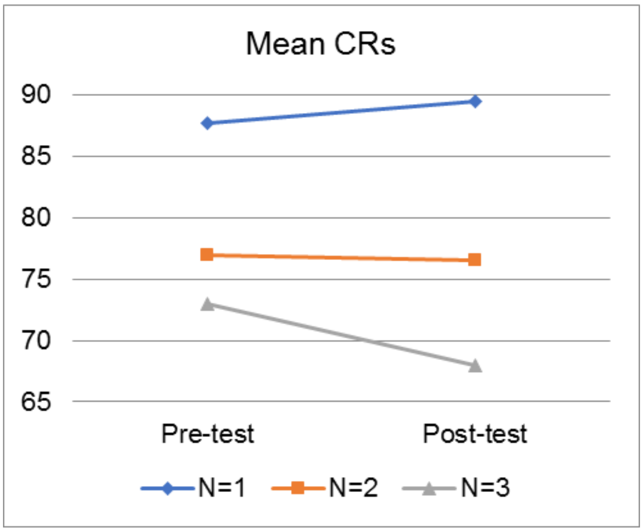


Figure 6. Interaction effect of N-back level × Time on the CR in the NBT.

Table 1.

Means of all dependent variables.

			Pre-test				Post-test				Difference score	
			Sit-stand desks		Normal desks		Sit-stand desks		Normal desks		Sit-stand desks	Normal desks
NBT	N=1	RT	698	(216)	712	(196)	771	(141)	696	(249)	73	−3
		CR	88.8	(10.7)	86.5	(14.5)	88.9	(11.01)	90.2	(11.4)	0.1	3.7
	N=2	RT	892	(286)	868	(282)	899	(251)	882	(306)	7	14
		CR	75.7	(8.6)	77.5	(11.6)	79.5	(10.6)	73.5	(15.7)	3.8	−4
	N=3	RT	938	(365)	909	(259)	951	(371)	909	(259)	13	0
		CR	71.9	(11.1)	54.6	(12.3)	68.5	(11.7)	67.5	(14.6)	−3.4	12.9
WCST		CC	5.9	(0.9)	5.6	(1.3)	5.3	(1.5)	5.5	(1.3)	−0.6	−0.1
		TT	59.8	(25.2)	78.4	(28.5)	77.3	(33.3)	63.7	(35.1)	17.5	−14.7
		PE	9.2	(9.3)	14.2	(10.6)	15.1	(13)	9.2	(11)	5.9	−5
		NPE	16.2	(10.4)	25.8	(14.5)	25.8	(16.2)	20.3	(15.7)	9.2	−5.5
TOL		ST	19001	(5453)	21379	(5523)	19541	(6214)	18523	(5052)	540	−2856
		TMS	5.2	(5.2)	5.5	(8.9)	2	(2.1)	4.1	(5.8)	−3.2	−1.4
		TCS	26.7	(5.4)	26.9	(5.2)	28.1	(5)	26.8	(4)	1.4	−0.1
FFT	Congruent	RT	700	(117)	673	(88)	669	(115)	675	(113)	-31	2
		PE	2.7	(3.3)	3.9	(5)	3	(2.8)	4.5	(5.5)	0.3	0.6
	Incongruent	RT	750	(141)	733	(119)	722	(119)	730	(126)	−28	−3
		PE	5.3	(5.1)	5.7	(4.1)	5.1	(3.2)	6.3	(5.8)	−0.2	0.6
Grammar			320	(35)	291	(26)	338	(35)	318	(28)	18	27
Math			222	(19)	208	(14)	234	(22)	225	(17)	12	17
Technical reading			82	(13)	70	(15)	84	(9)	74	(15)	2	4
Comprehensive reading			174	(20)	166	(18)	187	(27)	170	(22)	13	4

Standard deviations of means are reported within parentheses.

* Sit-stand desks = experimental group, Normal desks = control group.

** Difference score = Post-test - pre-test.

*** RTs and TMS are given in milliseconds, CRs and PEs (FFT) in percentages, CCs, TTs, PEs (WCST), NPEs, TMS and TCS in numbers and school scores in skill scores.

Wisconsin Card Sorting task

There were no overall significant differences on the CC, TT, PE and NPE in time, from pre-to post-test; all *p*'s > 0.26. This means that the children did not significantly decreased or increased their CC, TT or errors in the post-test compared to the pre-test, suggesting that no learning effects occurred.

Furthermore, there was no significant interaction effect between group and time on the CC, $p = 0.26$. This means that there was no significant difference on the CC from pre- to post-test between the experimental and the control group. In contrast, there were significant interaction effects between group and time on the PE, NPE and TT, $F(1, 33) = 7.160$, $p = 0.12$, $\eta^2 = 0.178$, $F(1, 33) = 7.250$, $p = 0.011$, $\eta^2 = 0.180$ and $F(1, 33) = 7.250$, $p = 0.008$, $\eta^2 = 0.195$. This means that there were significant differences on the PE, NPE and TT from pre-to post-test between the experimental and the control group. Table 1 gives an overview of these differences. To further explore the significant interaction effects, profile plots were visually inspected on the change of means of the PE, NPE and TT. Those plots show that the experimental group already made fewer PE and NPEs, and performed less TTs in the pre-test (reflecting a better performance), than the control group. However, during the post-test the results were in the opposite direction; the experimental group showed an increase in PEs, NPEs and TTs and the control group showed a decrease in PEs, NPEs and TTs (reflecting a better performance). See figure 7A, B and C. Additionally, planned comparison t-tests were performed to explore the effect of time per group. The control group did show a significant improvement in performance during the post-test on the PEs and TTs, $t(17) = 2.454$, $p < 0.05$ and $t(17) = 2.280$, $p < 0.05$. However, even though the plots in figure 7 indicate a decrease in performance of the experimental group, this decrease is not significant, all *p*'s > 0.05. In sum, there was an interaction effect between group and time on the performance of the PE and TT of the WCST. The control group significantly improved performance, while the performance of the experimental group worsened, although not significantly.

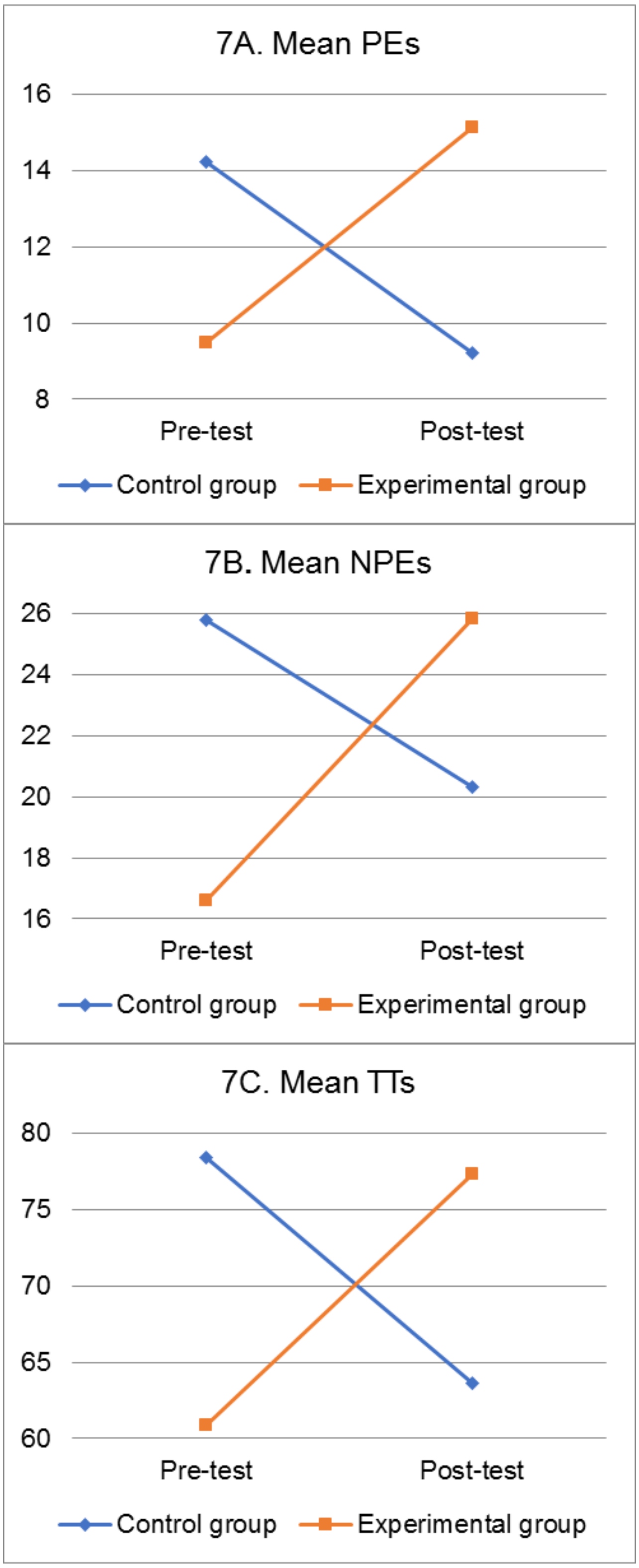


Figure 7. Significant interaction effects of group × time on the NPE, PE and TT in the WCST.

Tower of London task

There was an overall decrease of TMS in time, from pre-to post-test, reflecting a better performance $F(1, 33) = 4.132$, $p = 0.05$, $\eta^2 = 0.111$. This result indicates a learning effect: figure 8 depicts this. No learning effects occurred for the ST and TCS, all *p*'s > 0.31. Furthermore, there were no significant interaction effects between group and time on the ST, TCS and TMS, all *p*'s > 0.13. This means that there were no differences between the experimental and control group on the ST, TCS and TMS, in time from pre-to post-test. See Table 1 for an overview of all the mean scores. In sum, there were no significant differences between the experimental and the control group on performance of the TOL over time, from pre-to post-test.

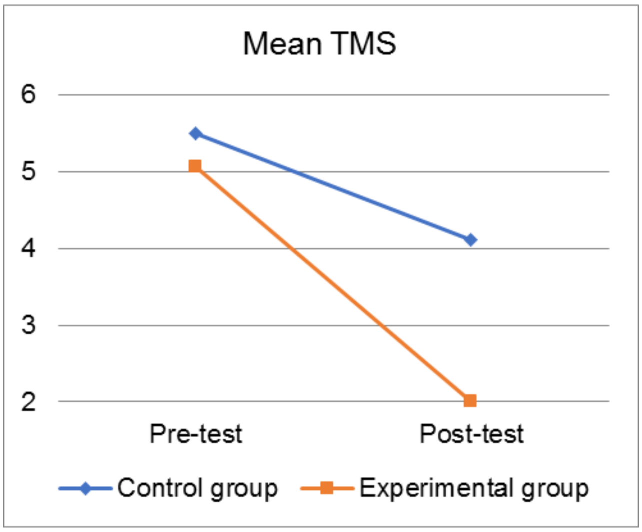


Figure 8. Main effect of time on the TMS in the TOL.

Flanker Fish task

As expected, the overall RTs and PEs were lower in the congruent trials than in the incongruent trials; the children performed better in the congruent trials than in the incongruent trials, $F(1, 33) = 45.745$, $p < 0.001$, $\eta^2 = 0.58$ and $F(1, 33)$, $p < 0.001 = 20{,}807$, $\eta^2 = 0.387$. Those main effects are shown in Figure 9A and B. However, there were no overall significant differences on the RT and PE in time, from pre-to post-test, all *p*'s > 0.27. This means that the children did not have a decrease or increase on their RT or PE in the post-test compared to the pre-test. This means that no learning effects occurred.

There were no significant interaction effects between time and group on the RT and PE, all p's > 0.50. This means that the RT and PE did not significantly differ between the experimental and control group in time, from pre- to post-test. Furthermore, there were also no significant interaction effects between time, group and congruency (congruent or incongruent trials). This means that there were no significant differences between the experimental and control group on the RT and PE and on the congruency effect in the post-test compared to the pre-test, all *p*'s > 0.40. See Table 1 for an overview of all mean scores. In sum, there were no significant differences of performance on the FF between the experimental and control group over time, from pre- to post-test.

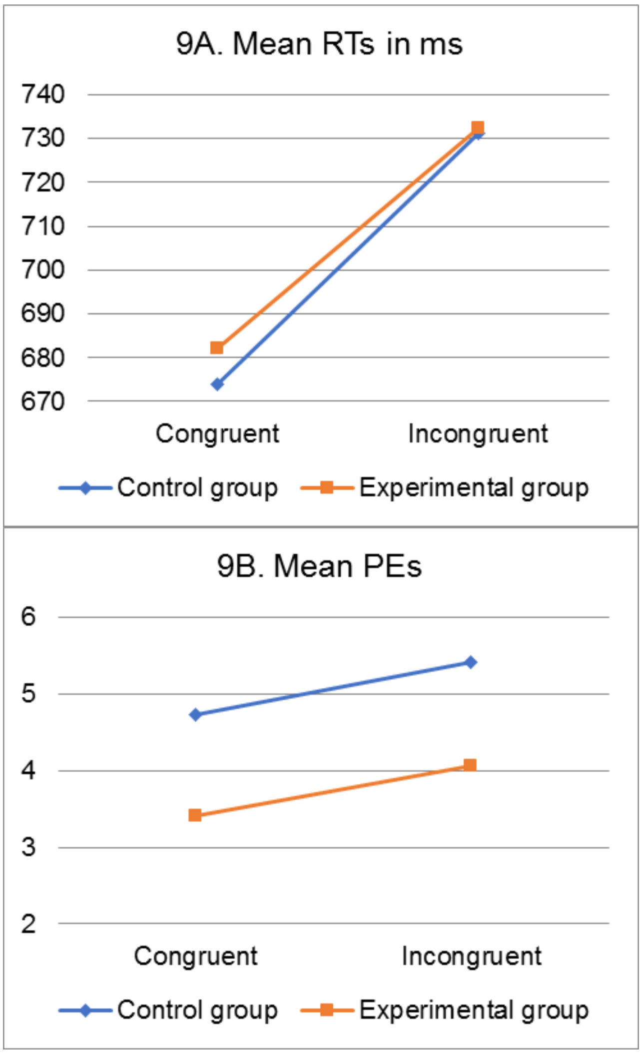
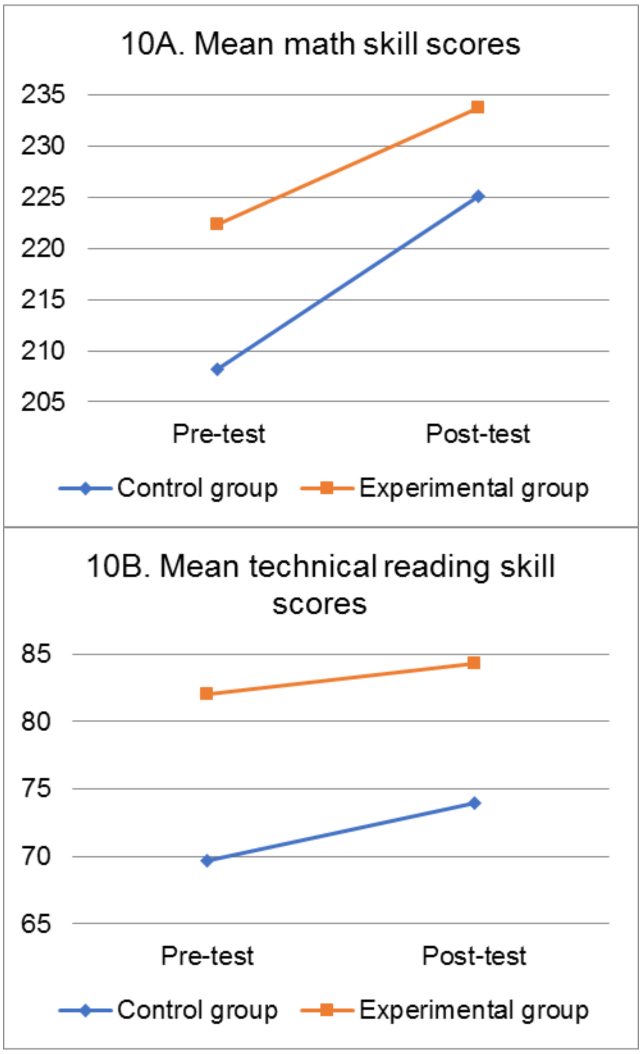


Figure 9. Main effects of congruence on the PE and RT of the FFT.

School performance

As one could expect, both the experimental and control group had higher skill scores in the post-test compared to the pre-test, on all courses: grammar (*M* = 338.22 vs *M* = 320.22 and *M* = 317.78 vs *M* = 391.22), math (*M* = 233.78 vs *M* = 222.28 and *M* = 225.06 vs *M* = 208.17), technical reading (*M* = 84.33 vs 82.06 and *M* = 74 vs 69.72) and comprehensive reading (*M* = 186.5 vs *M* = 174.11 and *M* = 169.83 vs *M* = 165.61), $F(1, 34) = 43.358$, $p < 0.001$, $\eta^2 = 0.560$, $F(1, 34) = 50.972$, $p < 0.001$, $\eta^2 = 0.600$, $F(1, 34) = 8.938$, $p = 0.005$, $\eta^2 = 0.208$ and $F(1, 34) = 6.508$, $p = 0.015$, $\eta^2 = 0.161$, respectively. Figure 10A-D show these learning effects. However, there were no significant differences between the experimental and control group in skill score changes over time, all *p*'s > 0.18. Table 1 shows an overview of all mean scores.



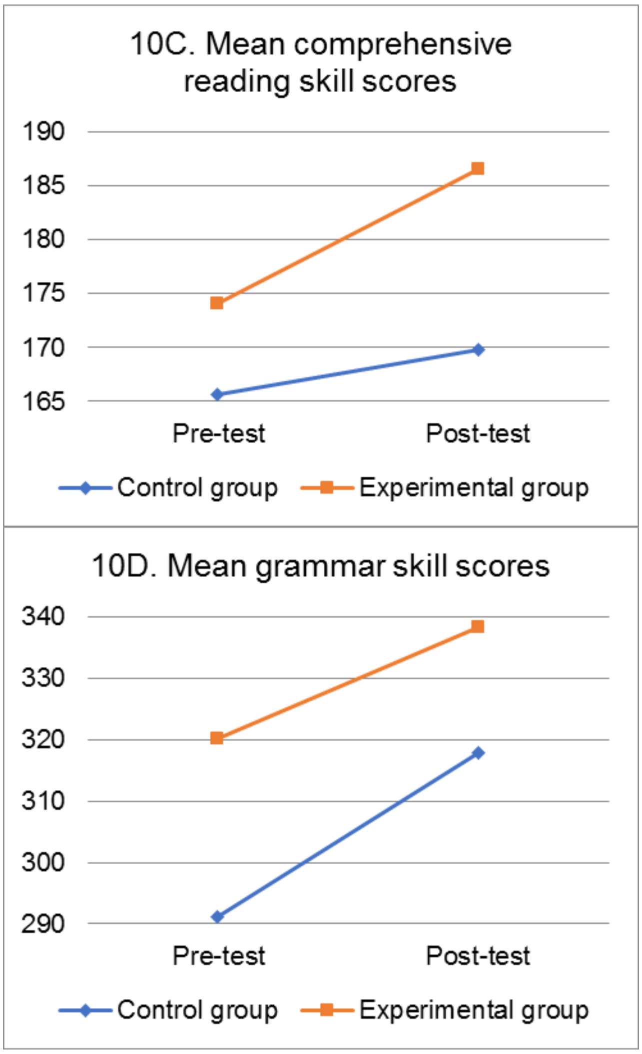


Figure 10. Main effects of time on the school skill scores.

School performance and executive functions

There were no significant correlations found between any of the school skill scores and indicators of executive functions, all *p*'s > 0.05.

Physiological and activity measurements

There were no overall significant differences between the pre- and post-test on the sitting, standing, light and high intensity activity percentages, all *p*'s > 0.15. However, the results revealed a small and non-significant change in the predicted direction, indicating a minimal increase in standing during school hours (M = 8.3 vs M = 7.6) and a minimal decrease in sitting during school hours (M = 68.7 vs M = 68.2) over time for the experimental group. However, there was also an increase of standing in the control group (M = 7.0 vs M = 6.2), all *p*'s > 0.46. Figure 11 depicts these non-significant changes of standing (11A) and sitting (11B). The same is the case for high intensity activity, a minimal non-significant increase in high activity is present for the experimental group in the post-test compared to the pre-test (M = 7.9 vs M = 7.0). Moreover, there were no significant interaction effects between group and time on the sitting, standing, light and high intensity activity percentages, all p's > 0.31. This means that there were no significant differences between the experimental and control group on sitting, standing, light and high intensity activity, from pre- to post-test.

The overall BMIs were significantly lower during the post-test (M = 16.1 and M = 17.2) compared to the pre-test (M = 16.6 and M = 17.7), $F(1, 30) = 56{,}609$, $p < 0.001$, $\eta^2 = 0.654$. However, there were no significant interaction effects between group and time on BMI and weight, both p's > 0.36. This means that there were no differences on BMI and weight changes over time between the experimental and control group.

The overall fat percentages were significantly lower during the post-test (M = 14.6 and M = 17) compared to the pre-test (M = 16.7 and M = 19.9), $F(1, 30) = 73{,}751$, $p < 0.001$. Moreover, overall muscle percentages were significantly higher during the post-test (M = 34.5 and M = 33.8) compared to the pre-test (M = 34.4 and M = 33.1), $F(1, 30) = 44{,}122$, $p < 0.001$, $\eta^2 = 0.595$. However, there were no significant interaction effects between group and time on fat and muscle percentages, all p's > 0.08. This means that there were no significant differences between the two groups on the fat and muscle percentages.

The overall physical fitness was higher in the post-test (M = 5.7 and M = 5.2) compared to the pre-test (M = 5.3 and M = 4.4), $F(1, 29) = 5{,}792$, $p = 0.023$ $\eta^2 = 0.166$. However, there was no interaction effect between group and time on physical fitness, p = 0.44. This means that there were no significant differences between the two groups on physical fitness in the post-test compared to the pre-test. In sum, there were no significant differences between the experimental and the control group on physiological and activity measurements in the post-test compared to the pre-test.

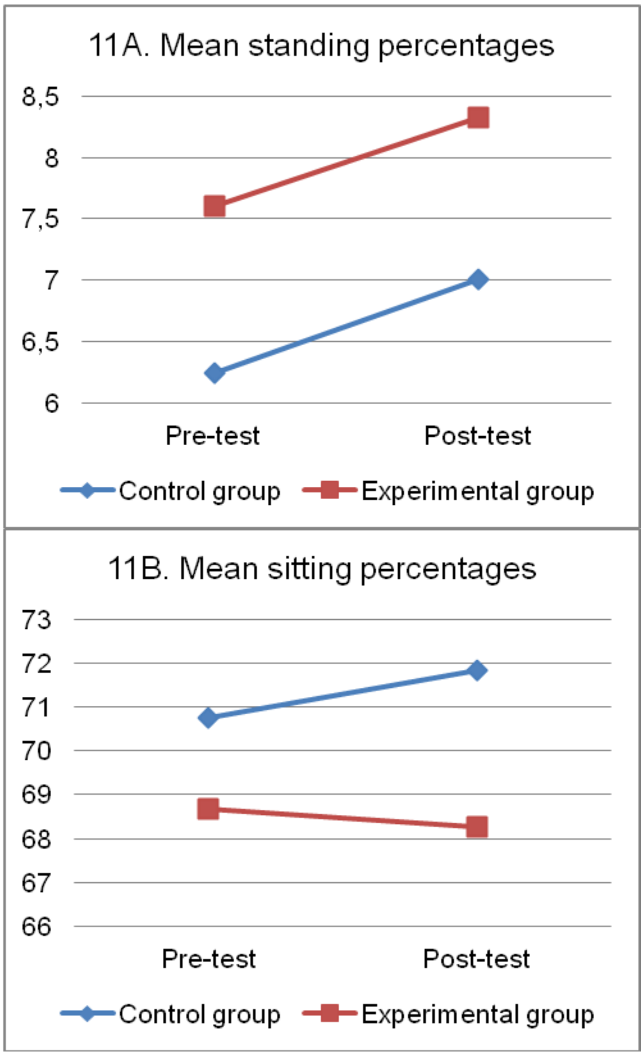


Figure 11. Non-significant changes of the standing and sitting percentages.

Additional correlation analyses

Because the outcomes showed no effect of the sit-stand desks on sit, stand, high activity, low activity, BMI, weight, body composition and physical fitness, additional correlations on the difference scores (post – pre-test) of these variables were conducted between indicators of executive functions and school skill scores. Significant positive correlations were found between standing and the math skill scores, r = .418, 95% BCa CI [.092, .719], p = 0.019 and between running and technical reading skill scores, r = - .385, BCa CI [-.002, -.671], p = 0.033. Those correlations suggest that there is a positive relationship between an increase in standing activity and an improvement on math. Moreover, there is a positive relationship between an increase in running and an improvement on technical reading.

Discussion

The aim of this study was to investigate if the use of sit-stand desks at primary schools influences the executive functions and school performance of children. Because of the previous findings about the effect of sit-stand desks and the effect of exercise that involves similar mechanisms (Sibley & Etnier, 2003; Etnier et al., 1997; Alesi et al., 2016; Ishiara et al., 2016; Scudder et al., 2014; Chaddock et al., 2010; Brisswalter et al., 2002; Ebara et al., 2002 Haapala et al., 2015; Hillman et al., 2008; Hogan et al., 2013; Danquah et al., 2017; Benden et al., 2011; Grunseit et al., 2013; Vink et al., 2009; Tomporowski et al., 2008), the expectations were that the use of sit-stand desks would positively influence executive functions and school performance. The concrete hypotheses were 1) The use of sit-stand desks has a positive effect on executive functions; 2) The use of sit-stand desks has a positive effect on school performance and 3) Executive functions indicate directions correlated with school performance.

Findings

However, the experiment that was set-up to test those hypotheses showed no positive effects of sit-stand desks on executive functions and school performance. Also, the only learning effect that occurred between the post- and pre-test was on the TMS of the TOL. Furthermore, the results of the N-back level showed a significant decrease in performance on the CR in the 3-back level between the two moments of testing compared to the 1 and 2-back levels. A logical explanation for this could be that the children experienced the 3-back level as too difficult in the pre-test and were therefore less motivated to perform well on the post-test. Moreover, before interpreting the results it is important to emphasize the fact that the results showed no effect of the sit-stand desks on the children's sit- and stand percentages of time during school hours. Therefore, there is no indication that the children in the experimental group actually used the stand function of the tables. This should be taken into account when interpreting the outcomes.

Based on our findings, we cannot confirm the first hypothesis: The use of sit-stand desks has a positive effect on executive functions. Analyses of the indicators of three executive functions, working memory capacity, planning, and response inhibition showed no significant differences between the experimental and control group when comparing the post-test to the pre-test scores. However, in contrast to the indicators of executive functions mentioned above, the indicators of task switching showed more divergent results. Where there was no difference on the CC, there were differences on the PE, NPE and TT on the

WCST from pre-to post-test between the experimental and control group. However, the direction of this interaction effect was the opposite of what was expected. It seems that there already was a difference between the experimental and control group in the pre-test: the experimental group performed significantly better on these variables than the control group. However, they switched places during the post-test. The control group improved performance on the WCST, whereas the experimental group (non-significantly) worsened in performance. Those outcomes are in contrast with comparable studies about the effect of physical activity on task-switching abilities: Hillman, Kramer, Belopolsky and Smith (2016) investigated whether physical activity positively influences task switching performance for both younger and older adults. They observed a better performance of task switching in the active group compared to the sedentary group, for both older and younger adults. Another study by Hillman et al. (2014) assessed the effect of physical activity on cognitive flexibility and found a positive effect of their fitness program on cognitive flexibility. The contradictory outcomes of other comparable research, together with the sit-stand desks not leading to significant more standing, may indicate that the control group significantly improved their performance on the WCST due to other unknown external factors. For example: better sleeping, higher motivation, or perhaps they (consciously or unconsciously) trained their task-switching abilities in the month between the pre-and post-test.

Moreover, even though we did not find positive effects of the sit-stand desks on cognitive functions and school performance, we did not find (significant) negative effects of the implementation of the sit-stand desks either. This is in line with the systematic review of Sherry, Pearson and Clemes (2016), who concluded that there are no negative outcomes of sit-stand desks in school classrooms on learning related outcomes. Even though we still do not know if this would also be the case when children actually use the stand-function of the tables, it gives an indication of the harmlessness of the sit-stand desks.

Additionally, explorative correlations between indicators of executive functions and variables that reflect fitness and activity (sitting, standing, physical activity, physical fitness, body composition) also showed no relationship. Those are contrary outcomes compared to other studies, which found a positive relation between exercise, children’s physical fitness, body fat percentage, activity level and cognitive performance (Sibley & Etnier, 2003; Etnier et al., 1997; Alesi et al., 2016; Ishiara et al., 2016; Scudder et al., 2014; Chaddock et al., 2010; Brisswalter et al., 2002; Ebara et al., 2002 Haapala et al., 2015; Hillman et al., 2008; Hogan et al., 2013; Danquah et al., 2017; Benden et al., 2011; Grunseit et al., 2013; Vink et al., 2009; Tomporowski et al., 2008).

The second hypothesis: The use of sit-stand desks has a positive effect on school performance, could partly be confirmed based on the results of this study. On the one hand, no differences were found between the experimental and control group when comparing post-test to pre-test skill scores of grammar, math, technical and comprehensive reading. However, additional explorative correlations showed a positive relationship between standing and math. Furthermore, a positive relationship was found between running and technical reading. Those results are in line with the meta-analysis of Sibley and Etnier (2003), who found positive effects of chronic exercise on math tests and academic readiness. Especially the finding that standing is positively related to math may suggest a positive effect of the use of sit-stand desks on school performance. However, it should be noted that these results come from explorative correlation analyses and the relationships are therefore not causal. It is possible that children who increased their standing behaviour also performed better on math due to a third factor that was not controlled for in the current study, such as general health or motivation. The correlations found in the present study would need to be replicated in future research that controls for such alternative explanations.

In contrast with the findings of St Clair-Thompson and Gathercole (2006), Alloway and Alloway´s (2010) and Sikora, Haley, Edwards & Butler (2002), no correlations between indicators of executive functions and school performance were found in this study. Therefore, we cannot confirm the third hypothesis. This matches the fact that we found some positive relations between standing and school performance, but not between standing and executive functions.

Analyses of physiological and activity measurements showed no significant differences between the experimental and control group when comparing post-test to pre-test on physical activity (light or high), BMI, weight, body composition and physical fitness. Therefore, it seems that the sit-stand desks did not influence these variables. However, BMI, body composition and physical fitness of both groups did seem to differ over time. All children had a lower BMI, a lower fat percentage, a higher muscle percentage and a better score on the shuttle run test in the post-test compared to the pre-test. It is normal for children to have a significantly changing BMI, because of their growth and development (McCarthy, Cole, Fry, Jebb & Prentice, 2006). Therefore, the same explanation could probably be given for the significant lower fat percentage. Another explanation could be that in the months before the end of the school year, more outdoor activities took place compared to the rest of the school year. The children played more outside and had more sport days. It is likely that this seasonal factor influenced BMI, fat percentage and physical fitness of the children.

Theoretical and practical significance

This study definitely has theoretical and practical significance for the field of research. To begin with, this was the first study which investigated the long-term effects of sit-stand desks on executive functions of primary school children. Studies who researched direct effects of activity on cognitive performance are much more common than long(er) term effects. The same is the case for studies about this subject with children: studies involving adults are much more common than studies involving children. Therefore, this study serves as a pilot study whereof future research about the effect of sit-stand desks and activity on cognitive performance can learn a lot from. In addition, real life experiments are quite uncommon in the field of psychological research. Testing is still often done in labs or simulation environments. By using the natural environment of the children for the intervention and tests, the results are better generalizable to the real world than when there would be chosen for a lab or simulation environment. Even though real-life experiments have their own restrictions (harder to control and more external influences, see 'Future research and limitations'), this study contributes to research involving naturalistic environments.

Even though the results are inconclusive, the findings of the explorative correlation analyses plead for more standing and more activity in the classroom and therefore supports the idea for the need of interventions to stand more in the classroom. Those interventions will perhaps be most effective when they focus on the children to both stand and be more active in the classroom. Cardon, de Clercq, de Bourdeaudhuij and Breithecker (2004) already studied the sitting habits of children in a traditional versus a "moving" school. This involved implementing stand-at places, dynamic sitting possibilities (such as physio balls), creating more floor space for variations in the working condition and behavioural influences such as good examples, information and training about the importance of moving around more. The results of this study showed that the children of the "moving" school are more physical active than the traditional school. The intervention of this study could also be used for future research, to study the effect of these "moving schools" on executive functions and school performance of children.

Future research and limitations

Because our findings indicate that the children did not use the stand function of the tables (at least not during the post-test week), we cannot conclude that using the stand function of the sit-stand desks does or does not influence executive functions. However, we can carefully conclude that implementing sit-stand desks with no further clear instructions about when to use them, is perhaps not enough to tempt the children to stand more. Those findings are remarkable though, because several studies with a similar research design showed that implementation of sit-stand desks in primary schools did lead to significant more standing and less sitting (Benden, Blake, Wendel & Huber, 2011; Clemes et al., 2015; Cardon, Clercq, Bourdeaudhuij & Breithecker, 2004). Therefore, we suggest for future research to measure the sit- and stand percentages for a longer period or a few weeks spread out through several months. This way there will be enough data to generalize the activity outcomes to the whole period between the pre- and post-test.

Based on the findings that the children did not use the stand-function during the post-test week, an important recommendation for future research and primary schools, is that the teachers should be provided with enough information about how, when and why to encourage the children to use the stand function of the sit-stand desks. Teachers could be provided with a desk-adjustment training, just as implemented in the experiment of Clemes et al. (2016). During the experiments of this study, the teacher was told that the children could determine for themselves if they wanted to sit or stand when they work individually. However, during the classical teaching, the teacher told the children when she wanted them all to sit or stand. For this to work in a way that teachers will encourage the children to stand more, it is important that the teacher is motivated to do this. This also became clear in the study by Hinckson et al. (2013), where the impact and acceptance of the sit-stand desks was greater for the class where the teacher was motivated than the class where the teacher was demotivated

This brings us to another limitation of the present research, which perhaps partly explains why it seems that the children did not use the sit-stand desks. This limitation is that the sit-stand desks were technically not in good shape. The manually adjusting function worked not that well and a lot of desks were crooked or had other dysfunctions. This did not only lead to constraints for using the tables, but also led, according to the teacher, to stress and demotivation of the teacher to encourage the children to use the stand-function. Luckily, it did not seem to lead to poorer performance on the cognitive tasks and school performance of the children.

Furthermore, for sequel research about this subject it is recommended to have a longer period between the pre- and post-test and between comparable months. This means that it would be best to do the post-test approximately 1 year after the pre-test. This way, the children and teachers have more time to get used to the sit-stand desks. This is also in line with the research of Benden et al. (2011), who found that the children needed 12 weeks to acclimate to their sit-stand desks.

Another restriction of this research is that during the pre-and post-test 5 children in total, 4 of the experimental and 1 of the control group, did not wear the Activ8 monitor. Moreover, 4 others did not wear the activity monitor for the full 5 days. Because of the missing data, on top of the already small sample size, no general conclusions can be drawn on the effect of sit-stand desks on positions and activities. To decrease the chance of "activity-tracker drop-outs" in future research, it is recommended not to conduct the experiment in springtime anymore. This way, the influence of the possible heat will not lead to of falling activity trackers. Besides, the chance that the children go swimming would be smaller and therefore there would be less need to take the activity trackers off. Furthermore, we also recommend involving more primary schools and/ or school classes, to increase the sample size. This way, when there will be activity-tracker drop-outs this will not immediately have a great impact on the results.

A further advantage of not doing the experiment in spring, would be that there will be no rehearsals of end-musicals. During the current experiment, those rehearsals led to a lot of noise disturbance at the time that the children were performing the cognitive tasks in the post-test. This could possibly have influenced their performances on the tasks. This could perhaps explain why almost no learning effects took place during the post-test compared to the pre-test.

A final limitation and consequently a suggestion for future research, is the fact that we did not measure how many times the children in the experimental condition changed from sitting to standing. The study of Balci and Arghazadeh (2003) compared four different work-rest schedules to see which one led to the best task performance in students. The results showed that the work-rest schedule which existed of three breaks of 30 seconds and 1 break of 3 minutes during one hour of work resulted in the highest speed, accuracy and performance for the tasks, compared to the other work-rest schedules that all existed of longer breaks. This so called micro break effect could therefore also occur by using sit-stand desks, because of the opportunities for body movements that these desks provide (Ebara et al., 2008). By measuring those body movement changes in follow-up research, this possible micro break effect of the use of sit-stand desks could be investigated.

Conclusion

In conclusion, although the current results of this research do not support the hypothesis that (the use of) sit-stand desks have a positive influence on executive functions, limitations and shortcomings could have overshadowed true effects. The question if the use of sit-stand desks influences children's cognitive and academic performance remains therefore still unanswered. However, a positive conclusion that we can make based on this study is that implementing sit-stand desks does not seem to negatively influence children's cognitive and academic performance. Moreover, we found some indications that standing and being highly active are positively related with school performance. This was the first study that investigated the long-term effects of sit-stand desks on executive functions of primary school children. Therefore, this study provides several opportunities for improvement in future research. More longitudinal experimental research involving sit-stand desks with empathizing on using them are needed. This way, a clearer insight could be gained on the influences of the use of sit-stand desks on cognitive and academic performance of children.

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Appendix

Appendix A:
Informed consent parents and children

Datum: dd/mm/yyyy Betreft: informatiebrief onderzoek zit/sta-tafeltjes Lorentzschool

Geachte ouder/verzorger,

De Lorentzschool en de Leyden Academy on Vitality and Ageing willen een uniek driejarig onderzoek uitvoeren naar de effecten van zit/sta-tafeltjes bij basisschoolleerlingen. Het doel van dit onderzoek is inzichtelijk krijgen of zit/sta-tafeltjes kinderen verleiden en uitnodigen om vaker te staan en bewegen en, indien dit het geval is, welke gevolgen dit heeft voor de leerprestaties, cognitieve functies, de fysieke fitheid en het welzijn van deze leerlingen. De eerste resultaten van Australisch en Amerikaans onderzoek laten zien dat kinderen in klaslokalen met zit/sta-tafeltjes vaker en langer staan, dat hun schoolprestaties even goed tot beter zijn en dat zij een hoger energieverbruik hebben gedurende de dag (zij verbranden meer calorieën). Bovendien waren de kinderen in deze onderzoeken overwegend enthousiast over de zit/sta-tafeltjes (met alle plezier sturen we u enkele artikelen over deze onderzoeken).

Het is al langer bekend dat vaak en langdurig zitten nadelige gezondheidseffecten met zich meebrengt. Reeds op jonge leeftijd, maar zeker ook op de lange termijn kunnen door veel zitten chronische ziektes ontwikkelen, zoals diabetes, obesitas en hart- en vaatziekten. Met dit onderzoek wordt gekeken of het verleiden tot staan tijdens de les een goed alternatief is om de gewoonte van het vaak en langdurig zitten op jonge leeftijd te doorbreken.

Betrokken partijen

Om te beginnen ontwikkelt en produceert Presikhaaf – marktleider op het gebied van schoolmeubilair en leverancier van het huidige schoolmeubilair van de Lorentzschool – een dertigtal speciale zit/sta-tafeltjes die gebruikt zullen worden voor het onderzoek. Een viertal van deze tafeltjes is inmiddels al uitvoerig getest in verschillende groepen van de Lorentzschool. Het onderzoek zal worden geleid door dr. Lex van Delden; hij heeft gewerkt als fysiotherapeut, heeft daarna cognitieve neurowetenschappen gestudeerd en is gepromoveerd in bewegingswetenschappen. Als onderzoeker is hij verbonden aan de Leyden Academy on Vitality and Ageing, een kennisinstituut dat zich onder andere bezighoudt met de invloed van de omgeving op leefstijl. Tijdens het onderzoek wordt Lex van Delden geassisteerd door een student-assistent en leveren verschillende afstudeerders, stagiairs en docenten van zowel de Hogeschool Leiden als de Universiteit Leiden ook hun bijdragen aan het onderzoek.

Het onderzoek

In het onderzoek zullen twee klassen (groep 5) voor een periode van 3 jaar gevolgd worden. In één van deze klassen – de interventiegroep – worden 30 speciale zit/sta-tafeltjes geplaatst. Deze tafeltjes zijn qua afmetingen identiek aan het huidige schoolmeubilair van de Lorentzschool. Dit reguliere schoolmeubilair wordt, zoals nu ook het geval is, gebruikt in de andere klas, die daarmee fungeert als controlegroep. De leerlingen in de interventiegroep mogen zelf bepalen of ze hun tafeltje omhoog of omlaag zetten om ofwel te gaan staan ofwel te gaan zitten tijdens de les. De leerkracht krijgt eveneens een in hoogte verstelbaar bureau en zal als rolmodel zelf het voorbeeld van meer en vaker staan geven en de leerlingen uitnodigen ook meer en vaker te staan tijdens de les. In dit onderzoek ligt de nadruk op het veranderen van gedrag door een omgeving te bieden die verleidt en uitnodigt tot die verandering en niet door verboden en geboden op te leggen. Als de leerlingen overgaan naar een andere klas, dan verhuist het meubilair mee tot het einde van de onderzoeksperiode.

De metingen

Twee maal per jaar zullen gedurende een week diverse metingen plaatsvinden: een week in januari en een week in juni. Allereerst zijn we geïnteresseerd in de vraag of de zit/sta-tafeltjes daadwerkelijk verleiden en uitnodigen tot meer staan en bewegen, ook buiten de schooluren. Dit wordt inzichtelijk gemaakt door het gebruik van speciale *activity trackers*. Deze apparaatjes zijn wetenschappelijk gevalideerd en veilig te gebruiken door kinderen. Tijdens de meetweken (januari en juni) zullen de kinderen in de interventie groep én in de controlegroep deze apparaatjes 24 uur per dag gedurende de hele week dragen. De apparaatjes worden op het bovenbeen bevestigd met huidvriendelijke tape; dit wordt gedaan door de onderzoeker en een assistent (uiteraard zullen hiervoor ook instructies worden gegeven aan de ouders). Met deze apparaatjes geplakt op het bovenbeen kan gewoon gedoucht worden. Naast lichamelijke activiteit, wordt er ook gekeken naar de fysieke fitheid van de leerlingen. Hiervoor worden tijdens de gymlessen conditietestjes en krachtmetingen gedaan onder toezicht van de docent lichamelijke opvoeding. Er worden ook metingen verricht naar lengte en gewicht. De stoelgang en het slaappatroon worden nagevraagd met behulp van dagboekjes; u wordt als ouders verzocht te helpen bij het invullen van de dagboekjes. Verder zullen er cognitieve testen naar werkgeheugen, planning, impuls controle en taak wisselen afgenomen worden door een psycholoog van de faculteit sociale wetenschappen (sectie psychologie) van de Universiteit Leiden. En uiteraard wordt er ook gekeken wat het effect van het gebruik van zit/sta-tafeltjes is op de schoolprestaties van de leerlingen. Daarvoor wordt het reguliere leerlingvolgsysteem geraadpleegd. Er wordt geprobeerd de testen en metingen met de minst mogelijke belasting te laten plaatsvinden. Alle apparatuur is getest en gevalideerd en er worden geen invasieve handelingen verricht (er wordt bijvoorbeeld geen bloed geprikt).

De onderzoeksresultaten en anonimiseren

De gegevens en onderzoeksresultaten worden vertrouwelijk behandeld. Deze zullen allemaal geanonimiseerd worden. Dit houdt in dat de gegevens in correspondentie, rapportages en publicaties niet te herleiden zullen zijn tot uw kind of een andere specifieke leerling. De gegevens worden gecodeerd opgeslagen. Alle leerlingen krijgen random een uniek dubbelcijferig nummer toegewezen tussen 01 en 99. De nummers worden gegenereerd met een 'random number generator' en vervolgens alfabetisch aan de leerlingen toegewezen. De leerlingen krijgen een sleutelhanger met dit nummer, opdat zij elke keer dit nummer kunnen tonen bij elke test/meting gedurende het hele project. De assessor zal bij het testen/meten alleen vragen om het nummer voor registratie en nooit de naam noteren bij de gegevens van de leerling. De sleutel van de codering blijft op de school in het beheer van de directeur. Alleen de directeur en (bij diens afwezigheid) de adjunct-directeur hebben toegang tot de sleutel van de codes. Alle onderzoeksgegevens worden buiten de school bewaard op een beveiligde server van Leyden Academy.

Vrijwillige deelname en informed consent

Het is aan de leerling en diens ouder(s) om te bepalen of er deelgenomen wordt aan het onderzoek. Deelname is daarmee geheel vrijwillig. Indien er besloten wordt deel te nemen aan het onderzoek, dient u als ouders een formulier te ondertekenen waarmee u dit uitdrukkelijk aangeeft. Hoewel het wettelijk niet verplicht is, vragen we ook de leerlingen zelf of zij akkoord gaan met deelname en het formulier te ondertekenen. Op dit formulier, het zogeheten *informed consent* formulier, staat tevens vermeld dat zowel de leerling als de ouder(s) op elk moment en zonder opgaaf van reden kan besluiten niet langer deel te nemen aan het onderzoek. Dit geldt eveneens voor de deelname aan specifieke testjes en metingen. Indien u niet wilt dat uw kind meedoet aan dit onderzoek, dan tekent u het betreffende formulier niet en hoeft u verder niets te doen. Overigens vragen we u ook om inzage in het leerlingvolgsysteem om de schoolprestaties te kunnen koppelen aan de overige uitkomstmaten. Op hetzelfde informed consent formulier vragen we u en uw kind of we over 7, 14 en 21 jaar nogmaals contact mogen opnemen om met dan logische, maar wellicht dezelfde meetinstrumenten en vragenlijsten na te gaan hoe het verder gegaan is met de academische ontwikkeling, werk en gezondheid.

Aanvullende informatie
Indien u aanvullende informatie wilt over dit onderzoek, dan kunt u contact opnemen met Lex van Delden via de contactgegevens die onderstaand vermeld staan.

Dr. Lex van Delden (06-47474513, delden@leydenacademy.nl) Henk Lardée
Senior onderzoeker Leyden Academy Directeur Lorentzschool

……………………………........ ……………………………........

Voor de ouders / verzorgers:
Ik verklaar hierbij op een voor mij duidelijke wijze, mondeling en schriftelijk, te zijn ingelicht over de aard, de methode, het doel, de eventuele risico's en belasting van het onderzoek. Ik weet dat de gegevens en onderzoeksresultaten anoniem en vertrouwelijk behandeld worden, alleen anoniem en vertrouwelijk in rapportages, publicaties en aan derden bekend gemaakt zullen worden en noch naar mij noch naar mijn kind te herleiden zijn. Ik verklaar eveneens voldoende tijd te hebben gehad om te beslissen of mijn kind deelneemt in het onderzoek.
Ik stem geheel vrijwillig in met deelname aan dit onderzoek en geef de onderzoekers toestemming tot inzage in de gegevens van mijn kind in het leerlingvolgsysteem van de Lorentzschool. Ik behoud daarbij het recht deze instemming weer in te trekken zonder dat ik daarvoor een reden behoef op te geven.
naam eerste ouder / voogd: ....
.... (datum) .... (handtekening)

naam tweede ouder / voogd: ....
.... (datum) .... (handtekening)

Voor de deelnemer (leerlingen):
Ik wil aan het onderzoek met zit/sta tafeltjes mee doen. Ik begrijp de uitleg van het onderzoek en begrijp wat de onderzoekers willen meten en hoe ze dit willen doen. Ik heb het recht om altijd te besluiten niet langer mee te doen met het onderzoek of met bepaalde testjes of metingen. Als ik dit besluit, hoef ik hiervoor geen reden te geven.
naam leerling: ....
.... (datum) .... (handtekening)

Voor de onderzoeker:

Ik heb mondelinge en schriftelijke toelichting verstrekt op het onderzoek. Ik verklaar mij bereid nog opkomende vragen over het onderzoek naar vermogen te beantwoorden. Noch de deelnemer noch diens ouder(s) zal van een eventuele voortijdige beëindiging van deelname aan dit onderzoek nadelige gevolgen ondervinden.
naam onderzoeker: ....
.... (datum) .... (handtekening)

Opvolging 7, 14 en 21 jaar later
Omdat in dit onderzoek gepoogd wordt gezond gedrag te bevorderen, dat mogelijk op de lange termijn pas zichtbare gezondheidseffecten laat zien, zouden we graag in de gelegenheid zijn om over 7, 14 en 21 jaar nogmaals contact op te nemen en na te gaan hoe het de leerlingen is vergaan. We zullen op die momenten (met voortschrijdend inzicht) voor dan logische meetinstrumenten en vragenlijsten willen voorleggen. We zullen telkens opnieuw vragen of we u/uw kind 7 jaar later mogen benaderen. Kunt u hieronder aangeven of wij wederom contact mogen opnemen voor zo'n eerste follow-up over 7 jaar?

Voor de ouders / verzorgers:
Ja / Nee *
naam eerste ouder / voogd: ....
.... (datum) .... (handtekening)

naam tweede ouder / voogd: ....
.... (datum) .... (handtekening)

Voor de deelnemer (leerlingen):
Ja / Nee *
naam kind: ....
.... (datum) .... (handtekening)

Voor de onderzoeker:
Ik heb mondelinge en schriftelijke toelichting verstrekt op het onderzoek. Ik verklaar mij bereid nog opkomende vragen over het onderzoek naar vermogen te beantwoorden. Noch de deelnemer noch diens ouder(s) zal van een eventuele voortijdige beëindiging van deelname aan dit onderzoek nadelige gevolgen ondervinden.
naam onderzoeker: ....
.... (datum) .... (handtekening)

* Doorhalen wat niet van toepassing is.