The relationship between physical fitness and executive function in first year pre-vocational students.

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Date: 14 June 2012

Subject: Master research, programme youth sports

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Abstract

Recent investigation has shown that only forty per cent of the Dutch child population, is exercising enough to stay physically healthy. Recent literature, however, revealed the relation of physical fitness in relation to different executive functions for example inhibition, planning, cognitive flexibility and working memory. The purpose of this study was to investigate the relation between physical fitness and executive function in first year pre-vocational students. The additional purpose is to explore the differences in physical fitness between the two educational levels within pre-vocational education.

The sample consisted 186 first year Dutch pre-vocational students who completed all tests. Of those students, 92 came from pre-vocational-theoretical practice (TL) (males: 48) and another 94 came from the education level pre-vocational-basic vocational (BB) (males: 45). Three aspects of the Eurofit-test (aerobic fitness, speed and muscle strength) were used to measure physical fitness and a total physical fitness score (TPF) was computed out of these three measurements. Four tests were used to measure different characteristics of executive function (cognitive flexibility, visual working memory, planning and inhibition).

Results showed that higher TPF was related to higher performance on execution time of the planning task, working memory (forward and backward) and cognitive flexibility. For inhibition, better scores on TPF related to lower inhibition skills. Mean scores of the four executive function tests show that students at the pre-vocational-TL perform significantly better, compared to pre-vocational-BB students on planning, working memory and cognitive flexibility. Students in higher education, run significant faster on the ten times five meter run.

Physical fitness has a relationship with aspects of executive functioning in first year pre-vocational students.

Key words: executive function, physical fitness, students, education

Introduction

After the age of twelve, there is a drop in sport participation, declining consistently till the age of eighteen (Armstrong & Welsman, 2006; Tiessen-Raaphorst, Verbeek, Haan & Breedveld, 2010). Between the ages of four to seventeen 12.5 per cent of Dutch children fall in the group of "non-active" (Bernaards, 2011). Children between the ages of twelve and seventeen are highly represented in this non-active group. Research shows that only forty per cent of the Dutch child population is exercising enough to stay healthy (Bernaards, 2011; Armstrong & Welsman, 2006). The group of active children is even smaller, at the lower levels of academic education (Tiessen-Raaphorst et al., 2010; Boonstra & Hermens, 2011). Breedveld K. (as cited in Boonstra & Hermens, 2011) stated that students in higher academic levels (pre-university and higher) are more physically fit compared to their peers at lower academic levels (pre-vocational). Especially students in the lowest levels of pre-vocational education which are more practically oriented, for example basic vocational and mixed practice vocational education, are suffering from high inactivity rates (Lucassen, Wisse, Smits, Beth & Werff. van der., 2011). Even during physical education lessons, a smaller amount of students at pre-vocational level is active, compared to pre-university level students (Lucassen et al., 2011). It appears that twelve year old pre-vocational students are most unlikely to be physically fit.

Physical activity and executive function are both located in same brain areas (Diamond, 2000; Pangelinan et al., 2011). Regular physical activity on a moderate to vigorous intensity has a relation with physical fitness (Rowland & Freedson, 1994). This is one of the reasons that a relation between physical fitness and executive function is assumed. According to (Best, Miller, & Jones, 2009; Best, 2010) , there are at least three general pathways at which aerobic exercise may facilitate executive functioning in children: (1) the cognitive demands inherent in the structure of goal-directed and engaging exercise, (2) the cognitive engagement required to execute complex motor movements and (3) the physiological changes in the brain induced by aerobic exercise. Executive function refers to mental processes which involve uptake and absorption of information, learning and thinking (Anderson, 2002). Executive functions contain goal directed behaviour, planning, inhibition, set shifting, attention and working memory (Anderson, 2002).

Physical fitness was found to relate to executive function in healthy children (Sibley & Etnier, 2003) (Vuijk, Hartman, Mombarg, Scherder, & Visscher, 2011). An increase of physical fitness relates to an improvement of executive function in elementary and secondary school children (Sibley & Etnier, 2003; Tomporowski, Lambourne, & Okumura, 2011). More complex physical activity relates to a larger improvement in cognitive skills (Vuijk et al., 2011; Wassenberg et al., 2005). Talented sport athletes have better planning skills compared to their classmates (Jonker, Elferink-Gemser, Toering, Lyons, & Visscher, 2010). Another important finding, is that, in general pre-university students had better planning skills compared to their pre-vocational peers (Jonker et al., 2010). However, talented sport athletes at pre-vocational level scored better on aspects of planning compared to their non-sportive pre-university level students (Jonker et al., 2010). This implies that sport activity plays an important role in the development of self regulation skills and may bring pre-vocational level and pre-university level on executive function closer together.

In general, there seems to be a relation between physical fitness and executive function (Tomporowski, Lambourne, & Okumura, 2011). Where physical fitness includes aspects of body composition, endurance capacity, strength and speed (Davis et al., 2000). A part of physical fitness is aerobic fitness, this was found to related to planning (Davis et al., 2007), inhibition (Hillman, Buck, Themanson, Pontifex, & Castelli, 2009; Buck, Hillman, & Castelli, 2008), attention and working memory (Niederer et al., 2011). Aerobic fitness may shape cognitive processes and their neural underpinnings (Hillman et al., 2009). Considering the aspect of cardio-vascular fitness, also an aspect of physical fitness, Van Dusen, Kelder, Kohl, Ranjit, & Perry (2011) showed a positive relation with academic performance, independent of other socio-demographic and other fitness variables in school children. The evidence toward the relationship between strength and executive function is limited but present in children (Van Dusen et al., 2011). Running speed was found to relate to learning and memory (Winter et al., 2007).

The purpose of this study was to investigate the relationship between physical fitness and executive function in first year pre-vocational students. These are children between the ages of twelve and fourteen years who are in the pre-vocational level of Dutch education for typical developing children. No previous research was done, according to the author’s knowledge, on this specific group of students. It was hypothesized that a total higher physical fitness would relate to higher scores on the four different executive function tasks. A relation between physical fitness to planning (Davis et al., 2007), inhibition (Buck et al., 2008) and working memory (Hillman, Castelli, & Buck, 2005) was expected according to previous research. Educational level itself can also be seen as a measure of executive function. Therefore, the additional purpose of this study was to determine if level of education was related to physical fitness. TL students are expected to perform better than BB students on both physical fitness and executive function scores. There may be different relations between physical fitness and executive function in both groups. This study was performed to increase the understanding in the relationship between physical fitness and executive function skills in pre-vocational students. Each tested child participated in a series of physical fitness tests and four tests to measure aspects of executive function.

The relevance of improving executive functioning in children, lies in the world of education. Especially executive functions like planning, inhibition and self-monitoring seem crucial in the school years toward academic achievement (Eslinger et al., 1996; Elferink-Gemser, Kannekens, Lyons, Tromp, & Visscher, 2010). Considering that physical fitness may be related to those aspects of executive function, it may also relate to school performance in children. Marsh & Kleitman (2003) found that athletic sport participation is positively related to cognitive skills, such as self-concept and academic grades. Physical fitness is far more important than just health related issues. Therefore, it may be interesting for local and national governments to improve the physical fitness of their youth. The most vulnerable group is the 12 to 17 year old pre-vocational students. These children may benefit the most by improving their physical fitness to improve their executive function skills.

Method

Participants.

Two hundred and twenty eight first year Dutch pre-vocational students (males=104) between the ages of 11 and 14 (mean=12.7 yr, SD=.62 yr) were recruited from four schools in the Netherlands, to participate in this study. One hundred and eighty six students completed all tests and their results were used for analysis. Ninety-two students were in the pre-vocational-theoretical practice level (TL) (males= 48) and another 94 were in the pre-vocational-basic vocational level (BB) (males= 45). Pre-vocational student are in the lowest level of Dutch secondary school education. Within pre-vocational education there are four levels. In this study the students came from the highest level (TL) and the lowest level (BB). TL students are more theoretical educated compared with the BB students. BB students are more practical and vocational focus. None of the students in the sample received special education services related to cognitive or physical disabilities. All participating schools gave consent and students were informed by letter.

Fitness testing.

The European Physical Fitness Test Battery (Eurofit) was used to measure aspects of physical fitness (van Mechelen et al., 1991). For this study, the variables aerobic capacity (shuttle-run), muscle strength (standing broad jump) and speed (10x5m run) were used to compute a total physical fitness (TPF) score. The shuttle-run test was performed on a 20-m track with a starting speed of 8.0 km/h (Leger & Lambert, 1982). Participants received continuous acoustic signals in a given frequency as pacing signals. The running speed was increased by 0.5 km/h at 60 second intervals, until exhaustion was reached. The stage reached was the end score on aerobic capacity. The distance jumped from standing, in centimetres, was used as end value for muscle strength (van Mechelen et al., 1991; Halme, Parkkisenniemi, Kujala & Nupponen, 2009). The test was measured twice and the best result was used for analysis. Speed was measured by ten times five meter run, in seconds (van Mechelen et al., 1991). All three the tests were planned in one physical education lesson that ended with the shuttle run. These tests are valid and reliable assessment for measuring physical fitness for ages between twelve and sixteen. All three aspects of the physical fitness test, except the shuttle-run test(r=0.68) for boys, had a validity of r=0.75 (Vrijkotte, Vries, de. & Jongert, 2007). The fitness tests were completed during a regular, scheduled physical education class and administrated by the researcher to ensure consistency.

Executive function tests.

The participants had to perform four different executive function tests measuring inhibition, visual working memory, planning and cognitive flexibility.

Inhibition was measured with the stroop colour/word test (Buck et al., 2008). In all three conditions (word, colour, and incongruent colour- word pairs) the participants had 45 seconds to read out aloud as many items as possible. At the word condition they had to read the names of the colours, the colour conditions the colours and at the incongruent conditions they had to read the colour in what the colour name was written. The number of correct items was the final score in each condition. Subsequently an interference score of inhibition was calculated by subtracting the colour-word score from the colour score. The interference score was used for analysis (Buck et al., 2008).

Working memory was measured by the visual memory span (Conway et al., 2005). The participants had to repeat a path of increasing length, which the instructor showed them on a card with eight squares. There were two paths of same length and when two paths of the same length were wrong the test was stopped. This test contains two cards for a forward and backward memory span. In the forward condition, the students had to repeat seven lengths that the instructor showed. In the backward condition they had to repeat the path in the opposite direction for six different lengths. Each length was counted if the paths were correct (Conway et al., 2005). A partial sum score was calculated by submitting each length score to the total score. The total score was divided by the maximum score on the card as the final score. (Conway et al., 2005).

The Tower of London was used to measure the executive function aspect of *planning* (Krikorian, Bartok & Gay, 1994; Kaller, Unterrainer, & Stahl, 2012). There were three beads (red, blue and yellow) on a plate with three pegs of increasing height. The participants had to move the beads by a given number of steps, to the finishing position. The restrictions: they could only move one bead at a time; the shortest peg could only handle one bead, the middle peg two beads and the longest peg three beads. Each of the twelve items had to be performed correctly in a maximum of three trials. As soon as three items in a row were wrong the test was stopped. The sum of scores of the items (four minus the number of trials used to complete item) was used for analysis. Also the time between start and the beginning of movement (decision time) and the execution time of the correct trial, was used for analysis (Kaller et al., 2012).

Cognitive flexibility was measured by the trail making test (Liu-Ambrose et al., 2010). With this test, the participants were given two cards with numbers and letters randomly spread over each card. The first card (part A) contained the numbers 1 to 25. The students had to draw a line between the increasing numbers in sequence. The second card (part B) had the numbers 1 to 13 and the letters A to M. The students had to draw a line from 1 to A to 2 to B etc. till M. The time to finish each part was used as a score. Cognitive flexibility was measured by subtracting the time of part A from the time of part B. Smaller difference means a better score (Sanchez-Cubillo et al., 2009).

Statistical analyses.

All analyses were performed using SPSS version 17.0 windows (SPSS inc. Chicago, Illinois).

Relationships between the three aspects physical fitness were investigated with Pearson correlations. If the correlations were medium to strong it was seen as possible to create a total physical fitness variable. Also Pearson correlations between the TPF and the executive functioning tasks were investigated.

The three aspects of physical fitness were divided into three division (low-: 1, middle-: 2 and high-: 3 fit) based on the achieved scores of the total group (Table 1) (Joshi, Bryan, & Howat, 2012; Le Masurier & Corbin, 2006). For each student, the achieved division score of the three physical fitness tests were added to each other to create a total physical fitness score (TPF). This procedure, of calculating division scores and calculate a TPF score, was also done at the BB and TL level.

The main purpose of this study was to investigate the relation between physical fitness and executive functioning. This was done with an independent-sample t-tests of the total pre-vocational group. Group differences were computed between the low fit group (Lf) (N: 45), middle fit (MF) (N:91) and the high fit group (HF) (N: 50). Also a more extreme comparison was made between the lowest fit group (LF2)(N: 29) and the highest fit group (HF2) (N: 24) (Hillman et al., 2005) of the total physical fitness score on the executive function tests. Also effect sizes were calculated for the significant results ($r \leq .1$: small, $r = .3$: medium and $r \geq .5$: large)

Mean scores and standard deviation for each executive function variable and the three aspects of physical fitness were calculated for the pre-vocational group in total, for both the pre-vocational groups (TL and BB) and gender. An independent sample t-test was done to conduct group differences of BB and TL on executive functioning. Effect sizes of the significant results were calculated.

Since the level of education itself can be seen as a measure of cognitive function, a comparison between BB and TL on physical fitness was performed as additional purpose. No significant effect of age and gender were found, therefore a MANOVA test was used to explore the relationship between the level of education with the total fitness variable and the three separate physical fitness variables.

Table 1. Division classification in three groups for the three physical fitness variables N: 186

	Three divisions total group		
	Low 1[b]	Middle 2[c]	High 3[d]
standing broad jump (cm)	< 134	134-158	>158
Ten times five meter run (s)	>22.9	20.,9-22.9	<20.9
Shuttle-run [a]	<4	4-6	>6

[a] stage reached at shuttle-run
[b] N: TL: 14 BB: 32
[c] N: TL: 52 BB: 40
[d] N: TL: 29 BB: 22

Findings on pre existing conditions

Relationship between physical fitness and executive function

Pearson correlations between the physical fitness variables were found to ensure the possibility to construct a total physical fitness (TPF) score (Table 2). A medium till strong relationship was found between the physical fitness variables.

Table 2. Correlations between the physical fitness variables.

Fitness variables		
Ten times five meter run	-0.608*	
Shuttle-run	0.428*	-0.533*
Fitness variables	Standing broad jump	Ten times five meter run

**p=<0.05*

In table 3, Pearson correlations between the TPF and the executive function test were shown. Correlations between the total physical fitness variable and inhibition and execution time of the planning task were found to be significant.

Table 3. Correlations between the Total physical fitness variable and executive function scores.

Total physical fitness	inhibition	working memory forward	working memory backward	total points planning task	decision time planning task	execution time planning task	cognitive flexibility
Pearson cor.	.176 *	0.112	0.131	0.081	0.01	-0.214*	-0.112
Sign. (2-tailed)	0.015	0.126	0.071	0.265	0.922	0.042	0.124
N	186	186	186	91	91	91	186

**p=<0.05*

Results

Level of physical fitness and executive function scores

Comparison between the low fit (Lf) and middle fit (MF) group of students, revealed relations between the TPF score with working memory backward (t (136)=1.260,p<0.05 r=.11). MF students were scoring better than the LF students. Comparing the MF with the high fit (HF) student group revealed a relationship with inhibition (t (141)=2.548, p<0.05 r=.21). MF students had the best inhibition score. Mean scores with standard deviation of the significant results between the total physical fitness (TPF) of the LF, MF and HF groups are shown in Figure 1.

A comparison between the HF and LF group of students, revealed relations between the TPF score with execution time of the planning task (t (46)=2.236, p<0.05 r=.31), working memory backwards (t (95)=-2.141, p<0.05 r=.24) and inhibition (t (95)=-2.208, p<0.05 r=.22). Except on inhibition, HF students perform better compared with the LF students on the executive function tasks.

A more extreme comparison between the lowest fit (LF2) and highest fit (HF2) students of the TPF also revealed a relationship between execution time of the planning task (t (14.779)=2.203, p<0.05 r=.45) and inhibition (t (53)=-2.282, p<0.05 r=.30). In addition, a relationship between working memory forward (t (53) =-2.125, p<0.05 r=.28) and cognitive flexibility (t (53) =2.217, p<0.05 r=.29) was found on TPF. Students in the HF2 group perform better on the executive function tasks, except for inhibition compared with students in the LF2 group. Mean scores with standard deviation of the significant results between the TPF of the HF2 and LF2 groups are shown in Figure 1.

Within the different levels of education, BB and TL, no relationships were found between TPF and executive functions. Mean scores and standard deviation between the different educational levels and the physical fitness groups on executive functions are shown in Figure 1.

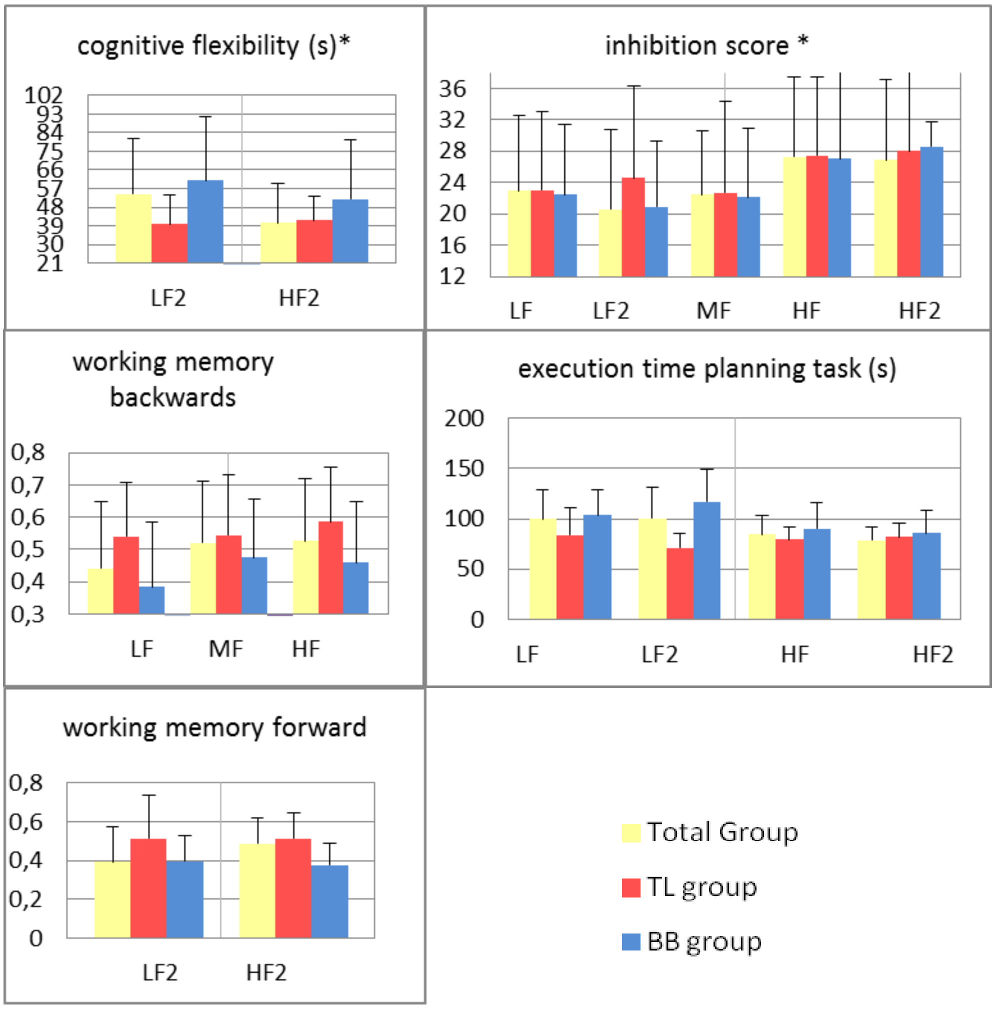

Figure 1 Mean scores and standard deviation of the significant results found in the fit group comparison.

N: total group: *LF (N: 45),MF (91) and HF(N: 50) and LF2 (N: 29) and HF2(N: 24).* ***TL:*** *LF(N:24),MF (N:44) and HF(N:24): and LF2 (N:14) and HF2(N:15) fit group comparison results t-test and* ***BB****: LF (N:27),MF (N:41) and HF(N:26) and LF2 (N:15) and HF2(N:11)*

N Execution time planning task: total group*: LF (N:21), MF (N: 43), HF (N:27), LF2 (N:12), HF2 (N:12).* ***TL****: LF (N:10), MF (N: 19), HF (N:14), LF2 (N:4), HF2 (N: 8).* ***BB****: LF(N:14), MF (N:21), HF (N:13), LF2 (N: 6), HF2 (N:3).*

** Lower scores are better*

Effect of level of education and executive function and physical fitness

In Table 4 the mean scores and standard deviation of the executive function variables are shown for the group in total, the two educational levels and gender. Better mean scores of the students at the academic level TL reveal higher performances compared to the students of BB on executive function. An independent t-tests revealed a relationship between academic level and executive function. TL students perform significantly better on the execution time of the planning task (t (89) =4.060, p<0.05 r=.39), working memory forward (t (187) =-4.452, p<0.05 r=.31), working memory backwards (t (187) =-4.296, p<0.05 r=.30) and cognitive flexibility (t (175.542) =4.302, p<0.05 r=.31). Students at BB level had a longer decision time (t (89) =3.130, p<0.05 r=.31) compared with the TL students.

Table 4. Mean scores and standard deviation for executive function variables for the different academic groups and gender.

	Total group	TL total	Mean (SD)	Mean (SD)	BB total	Mean (SD)	Mean (SD)
Executive function	Mean (SD)	Mean (SD)	Female	Male	Mean (SD)	Female	Male
Total points planning	28.6 (3.1)	28.5 (3.1)	27.9 (3.1)	29.0 (3.1)	28.7 (3.2)	28.9 (3.0)	28.5 (3.4)
N	186	92	44	48	94	49	45
Decision time planning (s)*	55.9 (25.9)	47.3 (22.0)	38.3 (16.6)	54.5 (23.4)	63.6 (27.0)	61.1 (26.6)	66.7 (27.8)
N	91	43	19	24	48	27	21
Execution time planning (s)*	90.2 (22.2)	81.0 (18.8)	84.1 (22.9)	78.6 (14.8)	98.5 (21.9)	104.3 (23.0)	90.9 (18.1)
N	91	43	19	24	48	27	21
Working memory forward*	0.41 (.17)	0.47 (.19)	0.46 (.2)	0.48 (.18)	0.35 (.15)	0.37 (.17)	0.34 (.13)
N	186	92	44	48	94	49	45
Working memory backward*	0.50 (.19)	0.56 (.18)	0.54 (.18)	0.57 (.19)	0.44 (.20)	0.42 (.19)	0.47 (.19)
N	186	92	44	48	94	49	45
Cognitive flexibility *[a]	48.3 (21.9)	41.7 (18.2)	41.3 (17.0)	42.1 (19.4)	54.9 (23.4)	53.8 (22.7)	56.0 (24.3)
N	186	92	44	48	94	49	45
Inhibition score [a]	23.89 (9.3)	24.22 (8.8)	21.8 (8.8)	26.4 (8.3)	23.56 (9.8)	23.31 (9.3)	23.84 (10.4)
N	186	92	44	48	94	49	45

[a] lower score is better

[*] Significant differences between TL and BB

The level of academic achievement can also be seen as a measure of cognitive function. Mean scores and standard deviation of the physical fitness variables for the different academic groups were plotted in table 5. A MANOVA analysis revealed a relationship between academic level and the ten times five meter run F (1.195)=7.108, p=0.008. TL scored higher on the ten times five meter run compared to BB.

Table 5. Mean scores and standard deviation for the physical fitness variables for the different academic groups

	Total group		TL group		BB group	
Physical fitness variable	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N
Standing broad jump (cm)	147.68 (24.9)	186	149.98 (23.5)	92	145.4 (26.2)	94
10*5 m run (s) [a]	22.1 (2.6)	186	21.5 (2.3)	92	22.7 (2.8)	94
Shuttle run [b]	5.3 (2.1)	186	5.5 (1.9)	92	5.2 (2.3)	94

[a] lower score is better

[b] Stage reached at shuttle-run

Discussion

The purpose of this study was to examine the relationship between physical fitness and executive function in first year Dutch pre-vocational students. Relationships between total physical fitness (TPF) and important aspects of executive function are found. Pearson correlations show the relationship between TPF and inhibition and execution time of the planning task. Comparing the low fit (LF) and middle fit (MF) group of total physical fitness reveals a relationship to working memory backward and the MF and high fit (HF) group reveals a relationship to inhibition. A comparison of the LF and HF group of TPF revealed relations with execution time of the planning task, working memory backward and inhibition. Looking at a more extreme comparison of the low fit 2 (LF2) and high fit 2 (HF2) groups of TPF, relationships were found with execution time of the planning task, inhibition, working memory forward and cognitive flexibility. The additional purpose of this study was to explore the relation between aspects of physical fitness and level of education. Mean scores reveal that TL students are scoring better on all three aspects of physical fitness and execution time of the planning task, working memory forward/backwards and cognitive flexibility compared with BB students. Students in a higher level of education, run significant faster on the ten times five meter run.

None of the participants had both physical fitness test and executive function tests on the same day. All executive function tests were performed before the physical fitness tests were done. No differences between the circumstances on the four schools were found. In all schools there was a separate room for each executive function task to create a quiet testing environment. The data was, therefore, reliable. All students were about the same age and the gender distribution was equal in both groups. The results on the shuttle-run test are comparable with the norm scores, of their age, constructed by van Mechelen et al. (1991).

Pearson correlations between the three physical fitness variables were computed to ensure the possibility of constructing a total physical fitness variable. All correlations have a medium to large effect on each other. Also, in theory a relationship between the shuttle-run, the standing broad jump and the ten times five meter run was expected (Halme et al., 2009; Davis et al., 2000). Therefore, it was justified to create a total physical fitness variable.

Correlations between the total physical fitness variable and inhibition and execution time of the planning task were found. The effect sizes of those two correlations are small. A comparison of the LF, MF and HF group revealed several positive and one negative relation with aspects of executive function. There was a positive relationship between TPF in the LF and MF group comparison on working memory backwards. A negative relationship between the MF and HF group of the TPF on inhibition was found. However, both results have a very small effect size.

Comparing the HF and LF group of TPF, it was found that students with higher physical fitness levels performed better on working memory backwards and execution time of the planning task. These results have medium to strong effect size and are in agreement with the expectations. Davis et al. (2007) found a relationship with high physical fitness and scores of the Cognitive Assessment System (CAS) planning task which is comparable with the result found in the present study. Both Hillman et al. (2005) and Niedere et al. (2011) conducted a different type of working memory which only includes a forward conditions. But they also found a positive effect of fitness on working memory. No explanation can be found for the backward working memory condition.

Buck et al. (2008) found a positive relationship between physical fitness and inhibition measured by the Stroop task. The same positive relationship was found by Hillman et al. (2009) on the Flanker inhibition task. Both studies of Buck et al. (2008) and Hillman et al. (2005), used only the shuttle run test as fitness variable. In the present study, however, a negative relationship between inhibition and physical fitness was found. This result is in contrast with the assumption that higher physical fit children perform better on inhibition. A possible explanation for this could be the large spread of standard deviation of the total group. Also research by (McGivern, Andersen, Byrd, Mutter, & Reilly, 2002) found that, at the onset of puberty there is a decline in performance of the match to sample task (short working memory and inhibition). It may be that the high fit children are already in the onset of puberty in comparison with the low fit children. No data is present about the status of maturation of the children, therefore this is only a possible explanation.

Independent t-tests on the HF2 and LF2 group of TPF were carried out, to explore if the rate of physical fitness was important for the executive function scores. It was found that beside the execution time of the planning task and inhibition score, which were also found in the LF and HF group comparison, also working memory forward and cognitive flexibility are related to total physical fitness. Pre-vocational students with high physical fitness levels scored better on the execution time of the planning task (Davis et al. (2007); Hillman et al. (2005)) and worse on the inhibition task. Higher physical fitness has also a positive relationship with working memory forward and cognitive flexibility. The positive relation with working memory forward was also found by Hillman et al. (2005). The only study found on cognitive flexibility, was performed on elderly Japanese. These results confirm a positive effect of physical fitness to cognitive flexibility (Hirota et al., 2010).

Within TL and BB group, no significant relations were found on total physical fitness and executive function. The mean scores, however, reveal a positive trend toward total physical fitness and some executive function tasks. Higher physical fitness by TL students reveals a trend to positive effect with working memory forward and cognitive flexibility. Higher physical fitness by BB students also reveals a positively affect with the execution time of the planning task and working memory backward.

Mean scores of the executive function test show that TL students perform significant better on most tasks than BB students. This with exception of the decision time of the planning task where BB student perform significant better. Also on the total points of the planning task and inhibition BB students perform better, but these differences are not significant. This suggests that educational level is an important factor on the results on the executive function scores. Elferink-Gemser et al. (2010) and Jonker et al. (2010) already found that the level of academic has a relationship with executive function and self-regulation skills. However, they only compared the different education levels of pre-university and pre-vocational. Even within the pre-vocational level there appears to be a relationship between physical fitness and executive functions. It also appears that TL students are better performing on both physical fitness and executive function compared to BB students. This means that, in a pre-vocational setting there should be a higher priority to improve physical levels of students as this has a relationship on their executive function abilities. Looking at the different relations found in this study, TL and BB students may need different types of physical training to improve the same skills.

The level of academic seems to be explained by or has a relationship with executive function. Therefore also a relationship between level of academic and physical fitness is thought to exist. It is found that TL students surpass their counterparts at BB level on ten times five meter run. There is also a trend toward a higher stage reached at the shuttle-run test and further jumping in the standing broad jump test. This means that academic level has a relationship with the physical performance of the students, even in pre-vocational level. Students of higher educational levels, for example pre-academic level, are physically fitter compared to their pre-vocational counterparts (Boonstra & Hermens, 2011).

A limitation of this study was that ninety-eight students were not able to solve every stage of the planning task. As a consequence of that, no total decision time and total execution time could be calculated for those students. Therefore, only ninety-one students were used for analysis with total physical fitness on the planning task. This suggest that the tower of London to measure an aspect of planning is not totally appropriate for this group of students. Another limitation of this study was the influence of motivation on the test scores. This was especially the case at the shuttle-run test. Demotivation, however, is one of the main characteristics in pre-vocational education. To prevent for this effect, one of the researchers run with the participants. A very strong part of this research was the distribution of the sample size. In both academic layers there was an equal number of boys and girls. For further research, it will be beneficial to perform an intervention study of aerobic fitness, to discover which executive function variables are mostly affected by physical fitness training. It may also be interesting to investigate if there is a different effect of physical fitness training between the

BB and TL levels. It could be that BB students are more sensitive to higher physical fitness compared to TL students.

Conclusion

In pre-vocational students a relationships between total physical fitness and planning and inhibition was found. Independent t-test found that children in the high fit group of total physical fitness also had better scores on the execution time of the planning task, working memory forward/backward and cognitive flexibility. In contradiction, physically fitter fit students performed worse on the inhibition task. Students at TL level scored better on the physical fitness variables ten times five meter run compared with their counterparts at BB level. The present study proved a relationship between total physical fitness and aspects of executive function in first year pre-vocational students.

Acknowledgements

I would like to Rob Bisseling (NISB) and Chris Visscher (RUG) thank for the support and help in this master research. Further I would also like to thank Esther Hartman (RUG) and Anneke v.d. Niet (RUG) for reading and giving responses to previous drafts and the four schools for their participation in this research.

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