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The Relationship between Academic Achievement and Physical Fitness in Preadolescent Children

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Abstract

The purpose of the study was to determine whether students differ in terms of their physical fitness according to their academic achievements in mathematics, language (Slovene) and PE. The sample comprised 467 participants: 250 males and 217 females. In order to assess physical fitness levels, eight different tests from the Eurofit test battery were conducted. The academic performance of children was defined on the basis of three criteria: final grades in mathematics, final grades in Slovene language and final grades in the subject of sports. An independent t-test and a multiple regression analysis were performed to determine the relationship between various physical fitness tests and academic achievement. The most important finding of our study is that physical fitness is related to academic achievement in preadolescent children. Children with better academic achievements performed better in most physical fitness tests than peers who had poorer academic performance.

Key words: *childhood; motor abilities; school grades.*

Introduction

Recent research suggests that there is a close reciprocal link between academic achievement and children's health. Physical activity is one of the key factors that ensure human health at all stages of life (Hillman, Erickson, & Kramer, 2008; Global Recommendations, 2011). Basch (2011) also highlights it as one of the most important health-related factors influencing academic achievement. Education and health experts

have always agreed that children who are physically active and physically fit are better at school (Castelli et al., 2007).

There is scientific evidence that children's physical activity is related to their physical fitness (Haugen et al., 2013; Martínez-Vizcaíno & Sánchez-López, 2008). As a rule, regular physical activity which is performed with appropriate intensity, which is frequent enough and in accordance with the recommendations, ensures good physical fitness (Rowland, 2007; Global Recommendations, 2011). Physical fitness is represented by various properties that a person has or can achieve (Caspersen et al., 1985) and consists mainly of cardiorespiratory fitness, muscle strength, speed, agility, movement coordination, flexibility, balance and body composition (Castro-Piñero et al., 2010; Pišot & Planinšec, 2005; Ruiz et al., 2009).

Physical activity not only results in better physical fitness, but also in better cognitive performance and academic achievement (Kwak et al., 2009). Research shows that there is a positive link between physical fitness and academic achievement (Fedewa & Ahn, 2011; Ruiz-Ariza et al., 2017). Students with better physical fitness are more successful than their peers with poorer physical fitness (Wittberg et al., 2010), which is true for both urban and rural children (Planinšec & Kokol, 2017).

Numerous studies have proven that academic achievement is positively related to the level of physical fitness. Among all components of physical fitness, a higher level of academic achievement is associated primarily with better cardiorespiratory fitness, speed, and agility (Esteban-Cornejo et al., 2015; Torrijos-Nino Martínez-Vizcaíno et al., 2014). Research also shows that students with better cardiorespiratory fitness achieve better academic results (Davis & Cooper, 2011; Dwyer et al., 2001) and better scores in standardized tests (Van Dusen et al., 2011; Wittberg et al., 2010; Davis & Cooper, 2011) compared to peers with a lower rate of cardiorespiratory fitness. The abovementioned studies also show that in addition to cardiorespiratory fitness, other components of physical fitness are also related to academic achievements, especially muscle strength and muscle endurance, but to a lesser extent. Voss et al. (2011) find that in children, differences in aerobic fitness were associated with cognitive control. As a result, children with lower physical fitness were less successful in performing academic tasks compared to peers with higher physical fitness. On the other hand, there are also studies that find that the relationship between physical fitness and academic achievement is negligible (Daley & Ryan, 2000), statistically insignificant (Ardoy et al., 2014) or even negative (Tremblay et al., 2000).

Physical fitness is most closely connected with achievements in mathematics and languages (Fedewa & Ahn, 2011; London & Castrechini, 2011). Van Dusen et al. (2011) and Wittberg et al. (2010) state that cardiorespiratory fitness is closely associated with achievements in mathematics and reading. Morales et al., (2008) report that better motor coordination is associated with better performance in linguistic and mathematical skills. Planinšec and Fošnarič (2006) found that learning achievements

in languages, mathematics, science, social sciences and general academic performance are positively related to physical activity. Therefore, in associations with physical fitness, primarily the areas of mathematics and language stand out. Among the components of physical fitness, cardiorespiratory fitness and muscle endurance were most closely associated with performance in mathematics and reading exams (Bass et al., 2013). In older students, better achievement in physical fitness is associated with better grades in mathematics and social science compared to students with lower physical fitness; among the components of physical fitness, muscle strength and muscle endurance were the most important features (Coe et al., 2013).

Researchers have highlighted quite a few important factors in the form of different physiological and developmental mechanisms as reasons for the links between physical activity, cognitive processes, and academic achievement (Haapala, 2013). Areas of the brain involved in movement and learning are closely connected (Trudeau & Shephard, 2008). Regular physical activity can strengthen these neural connections, while also affecting certain structural changes in the brain (Voss et al., 2011). Learning and using complex physical skills stimulates the prefrontal cortex, which is active in problem solving, and can consequently improve learning efficiency (Tomporowski et al., 2008). Furthermore, physical activity through various mechanisms raises the level of general central nervous system stimulation, which affects the child's attention in class. Under certain conditions, physical activity should stimulate cognitive processes, especially executive function, which is crucial for concentration, mental planning and organization, and problem solving (Hillman et al., 2008; Planinšec & Pišot, 2006; Voss et al., 2011). Some studies have shown that physical activity increases blood circulation speed in the brain and affects changes in brain neurotransmitters, especially elevated levels of endorphins, which in turn reduces stress, improves mood, and leads to a calming effect after exercise. All of these can have positive effects on cognitive functions and academic achievement (Hillman et al., 2008).

Physical activity affects many physiological changes in the brain associated with cognition and learning: increased growth of brain capillaries, increased blood flow to the brain, increased oxygen supply to the brain, increased synaptic plasticity, increased levels of brain-derived neurotrophic factor (BDNF), growth of neurons in the hippocampus (learning and memory centre), increased levels of neurotransmitters, especially adrenaline and endorphins, increased neurogenesis, increased neural network density, and improved neuroelectric functionality (Hillman et al., 2008; Haapala, 2013; Planinšec & Kokol, 2017).

Research problem

Research shows that there is a positive link between physical fitness and academic achievement (Ruiz-Ariza et al., 2017). Students with better physical fitness are more successful than their peers with poorer physical fitness (Wittberg et al., 2010). Given

the findings obtained so far, it is worthwhile to study the relationship between academic achievement and physical fitness in more detail, and above all, to determine the current situation in this field in Slovenia.

Methods

Aim

Therefore, we conducted a cross-sectional study on Slovenian children with the main purpose of determining whether students differ in terms of their physical fitness according to their academic achievements in mathematics, language (Slovene) and PE. We also wanted to determine which components of physical fitness are mostly associated with academic achievements, the strength of these connections, and the contribution of individual components of physical fitness in understanding the potential impact on academic achievements. Based on several findings, we hypothesized that students with better academic achievements will have better physical fitness, especially cardiorespiratory fitness and strength, compared to peers who are less successful academically.

Research sample

Informed parental consent was obtained from all fourth-, fifth- and sixth grade students (n = 672) enrolled across eight schools. Any student who did not complete all of the Physical fitness tests, or whose Academic achievement in Math, PE or mother tongue was missing, was excluded from the study. After these exclusions, the study sample comprised 467 participants: 250 males (M age = 10.25, SD = .925) and 217 females (M age = 10.30, SD = .928). Each of the participants completed eleven physical fitness tests. Math, PE, and Slovene language grades for participants were assigned by the students' teachers, according to the standards written in the curriculum.

Instruments and procedures

Physical fitness testing. In order to assess physical fitness levels, eight different tests from the Eurofit test battery (Adam et al., 1993), that cover explosive leg power (standing broad jump), repetitive trunk strength (sit-ups), lower back flexibility (sit and reach), dynamic balance (flamingo balance), speed of limb movement (plate tapping), agility (10x5-metre shuttle run), aerobic fitness (20-metre endurance shuttle run) and body mass index have been used. The Eurofit test battery has been used in various studies around the world and has proved to be suitable for children and adolescents (Tomkinson et al., 2007). In addition, Polygon backwards, Basketball compass drill and Rope jumps in 20 seconds tests were performed. The Polygon backwards test is a test of whole-body coordination, which has been used in many Slovenian studies and has proven to be very suitable for children (Jurak et al., 2013). Basketball compass drill is an agility and ball-handling skills test (Wood, 2010). Rope jumps in 20 seconds test

is a composite test for lower body strength endurance and upper-lower extremities coordination assessment. Measurements were carried out in spring 2013, always in the morning, in a specially equipped room. Complete testing lasted less than one hour per participant. Measurements were performed by specially trained measurers.

Academic Achievement assessment. Academic achievement can be determined by standardized national tests for academic achievement, literacy, knowledge of arithmetic, reading skills, subjective knowledge assessments by the participants, subjective assessments by the teachers or principals, grade point average, general academic achievement, and mathematics grades (Trudeau & Shepard, 2008). Reading skills, and especially the knowledge of mathematics in the early period of education are the most reliable indicators of general academic achievement, i.e. school performance in higher grades (Duncan et al., 2007). Therefore, we decided to define the academic performance of children on the basis of three criteria: final grades in mathematics, final grades in Slovene language and final grades in PE. According to the final grade, the subjects were divided into two groups: low performing (grades 1, 2, or 3) and high performing (grades 4, 5). Math, PE and Slovene language grades for each participant were obtained by students' teachers according to achieved standards at the end of the school year.

Data analysis

Descriptive statistics were calculated for each physical fitness variable for the Low performing and High performing groups. An independent t-test was used to determine the differences in physical fitness tests between the Low performing and High performing groups. Pearson product-moment correlation analyses were initially conducted on the three dependent variables (mathematics achievement, SLV achievement and PE achievement) and individual physical fitness tests. Next, a multiple regression analysis was performed to determine the relationship between various physical fitness tests and academic achievement in mathematics, SLV and PE.

Results

Descriptive statistics were calculated for each variable (Table 1) for the Low performing Math and High performing Math groups. In the Flamingo balance, 10x5-metre shuttle run, Polygon backwards, Basketball compass drill and Plate tapping tests, a lower value indicates a better result. An independent t-test was used to determine the differences between the Low performing and High performing Math groups.

The results show that the High performing Math group achieves statistically significantly better results in most physical fitness tests than the Low performing Math group. The only exceptions are the Plate tapping and Sit-and-reach tests, where the differences between the groups are not statistically significant

Table 1
Mean score by academic achievement in Math

Academic achievement in Math	Low performing Math	High performing Math
Flamingo balance	10.11	8.21**
10x5-metre shuttle run	22.81	22.07**
20-metre shuttle run	25.37	27.71**
Polygon backwards	17.02	15.76**
BMI	19.80	18.82**
Rope jumps in 20 seconds	23.46	26.81**
Basketball compass drill	14.38	13.41**
Sit-ups in 30 seconds	18.98	20.52**
Plate tapping	13.20	12.94
Sit-and-reach	18.05	18.37
Standing broad jump	151.03	158.17**

**Significantly different at $p < 0.01$; *Significantly different at $p < 0.05$

Table 2
Mean score by academic achievement in Slovene language (SLV)

Academic achievement SLV	Low performing SLV	High performing SLV
Flamingo balance	9.93	8.50**
10x5-metre shuttle run	22.75	22.18**
20-metre shuttle run	25.93	27.20**
Polygon backwards	16.85	15.98
BMI	20.30	18.71**
Rope jumps in 20 seconds	23.61	26.36**
Basketball compass drill	14.16	13.62
Sit-ups in 30 seconds	19.06	20.32**
Plate tapping	13.18	12.97
Sit-and-reach	17.37	18.64
Standing broad jump	151.87	156.99**

**Significantly different at $p < 0.01$; *Significantly different at $p < 0.05$

Descriptive statistics were calculated for each variable (Table 2) for the Low performing SLV and High performing SLV groups. The results show that the High performing SLV group achieves statistically significant better results in the Flamingo balance, 10x5-metre shuttle run, 20-metre shuttle run, BMI, Rope jumps in 20 seconds, Sit-ups in 30 seconds, and Standing broad jump than the Low performing SLV group. However, in the Polygon backwards, Basketball compass drill, Plate tapping and Sit-and-reach tests, the differences between the Low performing SLV and High performing SLV groups are not statistically significant.

Table 3
Mean score by academic achievement in PE

Academic achievement PE	Low performing PE	High performing PE
Flamingo balance	11.68	8.47**
10x5-metre shuttle run	23.50	22.12**
20-metre shuttle run	23.48	27.54**
Polygon backwards	20.68	15.26**
BMI	21.14	18.69**
Rope jumps in 20 seconds	20.53	27.08**
Basketball compass drill	15.06	13.62**
Sit-ups in 30 seconds	17.33	20.56**
Plate tapping	13.90	12.79**
Sit-and-reach	15.78	18.85**
Standing broad jump	139.42	158.89**

**Significantly different at $p < 0.01$; *Significantly different at $p < 0.05$

Descriptive statistics were calculated for each variable (Table 3) for the Low performing PE and High performing PE groups. The results show that the High performing PE group achieves statistically significantly better results in all physical fitness tests, and this is at the level of $p < 0.01$.

Pearson product-moment correlation analyses (Table 4) were initially conducted on the three dependent variables (mathematics achievement, SLV achievement and PE achievement) and individual physical fitness tests. Only the variables that correlated ($p < 0.01$) with either mathematics achievement, SLV achievement or PE achievement were included in subsequent regression analyses. The results of the correlation analyses indicated that four Physical fitness tests (20-metre shuttle run, Rope jumps in 20 seconds, Sit-ups in 30 seconds, Standing broad jump) were positively correlated with all three achievement test measures ($p < .01$). The mean scores for sit-and-reach were positively correlated with PE achievement ($p < .01$) and SLV achievement ($p < .05$), but were unrelated to Math achievement. Three Physical fitness tests (Flamingo balance, 10x5-metre shuttle run, BMI, Standing broad jump) were negatively correlated with all three achievement test measures ($p < .01$). Polygon backwards, Basketball compass drill, and Plate tapping were negatively correlated with PE achievement ($p < .01$) and SLV achievement ($p < .01$). In addition, the mean scores for Polygon backwards were negatively correlated with SLV achievement ($p < .05$). Finally, the mean scores for Basketball compass drill and Plate tapping were unrelated with SLV achievement ($p > .05$).

Next, a multiple regression analysis (Table 5) was performed to determine the relationship between various physical fitness tests and academic achievement in Math. With regards to Math academic achievement, the results from the analysis did reveal a significant relationship, (adjusted $R2=.104$, $F (11, 449) = 4.756$, $p = .000$), indicating

Table 4
Intercorrelations between variables for all participants

	1	2	3	4	5	6	7
Math achievement	_						
SLV achievement	.742**	_					
PE achievement	.294**	.295**	_				
Flamingo balance	-.220**	-.208**	-.301**	_			
10x5-metre shuttle run	-.231**	-.133**	-.377**	.390**	_		
20-metre shuttle run	.236**	.120**	.376**	-.277**	-.578**	_	
Polygon backwards	-.141**	-.111**	-.482**	.431**	.523**	-.458**	_
BMI	-.153**	-.196**	-.276**	.246**	.352**	-.392**	.387**
Rope jumps in 20 seconds	.208**	.154**	.309**	-.353**	-.387**	.355**	-.367**
Basketball compass drill	-.217**	-0.072	-.278**	.336**	.556**	-.466**	.379**
Sit-ups in 30 seconds	.209**	.135**	.357**	-.279**	-.461**	.488**	-.436**
Plate tapping	-.136**	-0.075	-.291**	.211**	.332**	-.255**	.365**
Sit-and-reach	0.051	.096**	.209**	-.157**	-0.082	-0.011	-.300**
Standing broad jump	.218**	.155**	.428**	-.411**	-.672**	.582**	-.625**

	8	9	10	11	12	13	14
Math achievement							
SLV achievement							
PE achievement							
Flamingo balance							
10x5-metre shuttle run							
20-metre shuttle run							
Polygon backwards							
BMI							
Rope jumps in 20 seconds	-.236**	_					
Basketball compass drill	0.062	-.272**	_				
Sit-ups in 30 seconds	-.324**	.387**	-.357**	_			
Plate tapping	-0.023	-.299**	.392**	-.301**	_		
Sit-and-reach	-0.025	.195**	-0.016	.130**	-0.060	_	
Standing broad jump	-.390**	.431**	-.461**	.510**	-.355**	.190**	_

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

that the physical fitness variables explain 10.4% of the variability of Math academic achievement. There was a significant effect for Flamingo balance, $p < .05$, $\beta = - 0.116$, indicating that greater Math academic achievement scores were associated with better dynamic balance (see Table 5). It should be noted that lower score in Flamingo balance test indicates better dynamic balance.

Table 5
Summary of multiple regression analysis for physical fitness variables predicting academic achievement in math

Variable	B	*SE* B	β
Flamingo balance	-0.027	0.012	-0.116**
10x5-metre shuttle run	-0.018	0.034	-0.035
20-metre shuttle run	0.019	0.012	0.102
Polygon backwards	0.022	0.012	0.118
BMI	-0.017	0.014	-0.067
Rope jumps in 20 seconds	0.008	0.005	0.076
Basketball compass drill	-0.033	0.021	-0.091
Sit-ups in 30 seconds	0.014	0.012	0.061
Plate tapping	-0.020	0.030	-0.035
Sit-and-reach	0.006	0.007	0.037
Standing broad jump	0.000	0.003	0.004

**$p < 0.01$; *$p < 0.05$; $R^2 = .104$, F (11, 449), p = .000

Table 6
Summary of multiple regression analysis for physical fitness variables predicting academic achievement in SLV

Variable	B	*SE* B	β
Flamingo balance	-0.034	0.011	-0.158**
10x5-metre shuttle run	-0.005	0.032	-0.010
20-metre shuttle run	0.002	0.011	0.011
Polygon backwards	0.020	0.012	0.115
BMI	-0.039	0.013	-0.164**
Rope jumps in 20 seconds	0.005	0.005	0.051
Basketball compass drill	0.005	0.020	0.014
Sit-ups in 30 seconds	0.006	0.012	0.029
Plate tapping	-0.024	0.028	-0.045
Sit-and-reach	0.012	0.007	0.084
Standing broad jump	0.001	0.003	0.020

**$p < 0.01$; *$p < 0.05$; $R^2 = .079$, F (11, 449), p = .000

In addition, multiple regression analysis (Table 6) was performed to determine the relationship between various physical fitness tests and academic achievement in SLV. With regards to SLV academic achievement, the results from the analysis did reveal a significant relationship (adjusted R2=.079, F (11, 449) = 3.484, p = .000), indicating that the physical fitness variables explain 7.9% of the variability of SLV academic achievement. There was a significant effect for Flamingo balance, $p < .01$, $\beta = -0.158$, and for BMI, $p < .01$, $\beta = -0.164$, indicating that greater SLV academic achievement scores were associated with better dynamic balance and lower BMI (see Table 6).

Table 7
Summary of multiple regression analysis for physical fitness variables predicting academic achievement in PE

Variable	B	*SE* B	β
Flamingo balance	-0.004	0.009	-0.020
10x5-metre shuttle run	0.007	0.026	0.018
20-metre shuttle run	0.021	0.009	0.138**
Polygon backwards	-0.039	0.009	-0.256**
BMI	-0.012	0.010	-0.057
Rope jumps in 20 seconds	0.003	0.004	0.041
Basketball compass drill	0.001	0.016	0.003
Sit-ups in 30 seconds	0.014	0.009	0.081
Plate tapping	-0.053	0.023	-0.112**
Sit-and-reach	0.010	0.005	0.083
Standing broad jump	0.002	0.002	0.048

**$p < 0.01$; *$p < 0.05$; $R^2 = .300$, F (11, 417), p = .000

A multiple regression analysis (Table 7) was performed to determine the relationship between various physical fitness tests and academic achievement in PE. With regards to PE academic achievement, the results from the analysis did reveal a significant relationship, (adjusted R2=.30, F (11, 417) = 16.214, p = .000), indicating that the physical fitness variables explain 30% of the variability of PE academic achievement. There was a significant effect for Polygon backwards, $p < .01$, $\beta = -0.256$, for 20-metre shuttle run, $p < .05$, $\beta = 0.138$, and Plate tapping, $p < .05$, $\beta = -0.112$, indicating that greater PE academic achievement scores were associated with better whole-body coordination, higher aerobic fitness and speed of limb movement (see Table 7). It should be noted that a lower Polygon backwards test score means a better whole-body coordination. In addition, lower Plate tapping test scores also mean better limb movement speed.

Discussion

The most important finding of our study is that physical fitness is related to academic achievement in preadolescent children. Children with better academic achievements performed better in most physical fitness tests than peers who had poorer academic performance.

This is consistent with the findings of some other studies (e.g., Fedewa & Ahn, 2011; Ruiz-Ariza et al., 2017; Wittberg et al., 2010). Assumptions that students with better academic performance will have better cardiorespiratory fitness and strength compared to less academically successful peers have been confirmed, but other components of physical fitness are also important for correlation.

Van Dusen et al. (2011), Fedewa and Ahn (2011), London and Castrechini (2011), and Wittberg et al. (2010) report on the links between achievements in Mathematics and physical fitness in their research. A more detailed analysis showed that variables measuring balance, speed, agility, cardiorespiratory fitness, movement coordination, endurance, and explosive power were statistically significantly related to Mathematics grades. Similar findings can be found in some other studies. Bass et al. (2013), Castelli et al. (2007), Fedewa and Ahn (2011), Van Dusen et al. (2011), and Wittberg et al. (2010) report on the links between Mathematics and cardiorespiratory fitness. Bass et al. (2013) and Coe et al. (2013) report on the association between Mathematics and muscle endurance, and Guillamón et al. (2020), Niederer et al. (2011), and Morales et al. (2011) report on the link between Mathematics and movement coordination. This is not surprising, as better coordination of movement is associated with better memory (Niederer et al., 2011). In addition, grades in Mathematics are also associated with a variable for measuring balance, which has already been established by Niederer et al. (2011). Our findings are consistent with data from studies in preadolescent children, which show that in addition to cardiorespiratory fitness, other areas of physical fitness, such as balance, coordination and ball skills, are associated with cognitive benefits in children (Livesey et al., 2006; Niederer et al., 2011; Voelcker-Rehage, 2005). There are no statistically significant links between Mathematics and flexibility, which was also found by Castelli et al. (2007), or speed of limb movement. The latter is somewhat surprising, as speed of movement is mostly associated with academic performance (Ruiz-Ariza et al., 2017).

Our finding that there is a positive relationship between the grade in a language and physical fitness is also consistent with previous research, although it is not as pronounced as in Mathematics. We found that balance, speed, cardiorespiratory fitness, muscle endurance and explosive power are the most important components of body fitness for association with academic achievement. Fedewa and Ahn (2011), Van Dusen et al. (2011), and Wittberg et al. (2010) report on the links between language performance and cardiorespiratory fitness, and Bass et al. (2013) and Coe et al. (2013) report on the links between language and muscle endurance. We have not proved the link between flexibility and learning achievements in languages – Castelli et al. (2007) reported similar findings – and we could neither link coordination and speed of limb movement, which, according to Ruiz-Ariza et al. (2017), is somewhat surprising.

The results of this study showed that students in the High performing PE group were better in all physical fitness variables than students in the Low performing PE group. This was expected, as a higher level of physical fitness also means more efficient and better performance of physical skills (Haapala, 2013), which allows for more successful participation in PE and a higher grade in PE (Chng & Lund, 2018). Students who are more physically fit are generally more physically active and have more physical knowledge and experience. However, some research to date suggests otherwise. Planinšec and Fošnarič (2006) found that there was no connection between physical activity and grades in PE, and Dexter (1999) reports a modest relationship

between physical activity and grades in PE. In our research, it was shown that most students have good grades in PE, which is different from Mathematics and languages. This may mean that students' sports knowledge is better and there are differences between students than in other subjects. On the other hand, a high proportion of good grades may also indicate more positive attitudes among teachers in the grading of PE, or that the grading criteria are less strict compared to other subjects (Planinšec & Fošnarič, 2006).

In the study, we found that BMI is negatively related with learning performance in Mathematics, Slovene language, and PE, meaning that the students with better learning performance have a lower BMI and vice versa. This finding is also consistent with the findings of some other research (Castelli et al., 2007) that students who are more successful in Mathematics, reading, and overall academic performance have a lower BMI. Donnelly et al. (2009) demonstrated that more physical activity in school is associated with lower BMI and better learning achievements. This can be attributed to the fact that lower BMI is closely associated with higher physical fitness (Hillman et al., 2009), especially cardiorespiratory fitness. It has also been found that obese children have lower cardiorespiratory fitness (Stigman et al., 2009) and poorer motor coordination (D'Hondt et al., 2013). On the other hand, higher BMI and higher body fat mass are associated with lower performance of cognitive tasks and also with lower academic achievement (Kamijo et al., 2012). The authors state that obesity is associated with less efficient neural processes, so obese children perform tasks that require high cognitive control more slowly and are less accurate.

The reasons for the link between physical fitness and academic achievements can be explained by the effect that physical activity and physical fitness have on the brain structure and function. Research with children shows that differences in the brain structure are related to aerobic fitness. Chaddock, Erickson, Prakash, Kim, Voss, et al. (2010) compared children with lower and higher values of VO2max, which measures aerobic fitness. In children with higher VO2max, greater circumference of hippocampus on both sides and consequently better memory were observed. Chaddock, Erickson, Prakash, VanPatter, Voss, et al. (2010) state that differences between children with better and poorer aerobic fitness are related to the circumference of basal ganglia, which is a subcortical structure that significantly affects cognitive functions; greater circumference of basal ganglia results in better performance of cognitive tasks. Children with better aerobic fitness had greater volume in the dorsal striatum, which is part of the basal ganglia, compared with children with lower aerobic fitness. In addition, aerobic exercise has been shown to increase angiogenesis, i.e. capillary density, and thus increase blood flow to the brain, while performing more complex physical skills causes synaptogenesis, i.e. an increased number of synapses (Adkins et al., 2006). Voss et al. (2011) and Chaddock, Erickson, Prakash, Voss, VanPatter, et al. (2012) compared children with higher and lower aerobic fitness and found that there were differences in brain activation between the groups. They noticed increased activation in prefrontal

and parietal brain regions in children with higher aerobic fitness. Therefore, children with higher aerobic fitness were more effective in tasks that require a high level of cognitive control, as they were able to better perform those tasks where higher-order cognitive processes are required. Children with better physical fitness have better attention and higher cognitive speed of information processing than children with lower physical fitness (Hillman, Pontifex, Raine, Castelli, Hall, & Kramer, 2009). Research findings show that children who are more physically active have increased activity of cognitive processes that support effective working memory (Kamijo, Pontifex, O'Leary, Scudder, Wu, et al., 2011). However, we must not forget that children who are more physically fit, compared to peers who are less physically fit, are less absent from school, more efficient in school work, more attentive, have fewer disciplinary problems, feel less strained and unwell, are more independent and need less teacher encouragement (Physical Activity, 2013; Planinšec & Kokol, 2017).

Conclusion

Today, there is ample evidence that the time children spend on physical activity is not only beneficial for better physical health, but it also significantly enriches cognitive development and lifelong brain health (Hillman et al., 2008; Physical Activity, 2013). In addition, research proves that better physical fitness is associated with positive changes in the brain structure and improved brain function, which has a significant impact on academic achievement. Therefore, children need to be encouraged to be moderately to highly intensely physically active for at least one hour each day, as this has a significant impact on physical fitness, which provides many benefits for children, not only in development, health and well-being but also in cognition, which promotes academic achievement (Planinšec & Kokol, 2017; Trudeau & Shephard, 2008). This is one of the reasons why it would be worthwhile to enrich the availability and scope of professionally guided physical activities in schools and to offer quality Physical Education to all students on a daily basis.

Studies show that there are still many children who are not physically active enough (Verloigne et al., 2012), which means that there are still many children with a predominant sedentary lifestyle who are not fit, so it is important to enable them to get involved in appropriate intervention programs for increasing physical activity, which affects cardiovascular, metabolic, and cognitive health (Haapala, 2013; Physical Activity Guidelines, 2018). It is also necessary to organize physical activities in the school environment that promote positive, healthy habits and significantly improve the current and future health of children.

We are also aware of the limitations of our research. The fact is that subjectivity cannot be completely avoided when assessing knowledge. Teachers did not report any specific difficulties in assessment. The problem is that there may be differences between teachers in the criteria for assessing school achievements, although this is the case in almost all studies (e.g. Dwyer et al., 2001; Planinšec & Fošnarič, 2006). Nevertheless,

due to the large number of classes and teachers who assessed children's learning performance, one-sided, systematic impact has been ruled out. The limitations are also related to the sample of children who participated in the study. In the future, it would be worthwhile to conduct interdisciplinary research to analyse the interdependence of physical fitness, academic achievements, and cognitive functions also in a sample of younger and older people, and also to conduct longitudinal studies in addition to cross-sectional studies.

References

Adam, C., Klissouras, V., Ravazzolo, M., Renson, R., & Tuxworth, W. (1993). *Eurofit: European Tests of Physical Fitness (second edition.)*. Strasbourg: Council of Europe, Committee for the development of sport.

Adkins, D., Boychuk, J., Remple, M., & Kleim, J. (2006). Motor training induces experience-specific patterns of plasticity across motor cortex and spinal cord. *Journal of Applied Physiology,* 101, 1776-1782. https://doi.org/10.1152/japplphysiol.00515.2006

Ardoy, D. N., Fernández-Rodríguez, J. M., Jiménez-Pavón, D., Castillo, R., Ruiz, J. R., & Ortega, F. B. (2014). A physical education trial improves adolescents' cognitive performance and academic achievement: The EDUFIT study. *Scandinavian Journal of Medicine & Science in Sports*, 24(1), e52–e61. https://doi.org/10.1111/sms.12093

Basch, C. E. (2011). Healthier students are better learners: A missing link in school reforms to close the achievement gap. *Journal of School Health,* 81, 593-598. https://doi.org/10.1111/j.1746-1561.2011.00632.x

Bass, R. W., Brown, D. D., Laurson, K. R., & Coleman, M. M. (2013). Physical fitness and academic performance in middle school students. *Acta Paediatrica,* 102(8), 832–837. https://doi.org/10.1111/apa.12278

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Public Health Reports,* 100(2), 126–131.

Castelli, D. M., Hillman, C. H., Buck, S. M., & Erwin, H. E. (2007). Physical fitness and academic achievement in third- and fifth-grade students. *Journal of Sport and Exercise Psychology,* 29(2), 239-252. https://doi.org/10.1123/jsep.29.2.239

Castro-Piñero, J., Artero, E. G., España-Romero, V., Ortega, F. B., Sjöström, M., Suni, J., & Ruiz, J. R. (2010). Criterion-related validity of field-based fitness tests in youth: A systematic review. *British Journal of Sports Medicine*, 44 (13), 934–943. https://doi.org/10.1136/bjsm.2009.058321

Chaddock, L., Erickson, K. I., Prakash, R. S., Kim, J. S., Voss, M. W., VanPatter, M., Pontifex, M. B., Raine, L. B., Konkel, A., & Hillman, C. H. (2010). A neuroimaging investigation of the association between aerobic fitness, hippocampal volume, and memory performance

in preadolescent children. *Brain Research,* 1358, 172-183. https://doi.org/10.1016/j.brainres.2010.08.049

Chaddock, L., Erickson, K. I., Prakash, R. S., VanPatter, M., Voss, M. W., Pontifex, M. B., Raine, L. B., Hillman, C. H., & Kramer, A. F. (2010). Basal ganglia volume is associated with aerobic fitness in preadolescent children. *Developmental Neuroscience,* 32(3), 249-256. https://doi.org/10.1159/000316648

Chaddock, L., Erickson, K. I., Prakash, R. S., Voss, M. W., VanPatter, M., Pontifex, M. B., Hillman, C. H., & Kramer, A. F. (2012). A functional MRI investigation of the association between childhood aerobic fitness and neurocognitive control. *Biological Psychology,* 89(1), 260-268. https://doi.org/10.1016/j.biopsycho.2011.10.017

Chng, L. S., & Lund, J. (2018). Assessment for Learning in Physical Education: The What, Why and How. *Journal of Physical Education, Recreation & Dance,* 89(8), 29-34. https://doi.org/10.1080/07303084.2018.1503119

Coe, D. P., Peterson, T., Blair, C., Schutten, M. C., & Peddie, H. (2013). Physical fitness, academic achievement, and socioeconomic status in school-aged youth. *Journal of School Health*, 83(7), 500–507. https://doi.org/10.1111/josh.12058

Daley, A. J., & Ryan, J. (2000). Academic performance and participation in physical activity by secondary adolescents. *Perceptual Motor Skills,* 91, 531-534. https://doi.org/10.2466/pms.2000.91.2.531

Davis, C. L., & Cooper, S. (2011). Fitness, fatness, cognition, behavior, and academic achievement among overweight children: Do cross-sectional associations correspond to exercise trial outcomes? *Preventive Medicine* 52 (suppl. 1), 65-69. https://doi.org/10.1016/j.ypmed.2011.01.020

Dexter, T. (1999). Relationship between sport knowledge, sport performance and academic ability: Empirical evidence from GCSE Physical Education. *Journal of Sport Sciences,* 17, 283-295. https://doi.org/10.1080/026404199366000

Donnelly, J. E., Greene, J. L., Gibson, C. A., Smith, B. K., Washburn, R. A., Sullivan, D. K., DuBose, K., Mayo, M. S., Schmelzle, K. H., & Ryan, J. J. (2009). Physical Activity Across the Curriculum (PAAC): A randomized controlled trial to promote physical activity and diminish overweight and obesity in elementary school children. *Preventive Medicine,* 49(4), 336-341. https://doi.org/10.1016/j.ypmed.2009.07.022

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., Pagani, L. S., Feinstein, L., Engel, M., Brooks-Gunn, J., Sexton, H., Duckworth, K., & Japel, C. (2007). School readiness and later achievement. *Developmental Psychology, 43*(6), 1428-1446. https://doi.org/10.1037/0012-1649.43.6.1428

Dwyer, T., Sallis, J. F., Blizzard, L., Lazarus, R., & Dean, K. (2001). Relation of academic performance to physical activity and fitness in children. *Pediatric Exercise Science, 13*(3), 225-237. https://doi.org/10.1123/pes.13.3.225

D'Hondt, E., Deforche, B., Gentier, I., De Bourdeaudhuij, I., Vaeyens, R., Philippaerts, R., & Lenoir, M. (2013). A longitudinal analysis of gross motor coordination in overweight and obese children versus normal-weight peers. *International Journal of Obesity,* 37(1), 61-67. https://doi.org/10.1038/ijo.2012.55

Esteban-Cornejo, I., Tejero-González, C., Castro-Piñero, J., Conde-Caveda, J., Cabanas-Sanchez, V., Sallis, J. F., & Veiga, O. L. (2015). Independent and combined influence of

neonatal and current body composition on academic performance in youth: The UP & DOWN Study. *Pediatric Obesity,* 10(3), 157-164. https://doi.org/10.1111/ijpo.239

Fedewa, A. L., & Ahn, S. (2011). The effect of physical activity and physical fitness on children´s achievement and cognitive outcomes: A meta-analysis. *Research Quarterly for Exercise and Sport,* 82 (3), 521-535. https://doi.org/10.1080/02701367.2011.10599785

Global Recommendations on Physical Activity for Health 5-17 years old. WHO. (2011). https://www.who.int/dietphysicalactivity/publications/physical-activity-recommendations-5-17years.pdf?ua=1

Guillamón, A. R., Cantó, E. G., & García, H. M. (2020). Motor coordination and academic performance in primary school students. *Journal of Human Sport and Exercise*, *in press*. https://doi.org/10.14198/jhse.2021.162.02

Haapala, E. (2013). Cardiorespiratory fitness and motor skills in relation to cognition and academic performance in children - A review. *Journal of Human Kinetics,* 36, 55–68. https://doi.org/10.2478/hukin-2013-0006

Haugen, T., Ommundsen, Y., & Seiler, S. (2013). The relationship between physical activity and physical self-esteem in adolescents: The role of physical fitness indices. *Pediatric Exercise Science,* 25 (1), 138-53. https://doi.org/10.1123/pes.25.1.138

Hillman, C., Erickson, K., & Kramer, A. (2008). Be smart, exercise your heart: Exercise effects on brain and cognition. *Nature Reviews Neuroscience,* 9, 58–65. https://doi.org/10.1038/nrn2298

Hillman, C. H., Buck, S. M., Themanson, J. R., Pontifex, M. B., Darla M., & Castelli, D. M. (2009). Aerobic fitness and cognitive development: Event-related brain potential and task performance indices of executive control in preadolescent children. *Developmental Psychology*, 45(1), 114–129. https://doi.org/10.1037/a0014437

Hillman, C. H., Pontifex, M. B., Raine, L. B., Castelli, D. M., Hall, E. E., & Kramer, A. F. (2009). The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children. *Neuroscience,* 159 (3), 1044. https://doi.org/10.1016/j.neuroscience.2009.01.057

Jurak, G., Kovač, M., & Starc, G. (2013): The ACDSi 2013 – The analysis of children's development in Slovenia 2013: Study protocol. *Anthropological Notebooks 19* (3), 123–14.

Kamijo, K., Pontifex, M. B., O'Leary, K. C., Scudder, M. R., Wu, C. T., Castelli, D. M., & Hillman, C. H. (2011). The effects of an afterschool physical activity program on working memory in preadolescent children. *Developmental Science*, *14*(5), 1046–1058. https://doi.org/10.1111/j.1467-7687.2011.01054.x

Kamijo, K., Khan, N. A., Pontifex, M. B., Scudder, M. R., Drollette, E. S., Raine, L. B., Evans, E. M., Castelli, D. M., & Hillman, C. H. (2012). The relation of adiposity to cognitive control and scholastic achievement in preadolescent children. *Obesity, 20*(12), 2406–2411. https://doi.org/10.1038/oby.2012.112

Kwak, L., Kremers, S. P., Bergman, P., Ruiz, J. R., Rizzo, N. S., & Sjöström, M. (2009). Associations between physical activity, fitness, and academic achievement. *The Journal of Pediatrics, 155*(6), 914–918.e1. https://doi.org/10.1016/j.jpeds.2009.06.019

Livesey, D., Keen, J., Rouse, J., & White, F. (2006). The relationship between measures of executive function, motor performance and externalising behaviour in 5- and 6-year-old children. *Human Movement Science,* 25(1), 50-64. https://doi.org/10.1016/j.humov.2005.10.008

London, R. A., & Castrechini, S. (2011). A longitudinal examination of the link between youth physical fitness and academic achievement. *Journal of School Health*, 81(7), 400–408. https://doi.org/10.1111/j.1746-1561.2011.00608.x

Martínez-Vizcaíno, V., & Sánchez-López, M. (2008). Relationship between physical activity and physical fitness in children and adolescents. *Rev Esp Cardiol,* 61(2), 108-11. https://doi.org/10.1157/13116196

Morales, J., González, L. M., Guerra, M., Virgili, C., & Unnithan, V. (2011). Physical activity, perceptualmotor performance, and academic learning in 9-to-16-years-old school children. *International Journal of Sport Psychology* 42(4), 401–415.

Niederer, I., Kriemler, S., Gut, J., Hartmann, T., Schindler, C., Barral, J., & Puder, J. J. (2011). Relationship of aerobic fitness and motor skills with memory and attention in preschoolers (Ballabeina): A cross-sectional and longitudinal study. *BMC Pediatrics* 11(1), 34. https://doi.org/10.1186/1471-2431-11-34

Physical Activity, Fitness, and Physical Education: Effects on Academic Performance. (2013). In H. W. Kohl, H. D. Cook (Eds.), *Educating the Student Body: Taking Physical Activity and Physical Education to School* (pp. 161-196). Washington, D.C.: The National Academies Press, Committee on Physical Education in the School Environment, Food and Nutrition Board, Institute of Medicine.

Physical Activity Guidelines for Americans, 2nd edition. (2018). Washington, D.C.: U.S. Department of Health and Human Services.

Pišot, R., & Planinšec, J. (2005). *Motor structure in early child development*. Založba Annales.

Planinšec, J., & Fošnarič, S. (2006). Gibalna aktivnost in šolski dosežki učencev drugega triletja [Physical activity and school achievements of second-year students]. *Annales*, 16 (2), 1-6.

Planinšec, J., & Pišot, R. (2006). Motor coordination and intelligence level in adolescents. *Adolescence*, 41, 164, 667-676.

Planinšec, J., & Kokol, D. (2017). Interaction of physical fitness, academic achievement and living environment of primary school students. In M. Plevnik et al. (Eds.), *Active childhood - the lever of a successful life: the book of abstracts* (pp.32-35). Znanstveno-raziskovalno središče Koper, Univerzitetna založba Annales.

Rowland, T. (2007). Evolution of maximal oxygen uptake in children. In G. R. Tomkinson, T. S. Olds (Eds.), *Pediatric Fitness. Secular Trends and Geographic Variability* (pp. 200-209). Med Sport Sci. Karger. https://doi.org/10.1159/000101392

Ruiz-Ariza, A., Grao-Cruces, A., Marques de Loureiro, N. E., & Martínez-López, E. J. (2017). Influence of physical fitness on cognitive and academic performance in adolescents: A systematic review from 2005–2015, *International Review of Sport and Exercise Psychology,* 10(1), 108-133. https://doi.org/10.1080/1750984X.2016.1184699

Ruiz, J. R., Castro-Piñero, J., Artero, E. G., Ortega, F. B., Sjöström, M., Suni, J., & Castillo, M. J. (2009). Predictive validity of health-related fitness in youth: A systematic review. *British Journal of Sports Medicine,* 43(12), 909–923. https://doi.org/10.1136/bjsm.2008.056499

Stigman, S., Rintala, P., Kukkonen-Harjula, K., Kujala, U., Rinne, M., & Fogelholm, M. (2009). Eight-year-old children with high cardiorespiratory fitness have lower overall and abdominal fatness. *International Journal of Pediatric Obesity* 4(2), 98-105. https://doi.org/10.1080/17477160802221101

Tomkinson, G. R., Olds, T. S., & Borms, J. (2007). Who are the Eurofittest? In G. R. Tomkinson, T. S. Olds (Eds.), *Pediatric Fitness. Secular Trends and Geographic Variability* (pp. 104–128). Medicine and Sport Science. Karger. https://doi.org/10.1159/000101355

Tomporowski, P. D., Davis, C. L., Miller, P. H., & Naglieri, J. A. (2008). Exercise and children's intelligence, cognition, and academic achievement. *Educational Psychology Review,* 20(2), 111–131. https://doi.org/10.1007/s10648-007-9057-0

Torrijos-Niño, C., Martínez-Vizcaíno, V., Pardo-Guijarro, M. J., García-Prieto, J. C., Arias-Palencia, N. M., & Sánchez-López, M. (2014). Physical fitness, obesity, and academic achievement in schoolchildren. *The Journal of Pediatrics* 165(1), 104–109. https://doi.org/10.1016/j.jpeds.2014.02.041

Tremblay, M. S., Inman, J. W., & Williams, D. (2000). The relationship between physical activity, self-esteem, and academic achievement in 12-year-old children. *Pediatric Exercise Science*, 12, 312-323. https://doi.org/10.1123/pes.12.3.312

Trudeau, F., & Shephard, R. J. (2008). Physical education, school physical activity, school sports and academic performance. *International Journal of Behavioral Nutrition and Physical Activity Act,* 5**,** 10, doi.org/10.1186/1479-5868-5-10

Van Dusen, D. P., Kelder, S. H., Kohl, III H. W., Ranjit, N., & Perry, C. L. (2011). Associations of physical fitness and academic performance among schoolchildren. *Journal of School Health, 81*(12), 733-740. https://doi.org/10.1111/j.1746-1561.2011.00652.x

Verloigne, M., Van Lippevelde, W., Maes, L., Yıldırım, M., Chinapaw, M., Manios, Y., Androutsos, O., Kovács, E., Bringolf-Isler, B., Brug, J., & De Bourdeaudhuij, I. (2012). Levels of physical activity and sedentary time among 10- to 12-year-old boys and girls across 5 European countries using accelerometers: An observational study within the ENERGY-project. *The International Journal of Behavioral Nutrition and Physical Activity, 9*(34). https://doi.org/10.1186/1479-5868-9-34

Voelcker-Rehage, C. (2005). Der Zusammenhang zwischen motorischer und kognitiver Entwicklung im frühen Kindesalter [Association of motor and cognitive development in young children]. *Deut Z Sportmed* 56(10), 358-363.

Voss, M., Chaddock, L., Kim, J., Vanpatter, M., Pontifex, M. B., Raine, L.B., Cohen, N. J., Hillman, C. H., & Kramer, A.F. (2011). Aerobic fitness is associated with greater efficiency of the network underlying cognitive control in preadolescent children. *Neuroscience,* 199, 166-176. https://doi.org/10.1016/j.neuroscience.2011.10.009

Wittberg R., Cottrell, L. A., Davis, C. L., & Northrup, K. L. (2010). Aerobic fitness thresholds associated with fifth grade academic achievement. *American Journal of Health Education,* 41(5), 284-291. https://doi.org/10.1080/19325037.2010.10599155

Wood, R. J. (2010). *Agility Cone Drill Test. Topendsports.com.* https://www.topendsports.com/testing/tests/agility-cone-drill.htm

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Povezanost akademskih postignuća i tjelesnoga fitnesa kod djece u predadolescentnoj dobi

Sažetak

Svrha studije bila je utvrditi razlikuju li se djeca u pogledu tjelesnoga fitnesa u skladu s njihovim akademskim uspjehom iz matematike, jezika (slovenski jezik) i tjelesne i zdravstvene kulture. Uzorak je obuhvaćao 467 sudionika: 250 dječaka i 217 djevojčica. Kako bi se procijenila razina tjelesnoga fitnesa, provedeno je osam različitih testova iz testne baterije Eurofit. Akademski uspjeh djece definiran je na temelju tri kriterija: završne ocjene iz Matematike, završne ocjene iz Slovenskog jezika i završne ocjena iz Tjelesne i zdravstvene kulture. Provedeni su neovisni t-test i višestruka regresijska analiza kako bi se utvrdio odnos između različitih testova tjelesnoga fitnesa i akademskoga uspjeha. Najvažniji nalaz našega istraživanja jest da je tjelesni fitnes povezan s akademskim uspjehom kod djece u predadolescentnoj dobi. Djeca s boljim akademskim uspjehom pokazala su bolje rezultate na većini testova tjelesnoga fitnesa u usporedbi s vršnjacima koji su imali slabiji akademski uspjeh.

Ključne riječi: *djetinjstvo; školske ocjene; tjelesne sposobnosti.*

Uvod

Nedavna istraživanja sugeriraju da postoji uska uzajamna veza između akademskih postignuća i zdravlja djece. Tjelesna aktivnost jedan je od ključnih čimbenika koji osiguravaju ljudsko zdravlje u svim fazama života (Hillman, Erickson i Kramer, 2008; Global Recommendations, 2011), a Basch (2011) također ju ističe kao jedan od najvažnijih zdravstvenih čimbenika koji utječu na akademski uspjeh. Stručnjaci za obrazovanje i zdravstvo uvijek su se slagali da su tjelesno aktivniji i motorički spremniji dječaci, uspješnjij u školi (Castelli, Hillman, Buck i Erwin, 2007).

Postoje znanstveni dokazi da je tjelesna aktivnost djece povezana s njihovom tjelesnim fitnesom (Haugen, Ommundsen i Seiler, 2013; Martínez-Vizcaíno i Sánchez-López, 2008). U pravilu redovita tjelesna aktivnost koja se izvodi s odgovarajućim intenzitetom te dovoljno često i u skladu s preporukama struke, osigurava visoku razinu tjelesnoga fitnesa (Rowland, 2007; Global Recommendations, 2011). Tjelesni fitnes predstavljaju

različita svojstva koja osoba ima ili ih može postići (Caspersen, Powell i Christenson, 1985), a sastoji se uglavnom od kardiorespiratornoga fitnesa, mišićne snage, brzine, agilnosti, koordinacije pokreta, gibljivosti, ravnoteže i tjelesne građe (Castro-Piñero, Artero, España-Romero, Ortega, Sjöström i sur., 2010; Pišot i Planinšec, 2005; Ruiz, Castro-Piñero, Artero, Ortega, Sjöström i sur., 2009).

Tjelesna aktivnost ne samo da rezultira boljim tjelesnim fitnesom, već rezultira i boljim kognitivnim učinkom i akademskim postignućima (Kwak, Kremers, Bergman, Ruiz, Rizzo i Sjöström, 2009). Istraživanja pokazuju da postoji pozitivna povezanost između tjelesnoga fitnesa i akademskih postignuća (Fedewa i Ahn, 2011; Ruiz-Ariza, Grao-Cruces, Marques de Loureiro i Martínez-López, 2017). Učenici s boljim tjelesnim fitnesom uspješniji su od svojih vršnjaka slabijega tjelesnog fitnesa (Wittberg, Cottrell, Davis i Northrup, 2010), što vrijedi i za urbanu i za ruralnu djecu (Planinšec i Kokol, 2017).

Brojne studije dokazuju da su akademska postignuća pozitivno povezana s razinom tjelesnoga fitnesa. Među svim komponentama tjelesnoga fitnesa viša razina akademskih postignuća povezana je prije svega s boljim kardiorespiratornin fitnesom, brzinom i agilnošću (Esteban-Cornejo, Tejero-González, Castro-Piñero, Conde-Caveda, Cabanas-Sanchez i sur., 2015; Torrijos-Nino Martínez-Vizcaíno, Pardo-Guijarro, García-Prieto, Arias-Palencia i Sánchez-López, 2014). Istraživanja također pokazuju da studenti s boljim kardiorespiratornim fitnesom, postižu bolje akademske uspjehe (Davis i Cooper, 2011; Dwyer, Sallis, Blizzard, Lazarus i Dean, 2001) i bolje rezultate u standardiziranim testovima (Van Dusen, Kelder, Kohl, Ranjit i Perry, 2011; Wittberg i sur., 2010; Davis and Cooper, 2011) u usporedbi s vršnjacima s nižim kardiorespiratornim fitnesom. Gore navedena istraživanja također pokazuju da su uz kardiorespiratorni fitnes i druge komponente tjelesnoga fitnesa povezane s akademskim postignućima, posebno mišićna snaga i mišićna izdržljivost, ali u manjoj mjeri. Voss, Chaddock, Kim, Vanpatter, Pontifex, Raine i sur. (2011) otkrivaju da su kod djece razlike u aerobnom fitnesu povezane s kognitivnom kontrolom, što znači da su djeca slabijega tjelesnog fitnesa bila manje uspješna u izvršavanju akademskih zadataka u usporedbi s vršnjacima s bolje razvijenim tjelesnim fitnesom. S druge strane, postoje i studije koje utvrđuju da je veza između tjelesnoga fitnesa i akademskih postignuća zanemariva (Daley i Ryan, 2000), statistički beznačajna (Ardoy, Fernández-Rodríguez, Jiménez-Pavón, Castillo i sur., 2014) ili čak negativna (Tremblay, Inman i Williams, 2000).

Tjelesni fitnes najjače je povezan s postignućima u matematici i jeziku (Fedewa i Ahn, 2011; London i Castrechini, 2011). Van Dusen i sur. (2011) i Wittberg i sur. (2010) navode da je kardiorespiratorni fitnes najjače povezan s postignućima u matematici i čitanju. Morales González, Guerra, Virgili i Unnithan (2008) izvještavaju da je bolja motorička koordinacija povezana s boljim performansama u lingvističkim i matematičkim vještinama. Planinšec i Fošnarič (2006) otkrili su da su postignuća u učenju jezika, matematike, prirodnih znanosti, društvenih znanosti i opće akademske uspješnosti pozitivno povezana s tjelesnom aktivnošću. Stoga se u asocijacijama na

tjelesni fitnes posebno ističu područja matematike i jezika. Među komponentama tjelesnoga fitnesa, kardiorespiratorni fitnes i izdržljivost mišića bili su najjače povezani s uspjehom na ispitima iz matematike i čitanja (Bass Brown, Laurson i Coleman, 2013). Kod starijih učenika bolja postignuća u tjelesnom fitnesu povezana su s boljim ocjenama iz matematike i društvenih znanosti u usporedbi s učenicima slabijega tjelesnog fitnesa; među komponentama tjelesnoga fitnesa najvažnija je bila mišićna snaga i mišićna izdržljivost (Coe, Peterson, Blair, Schutten i Peddie, 2013).

Istraživači su istaknuli dosta fizioloških i razvojnih mehanizama koji su važni čimbenici odnosa između tjelesne aktivnosti, kognitivnih procesa i akademskih postignuća (Haapala, 2013). Područja mozga koja su uključena u kretanje i učenje, usko su povezana (Trudeau i Shephard, 2008). Redovita tjelesna aktivnost može ojačati ove živčane veze, a istovremeno utječe na određene strukturne promjene u mozgu (Voss i sur., 2011.). Učenje i korištenje složenih motoričkih vještina stimulira prefrontalni korteks koji je aktivan u rješavanju problema i posljedično može poboljšati učinkovitost učenja (Tomporowski Davis, Miller i Naglieri, 2008). Nadalje, tjelesna aktivnost kroz različite mehanizme podiže razinu opće stimulacije središnjega živčanog sustava, što utječe na djetetovu pažnju u nastavi. Pod određenim uvjetima tjelesna aktivnost trebala bi potaknuti kognitivne procese, posebno izvršnu funkciju, koja je ključna za koncentraciju, mentalno planiranje i organizaciju te rješavanje problema (Hillman i sur., 2008; Planinšec i Pišot, 2006; Voss i sur., 2011.). Neke studije pokazuju da tjelesna aktivnost povećava brzinu cirkulacije krvi u mozgu, utječe na promjene u moždanim neurotransmiterima, posebno na povišenu razinu endorfina, što zauzvrat smanjuje stres, poboljšava raspoloženje i izaziva umirujući učinak nakon vježbanja. To sve može imati pozitivne učinke na kognitivne funkcije i akademska postignuća (Hillman i sur., 2008).

Tjelesna aktivnost utječe na mnoge fiziološke promjene u mozgu povezane s kognicijom i učenjem: povećani rast moždanih kapilara, povećani protok krvi u mozak, povećana opskrba mozga kisikom, povećana sinaptička plastičnost, povećana razina neurotrofnoga faktora izvedenoga iz mozga (BDNF), rast neurona u hipokampusu (centar za učenje i pamćenje), povećana razina neurotransmitera, posebno adrenalina i endorfina, povećana neurogeneza, povećana gustoća neuronske mreže i poboljšana neuroelektrična funkcionalnost (Hillman i sur., 2008; Haapala, 2013; Planinšec i Kokol, 2017).

Problem istraživanja

Istraživanja pokazuju da postoji pozitivna veza između tjelesnoga fitnesa i akademskih postignuća (Ruiz-Ariza i sur., 2017). Učenici s boljim tjelesnim fitnesom uspješniji su od svojih vršnjaka s lošijim tjelesnim fitnesom (Wittberg i sur., 2010). S obzirom na dosadašnja saznanja, vrijedi detaljnije proučiti vezu između akademskih postignuća i tjelesnoga fitnesa, a prije svega utvrditi trenutačno stanje na ovom polju u Sloveniji.

Metodologija

Cilj

Stoga smo proveli presječno istraživanje slovenske djece s glavnom svrhom utvrditi razlikuju li se učenici u pogledu njihova tjelesnoga fitnesa prema njihovim akademskim uspjehom iz matematike, jezika (slovenski jezik) i tjelesne i zdravstvene kulture. Također želimo utvrditi koje su komponente tjelesnoga fitnesa najviše povezane s akademskim uspjehom, nadalje jakost tih veza i doprinos pojedinih komponenata tjelesnoga fitnesa u razumijevanju potencijalnoga utjecaja na akademski uspjeh. Na temelju nekoliko nalaza pretpostavljamo da će učenici s boljim akademskim uspjehom imati bolji tjelesni fitnes, posebno kardiorespiratorni fitnes i snagu, u usporedbi s vršnjacima koji su akademski manje uspješni.

Uzorak

Pismeni pristanak roditelja dobiven je od svih učenika četvrtoga, petoga i šestoga razreda (n = 672) upisanih u osam škola. Svi učenici koji nisu ispunili sve testove tjelesnoga fitnesa ili kojima nedostaju akademska postignuća iz matematike, tjelesnog ili materinskoga jezika, bili su isključeni iz studije. Nakon ovih isključenja, uzorak studije obuhvaćao je 467 sudionika: 250 dječaka (AS dob = 10,25, SD = ,925) i 217 djevojčica (AS dob = 10,30, SD = ,928). Svaki od sudionika obavio je jedanaest testova tjelesnoga fitnes. Ocjene iz Matematike, Tjelesne i zdravstvene kulture i Slovenskog jezika dodijelili su nastavnici učenika prema standardima znanja, zapisanima u kurikulu.

Instrumenti i postupci

Ispitivanje tjelesnoga fitnesa. Da bi se procijenila razina tjelesnoga fitnesa, osam različitih motoričkih testova iz testne baterije Eurofit (Adam, Klissouras, Ravazzolo, Renson i Tuxworth, 1993), koji obuhvaćaju eksplozivnu snagu nogu (skok u dalj iz mjesta), repetitivnu snagu trupa (trbušnjaci), gipkost (doseg iz sjeda), dinamičko ravnoteže (flamingo ravnoteža), brzina kretanja udova (taping rukom), agilnost (trčanje 10 x 5 metara), aerobni fitnes (trčanje 20 metara) i indeks tjelesne mase. Testna baterija Eurofit korištena je u raznim studijama širom svijeta i pokazala se prikladnom za djecu i adolescente (Tomkinson, Olds i Borms, 2007). Uz to izvedeni su testovi poligon unatrag, zvijezda test za košarku i preskakanje užeta 20 sekundi. Test poligon unatrag mjeri koordinaciju cijeloga tijela koji se koristio u mnogim slovenskim studijama i pokazao se vrlo pogodnim za djecu (Jurak, Kovač i Starc, 2013). Košarkaški zvijezda test je test agilnosti i vještine rukovanja loptom (Wood, 2010). Test preskakanje užeta 20 sekundi kompozitni je test za procjenu repetitivne snage donjih ekstremiteta i koordinacije gornjih i donjih ekstremiteta. Mjerenja su provedena u proljeće 2013. godine, uvijek ujutro, u posebno opremljenom prostoru. Kompletno testiranje trajalo je manje od jednoga sata po sudioniku. Mjerenja su vršili posebno obučeni mjerioci.

Procjena akademskih postignuća. Akademska postignuća mogu se utvrditi standardiziranim nacionalnim testovima za akademska postignuća, pismenost, znanje aritmetike, vještine čitanja, subjektivne procjene znanja sudionika, subjektivne procjene učitelja ili ravnatelja, prosjek ocjena, opća akademska postignuća i ocjene iz Matematike (Trudeau i Shepard, 2008). Vještine čitanja i posebno znanje matematike u ranom obrazovnom razdoblju najpouzdaniji su pokazatelji općega akademskoga postignuća, tj. školskoga uspjeha u višim razredima (Duncan, Dowsett, Claessens, Magnuson, Huston i sur., 2007). Stoga smo odlučili definirati akademski uspjeh djece na temelju tri kriterija: završne ocjene iz Matematike, završne ocjene iz Slovenskog jezika i završne ocjene iz Tjelesne i zdravstvene kulture. Prema završnoj ocjeni sudionici su podijeljeni u dvije skupine: manje uspješni (ocjene 1, 2 ili 3) i visoko uspješni (ocjene 4, 5). Ocjene iz Matematike, Tjelesne i zdravstvene kulture i Slovenskog jezika za svakog sudionika dobili su učitelji učenika prema postignutim standardima na kraju školske godine.

Analiza podataka

Opisna statistika izračunata je za svaku varijablu tjelesnoga fitnesa za skupine manje uspješnih i vrlo uspješnih. Neovisni t-test upotrijebljen je za utvrđivanje razlika u testovima tjelesnoga fitnesa između skupina manje uspješnih i vrlo uspješnih iz Matematike, Slovenskog jezika i Tjelesne i zdravstvene kulture. Izračunali smo Pearsonove korelacije između tri ovisne varijable (ocjena iz Matematike, ocjena iz Slovenskog jezika i ocjena iz Tjelesne i zdravstvene kulture) i pojedinačnim testovima tjelesnoga fitnesa. Zatim je izvedena višestruka regresijska analizaa kako bi se utvrdio odnos između različitih testova tjelesnoga fitnesa i akademskoga postignuća iz Matematike, Slovenskog jezika i Tjelesne i zdravstvene kulture.

Rezultati

Opisna statistika izračunata je za svaku varijablu (Tablica 1) za grupe s nižom ocjenom iz Matematike i višom ocjenom iz Matematike. U testovima flamingo ravnoteže, trčanje 10 x 5 metara, poligonu unatrag, zvijezda test i taping rukom, niža vrijednost znači bolji rezultat. Nezavisni t-test upotrijebljen je za utvrđivanje razlika između grupa s nižom ocjenom iz Matematike i višom ocjenom iz Matematike.

Tablica 1.

Rezultati pokazuju da skupina s višom ocjenom iz Matematike postiže statistički značajno bolje rezultate u većini testova tjelesnog fitnesa od skupine s nižim uspjehom. Jedina iznimka su testovi taping rukom i doseg iz sjeda, gdje razlike među skupinama nisu statistički značajne.

Tablica 2.

Opisna statistika izračunata je za svaku varijablu (Tablica 2) za grupe s nižom ocjenom iz Slovenskog jezika i višom ocjenom iz Slovenskog jezika. Rezultati pokazuju

da grupa s višom ocjenom iz Slovenskog jezika postiže statistički značajne bolje rezultate u flamingo ravnoteži, trčanju 10 x 5 metara, trčanje 20 metara, indeksu tjelesne mase, preskakanje užeta za 20 sekundi, trbušnjacima i skok u dalj iz mjesta nego grupa s nižom ocjenom iz Slovenskog jezika. Međutim, u poligonu unatrag, košarkaškom zvijezda testu, taping rukom i doseg iz sjeda, razlike između grupe s nižom ocjenom iz Slovenskog jezika i višom ocjenom iz Slovenskog jezika nisu statistički značajne.

Tablica 3.

Opisna statistika izračunata je za svaku varijablu (Tablica 3) za skupine s nižom ocjenom iz Tjelesnog odgoja i višom ocjenom iz Tjelesnog odgoja. Rezultati pokazuju da skupina s višom ocjenom iz Tjelesnog odgoja postiže statistički značajno bolje rezultate u svim testovima tjelesnog fitnesa i to na razini $p < 0,01$.

Tablica 4.

Pearsonove korelacije (Tablica 4.) izračunate su između tri ovisne varijable (ocjena iz Matematike, ocjena iz Slovenskog jezika i ocjena iz Tjelesne i zdravstvene kulture) i na pojedinačnim testovima tjelesnoga fitnesa. U naknadnu regresijsku analizu uključene su samo one varijable tjelesnoga fitnesa koje su korelirale bilo ocjenom iz Matematike, ocjenom iz Slovenskog jezika ili ocjenom iz Tjelesne i zdravstvene kulture na razini $p < 0,01$. Rezultati korelacijskih analiza pokazali su da su četiri testa tjelesnoga fitnesa (trčanje 20 metara, preskakanje užeta za 20 sekundi, trbušnjaci, skok u dalj iz mjesta) pozitivno povezani sa sve tri mjere akademskoga uspjeha ($p < ,01$). Prosječni rezultati testa doseg iz sjeda bili su pozitivno povezani s ocjenom iz Tjelesne i zdravstvene kulture ($p < ,01$) i ocjenom iz Slovenskog jezika ($p <,05$), ali nisu bili povezani s ocjenom iz Matematike. Tri testa tjelesnog fitnesa (flamingo ravnoteža, trčanje 10 x 5 metara, indeks tjelesne mase, skok u dalj iz mjesta) negativno su korelirana sa sve tri mjere akademskoga uspjeha ($p < ,01$). Poligon unatrag, košarkaški zvijezda test i taping rukom negativno su povezani s ocjenom iz Tjelesne i zdravstvene kulture ($p < ,01$) i ocjenom iz Slovenskog jezika ($p < ,01$). Uz to, prosječni rezultati za poligon unatrag negativno su povezani s ocjenom iz Slovenskog jezika ($p < ,05$). Konačno, prosječni rezultati za košarkaški zvijezda test i taping rukom nisu bili povezani s ocjenom iz Slovenskog jezika ($p > ,05$).

Tablica 5.

Zatim je izvedena višestruka regresijska analiza (Tablica 5.) kako bi se utvrdio odnos između različitih testova tjelesnoga fitnesa i ocjene iz Matematike. Što se tiče ocjene iz Matematike, rezultati analize otkrili su statistički značajnu povezanost (prilagođeni $R2 = ,104$, $F (11, 449) = 4,756$, $p = ,000$), što ukazuje da varijable tjelesnoga fitnesa objašnjavaju 10,4 % varijabilnosti akademskoga uspjeha u matematici. Rezultati pokazuju značajan učinak testa flamingo ravnoteže ($p < ,05$, $\beta = -0,116$), što ukazuje da su bolji akademski rezultati iz matematike povezani s

boljom dinamičkom ravnotežom (Tablica 5). Treba imati na umu da niži rezultat u testu flamingo ravnoteže znači bolju dinamičku ravnotežu.

Tablica 6.

Uz to, izvedena je višestruka regresijska analiza (Tablica 6) kako bi se utvrdio odnos između različitih testova tjelesnoga fitnesa i akademskoga postignuća u Slovenskom jeziku. Što se tiče ocjene iz Slovenskoga jezika, rezultati analize otkrili su značajnu povezanost (prilagođeni R2 = ,079, F (11, 449) = 3,484, p = ,000), što pokazuje da varijable tjelesnoga fitnesa objašnjavaju 7,9 % varijabilnosti akademskoga postignuća u Slovenskom jeziku. Rezultati pokazuju značajan učinak testa flamingo ravnoteže ($p < ,01$, $\beta = -0,158$) i indeksa tjelesne mase ($p < ,01$, $\beta = -0,164$), što ukazuje da su bolje ocjenei iz Slovenskoga jezika povezane s boljom dinamičkom ravnotežom i nižim indeksom tjelesne mase (Tablicu 6).

Tablica 7.

Provedena je višestruka regresijska analiza (Tablica 7) kako bi se utvrdio odnos između različitih testova tjelesnoga fitnesa i akademskoga postignuća u Tjelesnoj i zdravstvenoj kulturi. Što se tiče akademskoga postignuća u tjelesnom odgoju, rezultati analize otkrili su značajnu povezanost (prilagođeni R2 = ,30, F (11, 417) = 16,214, p = ,000), što ukazuje da varijable tjelesnoga fitnesa objašnjavaju 30 % varijabilnosti ocjene iz tjelesnoga odgoja. Rezultati pokazuju značajan učinak testa poligon unatrag ($p < ,01$, $\beta = -0,256$), trčanje 20 metara ($p < ,05$, $\beta = 0,138$) i taping rukom ($p < ,05$, $\beta = -0,112$), što ukazuje da su bolje ocjene iz Tjelesne i zdravstvene kulture povezane s boljom koordinacijom cijeloga tijela, boljim aerobnim fitnesom i brzinom pokreta udova (Tablica 7). Treba imati na umu da niži rezultat testa poligona unatrag znači bolju koordinaciju cijeloga tijela. Uz to, niži rezultati testa taping rukom također znače i veću brzinu kretanja udova.

Rasprava

Najvažniji nalaz našega istraživanja jest da je tjelesni fitnes povezan s akademskim postignućima kod djece u predadolescentnoj dobi. Djeca s boljim akademskim postignućima bolje su se pokazala na većini testova tjelesnoga fitnesa od vršnjaka koji su imali slabija akademska postignuća.

To je u skladu s nalazima nekih drugih studija (npr. Fedewa i Ahn, 2011; Ruiz-Ariza i sur., 2017; Wittberg i sur., 2010). Potvrđene su pretpostavke da će učenici s boljim akademskim uspjehom imati bolji kardiorespiratorni fitnes i snagu u usporedbi s akademski manje uspješnim vršnjacima. Isto tako pokazalo se da su za odnos između akademskoga uspjeha i tjelesnoga fitnesa bitne i neke druge komponente tjelesnoga fitnesa.

Van Dusen i sur. (2011), Fedewa i Ahn (2011), London i Castrechini (2011) i Wittberg i sur. (2010) u njihovim istraživanjima isto tako izvještavaju o vezama

između uspješnosti u matematici i tjelesnom fitnesu. Detaljnija analiza pokazala je da su varijable koje mjere ravnotežu, brzinu, okretnost, kardiorespiratorni fitnes, koordinaciju pokreta, izdržljivost u snazi i eksplozivnu snagu statistički značajno povezane s ocjenom iz Matematike. Slična otkrića mogu se naći u nekim drugim studijama. Bass i sur. (2013), Castelli i sur. (2007), Fedewa i Ahn, (2011), Van Dusen i sur. (2011) i Wittberg i sur. (2010) izvještavaju o vezama između matematike i kardiorespiratornoga fitnesa. Nadalje, Bass i sur. (2013) i Coe i sur. (2013) izvještavaju o povezanosti matematike i mišićne izdržljivosti. Guillamón, Cantó i García (2020), Niederer, Kriemler, Gut, Hartmann, Schindle i sur. (2011), i Morales i sur. (2008) potvrdili su vezu između matematike i koordinacije pokreta. To ne čudi jer je bolja koordinacija pokreta povezana s boljim pamćenjem (Niederer i sur., 2011). Uz to, ocjene iz Matematike također su povezane s varijablom za mjerenje ravnoteže, što su već utvrdili Niederer i sur. (2011). Naša su otkrića u skladu s podatcima iz studija na djeci predadolescentne dobi koja pokazuju da su uz kardiorespiratorni fitnes i druga područja tjelesnog fitnesa, poput ravnoteže, koordinacije i vještine s loptom, povezana s kognitivnim postignućima kod djece (Livesey, Keen, Rouse i White, 2006; Niederer i sur., 2011; Voelcker-Rehage, 2005). Međutim, ne postoji statistički značajna veza između matematike i gipkosti, što su također pronašli Castelli i sur. (2007). Isto tako ne postoji statistički značajna veza između matematike i brzine kretanja udova. Ovo posljednje pomalo iznenađuje jer je brzina kretanja uglavnom povezana s akademskim uspjehom (Ruiz-Ariza i sur., 2017).

Naše otkriće da postoji pozitivan odnos između ocjene iz jezika i tjelesnoga fitnesa, također je u skladu s prethodnim istraživanjima, iako nije toliko izraženo kao u matematici. Otkrili smo da su ravnoteža, brzina, kardiorespiratorni fitnes, izdržljivost mišića i eksplozivna snaga najvažniji dijelovi tjelesnoga fitnesa za povezanost s akademskim postignućima. Fedewa i Ahn (2011), Van Dusen i sur. (2011) i Wittberg i sur. (2010) izvještavaju o vezama između ocjene iz materinskoga jezika i kardiorespiratornoga fitnesa. Bass i sur. (2013) i Coe i sur. (2013) izvještavaju o vezama između ocjene iz materinskoga jezika i izdržljivosti mišića. Naše istraživanje nije pokazalo povezanosti gipkosti i ocjene iz materinskoga jezika. Castelli i sur. (2007) izvijestili su o sličnim nalazima. Također nismo ustanovili povezanosti akademskih postignuća kod materinskoga jezika i koordinacije te brzine kretanja udova, što prema Ruiz-Ariza i sur. (2017), pomalo iznenađuje.

Rezultati ovoga istraživanja pokazali su da su učenici, koji su uspješniji u Tjelesnoj i zdravstvenoj kulturi, bolji u svim varijablama tjelesnoga fitnesa od učenika koji su manje uspješni u Tjelesnoj i zdravstvenoj kulturi. To je očekivano jer viša razina tjelesnoga fitnesa znači i učinkovitije i bolje izvođenje tjelesnih vještina (Haapala, 2013), što omogućuje uspješnije sudjelovanje u Tjelesnoj i zdravstvenoj kulturi i stoga i višu ocjenu (Chng i Lund, 2018). Učenici koji su fizički spremniji, uglavnom su tjelesno aktivniji i imaju više motoričkoga znanja i iskustva. Međutim, neka dosadašnja istraživanja sugeriraju suprotno. Planinšec i Fošnarič (2006) utvrdili

su da ne postoji veza između tjelesne aktivnosti i ocjene iz Tjelesnog odgoja, a Dexter (1999) izvještava o skromnom odnosu između tjelesne aktivnosti i ocjena iz Tjelesne i zdravstvene kulture. Naše istraživanje pokazalo je da većina učenika ima dobre ocjene iz Tjelesne i zdravstvene kulture, upravo suprotno od Matematike i Slovenskog jezika. To može značiti da je znanje učenika iz Tjelesne i zdravstvene kulture bolje i ujednačenije nego kod drugih predmeta. S druge strane, visok udio dobrih ocjena također može ukazivati na pozitivnije stavove učitelja u ocjenjivanju Tjelesne i zdravstvene kulture ili na to da su kriteriji ocjenjivanja manje strogi u odnosu na druge predmete (Planinšec i Fošnarič, 2006).

U studiji smo otkrili da je ITM negativno povezan s akademskim uspjehom u matematici, jeziku i tjelesnoj i zdravstvenoj kulturi, što znači da učenici s boljim akademskim uspjehom imaju niži ITM i obrnuto. Ovo je otkriće također u skladu s nalazima nekih drugih istraživanja (Castelli i sur., 2007) da učenici koji su uspješniji u matematici, čitanju i ukupnom akademskom uspjehu imaju niži BMI. Donnelly, Greene, Gibson, Smith, Washburn i sur. (2009) pokazali su da je dovoljno česta tjelesna aktivnost u školi povezana s nižim ITM-om i višim akademskim postignućima. To se može pripisati činjenici da je niži ITM značajno povezan s višim tjelesnim fitnesom (Hillman, Buck, Themanson, Pontifex, Darla i Castelli, 2009), posebno kardiorespiratornim fitnesom. Također je utvrđeno da pretila djeca imaju niži kardiorespiratorni fitnes (Stigman, Rintala, Kukkonen-Harjula, Kujala, Rinne i Fogelholm, 2009) i slabiju motoričku koordinaciju (D'Hondt, Deforche, Gentier, De Bourdeaudhuij, Vaeyens i sur., 2012). S druge strane, veći ITM i veća količina tjelesne masti povezani su s lošijom izvedbom kognitivnih zadataka, a također i s nižim akademskim postignućima (Kamijo, Khan, Pontifex, Scudder, Drollette i sur., 2012). Autori navode da je pretilost povezana s manje učinkovitim živčanim procesima, pa pretila djeca sporije i manje precizno obavljaju zadatke koji zahtijevaju visoku kognitivnu kontrolu.

Korelacije između tjelesnoga fitnesa i akademskih postignuća mogu se objasniti učinkom koji tjelesna aktivnost i tjelesni fitnes imaju na strukturu i funkciju mozga. Istraživanja na djeci pokazuju da su razlike u strukturi mozga povezane s aerobnim fitnesom. Chaddock, Erickson, Prakash, Kim, Voss i sur. (2010) uspoređivali su djecu s nižim i višim vrijednostima VO2max, a to je mjera aerobnoga fitnesa. U djece s višim VO2max uočen je veći opseg hipokampusa s obje strane i posljedično bolje pamćenje. Chaddock, Erickson, Prakash, VanPatter, Voss i sur. (2010) navode da su razlike između djece s boljim i lošijim aerobnim fitnesom povezane s opsegom bazalnih ganglija, što je podkortikalna struktura koja značajno utječe na kognitivne funkcije; veći opseg bazalnih ganglija rezultira boljim obavljanjem kognitivnih zadataka. Djeca s boljim aerobnim fitnesom imala su veći volumen u dorzalnom striatumu koji je dio bazalnih ganglija, u usporedbi s djecom slabijega aerobnog fitnesa. Uz to, dokazano je da aerobno vježbanje povećava angiogenezu, tj. gustoću kapilara. Na taj se način povećava protok krvi u mozak, dok izvođenje složenijih

tjelesnih vještina uzrokuje sinaptogenezu, tj. povećani broj sinapsi (Adkins, Boychuk, Remple i Kleim, 2006). Voss i sur. (2011) i Chaddock, Erickson, Prakash, Voss, VanPatter i sur. (2012) uspoređivali su djecu s višim i nižim aerobnim fitnesom i otkrili da postoje razlike u aktivaciji mozga između skupina. Primijetili su povećanu aktivaciju u predfrontalnoj i parijetalnoj regiji mozga kod djece s boljim aerobnim fitnesom. Stoga su djeca s boljim aerobnim fitnesom bila učinkovitija u zadatcima koji zahtijevaju visoku razinu kognitivne kontrole jer su mogla bolje obavljati one zadatke u kojima su potrebni kognitivni procesi višega reda. Djeca s višim tjelesnim fitnesom imaju bolju pažnju i veću kognitivnu brzinu obrade informacija od djece s nižim tjelesnim fitnesom (Hillman, Pontifex, Raine, Castelli, Hall i Kramer, 2009). Nalazi istraživanja pokazuju da djeca koja su tjelesno aktivnija, imaju povećanu aktivnost kognitivnih procesa koji podržavaju učinkovito radno pamćenje (Kamijo, Pontifex, O'Leary, Scudder, Wu i sur., 2011). Međutim, ne smijemo zaboraviti da djeca s višim tjelesnim fitnesom u usporedbi s vršnjacima s nižim tjelesnim fitnesom manje izostaju iz škole, učinkovitija su u školskom radu, pažljivija, imaju manje disciplinskih problema, osjećaju manji stres, samostalniji su i trebaju manje poticaja učitelja (Physical Activity, 2013; Planinšec i Kokol, 2017).

Zaključak

Danas postoje brojni dokazi da vrijeme koje djeca provode u tjelesnoj aktivnosti nije samo korisno za bolje tjelesno zdravlje, već također značajno obogaćuje kognitivni razvoj i cjeloživotno zdravlje mozga (Hillman i sur., 2008; Physical Activity, 2013). Uz to, istraživanja dokazuju da je bolji tjelesni fitnes povezan s pozitivnim promjenama u strukturi mozga i poboljšanom funkcijom mozga, što značajno utječe na akademska postignuća. Stoga djecu treba poticati da su tjelesno aktivni s umjerenim do visokim intenzitetom najmanje jedan sat svaki dan jer to značajno utječe na tjelesni fitnes, koji djeci pruža brojne koristi, ne samo u razvoju, zdravlju i dobrobiti, već i u kognitivnom području koje potiče akademska postignuća (Planinšec i Kokol, 2017; Trudeau i Shephard, 2008). To je jedan od razloga zašto bi vrijedilo obogatiti dostupnost i opsega profesionalno vođenih tjelesnih aktivnosti u školama te svakodnevno nuditi kvalitetno tjelesno vježbanje svim učenicima.

Studije pokazuju da još uvijek ima mnogo djece koja nisu dovoljno tjelesno aktivna (Verloigne, Van Lippevelde, Maes, Yıldırım, Chinapaw i sur., 2012), što znači da još uvijek ima mnogo djece s pretežitim sedentarnim načinom života koja nisu dovoljno fit, pa je važno omogućiti im da budu uključena u odgovarajuće intervencijske programe za povećanje tjelesne aktivnosti koja utječe na kardiovaskularno, metaboličko i kognitivno zdravlje (Haapala, 2013; Physical Activity Guidelines, 2018). Također je potrebno organizirati tjelesne aktivnosti u školskom okruženju koje potiče pozitivne zdravstvene navike i značajno poboljšavaju sadašnje i buduće zdravlje djece.

Također svjesni smo ograničenja našega istraživanja. Činjenica je da se subjektivnost ne može u potpunosti izbjeći prilikom procjene znanja. Učitelji nisu prijavili nikakve

posebne poteškoće u ocjenjivanju. Problem je u tome što između učitelja mogu postojati razlike u kriterijima za procjenu školskih postignuća, iako je to slučaj u gotovo svim studijama (npr. Dwyer i sur., 2001; Planinše i Fošnarič, 2006). Ipak, zbog velikoga broja odjeljenja i učitelja koji su procjenjivali akademsku supješnost, ne možemo govoriti o bilo kojem jednostranom, sustavnom utjecaju. Ograničenja su također povezana s uzorkom djece koja su sudjelovala u istraživanju. U budućnosti bilo bi vrijedno provesti interdisciplinarna istraživanja kako bi se analizirala međuovisnost tjelesnoga fitnesa, akademskih postignuća i kognitivnih funkcija također na uzorku mlađih i starijih ljudi, a uz brojne već provedene transverzalne studije također provesti longitudinalna istraživanja.