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Original Article

Practicing karate may improves executive functions of 8-11-year-old schoolchildren

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Abstract:
Problem: executive functions refer to the subject's ability to engage in goal-oriented behavior, performing voluntary, independent, self-organized and goal-directed actions, indeed, the general physical training, and the sports can enhance this functions, studys to determinate the effect of martial arts upon the executive functions in childrens are rare. Objective: to identify if the Karatekas has best executive functions that non karatekas. Methods: 66 volunteers were selected, including 36 male karatekas and a comparison group consisting of 30 non Karateka and non regular physical activity, with a mean of age of 11.26 + 0.95 years. The reaction time test and Stroop Test were used. The analysis of variance ANOVA TREE WAY with Dunnett's Post Test set up at 5% was used. Results: in reaction time for all ages, the Karatekas performed better; however, for selective attention and problem solving, 11-year-old karate children did not perform better, while for the other ages, the karate students were faster. Conclusions: Karate is an efficient tool for improving the executive functions of children from 8 to 11 years of age.
Key words: stroop test; motor reaction time; selective attention; karate benefits. executive functions.

Introduction

Executive functions refer to the subject's ability to engage in goal-oriented behavior, performing voluntary, independent, self-organized and goal-directed actions (Ardila & Ostrosky-Solís, 1996), statements that denote the importance of these functions. Therefore, changes in executive functions have been shown to be related to various cognitive and psychiatric disorders resulting from lesions or neurological dysfunctions, such as Attention Deficit Hyperactivity Disorder (Barkley, 1997).

Studies demonstrate that exercise is capable of promoting improvements in executive functions in healthy people of different ages (Padilla, 2016; Verburgh, 2012) and recent studies have focused on the positive influence of regular physical activity on executive functioning in children. Recreational activities are also capable of modifying functions such as memory and conflict resolution (Liu-Ambrose, 2015). It is assumed, therefore, that the physical exercise may assist in the development of cognition, memory, selective attention and motor reaction time (Padilla, 2016; Verburgh, 2012), especially in children (Diamond, 2011). Alesi and Bianco (2016) in their stud show that a football exercise program to children there were significant differences between sport and sedentary groups in coordinative skills and executive functions as visuo-spatial working memory, attention, planning and inhibition corroborating with Alesi and Bianco (2016).

Schmidt and Jäger (2015) in a group-randomized controlled trial stud affirm that the inclusion of cognitive engagement in physical activity seems to be the most promising type of chronic intervention to enhance executive functions in children, providing further evidence for the importance of the new studs. In general the activities and programs that improve children's executive functions (Hillman and Kramer, 2008) improving the 8–12 year-olds' cognitive flexibility and creativity, and significantly more so than did standard physical education (Diamond and LEE, 2011; TUCKMAN, 1986). Another authors postulate that bimanual coordination (CASTELLI and Hillman, 2007), resistance training (Coe, 2006), several sports practice that requiring sustained attention, work memory, and disciplined action may improve the executive function (Diamond and Lee, 2011) in this context the Karatê practice deserve more investigations about their effects upon this functions.

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Traditional martial arts emphasize self-control, discipline (inhibitory control), and character development. Children getting traditional Tae-Kwon-Do training were found to show greater gains than children in standard physical education on all dimensions of executive functions studied (e.g., cognitive [distractible—focused] and affective [quitting—persevering]) (Lakes, 2004). Tuss, studies indicate that practicing Karate provides one with benefits such as: (i) greater concentration, (ii) focus, (iii) self-control, (iv) calmness, as well as physical improvements such as cardiorespiratory functioning, bone and muscle health, immunity and increases the organism's resistance in general (Rodrigues, 2013; Prado, 2009; Ferreira, 2006). However, it is well known that individuals trained in different skills and sports may have specialized cognitive skills and motor strategies related to the characteristics of the activity and the effects of training and specialization (Sanchez-Lopes, 2014).

Demands on mindfulness increased over time as the first and third parts lengthened and the more goal-directed and less-reflective middle portion became briefer. Skills practiced in Parts 1 and 3 involved top-down control of attention (bringing attention to the present moment, noticing when attention had wandered [monitoring], and bringing it back non-judgmentally to the intended target (Flook, 2010).

Is important note that another factors may have influence upon the executives functions like the age and the aging. Frederico (2016) show that the aging may influence the attention skills and Sastre-Riba (2016) about the intellectual capacity, for exemple, So, thus, is important consider this variable in the investigations about the executive function.

These cognitive abilities – mental processing speed – have been measured by quantifying simple and complex reaction time and problem-solving tasks such as the ***Stroop Test*** (Colcombe and Krames, 2003; Tomporowski, 2003). Studies have shown that information processing speed is significantly improved by acute (COLCOMBE and Krames, 2003; Tomporowski, 2003) and chronic exercise (Davis et al., 2007; 2011). These effects have been observed in elderly people or in children (Best, 2010; Tomporowski, 2003), and seem to be influenced by factors such as habitual physical activity level and skill level (Vororrips *et al.,* 1993; Simonen *et al.* 1998), which supports the hypothesis that the practice of physical activity improves executive functions (Voorrips *et al.,* 1993; Mcmorris; Keen, 1994; Kuukkanen; Simonen *et al.*, 1998).

Most of the studies investigated motor differences in self-stimulated tasks in athletes, but not in tasks related to stimuli. Thus, the present study aimed to identify and compare whether or not the practice of Karate modifies executive functions of schoolchildren of different ages.

Material & methods

Study Type

This is a quanti-qualitative cross-sectional type, since it aims to quantify and qualify an existing phenomenon, of ex-post-facto. This study was approved after being evaluated by the Ethics and Research Council of the State University of Rio de Janeiro under protocol number CEP 363.010 from 2013.

Universe and Volunteer Group

The universe of this study is composed of 120 children including both sexes between the ages of 8 and 18 years old in the Ricardo Cantanhede State School of Primary and Secondary Education, State Elementary School of Mato Grosso, Rondônia and Maria de Abreu Bianco Elementary School, Brazil. In order to be included, the student needed to be properly enrolled in the school or the "Karate in School" program and, in that case, also properly enrolled in a school, and needed to turn in the informed consent form signed by a guardian. The non-fulfillment of these items is mentioned in the exclusion factors.

The Volunteer Group consists of 67 children between 8 and 17 years of age. For the purpose of this study, the age group of 8 to 11 years old was used, a group that is composed of a minimum number of participants needed to characterize and treat the data through inferential statistics.

The group of interest in the present study was made up of 36 male Karate students, called of KAR with a mean age of 9.63 ± 1.0 years old, mean total body mass of 37.81 ± 10.23 kg and mean height of 1.39 ± 0.09m. The comparison group consisted of 30 subjects who did not practice karate and did not practice regular physical exercise called CON with an average age of 11.26 ± 0.95 years old, mean total body mass of 40.48 ± 8.66 kg and height of 1.47 ± 0.08m. The 8-year-old karate group had n = 10 and the comparison group of the same age n = 8. The 9-year-old karate group n = 8 and the comparative group of the same age n = 7. The 10-year-old Karate group has n = 9 and the comparative group of the same age n = 7. The 11-year-old karate group has n = 9 and the comparative group of the same age n = 8.

A history of neurological, psychiatric and vascular diseases and the use of substances and drugs that could lead to altered states of consciousness, learning disabilities, changes in alertness and wakefulness, or any other state that could have interfered with outcomes such as sleep deprivation were considered exclusion criteria. All participants stated that they had no visual problem that could compromise their performance on the tests.

All Karatekas had been practicing regularly for at least six months, averaging three times a week and ninety minutes of class time.

Procedures

Reaction Time Test (RTT)

The reaction time of four choices was measured with software installed on a portable device (laptop). The subject supported the second and third fingers of the left and right hands on keys 1, 2, 3 and 4, respectively. When a number (between 1 and 4) appeared on the LCD screen, the participant attempted to press the correct key as quickly as possible. There were 10 habituations and 40 acquisitions, and the inter-stimulus interval ranged from 1 to 3 seconds to avoid anticipation of the stimulus. The mean and standard deviation (SD) of the correct and incorrect trials were calculated separately and the current analyses were based on the mean number of correct trials.

Stroop Test

This test is composed of two tasks, one reading and the other naming colors. The fact that there is an inconsistency between the word name and color causes an interference effect in naming the colors. This interference is known as the Stroop-Color effect. The Stroop Test (Teresa, 2014; Graf, 1995; Treneri, 1989) was used to evaluate selective attention and resolution of conflicts and the time difference between naming the ink color in which the words were printed (ignoring the word itself) and naming the color displayed in the images that were viewed on the Xs computer monitor was calculated. Lower time differences indicate better performance.

Participants were tested on computers that run the ***STROOP TEST***. The stimuli consisted of word names and colors in Portuguese VERDE (GREEN), AMARELO (YELLOW) and VERMELHO (RED) displayed in Arial fonts in green, yellow and red colors. The words were approximately 2 cm wide and 0.5 cm high. Participants had to react as quickly as possible by indicating the word's color using the index, middle or ring finger of their dominant (right) hand to press the 'c', 'v' or 'b' keys.

The stimuli were randomized by participant and presented in the center of the computer screen approximately 50 cm from the participant's eye and remained on display until a response key was pressed, after a gray fixation cross was presented for 750 ms, followed by the next stimulus. The nine possible word/color-color combinations were presented in random order, resulting in 33% congruent trials and 66% incongruent trials. For 33% of the trials, the irrelevant word was repeated, and for another 33% the relevant color (response repetitions) was repeated. No repetition was present in the remaining 33%. Participants were initially presented a practice block of 40 habituations with feedback, followed by a block of 90 acquisitions with no feedback (a total of 130 experimental trials).

Treatment of Data

The data was treated descriptively and inferentially through the mean and standard deviation. To make data inferences, the Kolmogorov-Smirnorv test was performed initially in order to verify the normality of the data. After confirming the normality of the data the ANOVA TWO WAY followed for Bonferroni's Post Test was performed for test the influence of age (Karate/Control x age) upon the time reaction time and ANOVA TREE WAY followed for Post Test of Dunnett's test was performed for stroop test (karate/control x age x congruent/incongruent) set up at 5% in the program Prism Graph 5.0.

Results

Karateka has more speed in reaction time that non Karateka

According to figure 01, KAR of 8-year-old obtained a mean motor reaction time of 0.301 $\pm$ 0.039 milliseconds (ms) while CON reached a mean of 1.833 $\pm$ 0.369 ms (P <0.0001). The KAR 9-year-old obtained an average reaction time of 0.626 ± 0.409 ms while CON reached 1.977 $\pm$ 0.756 ms (P <0.001). The KAR 10-year-old obtained an average reaction time of 0.705 $\pm$ 0.344 ms while CON reached 1.687 $\pm$ 0.395 ms (P<0.0001). Finally, KAR 11-year-old obtained a reaction time of 0.432 ± 1.442 ms while non-Karate subjects reached 1.96 ± 0.842 ms (P>0.05).

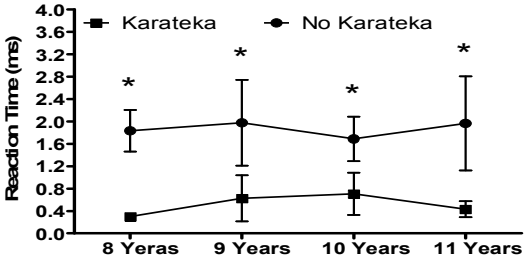

Fig 1. Reaction time. Booth groups was submitted at 40 habituations and 90 acquisitions of data. The KAR 8, 9, and 10-year-old had difference to theirs CON groups at the same age, but not to 11-year-old groups. The

ANOVA TWO WAY with Bonferroni's Post Test set up at 5%. (ms= milliseconds); (ns= non significant; *=*P*<0.0001; #*P*< 0,001).

Karatekas has more effectiveness in solve conflict in *Stroop Test*

Figure 2 shows that KAR 8-year-old obtained an average of 0.664 ± 0.686 milliseconds for selective motor attention, while CON reached a mean of 2.922 ± 2.42 ms (*P*<0.0001). The KAR 9-year-old obtained an average of 0.531 ± 0.118 ms for selective motor attention, while CON obtained 2.703 ± 0.763 ms (*P*<0.001). The KAR 10-year-old obtained an average of 2.079 ± 1.791 ms for selective motor attention, while CON subjects of the same age 3.695 ± 1.678 ms (*P*<0.0001). Finally, KAR 11-year-old obtained 2.211 ± 1.698 ms for selective motor attention, CON subjects of the same age reached 2.461 ± 2.319 ms (*P*<0.0001).

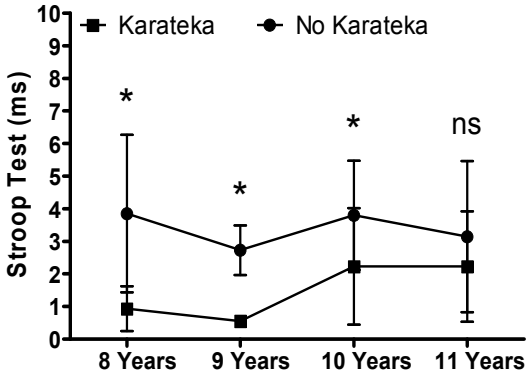

Fig 2. Selective attention and problem solving Booth groups was submitted at 40 habituations and 90 acquisitions of data. The KAR 8, 9, and 10-year-old had difference to CON groups at the same age, but not to 11-year-old groups. The ANOVA TREE WAY with Dunnett's Post Test set up at 5%.. (ms= milliseconds); (ns= non significant; *=P<0.0001; #P< 0,001).

Discussion

The main objective of the present study was to investigate whether or not the practicing the Karate modality could modify performance in executive functions of children. Thus, two procedures were conducted to determine motor reaction time, selective attention and conflict resolution. The modulation of reaction time, selective attention and conflict resolution aimed to increase the probability of detecting the possible relationship between the systematic practice of Karate and these higher cognitive functions, since the practice of physical exercise in general has been implicated in the development of the organism and central nervous system functions (Verburgh, 2014).

The most important findings of this study show that practicing Karate significantly improved executive functions related to reaction time, selective attention and processing speed for conflict resolution in KAR compared to CON students, and that functional maturation of physically active children's brains seems to occur earlier than in sedentary children. The present results demonstrated the beneficial transfer effects of practicing Karate in various executive functions in children.

In children, exercise has been linked to general development that culminates in the improvement of motor and cognitive capacity (Podilla, 2016; Verburgh, 2012). In this context, combat sports may prove to be capable of developing certain abilities, as Barcelos (2009) states, although little is known about other effects of these modalities, especially on the executive functions of children and adolescents; however, due to its "open" characteristic, that is, there is no possibility of predicting the movements, motor performance is directly related to the capacity to respond to the changes that occur in the environment, an affirmation corroborated by Fontani (2006).

Lakes (2004) postulate that the martial arts historically have emphasized the importance of self-regulation, using terms such as self-control, body control, and discipline. Iet the same author affirm that outcomes of martial arts training can be classified into two domains: physical (i.e., physical skill and psychological effects related to physical appearance and ability) and psychological (i.e., generalized psychological benefits). Cognitive factors influenced positively by martial arts training include concentration (Konzak & Boudreau, 1984) and a greater awareness of mental capacities as well as a cultivation of that potential. This factors can be associated with the results observed here.

For simple motor reaction time, the results found showed clear differences between the children from KAR group when compared to children from CON at all ages since they responded more quickly to the stimulus than the CON children, a fact that is corroborated by Antunes (2006). These findings suggest that Karate improves stimulus perception, information processing, planning and the emission of a motor response that is appropriate to the stimulus that may explain our results. These data corroborate the findings of Padilla (2016) who demonstrated a potent effect of aerobic physical activity on attention levels and implicit and explicit

memory in young adults and with several other studies that associate the time of experience in a sports modality with the improvement of the amplitude and flexibility of cortical processes besides modulating different executive functions according to the level of demand (Sanchez-Lopes, 2014; Bruzi, 2013; Tadei, 2012; Hack, 2009; Hung, 2004).

The phases of information processing, such as perception, learning, memory, attention, vigilance, reasoning and problem solving are understood to be cognitive functions, or the functional cognitive system. In addition, psychomotor functioning (reaction time, movement time, performance velocity, and conflict resolution) has often been included in this concept (Padilla, 2016; Verburgh, 2012; Gazzaninga, 2002; Duncan, 1997).

The present study also investigated the effects of karate on selective motor attention and problem solving since empirical evidence on the effects of this modality on this executive function is scarce. The findings of the present study show a notable difference between the Karate students when compared to the group of children who didn't practice karate from 8 to 10 years old and a marginally significant difference in the 11-year-old group ($p=0.09$). These data suggest that the practice of this modality is capable of promoting neural changes in cortical functioning that allows the acceleration of the information processing to solve the interference of conflicting visuospatial stimuli.

Best (2012) found that age suggests improvements in the accuracy of interference resolution and overall response time, but shows that physical activity influences executive function and how this effect differs from improvements that occur with maturational development, corroborating findings from the present study where it was observed that the KAR with 8-, 9- and 10-year-old have a faster response to conflicting visuospatial stimuli than children of equal or greater age who do not engage in physical activity. These findings may be important since notable functional development is evident independent of the structural development acquired with age.

From the previously established reasoning, exercise can be an instrument for neurological, cognitive and motor development. In the present context, Karate has proven to be an effective tool for this purpose by demonstrating a strong effectiveness in improving motor reaction time and selective attention of children who practice Karate when compared to non-Karate participants of the same age.

Conclusions

This study produced scientific evidence demonstrating that practicing karate had beneficial effects on cognitive functions (executive functions related to simple reaction time, selective attention and conflict resolution) in healthy children between 8 and 11 years of age. These results do not indicate that everyone should practice karate with the same effects because: (i) we did not compare the beneficial effects of karate with other martial arts or other sporting modalities, and (ii) some limitations apply to a larger age range such as young adults and elderly people. However, we believe that our results are relevant to educational, clinical, and sports fields. An important future direction is to examine whether or not karate can support educational and clinical activities. It seems correct to say, therefore, that Karate is an efficient tool in reducing reaction time, where elements of perception, planning and emission of a response motor action are involved in the selective attention capacity of children between 8 and 11 years of age when compared to children who do not practice karate, suggesting that this sport can be considered an important tool for cognitive, perceptive and motor development.

What does this article add

In oriental countries, several martial arts are used as method to learning and charater construction, and in this context, the Karate is a very good example and important sport around the word. But, the martial art practice, including the Karate, has a strong role in the development of the body and mental skills. Here, we describe one of this proprieties were the Karate may be used as a tool for development of strong executive functions that, in general, can be the background to the cognition and learning. But, after this paper, the relationship between the role of Karate practice in the development of the executive functions of 8 to 11 years old children do not was clear, but now, we are taking scientific light about this issue.

References

Alesi, M., Bianco, A., Luppina, G., Palma, A., & Pepi, A. (2016). Improving children's coordinative skills and executive functions: the effects of a football exercise program. *Perceptual and motor skills*, *122*(1), 27-46.

Antunes, H. K., Santos, R. F., Cassilhas, R., Santos, R. V., Bueno, O. F., & Mello, M. T. D. (2006). Exercício físico e função cognitiva: uma revisão. *Rev Bras Med Esporte*, *12*(2), 108-14.

Ardila, A., & Ostrosky-Solís, F. (1991). *Diagnóstico del daño cerebral: enfoque neuropsicológico*. México^ eDF DF: Trillas.

Lotério Barcelos, J., Pontes Morales, A., Nascimento Maciel, R., Anjos Azevedo, M. M. D., & Furtado da Silva, V. (2009). Tempo de prática: estudo comparativo do tempo de reação motriz entre jogadoras de voleibol. *Fitness & performance journal*, *8*(2).

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: constructing a unifying theory of ADHD. *Psychological bulletin*, *121*(1), 65.

Best, J. R. (2012). Exergaming immediately enhances children's executive function. *Developmental psychology*, *48*(5), 1501.

Bruzi, A. T., Fialho, J. V. A. P., de Souza Fonseca, F., & Ugrinowitsch, H. (2013). Comparação do tempo de reação entre atletas de basquetebol, ginástica artística e não atletas. *Revista Brasileira de Ciências do Esporte*, *35*(2).

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.

Coe, D. P., Pivarnik, J. M., Womack, C. J., Reeves, M. J., & Malina, R. M. (2006). Effect of physical education and activity levels on academic achievement in children. *Medicine & Science in Sports & Exercise*, *38*(8), 1515-1519.

de Oliveira, A. L., Gomes, F. R. F., & Suzuki, F. S. (2006). Conceito dos tipos de lutas a partir de uma visão de cultura corporal.

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science*, *333*(6045), 959-964.

Duncan Roger Johnson Michaela Swales Charles Freer, J. (1997). Frontal lobe deficits after head injury: Unity and diversity of function. *Cognitive Neuropsychology*, *14*(5), 713-741.

Ferreira, H. S. (2006). As lutas na educação física escolar. *Revista de educação Física*, *135*, 36-44.

Fontani, G., Lodi, L., Felici, A., Migliorini, S., & Corradeschi, F. (2006). Attention in athletes of high and low experience engaged in different open skill sports. *Perceptual and Motor Skills*, *102*(3), 791-805.

Federico, F., Marotta, A., Martella, D., & Casagrande, M. (2017). Development in attention functions and social processing: Evidence from the Attention Network Test. *British Journal of Developmental Psychology*, *35*(2), 169-185.

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2002). Cognitive Neuroscience, New York: W. W.

Graf, P., Uttl, B., & Tuokko, H. (1995). Color-and picture-word Stroop tests: performance changes in old age. *Journal of Clinical and Experimental Neuropsychology*, *17*(3), 390-415.

Hack, J., Rupp, A., & Memmert, D. (2009). Attentional mechanisms in sports via brain-electrical event-related potentials. *Research quarterly for exercise and sport*, *80*(4), 727-738.

Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: exercise effects on brain and cognition. *Nature reviews. Neuroscience*, *9*(1), 58.

Hung, T. M., Spalding, T. W., Maria, D. L. S., & Hatfield, B. D. (2004). Assessment of reactive motor performance with event-related brain potentials: attention processes in elite table tennis players. *Journal of Sport and Exercise Psychology*, *26*(2), 317-337.

Jäger, K., Schmidt, M., Conzelmann, A., & Roebers, C. M. (2015). The effects of qualitatively different acute physical activity interventions in real-world settings on executive functions in preadolescent children. *Mental Health and Physical Activity*, *9*, 1-9.

Lakes, K. D., & Hoyt, W. T. (2004). Promoting self-regulation through school-based martial arts training. *Journal of Applied Developmental Psychology*, *25*(3), 283-302.

Liu-Ambrose, T., & Eng, J. J. (2015). Exercise training and recreational activities to promote executive functions in chronic stroke: a proof-of-concept study. *Journal of Stroke and Cerebrovascular Diseases*, *24*(1), 130-137.

Padilla, C., Mayas, J., Ballesteros, S., & Andrés, P. (2017). The role of chronic physical exercise and selective attention at encoding on implicit and explicit memory. *Memory*, *25*(8), 1026-1035.

Prado, G. N. D. (2009). O karatê como conteúdo da educação física escolar: uma revisão de literatura.

Rodrigues, S. C. P. (2013). Estudo de correlação entre tempo de reação e tempo de movimento no karatê. *Kinesis*.

Sanchez-Lopez, J., Fernandez, T., Silva-Pereyra, J., Mesa, J. A. M., & Di Russo, F. (2014). Differences in visuo-motor control in skilled vs. novice martial arts athletes during sustained and transient attention tasks: a motor-related cortical potential study. *PloS one*, *9*(3), e91112.

Sastre-Riba, S., & Viana-Saenz, L. (2016). Executive functions and high intellectual capacity. *Revista de neurologia*, *62*, S65-71.

Trenerry, M. R., Crosson, B., DeBoe, J., & Leber, W. R. (1989). Stroop neuropsychological screening test. *Odessa, FL: Psychological Assessment Resources*.

Tuckman, B. W., & Hinkle, J. S. (1986). An experimental study of the physical and psychological effects of aerobic exercise on schoolchildren. *Health Psychology*, *5*(3), 197.

Verburgh, L., Königs, M., Scherder, E. J., & Oosterlaan, J. (2013). Physical exercise and executive functions in preadolescent children, adolescents and young adults: a meta-analysis. *Br J Sports Med*, bjsports-2012.