Revista de Psicología del Deporte/Journal of Sport Psychology Vol. 29. n.°4 2020. pp. 175–184
Universidad de Almería / Universitat Autónoma de Barcelona. ISSN 1132–239X ISSNe 1988–5636

The influence of sports practice in children aged 6 to 7 years on physical fitness, motor coordination and executive functions.

Rafaello Pinheiro Mazzoccante[1;2*]; Hugo de Luca Corrêa[2]; Ioranny Raquel Castro de Sousa[2;3]; Matheus Almeida Camarâ[1]; Gabriel de Sousa Alves[1]; Beatriz Raquel Castro de Sousa[1]; Frederico Santos de Santana[4]; Aparecido Pimentel Ferreira[2]; Gislane Ferreira de Melo[2].

Abstract

To compare motor coordination, aerobic fitness, body composition, attention and cognitive flexibility between sports practitioners and non-practitioners children. Participated in the study 68 children aged 6-7 years old, students of a private school. The aerobic fitness was measured using the Yo-Yo Intermittent Recovery Test - level 1 (YYIR1) adapted for children. The motor performance was measured by the körperkoordination für kinder (KTK) test, composed of four tasks: balance beam, monopedal jump, transfer on platforms and lateral jumps. Cognitive flexibility and attention were assessed by the attention cancellation test (ACT) (selective attention), trail making test A (sustained attention) and trail making test B (cognitive flexibility), both of which were composed by visual search task. Sports practitioners had higher scores than non-sports practitioners children (p <0.01) in YYIR1 performance (463.9±349.3 vs 221.17±138.5); motor coordination (343.3 ± 38 vs 309 ± 21.3), lower limb thrust force (jump to 90º (18.6 ± 4.6 vs 16.1 ± 4) and jumping countermovement (19.6 ± 4 .5 vs 16.5 ± 4.1); trail making test A (107.9 ± 7.9 vs 99.3 ± 19.6) and cognitive flexibility (116 ± 15.8 vs. 106.7 ± 17.1) variables. It is possible to observe through the results a possible influence of the sports practice concerning the development of aerobic, motor, sustained attention and cognitive flexibility

***Keywords*:** Sport; Aerobic fitness; Motor coordination; cognitive flexibility; selective and sustained attention.

Resumen

Comparar la coordinación motora, la aptitud aeróbica, la composición corporal, la atención y la flexibilidad cognitiva en niños practicantes y no practicantes de deportes Participaron en el estudio, 68 niños de 6 a 7 años, alumnos de una escuela privada. La aptitud aeróbica se midió utilizando la recuperación Yo -Yo intermitente Nivel 1 (YYIR1) adaptado para niños. El rendimiento motor se midió mediante pruebas de körperkoordination für Kinder (KTK), que constan de cuatro tareas: barra de equilibrio, saltos de una sola pierna, plataformas de transferencia y saltos laterales. La atención y la flexibilidad cognitiva se evaluaron mediante la prueba de atención para la cancelación (atención selectiva), Trail Making Test A (atención sostenida) y Trail Making B (flexibilidad cognitiva), ambos compuestos por la tarea de búsqueda visual. Los niños practicantes de deportes tuvieron puntajes más altos que los niños no practicantes (p <0.01) en las siguientes variables: aptitud cardiorrespiratoria (463.9 ± 349.3 frente a 221.17±138.5); coordinación motora (343.3 ± 38 frente a 309 ± 21.3), fuerza de empuje de las extremidades inferiores (salto en 90 grados) (18.6 ± 4.6 frente a 16.1 ± 4) y contra movimiento de salto (19.6 ± 4.5 frente a 16.5 ± 4.1); trail making test A (107.9 ± 7.9 frente a 99.3 ± 19.6) y flexibilidad cognitiva (116 ± 15.8 frente a 106.7 ± 17.1); respectivamente. Y es posible observar por medio de los resultados una influencia de la práctica de los deportes en relación con el desarrollo de la capacidad aeróbica, coordinación motora, de atención sostenida y flexibilidad cognitiva.

Palabras clave: deporte; Capacidad aeróbica; Coordinación motriz; flexibilidad cognitiva; Atención selectiva y sostenida.

Childhood is a sensitive period for motor learning and development, especially because both gross and fine motor skills are essential in this stage of biological development. The high motor competence acquisition is dependent on appropriate stimulation in respect of the motor development stage. Generally, the practice of physical exercise and motor experiences are provided by school education, sports practice, and an active lifestyle(Bardid et al., 2016; Hoeboer et al., 2016). Sports seem to play an important role in expanding children's motor repertoire, which is related to biological growth, aerobic and neuromuscular performance (Laukkanen, Pesola, Havu, Sääkslahti, and Finni, 2014).

1Euro-American University Center (UNIEURO), Brasília, Brazil.
2Master and Doctoral Program in Physical Education, Catholic University of Brasília, Brasília, Brazil.
3Federal District University Center Brasília (UDF), Brazil.
[4]Master and Doctoral Program in Physical Education, University of Brasília (UNB), Brazil.
Endereço: Av. Castanheira, lote 3700, Águas Claras – Brasília – DF. CEP 71900-100. Fone: (61) 34455888. Degree and Bachelor of Physical Education course at Euro-American University Center - UNIEURO. e-mail: rafa_mazzoccante@hotmail.com

Furthermore, from a developmental perspective, motor competence, generated commonly with sports practice in childhood, is essential to enhance academic, physical, cognitive, and social development (Bardid et al., 2016; Laukkanen et al., 2014). This fact is due to the interrelation between the frontal cortex, a region responsible for controlling the executive function (EF), and the cerebellum region, responsible for motor control, that is, the neural circuits recruited during motor action also act on the neural circuits responsible for attention and EF (Chaddock, Neider, Lutz, Hillman, and Kramer, 2012; Diamond, 2000; Sigmundsson, Englund, and Haga, 2017).

EF is divided into three areas: cognitive flexibility (CF), inhibitory control, and working memory. It is defined by the ability to simultaneously deal with two or more pieces of information, self-control, an ability to store, manipulate, and temporarily utilize information (Budde, Voelcker-Rehage, Pietraßyk-Kendziorra, Ribeiro, and Tidow, 2008; Sigmundsson et al., 2017). These components are in charge of the abilities of planning, organization, creativity, and self-control, essential to cognitive development (Baumeister, Reinecke, Liesen, & Weiss, 2008a; Bugge et al., 2014; Whedon, Perry, Calkins, & Bell, 2015). Thus, the development of attention and EF are important predictors of educational and social success (Whedon et al., 2015).

Among the activities related to the improvement of EF and attention stand out computer games, aerobic exercises, sports, yoga, and mindfulness (Diamond, 2000). Sports practice is one of the most complete activity in order to achieve benefits related to CF, selective and sustained attention, since children have to deal with the processing of internal and external information, during practice, a match, competition, game, or fight (Baumeister et al., 2008; Tudos, Predoiu, and Predoiu, 2015).

Sports unveil itself as a singular element to improve aerobic performance, motor competence, attention, and executive function (Laukkanen et al., 2014). Cognitive and executive domains are necessary during sports practice mainly in decision-making, strategic, precision, concentration, reaction time, motor dexterity, among other factors, but each sport modality requires different degrees of motor complexity, aerobic capacity, attention, and EF performance (Tudos et al., 2015).

Sports performance is influenced and influences the ability of attention and EF. The positive action of the EF arising from sports practice is directly dependent on the degrees of cognitive information that the practitioner will have to solve during the performance of the sport. These demands of EF are better explored in sports that constantly have the requirement of new motor tasks and/or complex movements. Furthermore, strictly aerobic sports have a greater benefit on neural and cognitive recruitment, once motor learning influence on cognitive, associative, and autonomous domains. In this sense, learning is represented by the understanding of the movement, internalization of information by the execution of the movement and finally learning becomes autonomous and consistent (Assis, Alves, Silva, Moreira, and Dantas, 2018; Kamijo, Takeda, Takai, and Haramura, 2016; Koutsandréou, Wegner, Niemann, and Budde, 2016). Also, the motor task seems to have greater cognitive demands related to diversify and explore the complexity of the movement. This integrated action will provide the specific adaptations between the different areas of the brain responsible for the motor and cognitive abilities, providing better answers on EF (Assis et al., 2018; Kamijo et al., 2016; Koutsandréou et al., 2016).

In this way, sports practice seems to promote a positive effect on motor and cardiorespiratory development, as well as, physical and cognitive benefits, nonetheless, the effects of sports practice with the focus on the components of EF are little explored in children. However, it is well-known how it responds to adults and adolescents (Huijgen et al., 2015; Verburgh, Scherder, Van Lange, and Oosterlaan, 2014). Thus, it is necessary to investigate the effects of sports practice during childhood. Therefore, the present study aimed to verify the influence of practicing sports modalities on motor coordination, aerobic fitness, attention, and cognitive flexibility in children aged 6 and 7 years. We hypothesize that sports practice is related to higher physical, motor, and cognitive performance.

Method

Participants

A total of 68 children aged 6-7 years old from a private school in the city of Ceilandia, Federal District, participated in this study and composed two groups: Sports Group (SG) – with sports practitioners children (n = 34; 12♀; 22♂; 6.94 ± 0.23 years); Control Group (CG) – with non-sports practitioners children (n = 34; 26♀; 8♂; 6.64 ± 0.48years).

Children had free informed consent signed by parents or guardians and the study was approved by the Ethics and Research Committee of the Catholic University of Brasilia (Nº 2.071.564). The volunteers were free from a diagnosis of neurological or psychiatric diseases, articular problems, and medication use. Scholar disapproved participants and who did not complete all the tests were excluded.

Procedure

The anamnesis was carried out by separate interview between children and parents; it was used to ensure the inclusion criteria of the study, such as schooling, history of school disapproval, medication in use and neurologic-al disorders. The researchers executed three visits to implement the research instruments, which were randomly performed in the school divided into three stages: 1) Attention Cancellation Test (ACT) and trail making test A and B (applied collectively); 2) Jumping tests and Intermittent Recovery test – Level 1 (Yo-Yo_1); 3) Body composition and the Körperkoordinationstest für Kinder (KTK). They were performed by experient evaluators trained for at least one week before the research. Attention cancellation and trail testing test A and B were applied collectively in the classroom with at least three raters to maintain the reliability.

Trail making test A and B.

Trail Making Test A is composed of two sheets. One of them contains letters, while the other includes numbers, both randomly arranged. This test consists of linking points in increasing alphabetical and numerical order. Trail Making Test B is composed of a sheet containing letters and numbers randomly arranged on the same sheet. The task consists of connecting letters and numbers alternately, in numerical and alphabetical orders. Both tests had their performance established at the maximum time of one minute for each test (Seabra and Dias, 2012).

The performance classification assessment for Trail Making Test A and B test was determined according to the criteria established by Seabra and Dias (2012), which splits groups based on the performance achieved in the test and the score categorized per age. They were categorized into five classifications: very high, high, average, low, and very low.

Anthropometric assessment and body composition.

The anthropometric and body composition variables were performed by waist and hip circumference, body mass, height, and skin folds equations described as follows: Body Mass Index ((BMI) = body weight (kg) / stature^2 (m)); Waist-to-Hip Ratio ((WHR) = waist circumference / hip circumference) and the sum of skinfolds (ΣSF) (Petroski, Pires-Neto, and Neto, 1995).

Cardiorespiratory fitness.

For the cardiorespiratory fitness was used Yo-Yo test characterized by sequences of runs with rhythm controlled by sounds of a CD player. The run distances were 16 and 20 meters, respectively, for 6-9 years and above 9 years, with the track width of 1.3 meters (Ahler, Bendiksen, Krustrup, Wedderkopp, and George, 2012; Andersen, Andersen, Andersen, and Anderssen, 2008). The rhythm was increased progressively with rests interval of 10 seconds. The finish was determined when the volunteer failed to reach 16 or 20 meters, respectively. To guarantee the performance of the races at the speeds corresponding to each stage, at least two of the researchers participated in the test to ensure that the ideal pace was maintained.

Counter-movement and squat jump (90°).

Also, power performance was measured by Counter Movement Jump and Squat Jump (knees 90 degrees), both initiated with the parallel position of the feet. Vertical jumping performances were evaluated according to the descriptions of the Bosco protocols (Bosco, 2002).

Körperkoordinationstest für Kinder (KTK).

KTK is composed of four tasks: 1) balance beam: moving backward along three descending width beams, 2) monopedal jump: jumping on increasing height obstacles, 3) transfer on platforms: moving sideways on wood boards for 20 seconds, and 4) lateral jumps: jumping with both legs from one side to another for 15 seconds (Gorla, JI, Araújo PF, 2009; Hoeboer et al., 2016).

The coordination capacity was assessed by the motor quotient (MQ), originated from the gross values obtained in each KTK task; its sum resulted in the total MQ, classified in five Motor Coordination (MC) levels, referring to the total MQ score values: good motor coordination; normal motor coordination; insufficient motor coordination; and disruption in motor coordination (Gorla, JI, Araújo PF, 2009)

Data analysis

Descriptive statistics with mean values and the standard deviation was performed. Data normality was tested by employing the Shapiro-Wilk test. To compare the aerobic fitness values, motor coordination, cancellation attention tests, and Trail Making Test A and B between the groups, the Student's t-test was used.

The ROC curve (Receiver Operating Characteristic) is generated by plotting sensitivity on the y-axis as a function of [1 - specificity] on the x-axis. Sensitivity refers to the percentage of individuals who presented the outcome (in the case of the present study, it was the high and very high classification for attention cancellation test, trail making test A, B, and B-A) and were correctly diagnosed through the indicator (true-positive), whereas the specificity describes the percentage of individuals who did not present the outcome and were correctly diagnosed through the (true-negative) indicator.

The criterion used to obtain the cutoff points were the values with sensitivity and specificity closest to each other and not lower than 60%. The statistical significance of each analysis was verified by the area under the ROC curve and by the 95% confidence interval (95% CI). In this sense, a perfect indicator shows the area under the ROC curve of 1.00, while the diagonal line represents the area under the ROC curve of 0.50. For an indicator to have a significant discriminatory ability, the area under the ROC curve should be between 1.00 and 0.50 and the larger the area, the greater the discriminatory power of the respective indicator. The 95% CI is another determinant of predictive capacity, and for the physical fitness, monopedal jump, and motor quotient, indicators are considered a significant predictor of the performance of attention and executive function, the lower limit of the CI (Li-IC) cannot be < 0.50 (Schisterman, Faraggi, Reiser, & Trevisan, 2001).

Additionally, the bivariate and multivariate regression models between the cancellation attention test scores, Trails B and B-A with the 70th percentiles of the following variables: sport, BMI, physical fitness, monopedal jump, transference of platform, and motor quotient indicators suggested and the attention and executive function were used to calculate the odds ratio (OR). The level of significance of the study was $p < 0.05$, and the software used was the Statistical Package for the Social Sciences, version 20.

Results

The sample characteristics are presented in Table 1. Children played the following sports: basketball (2), football (8), artistic gymnastics (4), Japanese martial art (8), and swimming (12). The sports practitioners group obtained higher values ($p<0.01$) in the height, 90º jumps, counter-movement jumps, performance Yo-Yo IR1, monopedal jump, lateral jump, the transference of platform and the sum of motor quotient, but body composition and other anthropometric variables were not different.

Table 1

Sample characteristics of anthropometric data, body composition, jumps, cardiorespiratory fitness, and motor coordination.

Variables	SG (n = 34)	CG (n= 34)	p-value
Pratice time (months)	21.1±11.7	-----	
Body mass (kg)	24.9±4	23.6±5.2	0.3
Height (m)	1.25±0.1	1.20±0.1	0.01
Body mass index (kg/m^2)	15.9±1.8	16.1±2.3	0.6
Waist circumference (cm)	55.9±4.8	54.5±5.5	0.3
Hip circumference (cm)	65.9±5.2	64.1±6.3	0.2
Waist-hip ratio	0.8±0	0.9±0.1	0.8
Conicity index	1.2±0.1	1.1±0.1	0.3
Tricipital fold (mm)	12.4±4	13.9±5.2	0.2
Subscapular fold (mm)	7.8±3.9	8.1±5.2	0.8
Sum of skin folds	20.3±7.5	21.9±9.7	0.4
90º jumps (cm)	18.6±4.6	16.1±4	0.01
Counter-movement jumps (cm)	19.6±4.5	16.5±4.1	0.01
Performance Yo-Yo IR1 (m)	463.9±349.3	221.17±138.5	0.01
Balance beam (score)	85±11	83.8±9.6	0.6
Monopedal jump (score)	93.8±16.4	80.5±10.1	0.01
Lateral jump (score)	96.4±13.2	81.6±9.3	0.01
Transference of platform (score)	68.2±12.1	63.1±7	0.01

Motor quotient (sum of score)	343.3±38	309±21.3	0.01
Motor quotient (score)	100±13.7	96±5.5	0.1

Note. SG = sports group; CG = control group; Yo-Yo IR1 = cardiorespiratory fitness test.

The results ACT and trail making test A and B scores are described in Table 2. The sports practitioners group obtained higher values (p<0.01) in the variables of the trail making test A and B scores compared to the non-practitioners group.

Table 2

Cancelation attention test and Trail making test scores of the sample.

Variables	SG (n = 34)	CG (n = 34)	*p*
CT 1	107±7.4	103.1±11.8	0.1
CT 2	130.6±17.9	124.7±28.6	0.3
CT 3	112±14.2	111.9±30.2	1.0
Total CT	118.1±11.5	113.1±17.9	0.2
Trail A	107.9±7.9	99.3±19.6	0.01
Trail B	116±15.8	106.7±17.1	0.01
Trail B-A	112±13.2	106.4±15.8	0.1

Note. Captions: SG = sports group; CG = control group; CT 1 = cancellation test, part 1; CT 2 = cancelation test, part 2; CT 3 = cancelation test, part 3; Total CT = the sum of the cancellation attention tests; Trail A = Trail A test; Trail B = Trail B test; Trail B-A = the difference between Trail tests A and B.

Two categories emerged from the odds ratio analysis for the executive function and attention performances: 1- very high and high; 2- medium, low and very low. These categories were related to the performances above and under 70th percentiles of variables (Table 3). Observing the results of the odds ratios for the ACT test, high values of the Yo-Yo IR1 performance variables, single-legged jump, platform transfer, and motor quotient showed a 1.52 to 1.77 times greater chance of obtaining a very high and high ACT rating. The performance of Trail B was influenced by the variables sports practice and monopedal jumping. Sports practice and performance in single-hop jumping demonstrated a 1.83 and 1.68 times higher chance of reaching the Trail B rating very high and high.

Table 3

An estimate of the prevalence ratio and 95% confidence intervals (95% CI) for the association between the cancellation attention test scores, Trails B and B-A with the 70th percentiles of the following variables: sport, BMI, physical fitness, monopedal jump, the transference of platform, and motor quotient.

	Variables	Estimate	95% CI
Total ACT (score)	Sport	1.5	0.98;2.28
	Body mass index (kg.m² (-1))	1.07	0.71;1.63
	Performance Yo-Yo IR1 (m)	1.75	1.26;2.43*
	Monopedal jump (score)	1.77	1.25;2.31*

	Variables	Estimate	95% CI
	Transference of platform (score)	1.6	1.11;2.31*
	Motor quotient	1.52	1.03;2.23*
Trail B (score)	Sport	1.83	1.09;3.08*
	Body mass index (kg.m² (-1))	0.69	0.38;1.26
	Performance Yo-Yo IR1 (m)	0.69	0.35;1.38
	Monopedal jump (score)	1.68	1.08;2.61*
	Transference of platform (score)	0.81	0.48;1.40
	Motor quotient	1.2	0.75;1.92
Trail B-A (score)	Sport	0.93	0.52;1.67
	Body mass index (kg.m² (-1))	0.94	0.49;1.80
	Performance Yo-Yo IR1 (m)	0.57	0.22;1.39
	Monopedal jump (score)	1.41	0.79;2.52
	Transference of platform (score)	0.98	0.52;1.82
	Motor quotient	1.41	0.79;2.51

Note. Total CT = the sum of the cancellation test results; Trail A = Trail A test; Trail B = Trail B test; Trail B-A = the difference between Trail tests A and B; Yo-Yo IR1 = cardiorespiratory fitness test.

The areas under the ROC curve only monopedal jump and motor quotient was showed a significant discriminatory power of ACT performance (95% CI<0.50). The predictive values indicated for the performance in the ACT test are related to the performance in the monopedal jump to reach values higher or equal to the score 73 and for the sum of the motor quotient, this prediction was equal to or greater than the sum of 295, 5 score on all tests applied by KTK.

Table 4

Area under the ROC curve, 95% CI, cut-off points, sensitivity and specificity of aerobic fitness indicators and motor coordination in the total group

	Variables	The area under the curve (95% CI)	Cut-off point Value	Sens.	Spec.
Total CT (score)	Performance Yo-Yo IR1	0.61 (0.48 – 0.75)	≥ 144	0.8	0.67
	Monopedal jump	0.67 (0.54 – 0.81)	≥ 73	0.9	0.71
	Motor quotient	0.63 (0.50 – 0.76)	≥ 295.5	0.82	0.71

Trail B (score)	Performance Yo-Yo IR1	0.53 (0.39 – 0.67)	≥ 144	0.79	0.7
	Monopedal jump	0.61 (0.49 – 0.75)	≥ 73	0.85	0.79
	Motor quotient	0.60 (0.47 – 0.74)	≥ 294	0.82	0.79
Trail B-A (score)	Performance Yo-Yo IR1	0.59 (0.45 – 0.73)	≥ 415	0.81	0.73
	Monopedal jump	0.55 (0.41 – 0.69)	≥ 73	0.85	0.8
	Motor quotient	0.55 (0.41 – 0.69)	≥ 300	0.77	0.7

Note. Total ACT= the sum of the attention cancellation test results; Trail A = Trail A test; Trail B = Trail B test; Trail B-A = the difference between Trail tests A and B; Yo-Yo IR1 = cardiorespiratory fitness test; Sens = sensitivity of the ROC curve; Spec = specificity of the ROC curve.

Discussion

The main findings of this study showed that sports practitioners children achieved greater cardiorespiratory fitness, jump, monopedal jump, lateral jump, the transference of platforms, motor quotient, sustained attention and cognitive flexibility compared to non-practitioners.

Corroborating the results of this study, Huijgen et al, (2015) found greater sustained attention responses and cognitive flexibility in elite soccer adolescent players compared to amateur ones. Moreover, Verburgh et al, (2014) found that there were better responses of inhibition and reaction time, and a lower percentage of errors in elite football players aged from 8 to 12 years compared to the amateur players of the same age. This indicates that the level of motor development and sports practice time may act as an EF influence factor.

The association found that attention component is more stimulated in activities requiring fine and bilateral coordination, agility, and motor complexity (van der Fels et al., 2015) maybe because the improvement in motor competence was mostly provided by sports practice. This relationship between sports practice and better selective, sustained, and CF responses in this study enable to explain the social, physical, and cognitive stimuli experienced by a child during sports practices. Development in these skills is largely related to educational and social success, since the greater children level of physical activity, better attentional and executive domains (Diamond, 2012; Diamond and Lee, 2011).

Furthermore, it was found that sports practice ability act not only on the cardiovascular and motor domains, it also influences the attentional and CF domains, as demonstrated by the study results. During sports practice, a child interacts with various tasks, presenting motor and cognitive complexities, and must interpret and process information before the execution of the motor gesture. This requires a motor and cognitive domain from the practitioner, as in the following tasks: perception of the game space, movement accuracy, decision-making, and information selection (Baumeister et al., 2008). Attention control must be highlighted as one of the main determinants of sports performance (Baumeister et al., 2008; Tudos et al., 2015).

In addition, it is interesting to highlight the requirement and development of the cognitive ability provided by each sport is unique. This relationship is very dependent on the amount of information that the practitioner must deal with during their sports practice. Exercises with greater motor complexity have a greater cognitive and executive requirement. However, sports practice is relevant in providing greater executive benefits compared to physically active children only, as highlighted by Koutsandréou et al (2016). The investigation showed the effect of ten weeks of intervention on three groups of children aged 9 to 10 years, one group performed strictly cardiovascular exercises, the second group performed physical exercises with great motor requirement and finally the control group who did not perform physical exercises. All groups obtained better responses compared to pre-intervention moments, but only motor exercise groups reached higher values of working memory in relation to control group (Drollette et al., 2014; Hillman et al., 2014; Koutsandréou et al., 2016).

Such response may be related to the development of aerobic and motor capabilities directly provided by sports practice. The benefits derived from sports practice are strictly related to motor learning, that occurs in three stages: first the cognitive phase which the practitioner will seek to understand the movement; followed by the associative phase represented on the practitioner's ability to internalize external information for the improvement of movement and finally; autonomous phase that movement is already learned and consolidated, being expressed more automatically. In addition, observing the evolution of motor learning, there is a great cognitive, executive and attentional recruitment at the beginning of the learning and this recruitment is diminishing as the movement internalization evolves. To continue the cognitive and executive requirement in the movement it is necessary to act constantly with new and complex motor tasks, especially when the motor tasks already reach a conscious degree of execution. For this reason, it is interesting to diversify and to explore the complexity of the movement to stimulate executive benefits. This integrated action will provide the specific adaptations between the areas of the brain responsible for motor and cognitive abilities, providing better answers about EF (Assis et al., 2018; Kamijo et al., 2016; Koutsandréou et al., 2016; Oliveira et al., 2013).

The greater complexity and/or novelty of the motor task is associated with better participation of the cognitive component (Diamond, 2000; Geertsen et al., 2016; Sigmundsson and Haga, 2016). Motor coordination seems to be related to executive organization and it could be controlled by the cerebellum and its neural circuits interconnected with the prefrontal cortex. Thus, the motor action with greater levels of complexity will lead the activation this neural circuits and the electric activity will also act in the regions responsible for the control of attention and EF. Consequently, sports practice seems to be an efficient strategy for motor, aerobic, attentional, and CF improvement. It stands out as an effective tool to aid improvement of cardiorespiratory performance, MC, attention, and CF in children aged six and seven years (Diamond, 2000; Fernandes et al., 2016; Geertsen et al., 2016; Sigmundsson and Haga, 2016).

The present study has some limitations that should be mentioned, firstly, this study was the impossibility of defining the likely neurophysiological mechanisms responsible for the results founded. This is a cross-sectional study, which did not enable a cause-effect relationship (Seabra, Alessandra Gotuzo; Dias, 2012). Secondly, sports practiced by the study volunteers are heterogeneous, once they have different characteristics and cognitive requirements among them and it could lead to heterogeneous results. However, the aim of the study was to verify the effects of practicing sports on motor coordination, aerobic fitness, attention, and cognitive flexibility in children aged 6 and 7 years. Therefore, our results lead to a possible influence of sports practice in children profile. Another limiting factor was the selected tests do not directly assess neural activity. On the other hand, they are instruments capable of measuring and discriminating different attentional and CF domains, validated for children and adolescents, and employed in several studies. Moreover, they are easily applicable, providing good accuracy and reproducibility; thus, they are ideal for use in the school environment.

There was no evidence (Seabra, Alessandra Gotuzo; Dias, 2012)(Seabra, Alessandra Gotuzo; Dias, 2012) of differences between the groups regarding the selective attention test (SAT); this result may be because both groups were physically active. This is already a favorable condition influencing attention levels and another relevant factor related to the SAT instrument for assessing attention. This test was insufficient to distinguish groups, albeit what was found by the Trail Making Test A and B analysis (Hillman et al., 2014).

Despite the limitations mentioned above, the applicability of the sports practice as described by the results enables interesting contributions for discussion. The aerobic, motor and cognitive capacities of children and adolescents must be considered to help improve educational and social performance, which are competences inherent in sports practice. Also, future studies should investigate the relationship between recreational sports practice and children, and their influence on the domains of cardiovascular fitness, motor coordination, attentional, and cognitive flexibility.

In conclusion, sports seemed to be a favorable strategy to develop aerobic, motor, attentional, and CF competences in children. This is an interesting approach for improving child development in different areas of activity since children practicing sports modalities obtained better responses regarding cardiorespiratory performance, MC, attention, and CF compared to those who did not practice sports.

References

Ahler, T., Bendiksen, M., Krustrup, P., Wedderkopp, N., & George, K. P. (2012). Aerobic fitness testing in 6- to 9-year-old children: Reliability and validity of a modified Yo-Yo IR1 test and the Andersen test. European Journal of Applied Physiology, 112(3), 871–876. https://doi.org/10.1007/s00421-011-2039-4

Andersen, L. B., Andersen, T. E., Andersen, E., & Anderssen, S. A. (2008). An intermittent running test to estimate maximal oxygen uptake: The Andersen test. Journal of Sports Medicine and Physical Fitness, 48(4), 434–437.

Assis, G. G. D. E., Alves, T., Silva, D. A., Moreira, P., & Dantas, S. (2018). Dual-task exercise as a therapy for executive motor function in parkinson's disease. Human Movement, 19(1), 57–63.

Bardid, F., Huyben, F., Deconinck, F. J. A., De Martelaer, K., Seghers, J., & Lenoir, M. (2016). Convergent and divergent validity between the KTK and MOT 4-6 motor tests in early childhood. Adapted Physical Activity Quarterly, 33(1), 33–47. https://doi.org/10.1123/APAQ.2015-0050

Baumeister, J., Reinecke, K., Liesen, H., & Weiss, M. (2008a). Cortical activity of skilled performance in a complex sports related motor task. European Journal of Applied Physiology, 104(4), 625–631. https://doi.org/10.1007/s00421-008-0811-x

Baumeister, J., Reinecke, K., Liesen, H., & Weiss, M. (2008b). Cortical activity of skilled performance in a complex sports related motor task. European Journal of Applied Physiology, 104(4), 625–631. https://doi.org/10.1007/s00421-008-0811-x

Bosco, C. (2002). La valutazione della forza con il test di Bosco. Societá Stampa Sportiva (2nd ed.). Roma.

Budde, H., Voelcker-Rehage, C., Pietraßyk-Kendziorra, S., Ribeiro, P., & Tidow, G. (2008). Acute coordinative exercise improves attentional performance in adolescents. Neuroscience Letters, 441, 219–223. https://doi.org/10.1016/j.neulet.2008.06.024

Bugge, A., Tarp, J., Østergaard, L., Domazet, S. L., Andersen, L. B., & Froberg, K. (2014). LCoMotion - Learning, cognition and motion; A multicomponent cluster randomized school-based intervention aimed at increasing learning and cognition - Rationale, design and methods. BMC Public Health, 14(1). https://doi.org/10.1186/1471-2458-14-967

Chaddock, L., Neider, M. B., Lutz, A., Hillman, C. H., & Kramer, A. F. (2012). Role of childhood aerobic fitness in successful street crossing. Medicine and Science in Sports and Exercise, 44(4), 749–753. https://doi.org/10.1249/MSS.0b013e31823a90cb

Diamond, A. (2000). Close Interrelation of Motor Development and Cognitive Development and of the Cerebellum and Prefrontal Cortex. Child Development, 71(1), 44–56. https://doi.org/10.1111/1467-8624.00117

Gorla, JI, Araújo PF, R. J. (2009). Avaliação motora em educação física adaptada: teste ktk. (3rd ed.). Sao Paulo: Phorte.

Hoeboer, J., De Vries, S., Krijger-Hombergen, M., Wormhoudt, R., Drent, A., Krabben, K., & Savelsbergh, G. (2016). Validity of an Athletic Skills Track among 6- to 12-year-old children. Journal of Sports Sciences, 34(21), 2095–2105. https://doi.org/10.1080/02640414.2016.1151920

Huijgen, B. C. H., Leemhuis, S., Kok, N. M., Verburgh, L., Oosterlaan, J., Elferink-Gemser, M. T., & Visscher, C. (2015). Cognitive functions in elite and sub-elite youth soccer players aged 13 to 17 years. PLoS ONE, 10(12), 1–13. https://doi.org/10.1371/journal.pone.0144580

Kamijo, K., Takeda, Y., Takai, Y., & Haramura, M. (2016). The relationship between childhood aerobic fitness and brain functional connectivity. Neuroscience Letters, 632, 119–123. https://doi.org/10.1016/j.neulet.2016.08.051

Koutsandréou, F., Wegner, M., Niemann, C., & Budde, H. (2016). Effects of Motor versus Cardiovascular Exercise Training on Children _ s Working Memory ′. Medicine & Science in Sports & Exercise, 1144–1152. https://doi.org/10.1249/MSS.0000000000000869

Laukkanen, A., Pesola, A., Havu, M., Sääkslahti, A., & Finni, T. (2014). Relationship between habitual physical activity and gross motor skills is multifaceted in 5- to 8-year-old children. Scandinavian Journal of Medicine & Science in Sports, 24(2), e102–e110. https://doi.org/10.1111/sms.12116

Petroski, E. E. L., Pires-Neto, C. S., & Neto, C. P. (1995). Validação de Equações Antropométricas para estimativa da densidade Corporal em Mulheres. Revista Brasileira de Atividade Física e Saúde.

Schisterman, E. F., Faraggi, D., Reiser, B., & Trevisan, M. (2001). Statistical Inference for the Area under the Receiver Operating Characteristic Curve in the Presence of Random Measurement Error, 154(2), 174–179.

Seabra A, G., & Dias N, M. (2012). Avaliação Neuropsicológica Cognitiva – Atenção e funções executivas (1st ed.).

Sigmundsson, H., Englund, K., & Haga, M. (2017). Associations of Physical Fitness and Motor Competence With Reading Skills in 9- and 12-Year-Old Children: A Longitudinal Study. SAGE Open, 7(2). https://doi.org/10.1177/2158244017712769

Tudos, S., Predoiu, A., & Predoiu, R. (2015). Topographical Memory and the Concentration of Attention in Top Female Tennis Players. Procedia - Social and Behavioral Sciences, 190(May), 293–298. https://doi.org/10.1016/j.sbspro.2015.05.001

Verburgh, L., Scherder, E. J. A., Van Lange, P. A. M., & Oosterlaan, J. (2014). Executive functioning in highly talented soccer players. PLoS ONE, 9(3). https://doi.org/10.1371/journal.pone.0091254

Whedon, M., Perry, N. B., Calkins, S. D., & Bell, M. A. (2015). Changes in Frontal EEG Coherence across Infancy Predict Cognitive Abilities at Age 3: The Mediating Role of Attentional Control. Dev Psychol, 52(9), 1173–1178. https://doi.org/10.1126/science.1249098.Sleep