HUMAN MOVEMENT
2017; 18(2): 56–61

COMPARISON OF HEALTH OUTCOMES AMONG CHILDREN WITH DIFFERENT LEVELS OF MOTOR COMPETENCE

original paper
doi: 10.1515/humo-2017-0018

DANIEL V. CHAGAS, LUIZ ALBERTO BATISTA
Rio de Janeiro State University, Rio de Janeiro, Brazil

ABSTRACT
Purpose. While evidence suggests that children with the developmental coordination disorder (DCD) have worse health outcomes than their typically developing peers, it remains unclear whether children with low motor competence but without DCD are also characterized by worse health outcomes than those with average motor competence. The main purpose of this study was to compare health outcomes between children with low motor competence without DCD and those with average motor competence.
Methods. The total of 127 children aged 12–14 years were recruited. Motor competence, physical activity, flexibility, and muscular strength/endurance were assessed with, respectively, the Körperkoordinationstest für Kinder, a validated self-administered questionnaire, sit-and-reach, and sit-up 60s tests. Skinfold thickness was measured to assess the children's adiposity. Multivariate analysis of variance, Kruskal-Wallis, and Mann-Whitney tests were performed.
Results. Children with average motor competence had lower body fat percentage and higher levels of physical activity and muscular strength/endurance than the groups with low ($p < 0.05$) and very low ($p < 0.01$) motor competence. Further, children with low motor competence had lower body fat percentage ($p < 0.01$) and higher levels of muscular strength/endurance ($p < 0.01$) than their peers with very low motor competence.
Conclusions. Our findings suggest that children with low motor competence without DCD have worse health outcomes than their peers with average motor competence. We suggest that both the development of motor competence and improvement of health outcomes should be targeted during childhood and adolescence by health professionals.
Key words: children, physical activity, fitness, motor coordination, body fat

Introduction

Human movement is so important for the life of a human being that their (in)ability to move remains in a close relationship with their health status across the lifespan [1], since early age. During childhood and adolescence, movement is considered as essential for the physical, cognitive, and social development of individuals [2]. Further, there is a consensus among paediatricians about the importance of movement for child development.

From birth onwards, children are agents who act in the world [3]. Therefore, children need to move coordinately their bodies in order to perform a great variety of goal-directed actions, from early arm movements towards a toy with purposeful reaching [4], to the sport-specific movement skills. For each goal-directed action experienced by a child, there is a specific demand imposed on their neural mechanisms underlying motor control and coordination.

It can be easily observed that most school-aged children who do not suffer from neurological conditions affecting movement (e.g. cerebral palsy), lesions, or pathogens have no difficulty to perform simple motor tasks, such as activities of the daily living. On the other hand, the prevalence of school-aged children who, owing to their low motor competence, show difficulty in structured and non-structured activities usually experienced during childhood, such as active play, games, participation in sports and physical education classes, seems to be high, that is, often above 50% [5, 6]. This phenomenon has been observed across different countries around the world, like Australia [5, 6], the United States [7], Portugal [8], and Brazil [9].

Besides the psychosocial issues associated with low motor competence in school-aged children, like anxiety and depression [10], it is also important to highlight other correlates of an inadequate development of motor skills. Emerging evidence supports associations between

Correspondence address: Daniel V. Chagas, Rio de Janeiro State University, Rua São Francisco Xavier, 524, Maracanã, CEP (Zip Code): 20550-900, Rio de Janeiro, Brazil, e-mail: chagas_daniel@yahoo.com.br

Received: April 07, 2017
Acepted for publication: May 30, 2017

Citation: Chagas DV, Batista LA. Comparison of health outcomes among children with different levels of motor competence. Hum Mov. 2017;18(2):56–61; doi: 10.1515/humo-2017-0018.

motor competence and a range of health outcomes among children and adolescents [11]. Overall, research suggests that motor competence is negatively associated with body mass index [1], as well as body fat percentage [12], and positively associated with physical fitness [13] and physical activity levels [14]. Therefore, it is expected that children with low motor competence have worse health outcomes than their peers with higher motor competence.

The hypothesis put forward above concerning school-aged children with low motor competence was supported by comparisons of health outcomes between children with the developmental coordination disorder (DCD), or with probable DCD, and their typically developing peers [15–18]. On the other hand, little is known about health outcomes among children with low motor competence without DCD. Thus, it remains unclear whether this group is characterized by worse health outcomes than children with average motor competence. Therefore, the main purpose of this study was to compare health outcomes between children with low motor competence without DCD and those with average motor competence.

Material and methods

The total of 127 children (57 boys, 70 girls) aged 12–14 years (mean, 13.8 ± 0.7) attending a public school in the city of Rio de Janeiro, Brazil were recruited to participate in the study. The descriptive statistics including demographic characteristics are provided in Table 1. Inclusion criteria were the following: age under 15 years and no history of injury or disease, including DCD, which could affect motor performance. Individuals with high motor competence were excluded from the study. The ethical approval for the research was obtained from the University's Ethics Committee, and both parental consent and each child's agreement for participation were provided.

The health outcomes considered in the current study were measures of physical activity levels, body fat percentage, flexibility, and muscular strength/endurance. Children were assessed according to their classroom group, each group within a period of one week. The tests for anthropometry, motor competence, flexibility, and muscular strength/endurance, in this order, were administered in a school gymnasium and lasted approximately 40 min per participant. An interval of 5 min before muscular strength/endurance test was secured.

Body mass was measured to the nearest 0.1 kg, with the use of electronic scales, with participants wearing their school uniforms. Standing height was assessed while unshod, with a meter wall, to the nearest 0.1 cm. Triceps and gastrocnemius skinfold thickness was measured with a skin calliper, and the Slaughter equation was applied to convert the mean values to body fat percentage.

The Physical Activity Questionnaire for Older Children (PAQ-C) [19], a self-administered 7-day recall instrument, was utilized to assess general levels of the participants' physical activity. The PAQ-C is appropriate for elementary school children, approximately 8–14-year-olds, who are currently in the school system and have recess as a regular part of their school week. The summary score from the PAQ-C is the mean of the nine item results, each scored on a 5-point scale.

Flexibility was assessed with a wooden box with 30 cm for each side and an overhang of 23 cm in the superior face [20]. A tape measure of 53 cm was centrally placed on the testing box, with the 0 cm positioned at the end of the overhang. The participants, unshod, sat on the floor with knees extended and the sole of the feet placed against the wooden box, under its overhang, with their toes coinciding with the 23th cm of the tape measure. The test consisted of trials to reach as far forward as possible on the tape measure, with one hand on top of the other and with the appraiser holding the legs of the participant to keep their knees extended. After two trials, the higher reach score was recorded.

To measure the muscular strength/endurance, the sit-up 60s test was applied in accordance with the 'Projeto Esporte Brasil' manual [21]. Initially, the subject was in supine position, knees at 90º, arms crossed over the chest, and feet held in the sole by the appraiser. With the verbal command to start, the chronometer was triggered and the subject flexed their trunk until to touch the thighs with the elbows. Then the child returned to the initial position. For each correct execution, one score was attributed. The movements were repeated as many times as possible during 60 s.

Motor competence was assessed with a gross motor coordination test: the Körperkoordinationstest für Kinder (KTK), a reliable and valid instrument [22] for middle school-aged children. KTK consists of four test items: 1) walking backwards along balance beams of decreasing width; 2) one-legged hopping over an obstacle, formed by an increasing pile of pillows; 3) two-legged jumping sideways across a wooden slat for 15 s as quickly as possible; and 4) moving sideways on wooden boards for 20 s as many times as possible. All the four test items included age-adjusted scores and a global motor quotient. The gross motor coordination score for each participant was derived from the sum of the scores obtained in the tests. Originally, these gross motor coordination scores classify children into the following categories: 'severe motor disorder' (scoring 70 or less), 'moderate motor disorder' (scoring between 71 and 85), 'normal' (scoring between 86 and 115), 'good' (scoring between 116 and 130) and 'high' (scoring 131 or higher).

While there is no consensus on terminology for motor competence levels across different tests, 'severe motor disorder,' 'moderate motor disorder,' and 'normal' categories were considered, respectively, as 'very low,' 'low,' and 'average' motor competence in the current study. 'Good' and 'high' classifications were considered as high motor competence. These interpretations were assumed with the purpose to unify the aforementioned KTK

Table 1. Mean (± *SD*) with 95% confidence interval (CI) of the demographics characteristics and health outcomes among the three groups of motor competence

	Average motor competence (n = 61)	Low motor competence (n = 29)	Very low motor competence (n = 31)
Age (years)	13.8 ± 0.7 CI: 13.6–14.0	13.8 ± 0.7 CI: 13.6–14.1	13.8 ± 0.7 CI: 13.5–14.0
Body weight (kg)	47.5 ± 10.7 CI: 44.8–50.3	50.6 ± 11.3 CI: 46.3–54.9	62.8 ± 17.2 CI: 56.5–69.1
Height (m)	1.58 ± 0.1 CI: 1.56–1.61	1.59 ± 0.1 CI: 1.56–1.62	1.62 ± 0.1 CI: 1.59–1.65
% body fat	17.1 ± 6.3 CI: 15.5–18.7	24.2 ± 9.1 CI: 20.7–27.6	33.5 ± 12.2 CI: 29.1–38.0
Sit-and-reach (cm)	22.9 ± 8.5 CI: 20.7–25.0	21.4 ± 10.6 CI: 17.4–25.1	21.2 ± 7.5 CI: 18.5–24.0
Sit-up	31.4 ± 9.1 CI: 29.1–33.6	23.1 ± 8.0 CI: 20.1–26.2	15.9 ± 10.6 CI: 12.0–19.8
Motor competence	100.2 ± 7.8 CI: 98.2–102.2	78.7 ± 4.0 CI: 77.1–80.2	55.1 ± 10.1 CI: 51.4–58.8
Physical activity level	2.9 ± 0.8 CI: 2.7–3.1	2.5 ± 0.9 CI: 2.1–2.8	2.2 ± 0.6 CI: 2.0–2.5

classifications around the term 'motor competence'. Six children (4 boys and 2 girls) classified as having high motor competence were excluded from the study, which resulted in the final number of 121 participants (Table 1).

Descriptive statistics were determined for all variables. The Kolmogorov-Smirnov test was used to verify the normality of the data distribution. For the data with an acceptable normality of distribution (i.e. levels of physical activity, flexibility, and muscular strength/endurance), the multivariate analysis of variance (MANOVA) was applied to identify differences in health outcomes among groups. Post-hoc comparisons were performed using the Tukey test. Kruskal-Wallis test was employed to identify differences in health outcomes among groups without an acceptable normality of data distribution (i.e. body fat percentage). In this case, Mann-Whitney test was used to verify which pairs of groups showed such a difference. The significance level of 5% ($\alpha = 0.05$) was adopted in all statistical tests. Data analysis was executed with the use of the Statistical Package for Social Sciences software (SPSS), version 22.0 (IBM, USA).

Results

The participants (53 boys, 68 girls) presented the following values (mean ± *SD*) for age, body weight, height, body fat percentage, flexibility, muscular strength/endurance, motor competence, and physical activity levels, respectively: 13.8 ± 0.7 years; 52.2 ± 14.2 kg; 1.59 ± 0.1 m; 23.0 ± 11.1; 22.1 ± 8.8 cm; 25.5 ± 11.3; 83.5 ± 20.4; 2.6 ± 0.8. The descriptive statistics for the participants depending on motor competence groups (average, low, and very low) are provided in Table 1.

Overall, the participants with average motor competence had better health outcomes than their peers with low and very low motor competence (Figures 1–4). The statistical analysis revealed that children with average motor competence had lower body fat percentage ($H = 44.862$, $U = 166.500$, $p < 0.0001$), as well as higher levels of physical activity ($F = 7.912$, $p < 0.001$) and muscular strength/endurance ($F = 30.235$, $p < 0.0001$) than the group with very low motor competence. Similarly, children with average motor competence also showed lower body fat percentage ($U = 481.500$, $p = 0.001$) and higher levels of physical activity ($p = 0.022$) and muscular strength/endurance ($p < 0.0001$) than those with low motor competence. Further, children with low motor competence had lower body fat percentage ($U = 251.000$, $p = 0.003$) and higher levels of muscular strength/endurance ($p = 0.003$) than their peers with very low motor competence. There were no significant differences in levels of flexibility among the three groups.

Discussion

The main purpose of the study was to compare health outcomes between children with low motor competence without DCD and those with average motor competence. The results indicated that children with average motor competence had lower levels of body fat and higher levels of physical activity and muscular strength/endurance than those with low motor competence. Additionally, children with low motor competence presented lower levels of body fat and higher levels of muscular strength/endurance than those with very low motor competence. Overall, these findings suggest that children with low

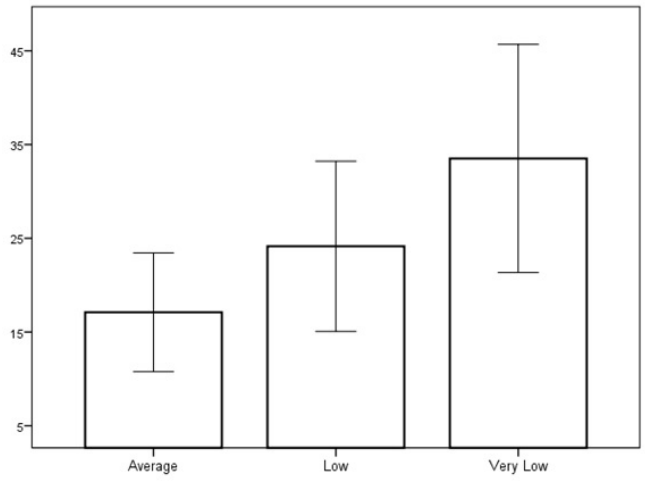

Figure 1. Body fat percentage according to motor competence levels

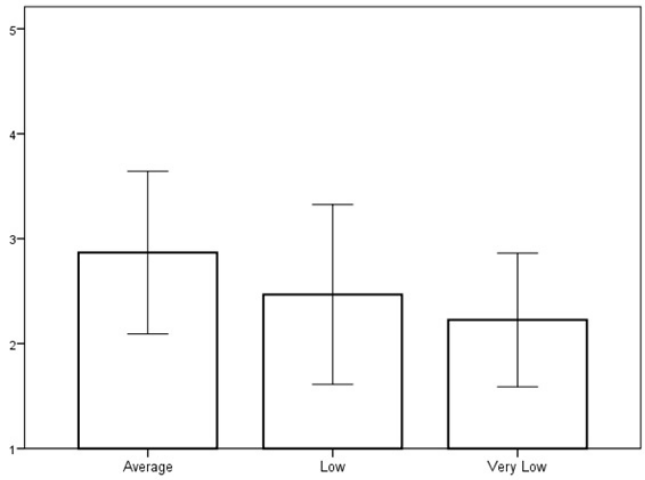

Figure 2. Physical activity level according to motor competence levels

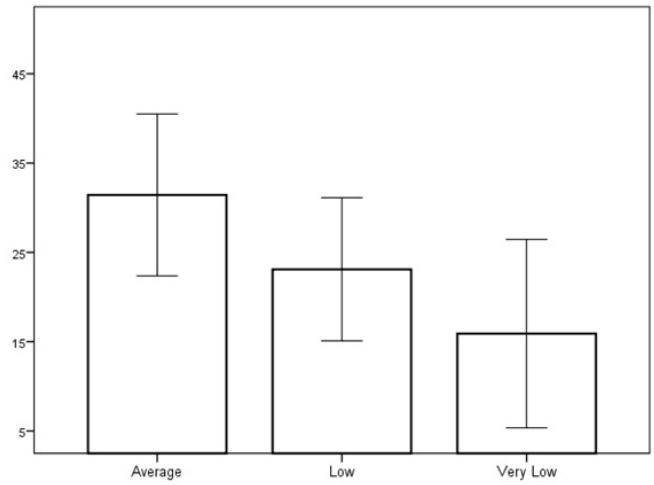

Figure 3. Strength/endurance muscular level (sit-up 60s scores) according to motor competence levels

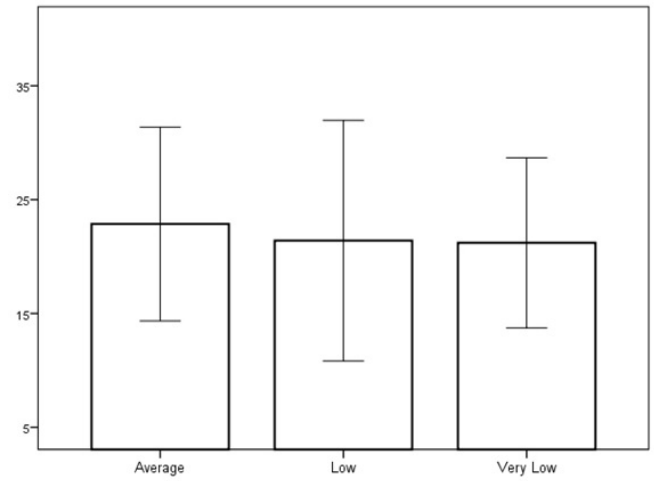

Figure 4. Flexibility level (sit-and-reach scores) according to motor competence levels

motor competence without DCD, as well as children with very low motor competence have worse health outcomes than their peers with average motor competence.

On the basis of previous results [13, 17, 23–25], it was expected that children with average motor competence would have lower levels of body fat, as well as higher levels of physical activity and muscular strength/endurance than those with very low motor competence. Our findings corroborated these hypotheses. These findings may be explained in the light of the conceptual model proposed by Stodden et al. [26]. The model points at a positive spiral of engagement, that is, children with average and high motor competence tend to have higher levels of physical activity and physical fitness, and lower levels of body fat. Likewise, children may have a negative spiral of disengagement, that is, individuals with low motor competence tend to present lower levels of physical activity and physical fitness, and higher levels of body fat. It seems that there is a dynamic and reciprocal relationship between these variables [26] so that motor competence may be considered, for example, to be both a precursor and a consequence of children's adiposity status [14].

The main aim of this study was to verify whether children with low motor competence without DCD were also characterized by worse health outcomes than children with average motor competence. Hardy et al. [5] found that low motor competence was associated with lower physical activity levels in children and adolescents. Further, Santos et al. [24] observed that children with higher motor competence had higher scores on muscular strength tests than their peers with lower motor competence. Similarly, according to Fransen et al. [23], children with higher motor competence had higher muscular strength/endurance, as well as participated in sports more often. Also, Chaves et al. [27] proved that children with low motor competence were more likely to have lower flexibility and explosive strength levels. Duncan et al. [28] found that body fat level was higher for girls with low motor competence compared with those with average or high motor competence. However, in these previous studies comparing health outcomes between

children with low and average levels of motor competence, subjects with low motor competence were included in the same sample group as those with very low motor competence. Specifically, all children who did not demonstrate mastery in fundamental movement skills [5] or scored below 86 on KTK [27] or had motor coordination scores below 33th [23] or 25th percentile [24] were classified as having low motor competence. This fact could lead to bias in these findings.

Altogether, our findings suggest that children whose levels of motor competence are below the average, regardless of whether they are low or very low, tend to have worse health outcomes than children with average motor competence. This is a matter of public health concerning the actual high prevalence of children and adolescents with low motor competence [5]. Therefore, besides the worldwide focus on the improvement of health-related attributes in children and adolescents, interventions should be implemented to develop adequate levels of motor competence in the population.

Additionally, the fact that children with low motor competence have shown lower levels of body fat and higher levels of muscular strength/endurance than those with very low motor competence suggests that the lower the motor competence levels, the lower muscular strength/endurance and the higher body fat levels in children. Thus, this study provides evidence that children with very low motor competence may have different and worse health outcomes than those with low motor competence.

The only measure of health outcomes analysed in this study that did not display significant differences among children with various motor competence levels was the sit-and-reach flexibility. While our findings are in line with some previous results [29, 30] other investigations suggested a positive relationship between motor competence and flexibility [27, 31–33]. To date, evidence concerning this relationship is controversial and limited. In a systematic review, Cattuzzo et al. [13] concluded that the lack of studies assessing associations between motor competence and flexibility did not allow conclusions to be drawn about their relationship. Although all of these aforementioned studies have applied sit-and-reach tests to assess flexibility, it is important to highlight that differences in study designs, such as inclusion of other variables in data analyses, may have led to dissimilar results across studies. Additional research examining associations between motor competence and flexibility in children and adolescents should be conducted in order to improve our knowledge about this relationship.

Apart from the fact that children with low motor competence also have difficulty in performing active play, games, sports, and physical education classes, this study provides evidence that they tend to present worse health outcomes than children with average motor competence. Additional studies should be performed to verify if children with low motor competence are also at increased risk for health problems like obesity or metabolic and musculoskeletal disorders.

While our cross-sectional design does not allow making causal inferences between motor competence and some health outcomes, we suggest that both the development of motor competence and improvement of health outcomes should be targeted during childhood and adolescence by health professionals, especially those who deal directly with interventions on motor performance, like physical educators. As a limitation of this study, we highlight that in the absence of a Brazilian normative database of KTK scores, the original German database was used for classifying the participants' motor competence.

Conclusions

This study provides evidence that children with low motor competence without DCD have worse health outcomes than those with average motor competence. Specifically, children with low and very low motor competence demonstrated higher levels of body fat, and lower levels of physical activity and muscular strength/endurance than their peers with average motor competence. This is a matter of public health taking into account the actual high prevalence of children and adolescents with low motor competence around the world. We suggest that both the development of motor competence and improvement of health outcomes should be targeted during childhood and adolescence by health professionals.

References

1. Chagas DV, Batista LA. Associations between motor coordination and BMI in normal weight and overweight/obese adolescents. J Hum Growth Dev. 2016;26(3):380–384; doi: 10.7322/jhgd.122914.
2. Cools W, Martelaer K, Samaey C, Andries C. Movement skill assessment of typically developing preschool children: a review of seven skill assessment tools. J Sports Sci Med. 2009;8(2):154–168.
3. Von Hofsten C. An action perspective on motor development. Trends Cogn Sci. 2004;8(6):266–272; doi: 10.1016/j.tics.2004.04.002.
4. Bhat AN, Galloway JC. Toy-oriented changes during early arm movements: hand kinematics. Infant Behav Dev. 2006;29(3):358–372; doi: 10.1016/j.infbeh.2006.01.005.
5. Hardy LL, Reinten-Reynolds T, Espinel P, Zask A, Okeley AD. Prevalence and correlates of low fundamental movement skill competency in children. Pediatrics. 2012;130(2):e390–e398; doi: 10.1542/peds.2012-0345.
6. Hardy LL, Barnett L, Espinel P, Okeley AD. Thirteen-year trends in child and adolescent fundamental movement skills: 1997–2010. Med Sci Sports Exerc. 2013;45(10):1965–1970; doi: 10.1249/MSS.0b013e318295a9fc.
7. Goodway JD, Robinson LE, Crowe H. Gender differences in fundamental motor skill development in disadvantaged preschoolers from two geographical regions. Res Q Exerc Sport. 2010;81(1):17–24; doi: 10.1080/02701367.2010.10599624.
8. Lopes VP, Stodden DF, Bianchi MM, Maia JA, Rodrigues LP. Correlation between BMI and motor coordina-

tion in children. J Sci Med Sport. 2012;15(1):38–43; doi: 10.1016/j.jsams.2011.07.005.
9. Chagas DV, Batista LA. Interrelationships among motor coordination, body fat percentage, and physical activity in adolescent girls. Hum Mov. 2015;16(1):4–8; doi: 10.1515/humo-2015-0019.
10. Cairney J, Rigoli D, Piek J. Developmental coordination disorder and internalizing problems in children: the environmental stress hypothesis elaborated. Dev Rev. 2013;3(3):224–238; doi: 10.1016/j.dr.2013.07.002.
11. Barnett LM, Lai SK, Veldman SL, Hardy LL, Cliff DP, Morgan PJ, et al. Correlates of gross motor competence in children and adolescents: a systematic review and meta-analysis. Sports Med. 2016;46(11):1663–1688; doi: 10.1007/s40279-016-0495-z.
12. Chagas DV, Carvalho JF, Batista LA. Do girls with excess adiposity perform poorer motor skills than leaner peers? Int J Exerc Sci. 2016;9(3):318–326.
13. Cattuzzo MT, Henrique RS, Ré AH, Oliveira IS, Melo BM, Moura MS, et al. Motor competence and health related physical fitness in youth: a systematic review. J Sci Med Sport. 2016;19(2):123–129; doi: 10.1016/j.jsams.2014.12.004.
14. Robinson LE, Stodden DF, Barnett LM, Lopes VP, Logan SW, Rodrigues LP, et al. Motor competence and its effect on positive developmental trajectories of health. Sports Med. 2015;45(9):1273–1284; doi: 10.1007/s40279-015-0351-6.
15. Cantell M, Crawford SG, Doyle-Baker PK. Physical fitness and health indices in children, adolescents and adults with high or low motor competence. Hum Mov Sci. 2008; 27(2):344–362; doi: 10.1016/j.humov.2008.02.007.
16. Farhat F, Masmoudi K, Cairney J, Hsairi I, Triki C, Moalla W. Assessment of cardiorespiratory and neuromotor fitness in children with developmental coordination disorder. Res Dev Disabil. 2014;35(12):3554–3561; doi: 10.1016/j.ridd.2014.08.028.
17. Joshi D, Missiuna C, Hanna S, Hay J, Faught BE, Cairney J. Relationship between BMI, waist circumference, physical activity and probable developmental coordination disorder over time. Hum Mov Sci. 2015;40:237–247; doi: 10.1016/j.humov.2014.12.011.
18. Zwicker JG, Missiuna C, Harris SR, Boyd LA. Developmental coordination disorder: a review and update. Eur J Paediatr Neurol. 2012;16(6):573–581; doi: 10.1016/j.ejpn.2012.05.005.
19. Kowalski KC, Crocker PRE, Faulkner RA. Validation of the Physical Activity Questionnaire for Older Children. Pediatr Exerc Sci. 1997;9(2):174–186; doi: 10.1123/pes.9.2.174.
20. Council of Europe. Eurofit, Handbook for the Eurofit Tests of Physical Fitness. Rome: Council of Europe; 1988.
21. Gaya A, Gaya A. The sports project in Brazil: test and evaluation manual [in Portuguese]. Porto Alegre: UFRGS; 2016.
22. Kipard EJ, Shilling F. Body coordination test for children [in German]. Göttingen: Hogrefe; 2007.
23. Fransen J, Deprez D, Pion J, Tallir IB, D'Hondt E, Vaeyens R, et al. Changes in physical fitness and sports participation among children with different levels of motor competence: a 2-year longitudinal study. Pediatr Exerc Sci. 2014;26(1):11–21; doi: 10.1123/pes.2013-0005.
24. Santos M, Ribeiro S, Pellegrini A, Rocha P, Hiraga C. Do children with motor difficulties show low levels of physical fitness? [in Portuguese]. Motriz Rev Educ Fis. 2012; 18(4):748–756; doi: 10.1590/S1980-65742012000400013.
25. Rivilis I, Hay J, Cairney J, Klentrou P, Liu J, Faught BE. Physical activity and fitness in children with developmental coordination disorder: a systematic review. Res Dev Disabil. 2011;32(3):894–910; doi: 10.1016/j.ridd.2011.01.017.
26. Stodden DF, Goodway JD, Langendorfer SJ, Roberton MA, Rudisill ME, Garcia C, et al. A developmental perspective on the role of motor skill competence in physical activity: an emergent relationship. Quest. 2008;60(2):290–306; doi: 10.1080/00336297.2008.10483582.
27. Chaves RN, Valdívia AB, Nevill A, Freitas D, Tani G, Katzmarzyk PT, et al. Developmental and physical-fitness associations with gross motor coordination problems in Peruvian children. Res Dev Disabil. 2016;53–54:107–114; doi: 10.1016/j.ridd.2016.01.003.
28. Duncan MJ, Bryant E, Stodden D. Low fundamental movement skill proficiency is associated with high BMI and body fatness in girls but not boys aged 6–11 years old. J Sports Sci. 2016;21:1–7; doi: 10.1080/02640414.2016.1258483.
29. Castelli DM, Valley JA. The relationship of physical fitness and motor competence to physical activity. J Teach Phys Educ. 2007;26(4):358–374; 10.1123/jtpe.26.4.358.
30. Nascimento RO, Ferreira LF, Goulardins JB, Freudenheim AM, Marques JC, Casella EB, et al. Health-related physical fitness children with severe and moderate developmental coordination disorder. Res Dev Disabil. 2013;34(11):4222–4231;doi:10.1016/j.ridd.2013.08.025.
31. Hands B, Larkin D, Parker H, Straker L, Perry M. The relationship among physical activity, motor competence and health-related fitness in 14-year-old adolescents. Scand J Med Sci Sports. 2009;19(5):655–663; doi: 10.1111/j.1600-0838.2008.00847.x.
32. Pereira SA, Seabra AT, Silva RG, Zhu W, Beunen GP, Maia JA. Correlates of health-related physical fitness levels of Portuguese children. Int J Pediatr Obes. 2011;6(1):53–59; doi: 10.3109/17477161003792549.
33. Vandendriessche JB, Vandorpe B, Coelho-e-Silva MJ, Vaeyens R, Lenoir M, Lefevre J, et al. Multivariate association among morphology, fitness, and motor coordination characteristics in boys age 7 to 11. Pediatr Exerc Sci. 2011;23(4):504–520; doi: 10.1123/pes.23.4.504.