

Associations between motor coordination and BMI in normal weight and overweight/obese adolescents

Daniel das Virgens Chagas^{1,3}, Luiz Alberto Batista^{2,3}

DOI: <http://dx.doi.org/10.7322/jhgd.122914>

Abstract:

Introduction: While evidence suggests that the levels of motor coordination and body mass index (BMI) are negatively correlated, little is known about the influence of levels of physical activity on associations between these variables among adolescents.

Objective: To analyse the relationships between levels of motor coordination and BMI in normal weight and overweight/obese adolescents, controlling for physical activity levels.

Methods: Fifty-six students (50% overweight/obese adolescents), aged 12–14 years old, participated in this study. The Physical Activity Questionnaire for Older Children and the Körperkoordinationstest für Kinder were used in order to assess the levels of physical activity and motor coordination, respectively. Bivariate and partial correlations were used to analyse the interrelationships among motor coordination, BMI and physical activity. The analysis of covariance test was used in order to compare the levels of motor coordination between normal weight and overweight/obese adolescents, considering the physical activity level as a covariate.

Results: Weak to moderate negative correlations ($p < 0.05$) were found between motor coordination and BMI in the sample as a whole, normal weight and overweight/obese groups. However, when controlled for physical activity levels, no significant correlation was observed in the normal weight group. Further, overweight/obese adolescents showed lower levels of motor coordination than their normal weight peers

Conclusion: Physical activity levels influence the association between levels of motor coordination and BMI in normal weight adolescents, but not in their overweight/obese peers.

Keywords: adolescent, motor activity, overweight, obese.

INTRODUCTION

Movement is so important to the life of a human being that their (in)capacity to move has a close relationship with their health status span life, whether in old age or even at an early age. In childcare, movement is considered as essential for the physical, cognitive and social development of children¹.

During childhood, the assessment of human development is made, in part, based on observation of children's movement patterns. Right after birth, for example, the movement pattern exhibited by the baby in response to the Apgar test is an important indication of the newborn's health status. Furthermore, the periods of emergence of milestones are also important information for the assessment of child development,

1 Departamento de Ginástica, Instituto de Educação Física e Desportos, Universidade do Estado do Rio de Janeiro. Rua São Francisco Xavier, 524. (Ginásio de Esportes, Laboratório de Biomecânica e Comportamento Motor) Maracanã. CEP: 20550-900. Rio de Janeiro, Brasil.

2 Departamento de Ciências da Atividade Física, Instituto de Educação Física e Desportos, Universidade do Estado do Rio de Janeiro. Rua São Francisco Xavier, 524. (Ginásio de Esportes, Laboratório de Biomecânica e Comportamento Motor) Maracanã. CEP: 20550-900. Rio de Janeiro, Brasil.

3 Programa de Pós-Graduação em Ciências Médicas, Faculdade de Ciências Médicas, Universidade do Estado do Rio de Janeiro. Avenida Professor Manuel de Abreu, 444. (2º andar). Vila Isabel. CEP: 20550-170. Rio de Janeiro, Brasil.

Corresponding author: Daniel das Virgens Chagas. e-mail: chagas_daniel@yahoo.com.br

Suggested citation: 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: <http://dx.doi.org/10.7322/jhgd.122914>

Manuscript submitted 14 Apr 2016, accepted for publication 17 May 2016.

because delays in these events may suggest motor disorders².

In the last century several motor tests were developed – such as the *Movement Assessment Battery for Children* (M-ABC), *Bruininks-Oseretsky Test of Motor Proficiency* (BOTMP) and *Körperkoordinationstest für Kinder* (KTK) – with the purpose of detecting probable motor disorders, not only in children but also in adolescents. Specifics aside, the usefulness of tools such as the aforementioned provide a motor competence index to the subject assessed. In general, subjects classified as having low motor competence levels can be classified as people with suspected motor disorders. Undoubtedly, information like this is extremely relevant to the assessment of human development throughout childhood and adolescence, since low motor competence levels are associated with developmental disorders³.

However, the results of motor tests like those mentioned above have gone beyond the clinical setting. Indeed, there is a growing body of evidence that has indicated associations between motor competence levels and health-related attributes, such as the body mass index (BMI). The actual state of the art about the topic suggests that motor competence levels and BMI are negatively associated⁴⁻¹⁰.

Specifically with respect to KTK, a recent meta-analysis¹¹ confirmed that the results of this motor coordination test are negatively associated with BMI among children and adolescents. Therefore, although there is still no well-defined relation of cause and effect, overweight and obese children and adolescents tend to have lower motor competence levels than their normal weight peers.

A plausible explanation for a negative association between motor competence levels and BMI in children and adolescents is based on biomechanical issues, because the higher the amount of body mass, the higher the mechanical work required to performing motor tasks which demand body weight-bearing. Therefore, among motor coordination tests that involve body weight-bearing, such as to jump and to move quickly, a negative association is expected between motor coordination levels and BMI.

Furthermore, there are other individual-related factors that can influence the motor coordination levels in

children and adolescents. One of these factors is the level of physical activity. Previous studies have indicated positive associations between levels of physical activity and motor coordination in children and adolescents¹²⁻¹⁶. Thus, it seems plausible to consider the hypothesis that levels of physical activity may influence the association between levels of motor coordination and BMI in children and adolescents.

To the best of our knowledge, however, there is no study that has tested the aforementioned hypothesis involving normal weight and overweight/obese groups to date. Previous studies about the topic, such as those cited above, have been based on bivariate analyses, that is, the associations between motor coordination levels and BMI were analysed without controlling statistically for physical activity levels.

Therefore, the purpose of this study is to analyse the associations between motor coordination levels and BMI in normal weight and overweight/obese adolescents, controlling statistically for physical activity levels.

METHODS

Initially, 122 adolescents (52 boys and 70 girls), between seventh and ninth grade of elementary school, from a public school in the city of Rio de Janeiro, were recruited to participate in the study. Inclusion criteria required students to be under 15 years old with no history of injury or disease that could affect motor performance. Underweight subjects were excluded. Ethical approval for this study was obtained from the university's Ethics Committee and parental consent and child assent were obtained prior to participation.

After initial recruitment, 21 overweight and 7 obese adolescents were detected. Thus, a group composed of 28 overweight/obese adolescents (n = 28) was formed. Further, seven subjects were excluded from the study due to their being underweight. Among the 87 remaining individuals in the sample initially recruited, 28 were randomly selected to compose the normal weight group, resulting in a final sample of 56 participants (n = 56), 21 boys and 35 girls. Descriptive statistics of age, body weight and stature are provided in Table 1.

Table 1: Descriptive data (mean, standard deviation and confidence interval), age, anthropometry, levels of motor coordination (MC) and physical activity (PA)

	Both groups (N = 56)	Group 1 (healthy weight) (n = 28)	Group 2 (n = 28)
Age (years)	13.7 (0.6) IC: 13.5 - 13.9	13.6 (0.7) IC: 13.3 - 13	13.8 (0.6) IC: 13.6 - 14.0
Weight (kg)	58.4 (16.0) IC: 54.1 - 62.6	47.1 (7.6) IC: 44.2 - 55.1	69.6 (14.2) IC: 64.1 - 75.1
Height (m)	1.61 (0.1) IC: 1.58 - 1.63	1.59 (0.1) IC: 1.55 - 1.62	1.62 (0.1) IC: 1.59 - 1.65
BMI (kg/m ²)	22.4 (5.0) IC: 21.1 - 23.8	18.6 (1.5) IC: 18.0 - 19.2	26.2 (4.4) IC: 24.5 - 27.9
MC	79.5 (23.7) IC: 73.1 - 85.8	90.3 (18.3) IC: 83.1 - 97.4	68.6 (23.8) IC: 59.4 - 77.9
PA	2.5 (0.8) IC: 2.3 - 2.7	2.7 (0.9) IC: 2.4 - 3.0	2.4 (0.7) IC: 2.1 - 2.6

Procedures

Body mass was measured to the nearest 0.1 kg using an electronic scale, with participants wearing their school uniform. Standing height was measured while unshod with a stadiometer wall to the nearest 0.1 cm. BMI (kg/m^2) was then calculated. World Health Organization¹⁷ age-specific cut-off points for BMI were used in order to determine the weight status of participants (underweight, normal weight, overweight and obesity) according to gender.

The Physical Activity Questionnaire for Older Children (PAQ-C), a valid¹⁸ self-applied 7-day recall instrument, was used to assess general levels of physical activity of participants. The PAQ-C is appropriate for elementary school-aged children approximately between 8–14 years old 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 average of the sum of the nine item questions, each scored on a 5-point scale, with 1 being the lower level of physical activity and 5 the higher level.

Motor coordination levels were assessed using the KTK, which is composed of four tasks. The first is walking backwards on balance beams with decreasing width. Each beam is crossed three times, where a maximum of eight steps per trial are allowed. The sum of steps in all trials determined the motor quotient 1. The second requires one-legged hopping over an increasing height obstacle. Only three trials are allowed for each obstacle and three, two or one point(s) are/is awarded for successful performance on the first, second or third try, respectively. The sum of scores reached in the second task determined the motor quotient 2.

The third task is two-legged sideways jumping across a wooden slat for 15 s as quickly as possible. The number of jumps performed correctly was summed over two trials to determine the motor quotient 3. The final task involved moving sideways on wooden plates as many times as possible in 20 s. One point is awarded for each time the plate is transferred and one more for stepping on it. Points obtained in two trials determined the motor quotient 4. All four scores were age-adjusted. The motor coordination level for each participant was derived from the sum of four motor quotients.

Data Analysis

Descriptive statistics were determined for all variables. The Kolmogorov–Smirnov test confirmed acceptable normality of the data distribution. Pearson's correlation coefficients were used to examine the bivariate relationships between levels of motor coordination, BMI and physical activity. Partial correlations were used to analyse the relationship between motor coordination levels and BMI, controlling for physical activity levels. Analysis of covariance (ANCOVA) was used to compare the motor coordination levels between normal weight and overweight/obese adolescents, considering the physical activity level as a covariate. A significance level of 5% ($\alpha = 0.05$) was adopted in all statistical tests. Data analysis was executed using Statistical Package for Social Sciences software (SPSS ver. 22.0, IBM, USA).

RESULTS

Weak to moderate negative correlations were found between BMI and motor coordination levels in the group as a whole ($r = -0.576$, $p < 0.0001$), as well as in the normal weight ($r = -0.376$, $p = 0.049$) and overweight/obese ($r = -0.427$, $p = 0.024$) groups. However, when statistically controlled for physical activity levels, significant correlations were only observed in the group as a whole ($r = -0.526$) and overweight/obese group ($r = -0.406$, $p = 0.036$).

Means and confidence interval values (Table 1) suggest that overweight/obese adolescents tend to show lower motor coordination levels than their normal weight peers. Results of ANCOVA test confirmed significant differences between these groups ($F = 10.884$, $p = 0.002$).

DISCUSSION

With the purpose of analyzing, in adolescents, the associations between motor coordination levels and BMI, statistically controlling for physical activity levels, the findings suggest that, in overweight/obese adolescents, levels of motor coordination and BMI were significantly negatively correlated, regardless of physical activity levels. However, in normal weight adolescents, the correlation between BMI and motor coordination did not reach statistical significance when controlled for physical activity levels.

Our investigation hypothesis was corroborated in the group of normal weight adolescents, that is, the physical activity levels can influence the association between motor coordination and BMI. Furthermore, the results of this study add to the body of evidence that suggests that overweight/obese individuals tend to have poorer levels of motor coordination than their normal weight peers.

Results of this study are in line with previous findings, in which negative correlations were identified between levels of motor coordination and BMI in children and adolescents⁴⁻¹⁰. Due to the study design adopted in this present investigation however, a cause-and-effect relationship between levels of motor coordination and BMI cannot be established.

In other words, it is still not known whether overweight/obese adolescents tend to have low motor coordination levels due to biomechanical difficulties related to moments of inertia and the mechanical work required in weight-bearing tasks, or whether adolescents with low motor coordination levels tend to have higher BMI because, due to low motor competence, they are discouraged from participating in sports and physical activities. Additional studies involving longitudinal follow-ups are necessary in order to improve the knowledge about the causal mechanisms of this relationship.

On the other hand, our findings suggest that the correlation between levels of motor coordination and BMI did not reach statistical significance in normal weight adolescents when controlled for physical activity levels. This means that physical activity levels can influence the association between these variables in normal weight

adolescents. However, this influence was not observed in overweight/obese adolescents. These results suggest that, in overweight/obese adolescents, levels of motor coordination and BMI are negatively associated, regardless of physical activity levels.

To date, there are only two studies^{19,20} in which the topic approached in this present study were investigated. In both studies^{19,20} negative correlations were found between levels of motor coordination and body fat percentage in two analysed situations: with and without controlling for physical activity levels. Our results were similar to these findings when the sample as a whole was analysed. However, in the previous studies the associations were not analysed according to the weight status of individuals.

There are two ways to discuss the findings of these correlations. The first is that in overweight/obese adolescents the levels of motor coordination and BMI are negatively associated regardless of physical activity levels, due to physical difficulties, such as increased moments of inertia and mechanical work experienced by these individuals, especially in tasks that require weight-bearing. From this perspective, the negative effect of excess body mass on motor coordination levels overlaps with the possible influence that the physical activity levels can have on the association between BMI and motor coordination.

The second way takes into account the low physical activity levels presented by overweight/obese adolescents. The physical activity levels of that group may have been so low to the point of not being able to influence the association between BMI and motor coordination levels, differently of what was observed in the group of normal weight adolescents. Additional studies are necessary in or-

der to investigate whether our findings are only explained by excess body mass, by the magnitude of the level of physical activity or by both variables.

In short, in this study it was observed that overweight/obese adolescents had lower motor coordination levels than normal weight adolescents. These results are in line with findings of previous studies^{5,6,10,21}. Furthermore, our results suggest that physical activity levels influence the association between levels of motor coordination and BMI in normal weight adolescents, but not in overweight/obese adolescents. This means that adolescents who are above the BMI cut-off points of normal weight have lower motor coordination levels than their normal weight peers, regardless of physical activity levels. Further studies are needed in order to investigate whether the differences observed between groups are only due to weight status, magnitude of level of physical activity or both variables. We recommend that the physical activity levels are taken into account in future studies about associations between levels of motor coordination and BMI in adolescents with different weight status.

The limitation of this study was the estimation of the physical activity levels of the participants by means of an indirect measurement tool. Finally, the fact that higher levels of coordination are related to lower levels of BMI indicates that understanding how these variables are associated in adolescents is a matter of public health. The school, as a space accessible to children and adolescents from all social strata, can promote actions aimed not only at the acquisition and/or maintenance of appropriate weight status, but also at the development of better levels of motor coordination of this population.

■ REFERENCES

1. Cools W, Martelaer K, Samaey C, Andries C. Movement skill assessment of typically developing preschool children: A review of seven movement skill assessment tools. *J Sports Sci Med.* 2009;8(2):154-68.
2. Spittle A, Orton J. Cerebral palsy and developmental coordination disorder in children born preterm. *Semin Fetal Neonatal Med.* 2014;19(2):84-89. DOI: <http://dx.doi.org/10.1016/j.siny.2013.11.005>
3. Zwicker J, Missiuna C, Harris S, Boyd L. Developmental coordination disorder: a review and update. *Eur J Paediatr Neurol.* 2012;16(6):573-81. <http://dx.doi.org/10.1016/j.ejpn.2012.05.005>
4. D'Hondt E, Deforche B, De Bourdeaudhuij I, Lenoir M. Relationship between motor skill and body mass index in 5- to 10-year-old children. *Adapt Phys Activ Q.* 2009;26(1):21-37. DOI: <http://dx.doi.org/10.1123/apaq.26.1.21>
5. D'Hondt E, Deforche B, Gentier I, De Bourdeaudhuij I, Vaeyens R, Philippaerts R, et al. A longitudinal analysis of gross motor coordination in overweight and obese children versus normal-weight peers. *Int J Obes (Lond).* 2013;37(1):61-7. DOI: <http://dx.doi.org/10.1038/ijo.2012.55>
6. D'Hondt E, Deforche B, Vaeyens R, Vandorpe B, Vandendriessche J, Pion J, et al. Gross motor coordination in relation to weight status and age in 5- to 12-year-old boys and girls: a cross-sectional study. *Int J Pediatr Obes.* 2011;6(2-2):556-64. DOI: <http://dx.doi.org/10.3109/17477166.2010.500388>
7. D'Hondt E, Deforche B, Gentier I, Verstuyf J, Vaeyens R, De Bourdeaudhuij I, et al. A longitudinal study of gross motor coordination and weight status in children. *Obesity (Silver Spring)* 2014;22(6):1505-11. DOI: <http://dx.doi.org/10.1002/oby.20723>
8. Lopes V, Stodden D, Bianchi M, Maia J, Rodrigues L. Correlation between BMI and motor coordination in children. *J Sci Med Sport.* 2012;15(1):38-43. DOI: <http://dx.doi.org/10.1016/j.jsams.2011.07.005>

9. Melo MM, Lopes VP. Associação entre o índice de massa corporal e a coordenação motora em crianças. *Rev Bras Educ Fís Esporte*. 2013;27(1):7-13.
10. Antunes AM, Maia JA, Stasinopoulos MD, Gouveia ÉR, Thomis MA, Lefevre JA, et al. Gross motor coordination and weight status of Portuguese children aged 6-14 years. *Am J Hum Biol*. 2015;27(5):681-9. DOI: <http://dx.doi.org/10.1002/ajhb.22715>
11. Luz L, Seabra A, Santos R, Padez C, Ferreira J, Coelho-e-Silva M. Associação entre IMC e teste de coordenação corporal para crianças (KTK). Uma meta-análise. *Rev Bras Med Esporte*. 2015;21(3):230-5. DOI: <http://dx.doi.org/10.1590/1517-869220152103144469>
12. Lopes VP, Rodrigues LP, Maia JAR, Malina RM. Motor coordination as predictor of physical activity in childhood. *Scand J Med Sci Sport*. 2011;21(5):663-9. DOI: <http://dx.doi.org/10.1111/j.1600-0838.2009.01027.x>
13. Kambas A, Michalopoulou M, Fatouros IG, Christoforidis C, Manthou E, Giannakidou D, et al. The relationship between motor proficiency and pedometer-determined physical activity in young children. *Pediatr Exerc Sci*. 2012;24(1):34-44. DOI: <http://dx.doi.org/10.1123/pes.24.1.34>
14. Vandorpe B, Vandendriessche J, Vaeyens R, Pion J, Matthys S, Lefevre J, et al. Relationship between sports participation and the level of motor coordination in childhood: a longitudinal approach. *J Sci Med Sport*. 2012;15(3):220-5. DOI: <http://dx.doi.org/10.1016/j.jsams.2011.09.006>
15. De Souza M, de Chaves R, Lopes V, Malina R, Garganta R, Seabra A, et al. Motor coordination, activity, and fitness at 6 years of age relative to activity and fitness at 10 years of age. *J Phys Act Health*. 2014;11(6):1239-47. DOI: <http://dx.doi.org/10.1123/jpah.2012-0137>
16. Barnett L, Lai S, Veldman S, Hardy L, Cliff D, Morgan P, et al. Correlates of gross motor competence in children and adolescents: a systematic review and meta-analysis. *Sports Med*. 2016; DOI: <http://dx.doi.org/10.1007/s40279-016-0495-z>
17. De Onis A, Onyango A, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ*. 2007;85(9):660-7.
18. Kowalski KC, Crocker PRE, Donen RM. Validation of the Physical Activity Questionnaire for Older Children. *Pediatr Exerc Sci*. 1997; 9(2):174-86.
19. Morrison K, Bugge A, El-Naaman B, Eisenmann J, Froberg K, Pfeiffer K, et al. Inter-relationships among physical activity, body fat, and motor performance in 6- to 8-year-old Danish children. *Pediatr Exerc Sci*. 2012;24(2):199-209. DOI: <http://dx.doi.org/10.1123/pes.24.2.199>
20. 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: <http://dx.doi.org/10.1515/humo-2015-0019>

This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (<http://creativecommons.org/publicdomain/zero/1.0/>) applies to the data made available in this article, unless otherwise stated.

Resumo:

Introdução: Enquanto evidências sugerem que níveis de coordenação motora e de índice de massa corporal (IMC) estão negativamente correlacionados, pouco se sabe sobre a influência dos níveis de atividade física na associação entre essas variáveis em adolescentes.

Objetivo: Analisar as associações entre os níveis de coordenação motora e o IMC em adolescentes com peso saudável e com sobrepeso/obesos, controlando pelos níveis de atividade física.

Método: Cinquenta e seis escolares (50% adolescentes com sobrepeso/obesos), entre 12 e 14 anos, participaram do estudo. Os instrumentos Physical Activity Questionnaire for Older Children e o Körperkoordinationstest für Kinder foram usados para avaliar os níveis de atividade física e de coordenação motora, respectivamente. Correlações bivariadas e parciais foram usadas para analisar o inter-relacionamento entre os níveis de coordenação motora, IMC e atividade física. O teste de Análise de Covariância foi utilizado para comparar os níveis de coordenação entre adolescentes com peso saudável e com sobrepeso/obesos, considerando o nível de atividade física como covariável.

Resultados: Foram encontradas correlações significativamente negativas ($p < 0,05$), de fraca a moderada, entre IMC e níveis de coordenação no grupo como um todo, nos grupos com peso saudável e com sobrepeso/obesos. No entanto, quando controladas pelos níveis de atividade física, não foram observadas correlações significativas no grupo com peso saudável. Ademais, adolescentes com sobrepeso/obesos apresentaram menores níveis de coordenação motora que adolescentes com peso saudável.

Conclusão: Os níveis de atividade física influenciam a associação entre os níveis de coordenação motora e IMC em adolescentes com peso saudável, mas não em adolescentes com sobrepeso/obesos.

Palavras-chave: adolescente, atividade motora, sobrepeso, obesidade.