Original Article

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Age- and Gender-Specific Levels and Differences in Children's Gross Motor Coordination During Prepuberty

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Abstract: *Introduction:* We are currently observing a decline and deterioration in gross motor coordination in prepubertal children. This also results in deterioration of the overall movement performance. The purpose of this study was to determine sex- and age-specific levels and differences in gross motor coordination among prepubertal children. The somatic parameters included body weight (BW), height (BH), and body mass index (BMI). *Methods:* The sample included elementary school children aged 7–10 years, who were divided according to their age at annual intervals. A total of 381 pupils (103 seven-year-olds, 104 eight-year-olds, 78 nine-year-olds, and 96 ten-year-olds) from elementary schools in the Presov region participated in the educational experiment. To test the children's motor coordination, the Körper-Coordination-Test für Kinder, which provides a complex assessment of coordination abilities, was administered: walking backward, hopping for height, jumping sideways (JS; lower-body frequency ability), and moving sideways (MS; complex body coordination). To process the collected data, they were transformed to MQ scores. The statistical characteristics and methods included percentage distributions, arithmetic means and standard deviations, and analysis of variance to compare the four age categories. *Results:* mean body height and weight increments accounted for 9.54 cm and 7.75 kg between 7 and 10 years of age. Gender differences in the mean motor quotient were significant between boys and girls aged 9–10 years. Motor quotients in both boys and girls decreased with age, and the highest mean motor quotients were found in 7-year-old boys and girls. Of all KTK subtests, motor coordination levels in walking backward and hopping for height decreased, while motor coordination levels in moving sideways and jumping sideways increased as children got older. *Conclusions:* The findings point to the current level of gross motor skills in preadolescent children with age and sex differences.

Keywords: fitness testing, KTK, primary school pupil, motor competence

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INTRODUCTION

Prepubertal children experience changes in physical growth. During prepuberty, physical age is relatively uniform and continuous, with significant changes at the beginning and end of the period [1]. Not all children had body height and weight equal to the average values. Somatic development during this period was moderate, calm, and balanced. From the viewpoint of physical development, prepuberty is considered one of the healthiest developmental periods. Statistics for this period showed a significantly lower incidence of disease than that in other stages of development. School-age is a period of excessive physical activity. Multiple authors consider the period between 6 and 10 years of age as the time during which the reservoir of the physical and mental power of the individual is formed. At this age, physical activity should include all kinetic patterns, alternate activities, and motivation should not be missing. Physical fitness dominates the hierarchy of children's values, and individuals with good fitness levels usually become team leaders [2].

Physical and sports education is a tool used for all-round physical development, performance capacity, physical fitness, and musculoskeletal system enhancement while taking into consideration individual psychomotor specificities and students' physiological levels of functioning [2–8].

In the development of every motor ability, it is necessary to consider sensitive periods, which represent the time when an individual is more responsive and sensitive to external stimuli, and the body is able to adapt more effectively. The genetics of every individual, which play a significant role during sensitive periods, must also be considered. A sensitive period refers to the period when the greatest interaction between heredity and the environment (i.e., the strongest dependence of genotype on the environment) occurs [9, 10]. Studies on coordination abilities during the sensitive period, which covers school age, are of special importance. The results of educational experiments have shown that the rate of improvement in experimental classes is 20% to 50% higher than that in control classes. Iivoven et al. [11] and Chovanová et al. [12] found that a 6-week period is sufficient for motor coordination development.

Testing is administered to assess motor coordination levels, compare results by sex and age, and determine changes induced by recommended exercise programs. Exercise testing is defined as intentional cognitive activity for the objective detection and evaluation of somatic and motor parameters of the population. The KTK test battery, in its entirety, the Körper-Coordination-Test für Kinder, was originally designed for children with cerebral dysfunction. Currently, its scope has been extended to research purposes in many other contexts [13]. It has been used to determine sports "talent" as well as to determine the level of motor skills in the general population. The inter-evaluation study for reliability, according to the Double Latin square design, carried out after eight days, showed high reliability. Iivonen et al. [11] evaluated its relatively easy applicability and suitability for use in the general population, showing its increasing popularity in European countries. Their study highlighted a meaningful KTK battery rating system that allows comparisons between studies. In contrast, it criticizes its narrow profile for locomotion and balance exercises as well as outdated standards of borderline results that are not sufficiently heterogeneous to distinguish the degree of motor coordination abilities.

Some authors opined that the standards for this test were collected long ago and were outdated [13, 14]. Thus, the use of KTK was recommended primarily as an orientation tool in determining the level of motor abilities, not as a detailed diagnostic tool for children outperforming the average [11] However, it is sufficient for normal school conditions. The task of educators who decide to test children using the KTK battery is to control and study the detailed aspects of each movement and to determine which ability to assess. Educators or other adults conducting the test must know when the movement is correct or when movement errors are reported. The issue of motor coordination assessment among schoolchildren has been addressed in various studies [15].

The purpose of this study was to determine sex- and age-specific levels and differences in gross motor coordination among prepubertal children.

MATERIAL AND METHODS

Participants

The sample included elementary school children aged 7–10 years, who were divided according to their age at yearly intervals. Three hundred eighty-one pupils (Σ_n = 381), 103 seven-year-olds, 104 eight-year-olds, 78 nine-year-olds, and 96 ten-year-olds, from elementary schools in the Presov region participated in an educational experiment. Only pupils with no health restrictions, who fully participated in two classes of school physical and sports education per week were included in the study. Individuals who engaged in organized sports training were excluded from the study.

Procedure

The somatic parameters included body weight (BW), height (BH) and body mass index (BMI). To test the children's motor coordination, the KTK test battery, which provides a complex assessment of coordination abilities, was administered [16]: walking backward (WB; dynamic balance), hopping for height (HH; coupling ability, kinesthetic-differentiation ability), jumping sideways (JS; lower-body frequency ability), and moving sideways (MS; complex body coordination).

Statistical analysis

We transformed the measured data into partial scores, MQ1, MQ2, MG3, and MQ4, and the sum of these points was the total MQ score with subsequent transformation. The sample age categories were characterized using averages and standard deviations. Data normality was tested using the Kolmogorov-Smirnov test. The skewing of the data guided us to use a non-parametric ANOVA, Kruskal-Wallis test; therefore, the equality of variances did not need to be verified. ANOVA detected a significant difference between means.

RESULTS

Table 1 shows the somatic parameters of the prepubertal children by age. The mean BMI values among 7- to 10-year-old children ranged from 16.30 to 18.88, which indicates normal weight. Children aged 7–10 years experienced active physical growth, especially in body height. Mean body height and body weight increments accounted for 9.54 cm and 7.75 kg between 7 and 10 years of age.

In the backward walking subtest, prepubertal children showed similar dynamic balance levels by age (Table 2). Children aged 7 years were able to walk backward three times in the shortest time compared with their older peers, with significant differences in dynamic balance between boys and girls. The dynamic balance levels in the backward direction decreased with age in both boys and girls. The differences in dynamic balance levels by age were not statistically significant (Table 2). At this age, children were able to maintain or restore their balance when fast and unexpected changes in positions occurred.

On the jumping sideways subtest, children aged 7, 8, and 9 achieved approximately the same test scores, reaching a level higher than that of the 10-year-olds (Table 2). Overall, boys aged 9 and 10 years had the highest number of lateral jumps in 15 s. Lower body frequency ability levels increased with age, particularly in girls. There were significant gender differences among the three age groups:8-, 9-, and 10-year-olds. Significant differences were found between the 10-year-old children and all the younger age groups (Table 3).

Table 1. Somatic parameters by age (n = 381).

Measured values	Age n	7 years (n = 103)	8 years (n = 104)	9 years (n = 78)	10 years (n = 96)
body height	M	129.11	130.02	132.61	138.65
	SD	7.35	7.90	5.84	6.50
body weight	M	28.87	29.93	30.67	36.62
	SD	6.40	7.90	6.04	4.89
BMI	M	16.30	17.14	17.36	18.88
	SD	4.44	4.71	2.88	4.20

n - sample size; M - mean; SD - standard deviation; BMI - body mass index

Table 2. KTK subtests: mean scores and gender differences (n = 381).

Subtests	Gender	Age	7 years	8 years	9 years	10 years
Walking backwards	boys	M	32.65	40.16	45.72	43.37
		SD	7.29	10.09	13.95	14.87
	girls	M	38.54	42.10	49.54	48.64
		SD	12.42	14.19	14.11	14.31
	p-value		0.03	0.59	0.15	0.08
Jumping sideways	boys	M	38.68	57.80	59.55	57.84
		SD	11.04	12.79	18.64	14.63
	girls	M	38.96	46.30	51.32	51.66
		SD	16.29	14.36	12.38	13.33
	p-value		0.94	0.006	0.006	0.033
Moving sideways	boys	M	28.32	25.40	21.89	22.29
		SD	8.25	7.74	3.94	4.08
	girls	M	31.65	30.55	20.72	20.86
		SD	7.97	8.17	3.71	4.06
	p-value		0.13	0.036	0.11	0.09
Hopping for height	boys	M	38.23	43.04	32.37	30.93
		SD	15.41	13.69	15.87	14.61
	girls	M	42.12	45.50	24.79	24.74
		SD	15.23	11.15	9.72	9.49
	p-value		0.34	0.52	0.002	0.015

n - sample size; M - mean; SD - standard deviation; KTK - Körper-Coordination-Test für Kinder, p-value - significance level

On the moving sideways subtest, 9-year-children achieved the best scores for all age categories. Complex body coordination levels increased with age, with significant gender differences between 8-year-old boys and girls (Table 2). Significant differences in complex body coordination were found among all age groups, except for the 9- and 10-year-old children (Table 3).

In the hopping for height subtest, 8-year-old children showed the highest levels of jumping abilities and kinesthetic differentiation. The jumping ability and kinesthetic differentiation levels decreased with age in both boys and girls. There were significant sex differences between boys and girls aged 9 and 10 years (Table 2). Significant differences in jumping ability and kinesthetic differentiation levels were found among all age groups, except for the 7- and 8-year-old children (Table 3).

Table 4 lists the overall sum of MQ points. Gender differences in the mean motor quotient were significant between boys and girls aged 9–10 years. Motor quotients of both boys and girls decreased with age. Interestingly, the highest mean motor quotients were found in the 7-year-old boys and girls.

Table 3. KTK subtests: differences by age (n = 381).

KTK subtests	Age [years]	Age 7	Age 8	Age 9
Walking backwards H=5.684; p=0.128	8	1.000	-	0.275
	9	0.907	0.275	-
	10	1.000	1.000	0.395
Jumping sideways H=22.582; p=0.000	8	0.519	-	0.096
	9	1.000	0.096	-
	10	0.043	0.000	0.028
Moving sideways H=122.138; p=0.000	8	0.006	-	0.000
	9	0.000	0.000	-
	10	0.000	0.000	0.407
Hopping for height H=136.955; p=0.000	8	1.000	-	0.000
	9	0.000	0.000	-
	10	0.000	0.000	0.002

KTK - Körper-Coordination-Test für Kinder, H - value of Kruskal-Wallis test, p-value - significance level

Table 4. Mean MQ values by age and gender (n = 381).

Motor quotient	Age	7 years	8 years	9 years	10 years
boys	M	93.48	91.04	80.44	71.51
	SD	16.13	10.33	14.39	14.07
girls	M	95.69	91.60	69.79	63.16
	SD	19.69	13.42	11.24	12.94
p-value		0.64	0.87	0.000	0.003

M - mean, SD - standard deviation, p-value - significance level

DISCUSSION

This study investigated age- and sex-related differences in gross motor coordination among children aged 7–10 years using the KTK test battery. Consistent with the results of the present study, Vandorpe et al. [13] reported significant sex differences for the subtests walking backward and hopping for height. In the dynamic balance task, girls scored significantly better than boys in all but one age group. In the hopping task, boys scored girls in every age group. Neither sex scored significantly different for MS and JS at any age. Girls scored better on the balance task and boys on the strength-oriented task. In a study by Adriyani, Iskandar, Camelia [17], there were significant differences in motor coordination between boys and girls, and mean motor quotient of boys (83.34) was significantly higher than girls (72.39). Boys outperformed girls in hopping height, moving sideways, and jumping sideways. Girls were similar to boys only when walking backwards. D'Hondt et al. [18] observed a main effect of gender on three KTK items. Boys achieved higher scores on jumping and moving sideways, whereas girls demonstrated better performance in walking backward. Bezzera-Santos et al. [19] reported that boys and older children had higher levels of gross motor coordination than did girls and younger children. According to Torralba et al. [20], boys presented better overall motor performance than girls, especially at the ages of 9 and 10. According to Lima et al. [21], boys aged 6 and 9 years had higher MQ scores than girls of the same age. Carminato [22] observed that girls had lower levels of motor performance than boys.

As for the components of coordinated motor performance, it was possible to verify that girls showed more difficulty in side and monopedal jumps than boys, who presented lower levels of balance. Chaves et al. [23] reported that with increasing age, children were better coordinated, boys outperformed girls in hopping for height and moving sideways tests, and those with higher fat mass levels were less coordinated. Freitas et al. [24] observed that girls scored significantly better than boys on jumping sideways and boys scored significantly better than girls on moving sideways. Their results support the

hypothesis that skeletal age or interaction with body size has a negligible influence on motor coordination tests in children. Antunes et al. [25] reported that biological and environmental forces might influence the raw scores observed in these motor coordination tasks, favoring both boys and girls. According to Vandorpe et al. [13], sex differences in gross motor coordination may be explained by weight status, especially by body fat percentage. Nascimento et al. [26] noted that body composition is the variable that exerts the greatest influence on the level of development of motor coordination in KTK. According to Antunes et al. [25], sex-related differences depend on age and MC test results. Adriyani et al. [17] pointed out that boys have more muscle mass than girls and therefore exhibit higher levels of strength and endurance. In their study, boys engaged in more physical activity than girls, which may have played a major role in motor coordination development. Bezerra-Santos et al. [19] found that biological maturation was significantly associated with the task of walking backward, with the most advanced subjects having the worst scores in this task, an effect mediated by the greater accumulation of fat in the waist region, characteristic of a more advanced maturational state in boys.

Main effects of age on gross motor coordination have been reported in numerous studies [27, 28]. According to Vandorpe et al. [13], a decline in coordination was observed, especially in tasks relying primarily on coordinative capacities (WB and MS), while improvements or the status quo in those tasks relying on strength and speed (JS and HH) may be explained by secular trends. Antunes et al. [25] reported a significant main effect of age on walking backward and moving sideways and observed that boys performed significantly better than girls on moving sideways. According to their results, raw scores for walking backward and moving sideways improved with age. Henrique et al. [29] observed an increase in GMC and physical fitness tests related to health and performance, whereas physical activity levels decreased over time. Reyes et al. [30] found that children with increasing body mass index were less coordinated, while those who were stronger and more agile had steeper trajectories of gross motor coordination with age. According to their study, children's gross motor coordination development is nonlinear. This finding is consistent with the results of our study on prepubertal children who showed developmental increases in motor coordination [31]. The mental and somatic parameters underlying motor control, such as concentration and attention, improved. The rapid and positive development of coordination abilities is facilitated by children's significant spontaneous mobility and favorable anthropometric relationships. The end of this period (before pubertal and growth changes occur) is referred to as the first peak of motor development, especially in terms of motor coordination, which was recorded in the sample of 7- to 8-year-old children.

CONCLUSION

Mean body height and body weight increments accounted for 9.54 cm and 7.75 kg between 7 and 10 years of age. Gender differences in the mean motor quotient were significant between boys and girls aged 9–10 years. Motor quotients in both boys and girls decreased with age, and the highest mean motor quotients were found in 7-year-old boys and girls. Of all KTK subtests, motor coordination levels in walking backward and hopping for height decreased, while motor coordination levels in moving sideways and jumping sideways increased as children got older.

Regarding practical recommendations, inform the educational community about the importance of monitoring the level of coordination skills of school-age children. In addition, the test batteries should be sensitively and specifically adapted to children in terms of their individuality during early school years. We also recommend increasing the standardization and plausibility of motor skills tests (with regard to the age and sex of children). through continuous validations.

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Conflicts of Interest: The authors declare that they have no conflict of interest. Each of the authors has read and concurs with the contact in the final manuscript. This study did not receive financial support. All authors read and approved the final version of the manuscript.

REFERENCES

1. Langmeier J, Krejčířová D. Vývojová psychologie [Developmental psychology]. Praha: Grada. 2006 [in Czech]
2. Bendíková E. Theory of health, movement and lifestyle of human beings. Debrecen: University of Debrecen. 2017
3. Bartholomew JB, Jowers EM. Physically active academic lessons in elementary children. Preventive Medicine. 2011; 52(Suppl 1): 51-54. doi: 10.1016/j.ypmed.2011.01.017
4. Chovanová E, Majherová M. The effect of physical activities on the development of coordination abilities in intact and overweight children. Sci Rev Phys Cult. 2017; 7(4): 82-86. doi:10.21125/edulearn.2017.1536
5. Bendíková E, Novotná B, Rozim R, Tomková Š, Fyodorov A, Palaščáková Špringrová I. Analysis of physical activity status and functional posture in Slovakia's young school-aged children with different body weight. Zdravotnícke listy. 2020; 8(2): 71-81. doi:10.36007/3778.2020.45
6. Bendíková E. Balkó I. Acral Coactivation Therapy method in terms of improving the musculoskeletal system in pupils in physical and sport education. Trends in Sport Sciences. 2021; 29(3): 107-114
7. Nemček D, Ladecká P. Úroveň osobnej pohody stredoškolákov s poruchami muskuloskeletálneho systému [The level of subjective well-being of high school students with musculoskeletal disorders]. Zdravotnícke listy. 2020; 8(2): 16-21 [in Slovak]
8. Polevoy G. Development of coordination and speed-power abilities in children 8-9 years with the help of exercise Classics. Phys Activ Rev 2020; 8(1): 46-50. doi: 10.16926/par.2020.08.06
9. Rozim R, Daubnerová J, Slováková M, Bendíková E. Changes in somatic characteristics and indicators of physical ability, physical performance and body posture in 10 and 11 years old pupils. In INTED 2022 Proceedings. 16th International Technology, Education and Development Conference. Online Conference. 7-8 March, 2022. ISBN: 978-84-09-37758-9, ISSN: 2340-1079 doi: 10.21125/inted.2022, Publisher: IATED, p. 547-556
10. Antara R, Welis W, Masrun, Irawan R, Mario DT, Alnedral, Umar, Wasik J. Effects of agility, coordination, and flexibility on dribbling skills in senior high school female field hockey players. Phys Act Rev. 2023; 11(2): 42-51. doi: 10.16926/par.2023.11.20
11. Iivonen S, Laukkanen A, Sääkslahti A. A review of studies using the Körperkoordinationstest für Kinder (KTK). European Journal of Adapted Physical Activity. 2015; 8(2): 18-36. doi: 10.5507/euj.2015.006.
12. Chovanová E. Majherová M. The relationship between BMI and motor coordination in 13-year-old children. Scientific review of physical culture. 2016; 6(4): 10-14
13. Vandorpe B, Vandendriessche J, Lefevre J, Pion J, Vaeyens R, Matthys S, Philippaerts R, et al. The Körperkoordinationstest für Kinder: reference values and suitability for 6-12-year-old children in Flanders. Scand J med Sci Sports. 2011; 21(3): 378-388. doi: 10.1111/j.1600-0838.2009.01067.x
14. Ribeiro ASC, David AC, Barbacena MM, Rodrigues ML, de França NM. Body coordination test for children (KTK): Applications and normative studies. Motricidade. 2012; 8(3): 40-51. doi: 10.6063/motricidade.1155
15. Sgrò F, Quinto A, Messana L, Pignato S, Lipoma M. (2017). Assessment of gross motor developmental level in Italian primary school children. Journal of Physical Education and Sport. 2017; 17(3): 1954-1959. doi:10.7752/jpes.2017.03192
16. Kiphard J, Schilling F. Körperkoordinationstest für Kinder KTK. Weinheim: Beltz Test. 2007 [in German]
17. Adriyani R, Iskandar D, Camelia LS. Gender differences in motor coordination and physical activity. Advances in Health Sciences Research 2020; 21, 122-126. doi: 10.2991/ahsr.k.200214.034
18. D'Hondt E, Deforche B, Vaeyens R, Vandorpe B, Vandendriessche J, Pion J, Philippaerts R, De Bourdeaudhuij I, Lenoir M. 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(S3): e556-564. doi: 10.3109/17477166.2010.500388
19. Bezerra-Santos DH, Luz LGO, Silva-Lima BP, Santos-Pinheiro IKA, Cunha-Júnior AT, Medeiros HJ. Effect of biological maturation on gross motor coordination in boys: a mediation analysis. Fisioter Mov Curitiba 2020; 33, e003366. doi:10.1590/1980-5918.032.AO65

20. Torralba MA, Vieira MB, Lleixà T, Gorla JI. Evaluación de la coordinación motora en educación primaria de Barcelona y provincia [Assessment of motor coordination in primary education of Barcelona and province]. Rev Int Med Cienc Act Fís Deporte. 2016; 16(62): 355-371. [in Spanish]
21. Lima RA, Bugge A, Pfeiffer KA, Andersen LB. Tracking of gross motor coordination from childhood into adolescence. Res Q Exerc Sport, 2017; 88(1): 52-59. doi: 10.1080/02701367.2016.1264566
22. Carminato RA. Desempenho motor de escolares através da bacteria de teste KTK. Curitiba: Universidade Federal do Paraná. 2010 [in Spanish]
23. Chaves R, Baxter-Jones A, Gomes T, Souza M, Pereira S, Maia J. Effects if individual and school-level characteristics on a child's gross motor coordination development. Int J Environ Res Publ Health. 2015; 12 (8): 8883-8896. doi: 10.3390/ijerph120808883
24. Freitas DL, Lausen B, Maia JA, Lefevre J, Gouveia ÉR, Thomis M, Antunes AM, Claessens AL, Beunen G, Malina RM. Skeletal maturation, fundamental motor skills and motor coordination in children 7-10 years. J Sports Sci. 2015; 33(9): 924-934. doi: 10.1080/02640414.2014.977935.
25. Antunes AM, Maia JA, Stasinopoulos, MD, Gouveia, ÉR, Thomis, MA, Lefevre, JA, Teixeira, AQ, Freitas DL. Gross motor coordination and weight status of Portuguese children aged 6-14 years. Am J Hum Biol. 2015; 27(5): 681-689. doi: 10.1002/ajhb.22715
26. Nascimento WM, Henrique NR, Marques MS. KTK Motor test: Review of the main influencing variables. Rev Paul Pediatr. 2019; 37(3): 372-381. doi: 10.1590/1984-0462/;2019;37;3;00013
27. Eliso M. Effects of early regular physical therapy treatment on gross motor function of children with cerebral palsy. Journal of Physical Education and Sport, 2017; 17(1): 284-287. doi:10.7752/jpes.2017 .01042
28. Moreira JPA, Lopes MC, Miranda-Júnior MV, Lage GM, Albuquerque MR. Körperkoordinationstest Für Kinder (KTK) for Brazilian Children and Adolescents: Factor Analysis, Invariance and Factor Score. Front Psychol. 2019; 10, 2524. doi: 10.3389/fpsyg.2019.02524.
29. Henrique RS, Bustamante AV, Freitas DL, Tani G, Katzmarzyk PT, Maia JA. Tracking of gross motor coordination in Portuguese children. J Sports Sci. 2017; 36(2): 220-228. doi: 10.1080/02640414.2017 .1297534
30. Reyes AC, Chaves R, Baxter-Jones ADG, Vasconcelos O, Barnett LM, Tani G, Hedeker D, Maia J. Modelling the dynamics of children's gross motor coordination. J Sports Sci. 2019; 37(19): 2243-2252. doi: 10.1080 /02640414.2019.1626570.
31. Roth K, Winter R. Entwicklung koordinativer Fähigkeiten. In Ludwig G., Ludwig B. eds. Koordinative Fähigkeiten, koordinative Kompetenz. Kassel: Universität. 2002. p. 97-103 [in German]