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THE RELATIONSHIP BETWEEN ANTHROPOMETRIC MEASURES AND MANIFESTATION OF COORDINATION IN PRESCHOOL CHILDREN

ABSTRACT: To investigate the connection between body measurements and the development of motor coordination in preschool-aged children, 77 children (54 boys, 23 girls) with an average age of 5.71±0.54 years were measured and tested. The study involved 9 tests to assess body measurements, which were used as predictive variables. Additionally, four tests from the KTK battery were used to evaluate motor skills and coordination. The data was analysed using descriptive and regression analyses. The average values of coordination (KTK) significantly positively correlated with anthropometric variable of body height (BH, r = 0.259, p = 0.013), and significantly negatively correlated with variables of abdominal skin fold (ASF, r = -0.209, p = 0.037), dorsal skinfold (DSF, r = -0.282, p = 0.007) and uper arm skin fold (UASF, r = -0.244, p = 0.018). The results of the regression analysis (backward method) showed that the model that best explains the variability of the dependent variable was defined by folloving variables: forearm circumferences (FCIRC), dorsal skinfold (DSF) and upper arm skin fold (UASF) with 23.4% of explained variance. Additionally, the results suggest that children between the ages of 5 and 7 who possess greater forearm circumferences, lower dorsal skinfold, and upper arm skinfold have better coordination abilities.

KEY WORDS: Anthropometric measures – Motor abilities – Preschool age – Coordination

INTRODUCTION

Coordination as a complex motor ability implies efficient and precise management of the body or parts of the body. As such, it is important when performing complex motor tasks that require accuracy, precision and adjustment of movements in order to solve problems (Bompa, 2006). The pre-puberty period

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should be used for adequate stimulation, with a special focus on coordination and speed (Hirtz, Starosta 2002). The sensitive period for the development of coordination covers approximately the ages of 5 to 16 years, and the greatest impact can be achieved between the ages of six and sixteen (Komes *et al*. 2005). For preschoolers aged 5–7 years, early intervention in the development of coordination is of particular importance, because coordination indirectly supports the development of other motor skills, improves the resolution of complex tasks and optimizes neuromuscular efficiency. Structured and goal-oriented activities during this phase allow the child to learn simple motor skills that will be the foundation for all other motor skills (Van der Walt *et al*. 2020). Coordination is considered the most important motor skill of early childhood by most researchers (Lopes *et al*. 2012). Previous studies have extensively examined how height, body mass, and body mass index influence coordination and other motor skills (De Toia *et al*. 2009; Lepes *et al*. 2014; Kakebeeke *et al*. 2017; Kojic *et al.* 2023). Anthropometric measurements are used to assess height, body composition, and their relationship to motor performance.

In this study, the predictive value of anthropometric assessments for coordination was actually quantified, such as effect sizes and R^2 values, so that it is simpler to identify how the physical characteristics influence the development of motor skills among preschoolers. Anthropometric monitoring also provides information about the impact of various factors such as growth and development activity, genetic factors, environmental factors, physical exercise, and physiological processes. This information can be compared to norms available for boys and girls of the same chronological age (Stupar *et al*. 2017).

The study had two major objectives. The first was to investigate the connection between anthropometric measures and coordination skill acquisition in preschool children. The second was to create a predictive model that can guide physical education teachers, educators, and coaches working with preschool children how the specific anthropometric characteristics influence the performance in motor coordination tests.

MATERIAL AND METHOD

Sample of participants

The study involved 77 children, out of which 54 were boys and 23 were girls, aged 5 years with an average of 5.71± 0.19. These children are part of the sports school organized by the "Super Active" youth sports association from Novi Sad, Serbia. The sports school follows the Bala's model (2002) of kinesiological exercise designed for preschool children. The parents of the children had given written consent for them to be measured as part of the study. All personal identifiers were removed from the data set before analysis, The study was conducted in accordance with the Declaration of Helsinki of the World Medical Association (World Medical Association 2013). All parents were informed about the research in advance, and the purpose and aims of the research were explained. Therefore, all parents supported the research with their written consent.

Sample of measures

Recent studies (Bala 1981) indicate that these measurements, in the case of children, cover a two-dimensional model of morphological dimensions: the dimensionality and voluminosity of the skeleton and subcutaneous adipose tissue. The manner and conditions under which the measuring took place were in accordance with the recommendations of the International Biological Program – IBP (Lohman *et al*. 1988).

The variables of anthropometric measures were as follows: – for assessment of skeleton dimensionality:

1) body height (cm), was measured using anthropometry according to Martin (GPM Anthropometer 100; DKSH Switzerland Ltd., Zurich, Switzerland; ± 0.1 cm).

For assessment of skeleton voluminosity and subcutaneous adipose tissue:

2) body mass, was measured using digital balance (BC1000, Tanita, Japan; ± 0.1 kg).
3) circumference of the chest (chest girth) (medium),
4) abdominal circumference
5) circumference of the upper arm (mid-arm girth) (in a relaxed position),
6) circumference of the lower arm (forearm girth);
for assessment of subcutaneous adipose tissue –
7) abdominal skin fold,
8) skin fold of the back (subscapular skin fold) and
9) skin fold on the upper arm (triceps skin fold).

The KTK test was used as a variable for evaluating motor coordination (the total result of all tests is taken).

The KTK test is a widely used tool for evaluating the coordination skills of preschool children. KTK consists of the following described tests Kiphard, Schilling 2007. The test is standardized and reliable (Valaei, Vandroemme 1999; Gheysen *et al.* 2008), and norms are defined according to gender. The ultimate goal of the test is to detect deficits in movement skills (Cools *et al.* 2009). The test protocol included the following four subtests:

1. Walking backward (WB) on a balance beam of 3 m in the length of decreasing widths (6 cm, 4.5 cm, 3 cm);

The test requires each respondent to complete a task on each of three beams with different widths – yellow, red, and green. The beams are 3 meters long and 6 cm, 4.5 cm, and 3 cm wide, respectively. The test is conducted on a flat surface measuring 5×5 meters, with the beams placed in parallel order. Before starting the task on each beam, the examinee can have a trial attempt to move the beam in advance. On the yellow beam, the test taker needs to cross the beam backward in a maximum of eight steps without touching the ground with one or both feet. If the test taker falls off the beam or touches the ground during the first attempt, they have two more attempts to complete the task. The task is performed on the red and green beams in the same way. The examiner follows the examinee throughout the test and records the number of attempts. The result is the sum of all nine attempts on three beams, and the maximum score is 72 since the maximum number of steps is eight. The test takes between three to four minutes per respondent and requires one examiner and one assistant.

2. One-legged hopping for height (HH) over a foam obstacle of increasing height (consecutive increments of 5 cm);

The test requires one examiner and one assistant. The task starts with five jumps on each leg and then one-legged sponge jumps. The subject jumps over sponges placed on three mats, increasing the height to 60 cm. Up to two more attempts are allowed for each height if there is a mistake. The task ends after three mistakes at one height with one leg. The maximum score is 78 points, i.e. 39 points for each leg.

3. Two-legged jumping sideways (JS) from side-to-side over a beam (60 cm × 4 cm × 2 cm) as fast as possible for 15 s;

The test takes about one minute per person and requires only one examiner. For this test, you will need a slat that is 60 cm long, 2 cm wide, and 4 cm high, as well as a stopwatch. Place the slat on a flat surface without any incline. The examinee's task is to jump over the slat with alternating left-right foot jumps for a maximum duration of 15 seconds. The task should be performed twice. Before starting, the test taker has the right to a trial attempt, where they can jump up to five times using alternating cross-legged jumps. The examiner should stand in front of the test taker and record the results. The score is the total number of successful jumps.

4. Moving sideways (MS) on the floor in 20 s by stepping from one plate (25 cm × 25 cm × 2 cm, supported on four legs 3.7 cm high) to the next, moving onto the first plate, stepping on it, and so on.

The task requires two wooden platforms measuring 25 cm wide, 25 cm long, and 5.7 cm high, as well as a stopwatch. The test is performed on a flat surface without slopes. One examiner is needed to record the number of switches. Before the test, the examinee is given a trial attempt to move the platform five times. The test itself lasts for 20 seconds. The subject stands on one platform in a standing position while the second platform is placed on the right or left side of the first one. At the examiner's signal, the subject starts moving to the adjacent platform, then moves the platform from which they started to the right side, and continues to move in this way for 20 seconds. The test is performed twice. The examiner stands in front of the examinee and records the number of switches. The score is calculated by adding up all the moves made by the subject. The test takes about one minute per respondent.

Statistical analysis. The statistical analysis of the data involved using the Statistical Package for Social Sciences (SPSS) version 26.0 by SPSS Inc. in Chicago, IL, USA. Firstly, the descriptive parameters of the variables were meticulously determined, which included calculating the arithmetic mean (Mean), standard deviation (SD), as well as the minimum and maximum values. Following this, Pearson's correlation coefficient was employed to thoroughly examine the relationship between motor coordination and anthropometric measures. Additionally, a comprehensive Backward method multiple-regression analysis was conducted to explore the association of motor coordination with significant predictor variables. The statistical significance of the results was set at $p < 0.05$ to ensure the rigor and reliability of the findings.

RESULTS

The descriptive statistics (*Table 1*) gives us an overview of the central tendency and dispersion of the variables under consideration. It's evident that the mean values vary across different measures, indicating diversity within the sample population. For instance, while the mean KTKTR (KTK total result tests) score is 108.76, indicating overall motor coordination, the

TABLE 1. Descriptive statistics of motor coordination and anthropometric measures. Legend: KTKTR (KTK total result tests), BH (body height), BM (body mass), CCIRC (chest circumference), ACIRC (abdominal circumference), UACIRC (upper arm circumference), FCIRC (forearm circumference), ASF (abdominal skin fold), DSF (dorsal skin fold), UASF (upper arm skin fold).

Variables	Mean	Std. Deviation	Minimum	Maximum
KTKTR	108.76	36.618	23	185
BH (cm)	117.649	7.1061	100.5	131.6
BM (kg)	22.277	5.3497	14.9	54.5
CCIRC	57.524	3.9157	49.0	68.2
ACIRC	55.400	5.1124	45.2	69.9
UACIRC	17.250	1.7000	14.3	23.2
FCIRC	16.966	1.4010	14.3	21.9
ASF (cm)	7.116	3.6936	3.0	18.0
DSF (cm)	5.709	2.1729	3.0	15.0
UASF	9.179	2.8993	5.0	19.0

TABLE 2. Pearson's correlation coefficient between motor coordination and anthropometric measures (n = 77). Legend: KTK (KTK tests), BH (body height), BM (body mass), CCIRC (chest circumference), ACIRC (abdominal circumference), UACIRC (upper arm circumference), FCIRC (forearm circumference), ASF (abdominal skin fold), DSF (dorsal skin fold), UASF (upper arm skin fold), CI (confidence interval).

Variables	KTK	p	CI lower	CI higher
BH (cm)	0.259	0.013	0.037	0.457
BM (kg)	0.032	0.392	-0.193	0.254
CCIRC (cm)	-0.114	0.168	-0.33	0.113
ACIRC (cm)	-0.013	0.458	-0.236	0.212
UACIRC (cm)	0.033	0.391	-0.192	0.255
FCIRC (cm)	0.142	0.114	-0.085	0.355
ASF (cm)	-0.209	0.037	-0.414	0.016
DSF (cm)	-0.282	0.007	-0.476	-0.062
UASF (cm)	-0.244	0.018	-0.444	-0.021

mean values for other anthropometric measures like body height (BH), body mass (BM), and circumferences differ significantly.

The correlation coefficients (*Table 2*) provide data on the degree and direction of the linear relationship of motor coordination with anthropometric measurements. The most significant correlations are negative with skin folds (DSF, ASF, UASF) and positive with height. Larger amounts of subcutaneous adipose tissue are associated with worse motor coordination, as would be predicted, because more mass will make accurate and coordinated motion more difficult. Body height is positively related to coordination, most probably due to the development of motor skills and proportionate development of this age. BM (body mass), CCIRC (chest circumference), ACIRC (abdominal circumference), UACIRC (upper arm circumference), FCIRC (forearm circumference) were not significantly related. The cause may be:

a) Varying body compositions – children of the same body weight might have different fat and muscle distribution.
b) Girth measurements don't assess functional mass or agility directly.

Multiple regression analysis (*Table 3*) allows us to determine the combined predictive power of multiple independent variables on a dependent variable. The backward method regression analysis presented in Table 3 reveals significant predictor variables for motor

TABLE 3. Backward method multiple-regression analysis of the association of motor coordination with significant predictor variables (n = 77). Legend: FCIRC (forearm circumference), DSF (dorsal skin fold), UASF (upper arm skin fold). Unstd. Beta = Unstandardized regression coefficient values. Beta = Standardized regression coefficient values. t = Standardized regression coefficients significance test. p = Standardized regression coefficients level of significance. R = Multiple correlation coefficient. R^2_{adjust} = Adjusted determination coefficient. Std. Err. Est. = Standard error of the estimate. F = Multiple regression analysis significance tests. P = Multiple correlation level of significance.

Variables	Unstd.Beta	Beta	t	p	R	R^2_{adjust}	Std.Err. Est	F	P
FCIRC (cm)	15.322	0.586	4,194	0.000					
DSF (cm)	-4.701	-0.279	-1,716	0.049					
UASF (cm)	-5.375	-0.426	-2,317	0.023	0.515	0.234	32.044	8.442	0.0001

coordination Forearm circumference (FCIRC), dorsal skin fold (DSF), and upper arm skin fold (UASF) emerge as significant predictors, with FCIRC having the strongest impact (Beta = 0.586, $p < 0.001$). The model's overall fit is significant ($F = 32.044$, $p < 0.001$), indicating that the combination of these variables explains a significant proportion of the variance in motor coordination.

DISCUSSION

Meta-analyses of studies by Rico-González *et al.* (2024) show strong associations between anthropometric variables such as height, body mass, and body mass index (BMI) with several measures of physical fitness and motor skills in preschoolers aged 2–6 years. Physical fitness can be more effectively predicted by measures of height and body mass than by BMI's as presence or absence of weight restrictions on motor function is important. Malnutrition as reflected in stunting and loss of weight is detrimental to motor development, indicating the importance of optimal nutrition. Motor performance is potentially complex and different in its interactions with the anthropometric measures and physical activity levels across studies.

The aim of this study is to determine the relationship between motor coordination measured by the KTK test and anthropometric measures of preschool children. The obtained results showed that the circumference of the forearm (FKRIC) is positively related to motor coordination, unlike the dorsal (DSF) and upper arm (USAIF) skin folds, which are inversely related. This actually confirms that children with a better body composition, which meant adequate (FKRIC) mass and reduced values of subcutaneous fat, actually achieved better results on tests for assessing motor coordination. At the same time, the findings of Garcia and Evans (2022) and Rostamzadeh *et al.* are confirmed. (2021) where the importance of the size of the forearm and hand as primary for the acquisition of motor skills was confirmed

Unlike in some of the previous studies, body mass (BM), chest circumference (CCIRC), abdominal circumference (ACIRC) and upper arm circumference (UACIRC) failed to correlate significantly with motor coordination in our group. It may imply that in preschool children local development and distribution of subcutaneous fat tissue have a more direct influence on motor ability than total body circumference.This is attested to by the study of Jaksic *et al.* (2020), which proved that nine months of physical activity intervention significantly improves the morphological profile, motor, and cognitive abilities of preschool children. Specifically, children who participated in structured physical activity had increased forearm circumference and improved coordination, speed, and strength-requiring task performance. These results confirm our observation that greater forearm circumference and less subcutaneous fat are linked with enhanced motor coordination, and accent the practical importance of directed exercise in preschool children.

The results of this study need to be interpreted cautiously given the potential influence of a variety of confounding factors not fully under control. One major one is the level of physical activity outside of the formally structured program at the sports school. Individuals who were more active in free play, outdoor recreation, or other sports activities may have displayed better coordination and anthropometric outcomes irrespective of the formal kinesiology model used. Another variable that enters into the picture is diet, which has a direct influence on development, body composition, and functional development. Well-balanced and well-nourished diets of such children result in their having better anthropometric profiles and motor skills, but their poor nutrition compromises their development.

Finally, differences in biological maturation among children of the same chronological age are an extremely important variable.Even within the short range of 5 to 7 years, variations in rate of growth, development of muscles, and neuromuscular maturity may contribute highly significantly to the explanation of individual differences in coordination and physical performance. These constraints suggest that future studies might need to integrate monitoring extracurricular physical activity, diet, and indicators of maturation to provide a fuller picture of preschool motor development determinants.

LIMITATIONS OF THE STUDY

The study was conducted on a specialized population of children in a sport school and thus restricting generalizability of the data. Physical activity outside of school, nutrition, and intra-individual variation in biological maturity were not controlled. Although a limitation of this research is that there is no data on the socio-economic status of the participants. It is known that socio-economic circumstances, including parents' education and occupation and living conditions, can have a great impact on anthropometric measures and motor skill development in children (eg Stodden *et al*. 2008). Future research should also include these indicators in order to gain a fuller picture of the determinants of motor development of preschool children. The sample size is relatively small (n = 77), which influences the reliability of the correlation. The children were considered a special sample, gender-free, as the initial analysis was not showing differences. This enables generalization of the findings to the preschooler population but limits the identification of possible subtle differences between the two sexes. This finding is supported by literature that demonstrates that at the early preschool age, motor skills are developing at an equal pace in both sexes (Voloshina 2020).

CONCLUSIONS

This research aimed to determine the relationship between motor coordination and anthropometric measures of preschool children. Based on the obtained results, it could be concluded that, first of all, the variables forearm circumference, dorsal skin fold and upper arm skin fold were significant predictors of the motor coordination ability of preschool children.. The study found that the circumference of the forearm (FCIRC) was the most influential factor in predicting motor coordination efficiency. It was observed that preschool children with larger forearm circumference (FCIRC) and smaller dorsal (DSF) and upper arm skin folds (UASF) showed a tendency towards better efficiency of motor coordination.

The obtained results indicate the importance of early intervention aimed at the proper growth and development of preschool children. In this context, it is necessary for educators and trainers to adapt their programs that are primarily related to children's motor competence. In this sense, concrete exercises or games with balls, which require precise catching and throwing (games between two fires, or mini basketball) are very useful. Balance exercises, with or without a balance board, as well as jumping, skipping, within different polygons, can contribute to motor development, ie coordination. Individual adaptation of activities to children with different anthropometric characteristics is also necessary. In essence, the study points to the huge potential of various kinesiology activities, first of all, on motor development, but finally on the health of children of preschool age.

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