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Motor Coordination in Primary School Students: The Role of Age, Sex and Physical Activity

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Abstract: The aim of this study was to assess the differences in motor coordination (MC) of primary school students based on sex, age, and physical activity participation (PAP), as well as investigation the binary and triple interactions of these variables on MC. In addition, ıt is aim to determine the validation and reliability of the KTK3+ test for Turkish schoolchildren aged 6-9. The sample consisted of 848 students from public primary schools, aged between 6-9 years, including 412 boys and 436 girls. Anthropometric characteristics such as height and body weight were measured, and Body Mass Index (BMI) was calculated. The Körperkoordinationstest für Kinder (KTK3+) test battery was utilized to evaluate the levels of MC of the students. One-way multivariate analysis of variance (MANOVA) was used to determine the binary and triple interactions of sex, age and PAP variables on the MC parameters of the participants. The study revealed that boys had higher scores than girls on eye-hand coordination (EHC) ($p < 0.05$). No significant difference was found balancing backwards (BB), jumping sideways (JS) and moving sideways (MS) ($p > 0.05$). When the subtests of the KTK3+ were compared by age levels, a significant difference was determined between the groups in all subtests ($p < 0.05$). With respect to PAP, students who PAP had a significant advantage in all subtests of the KTK3+ ($p < 0.05$). It was determined that none of the interaction terms between sex, age, and PAP created a significant difference in any KTK ($p= 0.294; 0.680; 0.471; 0.970$, $p > 0.05$, respectively). The results that the boys aged 6-9 performed better than girls in EHC, but girls Furthermore, an increase in age level and PAP resulted in higher scores in all subtests. This study presents evidence supporting sex differences in the motor skills of children within this age range and highlights the potential impact of age and physical activity on motor development.

Keywords: balance; coordination; jumping; motor competence; youth

1. Introduction

Motor coordination competence is a crucial aspect of child development, encompassing the integration of various motor skills and abilities. Motor coordination (MC) is defined as the ability to execute and control the degrees of freedom of the various body segments engaged in motion efficiently [1]. Purenovi-Ivanovi [2] highlights the paramount importance of MC to both human performance and motor behavior. It has been proposed that optimal MC acquisition aids children's physical, cognitive, and social development [3, 4]. A proper MC level is required for good general growth, as well as for health, psychological development, and well-being [5, 6]. In addition, there are many factors that affect the level of MC in children. Previous research has identified various biological (e.g., age, sex, body weight), behavioral (e.g., physical activity), socio-economic (e.g., parents' economic and educational level), and environmental (e.g. access to sports facilities) factors that affect MC in children [7, 8]. Motor coordination abilities can be influenced by biological, social, and environmental factors, including sex differences and age-related changes understanding the interplay between MC and sex and age can help better support a child's healthy development,

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especially in primary school students, where participation in physical activity is known to positively impact their development and health [9].

Research has indicated that there are often differences in motor coordination between boys and girls. In general, boys tend to exhibit higher levels of gross motor skills, such as running and throwing, while girls may excel in fine motor skills, such as handwriting and manipulative tasks [10, 11]. It was reported that a significant differences in locomotor skills between sex. In this study, the mean motor quotients KTK of boys (83.34) was significantly higher than girls (72.39). [12]. However, some studies report that girls and boys have similar MC [13, 14]. Despite this, existing research is inconclusive, highlighting the need for further studies to determine the effect of sex on MC. In addition, age is reported to affect MC level [15]. Bolger et al. [16] found that age had a significant effect on MC levels. Lee et al. [17] found that primary school children got older, their MC skills improved. In addition, several studies on the relationship between age and MC in athlete and non-athlete groups of different age groups have revealed that as the age level increases, the level of MC also increases [18, 19, 20].

The previous study indicated that MC was the best predictor for physical activity levels in children aged 6 to 10 years old [3]. By participating in physical activity, children gain more experience and refine their motor skill executions [21, 22]. Children can improve their MC skills through various physical activities during recess and extensive participation in physical education classes [23]. Also, many studies have identified positive relationships between physical activity levels and MC, particularly in primary school students [24, 25].

Additionally, there are studies that examine the effects of physical activity or sports participation on MC. However, there is a lack of research that evaluates the synergistic effects of all these factors on MC, especially in primary school-aged children, and the findings from these studies are insufficient in providing evidence. Therefore, findings of this study could address this prevailing gap in the literature. Moreover, determining the combined effect of all factors on MC can contribute to the development of more appropriate exercise strategies for individuals in childhood. In addition, another important factor that increases the importance of the study is that the validity and reliability of a newly designed MC test battery, KTK3+, will be performed for children aged between 6-9 years old.

2. Materials and Methods

2.1. Study Design and Participants

In this cross-sectional study, a total of 848 students (48.58 % boys, n = 412) aged between 6-9 years who attend official primary schools were evaluated. Participants with any orthopedic, cardiological or neurological diseases were excluded from the study. Additionally, they were instructed to refrain from engaging in strenuous physical activity prior to measurements and avoid the use of painkillers or sleeping pills one day before the measurements. This protocol was enforced to maintain consistency and accuracy in the measured outcomes.

Tekirdag Namik Kemal University Scientific Research and Publication Ethics Committee was applied for ethical committee approval, and necessary ethical committee approval (Protocol No: 2023.53.03.12) was obtained for the research. At the same time, an application was made to the Tekirdağ Provincial Directorate of National Education for the research to be conducted in primary schools. Necessary permissions were obtained with the approval of the Tekirdag Provincial Directorate of National Education and Tekirdag Governorship (Tekirdag Provincial Directorate of National Education letter number: 34272485, date: 11.10.2021). In addition, a voluntary and parental informed consent form containing information about the purpose, objective, method, and permission of the research was sent to student families, and students whose permission was obtained were included in the research.

2.2. Procedure

On the initial day of data collection, the participants completed a demographic questionnaire which captured their physical characteristics, followed by the recording of their anthropometric measurements such as height and weight. On the second day. On the second day of the research process involved explaining and demonstrating the measurement protocols for the KTK3+ battery in detail to the students, in accordance with the original testing manual guidelines [26, 27]. The sub-tests of the KTK3+ test battery, which included JS, BB, MS, and EHC, were administered in the same order to all participants in the study by the same researchers. A standard warm-up was performed prior to testing that involved 5 minutes of jogging and 5 minutes of dynamic stretching.

2.3. Instruments

2.3.1. Anthropometry

The participants' height was measured using a portable height device (Mesilife 13539) with a sensitivity of 0.1 cm. During the measurements process, the athletes were instructed to stand upright barefoot with their heads held high, feet flat on the ground, knees straight, heels together, and bodies erect in posture [28]. The participants' body weight measurements (in kilograms) was measured barefoot while wearing only shorts and a t-shirt using a digital scale (PoloSmart PSC05 Mood Glass Digital Scale) with a sensitivity of 0.01 kg [28]. The body mass index (BMI in kg/m2) was determined by dividing their body weight (in kg) by the square of their height.

2.3.2. KTK3+ Test Battery

In this study, students' MC levels and movement competencies were determined by applying the KTK3 [29] supplemented with eye-hand coordination task [30], resulting in the KTK3+ [31].

2.3.3. KTK3

KTK3 is a measurable (quantitative) test tool with high validity and reliability used to evaluate general gross MC [26, 29, 32]. KTK3 consists of three test elements commonly used on a global scale. The first test is lateral jumping, and participants are required to jump on a wooden platform with both feet for 15 seconds. The result score is obtained from the total number of skipped jumps during both trials. In the second test, participants are required to move sideways using two wooden platforms for 20 seconds. The total score is obtained by adding the number of times participants lowered one wooden platform and touched the moving wooden platform during both trials. The third and final test of KTK3 is backward balancing, which can be done on three narrowing balance beams (from 6.0 cm to 4.5 cm and 3.0 cm). The total number of steps is counted, and a maximum of 72 steps (or 8 steps on each balance beam in each trial) can be taken.

2.3.4. Eye-Hand Coordination Test (EHC)

The EHC task used by Platvoet et al. [30] requires an individual to throw a tennis ball against a wall with one hand and catch it with the other hand. This standardized test objectively evaluates an individual's ball control and capacity for anticipation. The EHC task can be easily administered in different (large) environments and is particularly relevant to sports [27, 30]. Platvoet et al. [30] reported a significant increase in raw scores across various age groups with boys showing higher scores as compared to girls. Although based on limited age range data, these findings clearly demonstrate that the KTK3 test can cover a wide range of general motor performance skills and distinguish between children with different levels of MC when combined with a EHC task. Coppens et al. [31] conducted a study to validate the KTK3+ test battery and provided updated normative MC values for boys and girls between the ages of 6 and 19 years old. Factor analysis with multidimensional scaling showed that the one-dimensional model provided the best fit and that all test items were associated with the same potential structure MC, which was further supported by moderate to good relationships between all four test items (r = 0.453-0.799).

2.4. Statistical Analyses

The data obtained in the research were analyzed using SPSS 18.0 program. Descriptive statistics (mean, standard deviation, frequency, and percentage values) were used to describe the characteristics of the participants. Skewness and kurtosis values were examined to determine whether the research data were normally distributed. In addition, Three-way multiple analysis of variance (MANOVA) in the research was used. The construct validity of the scale used was tested using the IBM AMOS 24.0 program through structural equation modelling to test whether the KTK3+ measures the intended construct (MC) and whether it is suitable for our research climate and culture based on the sample. Second, the correlation between all samples in which the scale was administered was examined using the SPSS 18.0 program, and then the internal consistency and reliability of the samples were calculated using Cronbach's alpha reliability coefficient.2.5.

3. Results

Table 3 represents the frequency and percentage of sex distribution across the children ages. Further description of the anthropometric measures of the children across the age was displays in Table 4.

Table 1. Structural equation model goodness of fit indices and normal values.

Fit indices	Good Fit	Acceptable Fit	All Sample	Male	Female	Age 6	Age 7	Age 8	Age 9
x^2 "p"	p>0.05	-	0.370*	0.299*	0.108*	0.625*	0.113*	0.226*	0.472*
x^2/df	<3	<5	0.995*	1.208*	2.223*	0.471*	2.184*	1.488*	0.750*
GFI	>0.95	>0.90	0.999*	0.997*	0.994*	0.998*	0.989*	0.993*	0.996*
AGFI	>0.95	>0.90	0.994*	0.986*	0.972*	0.990*	0.944*	0.963*	0.981*
CFI	>0.95	>0.90	1.000*	0.999*	0.995*	1.000*	0.976*	0.987*	1.000*
RMSEA	<0.05	<0.10	0.000*	0.022*	0.055*	0.000*	0.077*	0.049*	0.000*
RMR	<0.05	<0.10	1.149	1.521	2.311	0.769	2.846	3.364	2.692

***= the fit index values.**

The graphics of the models obtained by the structural equation modeling are given below.

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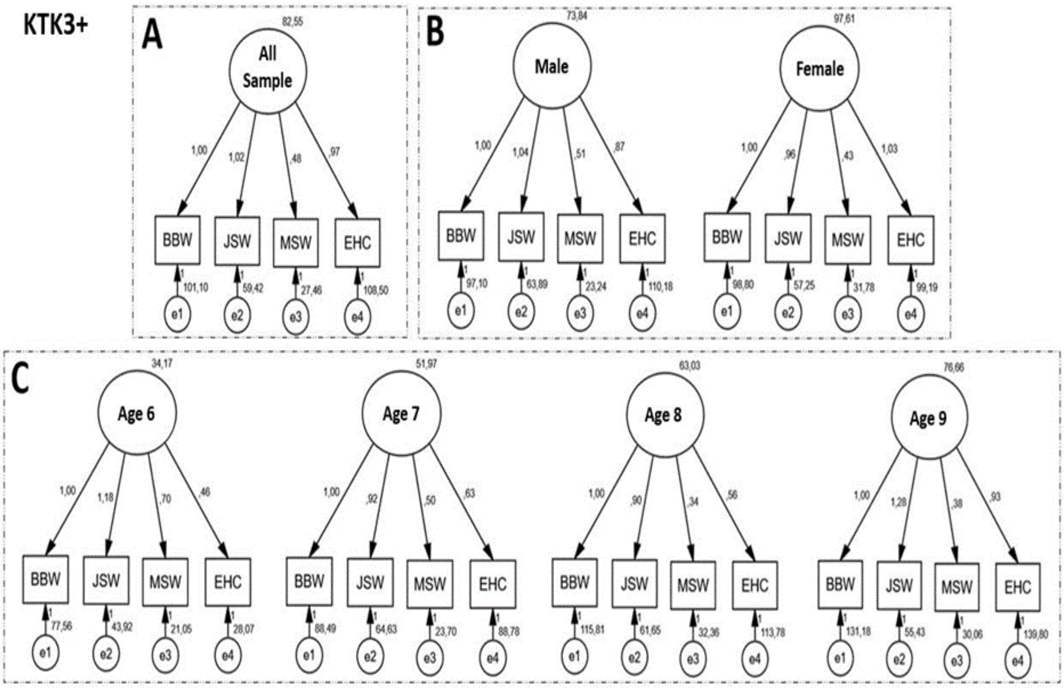

Figure 1. Structural equation models of the KTK3+ test. Structural Equation Models A: All Sample. B: Male and Female Sample. C: The 6 to 9 Age Sample.

The Cronbach's alpha coefficients, which are indicators of internal consistency and reliability, were calculated to determine the reliability of the KTK3+ measurement tool consisting of four tests. The reliability coefficients for the measurement phase (n = 848) of the KTK3+ scale were shown in the following table, including all sample groups and tests, to check the appropriateness of the scale.

Table 2. Cronbach's alpha reliability coefficients of KTK3+ scale.

KTK3+ Test	All Sample	Boy	Girl	Age 6	Age 7	Age 8	Age 9
Balancing backwards	0.86	0.85	0.88	0.81	0.81	0.81	0.84
Jumping sideways	0.88	0.87	0.89	0.85	0.82	0.82	0.88
Move sideways	0.77	0.78	0.75	0.82	0.76	0.65	0.67
EHC	0.85	0.83	0.88	0.73	0.76	0.75	0.83

When the reliability coefficients of the KTK3+ Scale were examined, it was found that the obtained values had very high reliability for all sub-tests of the KTK3+ test for all sample groups. The KTK3+ test provided highly consistent and reliable results for all samples simultaneously, only for females, only for males, and for all categories of the 6-9 age group. The findings of the research indicate that the KTK3+ test is a highly valid and reliable measurement tool to be used by Turkish child students (6-9 years old, girl, boy).

Table 3. Description of the age and sex of the study participants.

Variables	Age Group								Total	
	6 yrs		7 yrs		8 yrs		9 yrs			
	N	%	N	%	N	%	N	%	N	%

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Sex	**Boy**	102	12.03	100	11.79	107	12.61	103	12.14	412	48.57
	Girl	135	15.91	100	11.79	100	11.79	101	11.94	436	51.43
Total		237	27.94	200	23.58	207	24.40	204	24.08	848	100.0

Table 4. Descriptive statistics of the physical characteristics of participants by sex and age.

Variables	Sex	N	Mean±Sd	Age	N	Mean±Sd
Height (cm)	Boy	412	129.02±7.79	6 yrs	237	121.12±5.59
				7 yrs	200	126.11±5.63
	Girl	436	128.13±8.76	8 yrs	207	131.66±6.46
				9 yrs	204	136.46±5.99
Weight (kg)	Boy	412	29.84±8.65	6 yrs	237	24.12±5.83
				7 yrs	200	27.85±6.91
	Girl	436	29.42±8.69	8 yrs	207	31.95±8.31
				9 yrs	204	35.41±8.93
BMI (kg/m^2)	Boy	412	17.81±3.46	6 yrs	237	16.51±2.72
				7 yrs	200	17.45±3.08
	Girl	436	17.63±3.42	8 yrs	207	18.22±3.55
				9 yrs	204	18.87±3.91

Sd= Standard deviation; BMI= Body Mass Index

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Table 5. Description of the raw scores for each KTK3+ test by age category and physical activity participation.

Variables	Sex			Age			PAP			Sex x Age			Sex x PAP			Age x PAP			Sex x age x PAP		
	F	p	η^2	F	p	η^2	F	p	η^2	F	p	η^2	F	p	η^2	F	p	η^2	F	p	η^2
Multivariate	6.370	<0.001	0.030	26.782	0.000	0.114	12.213	0.000	0.056	1.177	0.294	-	0.577	0.680	-	0.975	0.471	-	0.383	0.970	-
KTK BB	3.964	0.047	0.005	32.854	0.000	0.106	8.629	0.003	0.010	1.855	0.136	-	0.247	0.619	-	0.693	0.557	-	0.299	0.826	-
KTK JS	0.445	0.505	-	35.656	0.000	0.114	47.928	0.000	0.054	0.648	0.584	-	0.021	0.885	-	0.776	0.507	-	0.326	0.807	-
KTK MS	4.307	0.038	0.005	33.833	0.000	0.109	7.304	0.007	0.009	1.214	0.303	-	0.261	0.609	-	3.108	0.026	-	0.146	0.932	-
KTK EHC	10.526	0.001	0.012	128.008	0.000	0.316	10.148	0.001	0.012	0.015	0.998	-	1.149	0.284	-	1.149	0.284	-	0.318	0.813	-

BB= Balancing backwards; JS= Jumping sideways; MS= Movie sideways; EHC= Eye-hand coordination

It has been determined that boy participants have higher EHC scores than girl participants ($p < 0.025$). No significant differences were found in the variables of BB, JS, and MS based on sex ($p > 0.05$).

Bonferroni correction was applied for age group, and a p value of 0.0125 was calculated. According to this result, it was found that all of the KTK variables showed significant differences based on age group (KTK_{BB} F=32.854; p=<.001; η2=0.106, KTK_{JS} F=35.656; p=0.000; η2=0.114, KTK_{MS} F=33.833; p=<.001; η2=0.109, KTK_{EHC} F=128.008; p=<.001 ; η2=0.316). Scheffe post-hoc analysis was conducted to determine which age groups were responsible for the differences, and it was found that KTK BB, JS, MS, scores increased with age. No significant differences were found between the scores of the 8 and 9-year-old age groups in BB, JS and MS parameters ($p > 0.05$). However, a significant difference were observed among all other age groups ($p<0.05$). EHC increased with age, and there were significant differences between all age groups ($p < 0.05$).

After the Bonferroni correction for PAP, p was calculated as 0.025. According to this result, it was determined that all KTK variables differed significantly by PAP (KTK_{BB} F = 8.629; p = 0.003; η2 = 0.010. KTK_{JS} F = 47.928; p = 0.000; η2 = 0.054. KTK_{MS} F = 7.304; p = 0.007; η2 = 0.009. KTK_{EHC} F = 10.148; p = 0.001; η2 = 0.012). The interaction of sex×age, sex×PAP, age×PAP, and sex×age×PAP did not significantly affect any KTK parameter ($p > 0.05$).

4. Discussion

The aim of the study was to investigate the influence of sex, age, and physical activity on the MC of primary school students. Furthermore, the interactions among sex, age, and physical activity in relation to the MC of students were analyzed.

Boys have higher EHC scores than girl participants. Also, the difference score among the groups is significance. No significant differences were found in the variables of BB, JS, and MS based on sex in the study. Among a group of 665 students between the ages of 5-7, it was observed that girls had a notable advantage on the BB subtest. However, the boy students showed higher scores in all other subtests, as well as the total MC score [33]. Some previous studies [10, 11] have found that boys have higher MC performance than girls. MC levels of tennis players between the ages of 6-14, no significant difference was found between boy and girl players in KTK subtest raw scores and total KTK motor coefficient values [14]. The author claimed that with equal opportunities for training, boy and girl children aged 6-14 may exhibit similar motor skills. Coppens et al. [31] revealed that boys systematically performed better than girls on three out of four KTK3+ test items, while girls were more successful than boys in the balance test. These results are in line with the proposition that sex affects general motor abilities in various ways and can be explained by biological effects on motor development, as previously theorized by Barnett et al. [7].

In our study, it was found that as age increased, scores on the trials also increased. A different study of 1,276 Portuguese children aged 6-14 who had their MC measured with the KTK test supported our research findings, as an increase in raw scores with age was also found [18]. Rommers et al. [19] examined the MC performance of young soccer players in different age groups. A total of 619 elite players (U10-U15) playing for the top league teams in Belgium participated in their study. The research results showed a significant increase in raw scores in the lateral jumping and lateral movement subtests between consecutive age groups of 11 and 14. On the other hand, there was no significant difference between consecutive age groups in the backward walking test. They reported that MC increased with age and that age influenced MC level. The age-related motor competence improvement observed in this study is consistent with the studies of Ahnert et al. [34], Vandorpe et al. [20], and Coppens et al. [31], showing older participants outperforming their younger counterparts. The findings of the study by Rodrigues et al. [35] and the systematic review by Barnett et al. [7] also show a positive relationship between age and motor competence.

The study found that students who PAP had higher scores on all sub-tests compared to their peers who did not PAP, regardless of sex and age group, and there was a statistically significant difference between the groups. In a study conducted by Iri and Aktug [36], a total of 396 children aged between 10-14 and regularly engaged in sports but it was not any organized sports outside of school were tested for MC using the KTK test. The results of the study indicated that boys and girls who participated in sports performed similarly in jumping sub-tests, while the group engaged in sports had significantly better scores in other assessments such as backward walking, sideways jumping, and lateral movements. Additionally, their total KTK motor quotient scores were higher. Furthermore, in a study by Sogut [37] which compared MC of young tennis players with different performance levels and taking into account variables such as experience, weekly training volume, and level of competition. The research found that players in the elite group exhibited statistically higher MC performance. Additionally, early involvement in sports and weekly training volume were suggested to have positive effects on MC. Previous studies have shown that physical activity in childhood, including participation in organized sports, has a positive effect on the development of motor competence [38]. Thus, the performance in a study by Coppens et al. [31] was compared based on whether or not participants engaged in organized sports using the KTK3+ test battery. Participants who were not engaged in organized sports systematically received lower scores in all motor tasks in the KTK3+ test battery compared to their peers who engaged in organized sports on a weekly basis. This difference was observed in both young and old age groups, although the effect size in this study was relatively small.

In the study, MANOVA analysis revealed no significant difference on the combined dependent variables for the interaction of sex*age, sex*PAP, age*PAP, and sex*age*PAP. It is noteworthy to mention that only one study utilizing the same analysis method and KTK3+ test battery was found in the literature. Coppens et al. [31] showed a tendency for significant sex*age group interaction effects in the JS test and significant effects in the EHC task. Further examination of this interaction revealed that boys outperformed girls in both the JS and EHC tasks in every age group. However, the difference between boys and girls in the JS test became more pronounced in older age groups (>16.00 years). For the EHC, the sex difference decreased as age increased. Girls outperformed boys in the BB test. The main effect of sex for the MS test was in favor of boys. Regardless of sex and PAP, a significant increase in scores was observed in all age groups for the four test components of the KTK3+ battery.

5. Conclusions

It has been determined that boys have higher EHC scores than girls. No significant differences were found in the variables of BB, JS, and MS based on sex. In all subtests, an increase in age was associated with an increase in test scores. However, statistically significant differences were not found in the BB, JS, and MS tests when comparing only the 8 and 9-year-old age groups. Students who PAP had higher scores in all subtests compared to those who did not participate.

There are some limitations to this study. Firstly, this is a cross-sectional study which will not investigate the causation effect. To obtain more extensive information about the development of motor skills, it is imperative to conduct longitudinal and experimental studies. Secondly, more detailed information about students' physical activity levels is required. For example, more comprehensive information about participation in organized sports or non-organized sports activities is necessary. Additionally, factors such as family sports history, socioeconomic status, and education level should be taken into account.

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