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Motor Competence across 6- to 10-year Old Children: A Cross-sectional Study in 1811 Elementary School Students

Greier K[1,2*], Drenowatz C[3], Ruedl G[1], Kirschner W[1], Lackner C[4], Feurstein-Zerlauth V[5], Kroell K[4] and Greier C[1]

[1]*Department of Sport Science, University Innsbruck, Innsbruck, Austria*
[2]*Division of Physical Education, Private University of Education (KPH-ES), Stams, Austria*
[3]*Division of Physical Education, University of Education Upper Austria (PHOOE), Linz, Austria*
[4]*Division of Physical Education, University of Education Tyrol (PHT), Innsbruck, Austria*
[5]*Division of Physical Education, University of Education Vorarlberg (PHV), Feldkirch, Austria*

Abstract

Background: The elementary school years (ages 6 to 10 years) are considered an important time period in motor development. The present study therefore, examines differences in motor competence from first to fourth grade in Austrian elementary school students. **Material and Methods:** A total of 22 elementary schools from the Federal state of Tyrol, Austria, participated in this cross-sectional study, resulting in a sample of 1811 (52% boys) children between 6 and 10 years of age. Motor competence was examined via the German Motor Test (DMT 6-18). Differences across age groups were analyzed via multi-variate analysis of variance (MANOVA). **Results:** Age by sex interaction effects were limited. Higher age was associated with better motor performance across all test items ($p<0.001$), except for flexibility. Boys performed significantly better than girls in the 20 m sprint, sideways jumping, sit ups, standing long jump, and 6-minute run ($p<0.001$), while girls displayed greater flexibility ($p=0.042$). **Conclusion:** Motor competence generally develops similarly in boys and girls between 6 and 10 years of age with an improvement with increasing age. In addition, there is already a sex difference in motor competence with higher speed, strength, endurance and agility in boys compared to girls. Girls, on the other hand, display better flexibility than boys.

Keywords: Motor development; Motor performance; Students; Primary school; Childhood

Introduction

There have been significant changes in the social and built environment over the last several decades, which have contributed to an increased sedentary lifestyle in children [1-3]. Accordingly, a majority of children does not meet current physical activity (PA) recommendations of 60 minutes of moderate-to-vigorous PA per day [4]. Given the reciprocal association between PA and physical fitness as well as motor competence, there is also an increasing number of children with low fitness and reduced motor competence [5].

Of particular concern are low fitness and motor competence at young ages as elementary school years are crucial in motor development and the promotion of PA [6,7]. Sufficient PA that facilitates motor development, therefore, is an important contributor to physical and psycho-social health during childhood and adolescence [8-11].

The elementary school years (ages 6 to 10) appear to be particularly important for motor development due to linear growth and the according changes in body proportion as well as the maturation of the central nervous system. Additionally, external influences such as peers, sports clubs and the school start to have a stronger influence on behavioral choices [12].

This age period is further characterized by a drive to explore and try new things, including various forms of PA and sports, which contributes to the development of various motor skills [13]. Depending on the respective learning and exercise opportunities a stabilization in movement patterns and motor skills can be observed. Especially in 9- and 10-year-old children (3rd and 4th grade) improved motor competence and movement economy has been observed [14].

This age range is further characterized by an ability to correct movement patterns in response to external and internal feedback. Movement speed, cardio-respiratory endurance and motor competence also continue to improve during childhood [15].

The current study, therefore, examines the development of motor competence across Tyrolean (Austria) elementary school children, with a special emphasis on the progression on strength, speed, endurance, agility, flexibility and balance. In addition to general patterns, sex differences in motor development will be explored.

Methods

A total of 25 elementary schools in the federal state of Tyrol, Austria were randomly selected for participation. Three schools could not participate due to organizational problems resulting in a final sample of 22 schools with more than 1800 students. The study protocol was approved by the respective school boards and the Institutional Review Board of the University of Innsbruck. Parents provided written informed

consent prior to data collection and students provided oral assent at the time of data collection.

Data collection occurred between March 2017 and May 2018. All measurements were taken by trained personnel at the schools during physical education (PE) classes. Anthropometric measurements were taken with participants wearing sports clothes and being barefoot. Height was measured to the nearest 0.1 cm with a portable stadiometer (SECA® 217, Seca, Germany). Body weight was measured to the nearest 0.1 kg with an electronic scale (SECA® 803, Seca, Germany). Subsequently BMI was calculated (kg/m²) and converted to BMI percentiles using the German reference system [16]. Motor competence was determined via the German motor test (DMT 6-18) [17]. The DMT 6-18 consists of 8 test items (20 m sprint, backwards balance, sideways jumping, standing long jump, sit ups, push ups, stand-and-reach test, 6-minute run) that examine speed, balance, agility, strength, flexibility and endurance. All tests were administered according to the instructions provided by the test manual during a single test session. All students performed the 20-m sprint at the beginning of the testing session and ended with the 6-minute run. Other tests were administered in random order.

Statistical analysis

Descriptive statistics were calculated; interval scaled data is shown as mean with standard deviation, while frequencies are shown for ordinal and nominal data. A 2 (sex) by 5 (age) multivariate analysis of variance (MANOVA) was used to examine differences in motor development by sex and age. The statistical analysis was performed using SPSS 24.0 with a significance level set at $p \leq 0.05$.

Results

A total of 1811 elementary school children (51.7% boys) with an average age of 8.2 ± 1.4 years (girls: 8.1 ± 1.4 years; boys: 8.3 ± 1.4 years) provided valid data. Anthropometric data by age group for the total sample and separately for boys and girls are shown in Table 1.

		6 years (N=300)	7 years (N=331)	8 years (N=351)	9 years (N=434)	10 years (N=395)
Total (N=1811)	Height (cm)	121.8 ± 6.1	126.6 ± 6.2	131.1 ± 6.5	137.4 ± 6.5	144.1 ± 7.4
	Weight (cm)	24.1 ± 4.5	26.1 ± 4.6	29.4 ± 5.9	34.0 ± 7.6	37.8 ± 8.5
	BMI percentile	56.4 ± 27.7	54.0 ± 27.5	55.2 ± 29.0	59.7 ± 30.1	55.4 ± 30.8
Girls (N=875)	Height (cm)	121.8 ± 6.3	126.3 ± 5.9	130.1 ± 6.3	136.9 ± 6.7	144.2 ± 7.5
	Weight (cm)	24.1 ± 4.3	25.9 ± 5.0	28.9 ± 5.9	34.1 ± 8.2	38.2 ± 8.4
	BMI percentile	57.4 ± 26.3	52.6 ± 27.1	55.5 ± 27.9	60.2 ± 30.2	57.1 ± 31.2
Boys (N=936)	Height (cm)	121.7 ± 6.0	126.9 ± 6.4	132.1 ± 6.5	137.8 ± 6.2	144.1 ± 7.3
	Weight (cm)	24.0 ± 4.3	26.2 ± 4.2	29.8 ± 5.9	33.9 ± 6.9	37.5 ± 8.7
	BMI percentile	55.2 ± 29.5	55.2 ± 27.8	55.0 ± 29.9	59.3 ± 30.1	54.1 ± 30.5

Table 1: Anthropometric characteristics by age and sex. Values are Mean ± SD.

Of the total sample 18.1% were considered overweight or obese with no difference between boys and girls (18.4% *vs.* 17.7%). Overweight/obesity, however, increased with increasing age from 15.0% to 20.8% (p for trend = 0.05).

Speed (20-m sprint)

There was a significant sex by age interaction effect (p=0.03) on sprint performance. Even though there was a significant improvement with increasing age (p<0.001) in boys and girls, the improvement was more pronounced in girls compared to boys. Nevertheless, boys displayed a better sprint performance compared to girls throughout the elementary school years (4.4 ± 0.4 *vs.* 4.6 ± 0.5 sec) (Figure 1).

Strength (push ups, sit ups, standing long-jump)

Three test items assess strength abilities. There were no interaction effects on any of the strength-related test items of push ups, sit ups and standing long jump. There was a significant improvement in upper body strength (push ups), core strength (sit ups) and power (standing long jump) with increasing age (p<0.001). Sex differences occurred in the standing long jump (133.7 ± 22.5 *vs.* 123.4 ± 22.7 cm; p<0.001) (Figure 2) and sit ups (20.1 ± 6.3 *vs.* 18.2 ± 6.0 repetitions; p<0.001) with better performance in boys compared to girls during elementary school years. No sex difference was observed for push up performance (14.5 ± 5.0 *vs.* 14.0 ± 4.9 repetitions) (Figure 3).

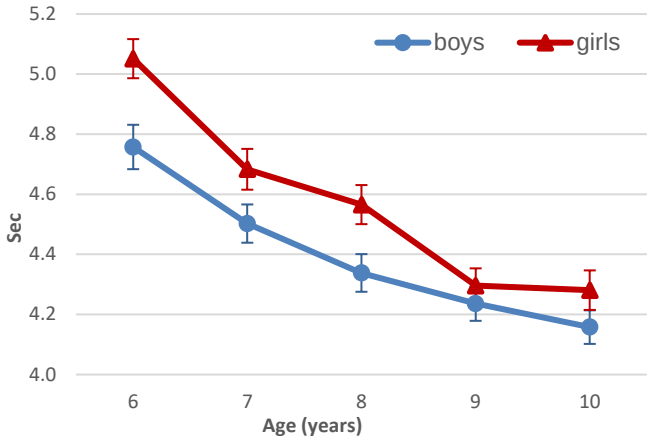

Figure 1: 20 m Sprint performance by age and sex (N=1811). Values are mean with 95% Confidence Interval**.**

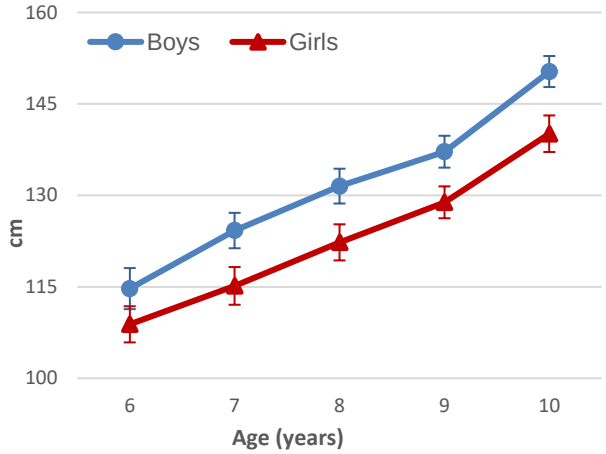

Figure 2: Standing long-jump performance by age and sex (N=1811). Values are mean with 95% Confidence Interval.

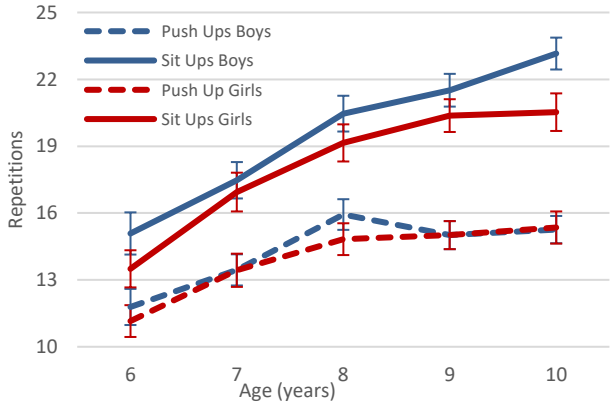

Figure 3: Strength performance by age and sex (N=1811). Values are mean with 95% Confidence Interval.

Endurance (6-min run)

There was no significant age by sex interaction effect on endurance performance. Distance covered in 6 minutes increased significantly across age groups ($p<0.001$). Further, average endurance performance during the elementary school years was better in boys compared to girls (950 ± 158 *vs.* 895 ± 142 m; $p<0.001$) (Figure 4).

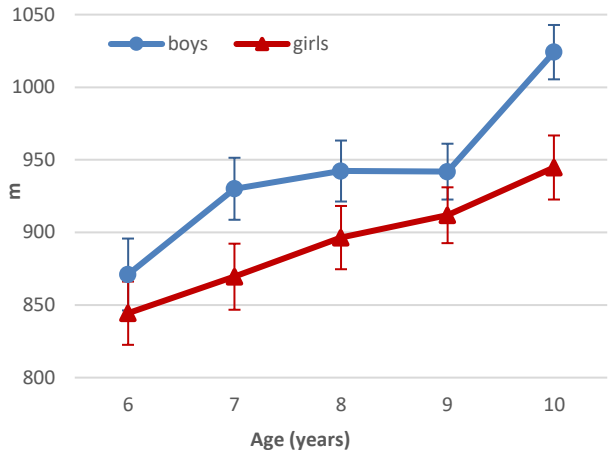

Figure 4: 6-minute run performance by age and sex (N=1811). Values are mean with 95% Confidence Interval.

Balance

There was no age by sex interaction effect on balance. Balance improved with increasing age ($p<0.001$) but there were no significant sex differences in balance during elementary school years (32.5 ± 10.5 *vs.* 32.5 ± 10.0 steps) (Figure 5).

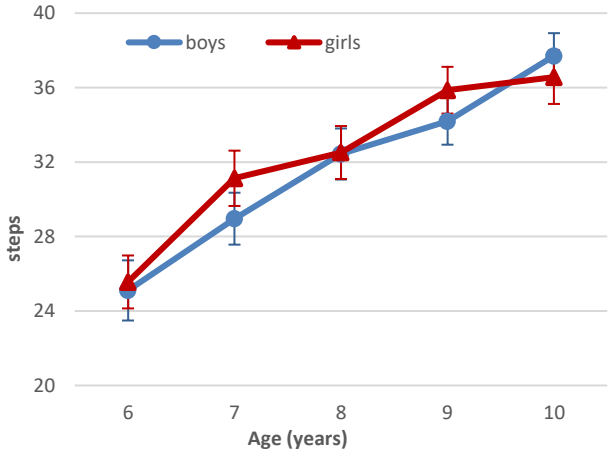

Figure 5: Backwards balance performance by age and sex (N=1811). Values are mean with 95% Confidence Interval.

Agility (sideways jumping)

There was no significant age by sex interaction effect on agility. Agility improved with increasing age ($p<0.001$), which was particularly pronounced between 6 and 9 years of age. Further, boys displayed better agility performance during the elementary school years compared to girls (32.4 ± 8.6 *vs.* 30.5 ± 8.3 repetitions; $p<0.001$) (Figure 6).

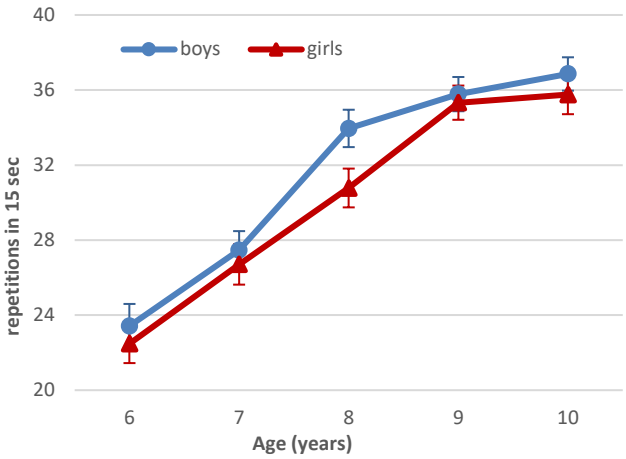

Figure 6: Sideways jumping performance by age and sex (N=1811). Values are mean with 95% Confidence Interval.

Flexibility (Stand and reach)

There was no age by sex interaction effect on flexibility. Flexibility declined with increasing age ($p<0.001$). Further, there was a significant sex difference in flexibility during the elementary school years, with lower flexibility in boys compared to girls (-0.1 ± 7.1 vs. 0.6 ± 6.4 cm; $p<0.042$), but this difference appears to disappear towards the end of elementary school (Figure 7).

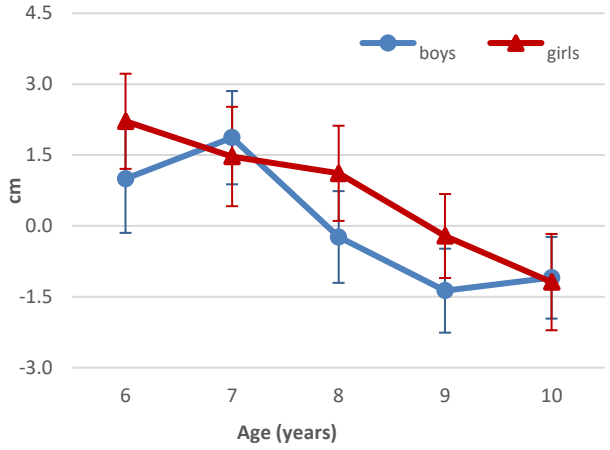

Figure 7: Performance on the stand and reach test by age and sex (N=1811). Values are mean with 95% Confidence Interval.

Discussion

The present study examined the development of motor competence during the elementary school years in Tyrolean (Austria) children. The limited interaction effects indicate that there is no sex difference in the development of motor competence during the prepubertal years. Nevertheless, boys displayed better motor competence on endurance, core strength, power, speed and agility tests, while girls displayed higher flexibility. No sex difference was observed for upper body strength and balance. In addition, it was shown that motor competence improves with increasing age.

The development of motor competence is an important component in the general development and overall health and well-being during childhood and adolescence as it facilitates participation in various forms of PA and sports [18]. Particularly, the elementary school years (ages 6 to 10) appear to be crucial in motor development as children at this age appear to be particularly responsive to motor stimuli [12]. This has been attributed to physiological and psychological processes that facilitate motor learning and improve physical fitness [19]. In addition, children tend to enjoy PA at this age and are highly motivated to move and engage in various sports [15]. Following the results of the various test items will be discussed in detail:

Speed

There appears to be a rapid improvement in speed during the elementary school years. This may be attributed to the maturation of the central nervous system and improved intermuscular coordination (f.ex. coupling of arm and leg movement). Further, physical growth and increased strength contribute to better sprint performance with increasing age during childhood. The present study also confirmed previous results of a better sprint ability in boys compared to girls already at young ages [20,21].

Strength

The development of strength and power is less pronounced during the elementary school years. Nevertheless, there was a significant improvement in strength- and power-related test items across age groups. Strength gains during childhood are predominantly due to improvements in intra- and intermuscular coordination, rather than an increase in cross-sectional area [10]. The present study also did not show a difference in upper body strength between boys and girls, which has been shown previously [20,22]. Core strength, on the other hand, differed significantly between boys and girls, with a better performance in boys compared to girls. Similar results have been shown in a large German study [20].

Muscular power also differed significantly between boys and girls as well as across age groups. As has been shown for core strength boys displayed higher power than girls, which is consistent with previous research [20-22]. Even though there were no significant sex by age interaction effects on strength and power-related test items, the differences appear to become more pronounced with increasing age, which may be attributed to hormonal changes as children get closer to puberty.

Endurance

Endurance capacity improved significantly with increasing age. This may be attributed to alterations in the cardio-respiratory system as well as increased stride-length due to physical growth. Boys also displayed higher endurance capacity compared to girls. As has been shown for strength tests, there was a greater improvement in boys (18%)

compared to girls (12%), which resulted in a larger difference in endurance performance at the age of 10 compared to younger ages. Bös et al. [20] also showed better endurance performance in 6- to 10-year-old children.

Balance and agility

As has been shown for fitness-related test items, balance and agility improved with increasing age. There was no difference in boys and girls in balance while boys displayed higher agility compared to girls. Albrecht et al. [22], on the other hand, showed better performance on these test items in girls in 3000 elementary school children. These differences may be explained by the fact that balance and agility are particularly emphasized in specific sports. Accordingly, sport selection, rather than sex, may have a stronger effect on these test items, and, possibly could explain the differences between studies.

Flexibility

In contrast to the other test items, flexibility decreased with increasing age. Similar results have been shown in other studies [20,22], which emphasizes the need to address flexibility early in life during physical education and leisure time activities. Further, girls displayed higher flexibility compared to boys. The better flexibility in girls has been attributed to a higher relative fat content and lower muscle mass, which positively affects flexibility [23].

Conclusions

Speed, strength, power, endurance, agility and balance appear to increase continuously during the elementary school years in boys and girls. Flexibility, on the other hand, already starts to decline during this age range. Further, boys displayed better performance for the 20-m-Sprint, sideways jumping, sit ups, standing long-jump and 6-minute run compared to girls between 6 and 10 years of age. As physiological differences are limited, participation in sports and PA may be a major influence on motor competence at these ages. Accordingly, girls may warrant additional attention in the promotion of PA already at young ages. Given the higher flexibility in girls compared to boys, a greater emphasis on flexibility training may be needed in boys as this also influences injury risk later in life. The improvement in motor competence in general, however, also emphasizes the need to promote motor development during the elementary school years as children may be particularly responsive at these ages. This may be achieved by providing a variety of movement experiences by implementing diverse motor tasks that emphasize physical fitness, locomotor abilities and object control. Further, basic motor skills (e.g. throw and catch, run and jump) can be improved, which may facilitate participation in various sports. A key element is also high movement time in game like situations to improve motivation towards an active lifestyle.

Disclosure

No relevant financial affiliations.

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***Corresponding author:** Klaus Greier, PhD, Professor in Physical Education, Division of Physical Education; Private University of Education (KPH-ES), Stiftshof 1, 6422 Stams, Austria, Tel: +43 (0) 5263/5253-11, e-mail: nikolaus.greier@kph-es

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