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ORIGINAL ARTICLE

Associations of motor abilities with biological, sociodemographic, and behavioural factors in children: results from the ToyBox study

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Abstract

Purpose In this cross-sectional study, we examined the association of selected basic motor abilities with biological (sex, age, and BMI), sociodemographic [socio-economic status (SES), migration status], and behavioural factors (membership of sport club) in children aged 3–6 years.

Methods We performed two motor tests, jumping from side to side (JSS) and standing long jump (SLJ) along with the anthropometric measurements in 1598 children (age 4.6 ± 0.70 years; 51% boys) from 58 kindergartens in Germany. GEE models were applied to examine cross-sectional associations between motor abilities and biological, sociodemographic, and behavioural factors.

Results Age was significant positively related to both tests, JSS ($p < 0.001$) and SLJ ($p < 0.001$). Boys reached significantly better results in SLJ ($p < 0.001$) but not in JSS. Children being member of a sport club performed better than those who were not (SLJ: $p < 0.001$, JSS: $p < 0.001$). BMI was inversely related to SLJ ($p = 0.014$) and tended to be inversely related to JSS ($p = 0.64$). No significant associations of migration background or SES with motor abilities were found.

Conclusion When designing effective promotion and teaching strategies targeting children's motor abilities, information on age and gender differences should be taken into account. Preschool children may benefit from being member in sport clubs. Lower scores of motor abilities in children with higher BMI underline the importance to act early in childhood for prevention.

Keywords Motor ability · Kindergarten · Preschool children

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Abbreviations

BMI	Body mass index
SES	Socio-economic status
JSS	Jumping from side to side
SLJ	Standing long jump
PA	Physical activity
SD	Standard deviation
GEE	Generalized estimating equation model

Introduction

Movement is one of the most important needs for a proper healthy physical and psychosocial development of children. Movement allows children to develop motor abilities like speed, strength, coordination and balance, which will serve as underlying foundational components for the acquisition of different motor skills like running and hopping [42]. Thus, abilities are part of individual traits that affect a child's capability of performing motor skills [14]. Consequently

well-developed motor abilities lead to good performance in motor performance. Well-developed motor abilities will be achieved through engaging in active play and physical activity. Research confirmed that children with higher levels of physical activity will develop better motor abilities than children with low level [11, 22, 30]. Motor abilities have enduring characteristic and are, therefore, difficult to change in adulthood [14].

The age period of 3–6 years is an important period for developing motor abilities as changes are very intensive and continuous [18, 27]. In this period children individually change in shape, size, maturity, physical activity behavior, and motor competence [27]. These changes are influenced by several critical factors, such as biological like growth and maturity characteristics and environmental factors. A recent review and meta-analyses found evidence for increasing age as the most important correlate of motor competence in children and adolescence [2]. Differences in gender and weight status may exist, but inconsistent findings appear depending on the aspects of certain motor abilities were investigated. Environmental factors were reviewed of Venetsanou et al. concluding that socio-economic status, mother educational levels and the existence of siblings affected children's motor development [38]. It has also been shown that migrant status have a negatively effect on children's activity levels and motor abilities [26]. Other systematic reviews in preschool children detected school based programs as a key correlate of motor abilities [21, 38] and organized sport participation [15, 41] indicating that it is worthwhile to provide opportunities at this young age. Understanding more about factors with potential influence on the developmental process of motor abilities will help to design effective programs, promotion, and teaching strategies with the aim of giving each child opportunities to reach all dimensions of their motor potential. This study, therefore, aimed to identify and highlight factors including biological [sex, age, body-mass index (BMI)], sociodemographic [socio-economic status (SES), migration status], and behavioural factors (member of sport club) which may affect selected basic motor abilities in children aged 3–6 years.

Methods

Study population

We used baseline data from the German cohort of the ToyBox study, a multi-component, kindergarten-based, family-involved intervention study in different European countries [28] (http://www.toybox-study.eu). All evaluated measurements were collected between May- June 2012, prior to the intervention [31]. A total of 1952 children between 3 and 6 years of age and their parents/caregivers out of 58 Kindergartens from nine municipalities with different socio-economic status in the region of Upper Bavaria agreed to participate. Following a standardized study protocol, a list of municipalities within a selected province was created and information about average annual income assigned. Tertiles (low, middle, high SES) were created, based on the mean income, and three municipalities randomly selected from each tertile. Then, kindergartens within these chosen municipalities were randomly selected. For the present study, valid data of 1598 children were included due to missing values of children because of family-holiday, illness, injury or other reasons; representing 81% of the enrolled children. Parents and School principals provided written informed consent forms. The study was approved by the LMU ethics committee. The ToyBox study is registered with the clinical trials registry clinicaltrials.gov ID: NCT02116296.

Measurements

All measurements were obtained in the kindergarten movement rooms in the morning in small groups by trained researchers. A protocol, which included specific instructions for conducting all measurements, was used by researchers to ensure consistency and accuracy. Weight, height and two motor tests were measured with each child.

Anthropometry

Height (cm) and weight (kg) were measured with children wearing underwear and no shoes. Height was recorded using a portable stadiometer (Seca® type 214, Hamburg, Germany) and weight using an electronic scale (Seca® type 861, Hamburg, Germany). Body mass index (BMI) was calculated (kg/m^2). In addition, BMI z scores were computed based on the WHO growth standards (http://www.who.int/childgrowth/software/en/, http://www.who.int/growthref/tools/en/).

Motor abilities

Motor ability is defined according to the theoretical model of Bös, namely endurance, strength, speed, coordination and flexibility [3]. In this study the dimension strength and coordination were assessed using two test items of the "Kinderturntest" [4]: standing long jump (SLJ) and jumping from side to side (JSS). The reliability of the test items is indicated as $r=0.84$ for JSS and $r=0.91$ for SLJ, respectively [1].

Jumping from side to side (JSS)

The children were asked to jump sideways as quickly as possible with both legs together over a marked line. Two trials of

15 s with a minute break were performed and the total numbers of successful jumps were summed. Jumps with mistakes (i.e., child touched the line, jump is not done with both feet, child is not jumping sideways) were not counted. This test is used to measure coordination, i.e., total body coordination under time pressure, speed and muscular endurance capabilities of the lower extremities [25].

Standing long jump (SLJ)

The children were asked to jump as far as possible with both legs together from a starting line. Swinging the arms and bending the knees to provide forward drive was allowed. After landing the distance from the starting line to the heels was measured in centimeters. Two correct attempts were allowed, the best valid result was used for analysis. Attempts were not valid if the jump was not done with both legs or the child was touching the ground backwards after landing. This test is an aid for measuring strength in the lower extremities, i.e., jumping power and speed strength [25].

Additional information

Child's sex and date of birth were assessed by parental questionnaire. Children's age was calculated from the date of birth and the date of the anthropometric measurements. Parents were asked if their child is a member in a sport club (yes/no), defined as participation in active sports at the club at least 1 h per week. Data on parental migration status were self-reported by the parents and defined as "at least one parent born outside of Germany".

Statistical analyses

Study population characteristics are reported as mean values and standard deviations (SD) for continuous variables and percentage (%) for categorical variables. Generalized estimating equation models (GEE), suitable for the analysis of clustered data, were used to examine the effect of the potential predictors on motor performance. We first fitted univariate models of the outcomes on each predictor. Those variables that had a p value of $p < 0.2$ were considered for variable selection using the quasi-likelihood under the independence model criterion (QIC) as criterion. Height and weight were not included to avoid collinearity with the z-BMI score. For all analyses, statistical significance level was assumed at $p < 0.05$. All analyses were performed using R (version 3.2.1).

Results

Results on the motor ability tests were available for 1598 children (age 4.6 ± 0.70 years; 51% boys). Table 1 shows the study population characteristics of the total sample as well as the results of the motor performance tests, SLJ and JSS, respectively.

The results of univariate GEE regression models (Table 2) showed that age has a significant effect on both tests, JSS (estimate 7.34 jumps, $p < 0.001$) and SLJ (estimate 17.8 cm $p < 0.001$). Looking at the age tertiles, we found that children linearly improved in both test items with age. Although boys were significantly more competent, on average, in SLJ (estimate 4.56 cm, $p < 0.001$), there was no significant difference in JSS ($p = 0.36$). Children's motor performance was significantly higher among those who were members of sport clubs in both tests (SLJ: estimate 6.73 cm, $p < 0.001$, JSS: estimate 3.58 jumps, $p < 0.001$). While BMI was significantly and negatively associated with SLJ (estimate 1.23 cm, $p = 0.014$), BMI was not significantly related to JSS ($p = 0.64$). No significant influence of migration background or SES on children's motor performance abilities was detected.

In accordance with these results, variable selection was performed with age and sport club participation (JSS) and age, sex, sport club participation, and z-BMI score (SLJ) (Table 3). All variables except for z-BMI in case of the SLJ were selected for the multivariate model. However, while the effect of age on the motor tests substantially remained the same, the effect of sport club participation was smaller than in the univariate models (JSS: from 3.58 to 1.94 jumps; SLJ: from 6.73 to 2.63 cm). We also

Table 1 Subject characteristics of the total sample ($N = 1598$)

	N	Value
Age (years)	1568	4.6 ± 0.70
Weight (kg)	1596	18.4 ± 2.99
Height (cm)	1598	107.7 ± 6.51
z-BMI[a]	1566	0.3 ± 0.95
Female	1598	776 (49%)
Socioeconomic status (SES)[b]		
Low	350	22%
Middle	557	35%
High	691	43%
Member in sports club	1404	692 (49%)
With migration background	1439	451 (31%)
Standing long jump (cm)	1592	78.1 ± 21.42
Jumping from side to side(# in 30 s)	1570	20.6 ± 9.40

[a] z-BMI classified according to WHO growth standards

[b] Socio-economic status classified according to annual income

tested for the interaction of age × sport club participation (Table 4). There was a borderline significant positive interaction effect regarding JSS ($p = 0.076$). No interaction effect between sex × sport club participation or *z*-BMI × sport club participation could be found for both tests (data not shown).

Discussion

The aim of this study was to identify factors that are associated with specific components of motor abilities in children aged 3–6 years.

The findings of the present study showed that age may have a significant effect on motor abilities of children. Older children performed better in SLJ and JSS than younger ones. By looking at the age tertiles, we could show a fairly linear

Table 2 Results from univariate GEE models testing for association of jumping from side to side (JSS) and standing long jump (SLJ) with age, sex, *z*-BMI, member in sports club, SES, and migration background

	JSS ($N = 1570$)			SLJ ($N = 1592$)		
	Estimate	95% CI	*p* value	Estimate	95% CI	*p* value
Age (years)	7.34	6.67; 8.01	**< 0.0001**	17.8	16.48; 19.12	**< 0.0001**
Age (percentiles)						
Age[a] low tertile (reference)	–	–	–	–	–	–
Age[a] medium tertile	6.7	5.85; 7.55	**< 0.0001**	16.4	13.82; 18.99	**< 0.0001**
Age[a] high tertile	11.71	10.73; 12.69	**< 0.0001**	27.67	25.45; 29.88	**< 0.0001**
Sex (female)	0.47	− 0.53; 1.47	0.36	− 4.56	− 6.98; − 2.14	**< 0.0001**
Member in sports club	3.58	2.69; 4.47	**< 0.0001**	6.73	4.52; 8.94	**< 0.0001**
z-BMI	− 0.12	− 0.6; 0.37	0.64	− 1.23	− 2.2; − 0.25	**0.014**
SES[b] (percentiles)						
SES[b] medium (reference)	–	–	–	–	–	–
SES[b] low	0.47	− 1.62; 2.56	0.66	− 2.17	− 5.87; 1.52	0.25
SES[b] high	0.62	− 1.07; 2.31	0.47	− 1.46	− 5.36; 2.44	0.46
Migration background	0.66	− 0.38; 1.7	0.22			

Significant results are typset in boldface

[a]Age: low tertile (3.03–4.26 years), medium tertile (4.27–4.98 years), high tertile (4.98–6.51 years)

[b]Socio-economic status classified according to annual income

Table 3 Results from multivariate GEE models. Variable selection was performed including age and sport club participation [jumping from side to side (JSS)] and age, member in sports club, sex, [standing long jump (SLJ)]

	JSS ($N = 1375$)			SLJ ($N = 1395$)		
	Estimate	95% CI	*p* value	Estimate	95% CI	*p* value
Intercept	− 13.92	− 16.73; − 11.11	**< 0.0001**	− 1.26	− 7.72; 5.21	0.703
Age (years)	7.27	6.61; 7.94	**< 0.0001**	17.37	15.98; 18.76	**< 0.0001**
Member in sports club	1.94	1.11; 2.77	**< 0.0001**	2.63	0.84; 4.43	**0.004**
Sex (female)				− 4.23	− 6.41; − 2.05	**0.0001**

Significant results are typeset in boldface

Table 4 Results from GEE models of jumping from side to side (JSS) and standing long jump (SLJ) with interaction term age*Member in Sports clubs

	JSS ($N = 1375$)			SLJ ($N = 1395$)		
	Estimate	95% CI	*p* value	Estimate	95% CI	*p* value
Intercept	− 11.84	− 14.95; − 8.72	**< 0.0001**	0.47	− 7.72; 8.66	0.91
Age (years)	6.81	6.06; 7.57	**< 0.0001**	16.98	15.19; 18.78	**< 0.0001**
Member in sports club	− 2.68	− 7.56; 2.2	0.28	− 1.34	− 14.43; 11.74	0.84
Sex (female)				− 4.19	− 6.37; − 2.01	**0.0002**
Age × member in sports club	0.995	− 0.1; 2.09	0.076	0.86	− 1.95; 3.66	0.55

Significant results are typeset in boldface

improvement which is in line with previous studies [19, 40]. Our results are not surprising as change in motor achievements over time is considered to be the product of maturation [17]. However, mature forms may only be achieved through general interaction with one's environment that provides opportunities for practice [21] for each age level. Programs with less complex activities for the youngest children but with a progressive nature can stimulate the development of children's individual motor potential. It is important that children gather not only from inductive movement experiences but also from instructed physical activity sessions which are optimally dosed in scope and intensity at all age levels.

Our study also confirmed significantly superior performance of boys in SLJ and girls performing better in JSS, indicating higher strength in boys in contrast to higher coordination ability in girls. Both results are in line with a meta-analyses about sex differences in motor performance in childhood reporting girls being the better performers on tasks that require flexibility and balance, whereas boys excel in tasks involving power and strength [36]. Prior to puberty boys and girls are very similar regarding their physical characteristics [36]; therefore, differences in motor abilities at the young age cannot only be explained by biological factors. Gender differences in motor abilities have been associated with children's socialization [36] and may emerge as a result of environmental conditions and different interests for motor activities [24, 29]. Girls prefer activities such as dancing and gymnastics, which include skills like skipping and hopping [32], while boys are in general more physically active and are involved in more competitive games [20, 33, 40]. Okely et al. suggested that if girls were provided with similar opportunities to practice, the differences between boys and girls could be reduced [32]. The observed gender differences may have occurred due to preferences of activities or missing opportunities to develop specific motor abilities. Thus it is important to consider potential differences when promoting motor abilities. More research is required to discover what kind and degree of physical activity is necessary to provide optimal support to motor development in both genders.

BMI was found to have a significant negative effect on the performance of SLJ and, a non-significant effect on JSS in this study, indicating that children with higher BMI performed worse. Hence, a higher BMI may have an adverse impact on motor abilities especially in endurance and weight-bearing tasks, which is confirmed by other studies in kindergarten [5, 13] and school children [11, 35]. The negative relationship between BMI and motor abilities, particularly in the more dynamic tests, may be explained by inefficient biomechanical movements caused by noncontributory mass [34]. Our results confirm this weight-bearing hypothesis and underline the importance to act early in childhood for prevention and especially in children at risk of becoming overweight.

We found evidence for a positive association between children's motor abilities and membership in a sport club, indicating that children profit from participation in organized sports. These results are in line with the findings of Krombholz et al. in preschool children [23] and Zahner et al. in first-grade primary school children [41]. Ebenegger et al. could show that children not participating in sport clubs were less physically active, had more media use, and ate less healthily compared to their counterparts [9]. While examining the interaction between membership in sport club and age we determined a borderline significance regarding JSS. When checking for the association stratified by the age tertiles, this trend was confirmed: the older the children are, the stronger is the association between sports club membership and motor ability. It could be stated that a persistent and long-term engagement in PA is required to generate effects. Younger children might not have participated long enough in sports clubs to perform better. However, further studies are needed to confirm the observed trend. Nevertheless, engagement in settings of organized sports like sport clubs provide an opportunity to increase children's PA and has a positive impact on psychosocial components [39]. Specific motor abilities are systematically trained which will lead to an improvement of motor abilities. Thus, we highlight the promotion of participation in organized sports.

Previous studies reported significantly lower motor performance of immigrant preschool children [12] and school children with a lower SES background [16, 37]. Authors attributed this to an adverse and insufficient level of activity caused by socio-environment factors in low SES, e.g., lack of PA opportunities and unsafe playgrounds [6, 10]. The results of our study showed that neither the migration background nor the SES was associated to the children's motor abilities. These unexpected results might be explained by the type of survey, as data of per capita income of each municipality have been used as the single indicator for SES. This may not reflect all aspects of the socio-economic status of the study participants. Bundling of several characteristics may be advantageous for determining a social hierarchy. The socio-economic status may be defined by the combination of parental occupation, income and education level [8]. Hence, the respective results of our study should be interpreted with caution.

Strengths and limitations

The strength of this study is the large and diverse sample of preschool children and the standardized assessments done by trained field workers. In addition, this study considered different factors including biological, socio-economic and behavioural factors. However, there are some limitations that

should be noted. The main limitation is the implementation of only two test items which give evidence about the dimension of coordination and strength. These factors are defined as the most integrated motor abilities in learning fundamental motor skills [7]. However, even so we could not give any conclusion concerning the dimension flexibility and endurance. To give a full description of children's motor ability spectrum research implies that motor ability is a complex multidimensional construct and cannot be described using only a single parameter [25]. It should be also considered that a cause–effect relationship between sports club participation and motor performance cannot be inferred via cross-sectional design. Thus we have no clear evidence that our findings are the direct result of children's participation in sport clubs or a result of a generally more active lifestyle. In addition, the type, amount and intensity of exercise during sport club participation could influence our results and should be part of further investigations.

Conclusion

It is essential to identify important factors which influence the development of motor abilities in early childhood to design effective promotion and teaching strategies that target children from young age. This information will help educators and parents to determine the optimal conditions for childhood motor development. Our study shows that different factors are associated to motor abilities: age, gender, membership in sport clubs, and BMI. Based on this, some recommendations can be made to be considered when designing promotion strategies in children 3–6 years: (1) programs should take the child's age and sex into account; (2) children should be encouraged to participate in organized physical activities such as sport clubs; (3) act early in childhood for prevention and especially in children at risk of becoming overweight.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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