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A longitudinal study on gross motor development in children with learning disorders

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ABSTRACT

This longitudinal study examined the development of gross motor skills, and sex-differences therein, in 7- to 11-years-old children with learning disorders (LD) and compared the results with typically developing children to determine the performance level of children with LD.

In children with LD ($n = 56$; 39 boys, 17 girls), gross motor skills were assessed with the Test of Gross Motor Development-2 and measured annually during a 3-year period. Motor scores of 253 typically developing children (125 boys, 112 girls) were collected for references values.

The multilevel analyses showed that the ball skills of children with LD improved with age ($p < .001$), especially between 7 and 9 years, but the locomotor skills did not ($p = .50$). Boys had higher ball skill scores than girls ($p = .002$) and these differences were constant over time. Typically developing children outperformed the children with LD on the locomotor skills and ball skills at all ages, except the locomotor skills at age 7. Children with LD develop their ball skills later in the primary school-period compared to typically developing peers. However, 11 year-old children with LD had a lag in locomotor skills and ball skills of at least four and three years, respectively, compared to their peers.

1. Introduction

Children typically attain proficiency in gross motor skills such as running, hopping, throwing, and catching during their primary school years through a process of maturation and practice (Davies & Rose, 2000; Gabbard, 2008). These are all basic skills that help children function as fully and as independently as possible in their surroundings (Pangrazi, 2007) and are commonly considered the building blocks for the development of more complex motor and sport-specific skills (Stodden et al., 2008; Wall, 2004). Additionally, gross motor skills are positively related to children's cognitive functioning, e.g. academic achievement and executive functioning (Lopes, Santos, Pereira, & Lopes, 2013; Murray et al., 2006; Piek, Dawson,

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Smith, & Gasson, 2008). Thus, sufficiently developed gross motor skills are thought to boost children's participation in physical activities and sports as well as the development of their cognitive abilities.

It has been shown that primary-school-age children with learning disorders[1] (LD) have inferior gross motor skills compared to typically developing peers (Simons, Daly, Theodorou, Caron, Simons, & Andoniadou, 2008; Westendorp, Hartman, Houwen, Smith, & Visscher, 2011b; Westendorp, Houwen, Hartman, & Visscher, 2011a). However, far less is known about the gross motor development of children with LD during the primary-school years. One cross-sectional study in children with mild intellectual disabilities (a subgroup of children with LD), ages 7–10 years, showed a positive age effect with small effect sizes for ball skills. No age effects were found for locomotor skills (Simons et al., 2008). Longitudinal research considering the development of gross motor skills in children with LD has not yet been conducted. Longitudinal research is important as it provides information about within-individual changes with age rather than changes between different individuals. Identifying possible developmental changes in gross motor skill performance in children with LD will give insight into possible accelerations or stabilization in the development. This knowledge is crucial as it is likely to provide clues for interventions directed at improving motor performance in this population.

Besides age, sex differences may play a role in the gross motor skill development of children with LD. Sex differences in gross motor skill development have been established in typically developing children. The ball skill scores of boys generally exceeded that of girls (Barnett, van Beurden, Morgan, Brooks, & Beard, 2010; Butterfield, Angell, & Mason, 2012), but boys and girls did not differ in their locomotor skill scores (Barnett et al., 2010; Ulrich, 2000). In children with LD mixed results have been found regarding sex differences in gross motor skill performance. Simons et al. (2008) found that boys outperformed girls in ball skills, however, Woodard and Surburg (1997) reported higher scores for boys on both locomotor skills and ball skills compared to girls. Until now, it is still unknown whether the developmental trajectory of gross motor skills is different for boys and girls with LD. This information is important whether or not interventions should be different for boys and girls.

In sum, it is generally agreed that children with LD have lower gross motor skill performance compared to typically developing children. However, no studies focused on the developmental trajectory of gross motor skills using longitudinal research. Insight in the longitudinal development of gross motor skills contribute to the current knowledge about the gross motor skill performance in children with LD.

The aim of this longitudinal study was, therefore, to chart the developmental trajectory of gross motor skills (i.e. locomotor skills and ball skills), and sex-differences therein, in 7- to 11-year-old children with LD and to compare the results with typically developing children to determine the performance level of children with LD. Based on the developmental skill-learning gap hypothesis (Wall, 2004), we hypothesized that the gap between children with LD and their more competent peers becomes wider. Children with a normal or high gross motor proficiency begin to use their motor skills in more open and complex settings, whereas children with less adequately developed gross motor skills find it difficult to participate in these complex settings, making it more difficult for them to acquire the expertise they require to participate (Wall, 2004). Given that children with LD tend to have poorer gross motor skills than their typically developing peers, the gap between the two groups may become larger with age.

2. Material and methods

2.1. Participants

Fifty-six children with LD (39 boys and 17 girls), aged between 7 and 11 years old in the year of enrolment, participated in this longitudinal study. They were recruited from a special-needs primary school located in the northern Netherlands. Over a period of three years children's gross motor skills were measured annually in January. Not all 56 children participated in all three measurements, as some children enrolled in the school during the 3-year period, some others left or were absent due to illness. Thirty-five children performed all three measurements, 16 children performed two measurements, and five children were assessed one time. An overview of the numbers of children per measurement per age group is given in Table 1, with a total of 142 measurements.

For each child, the individual school files containing information about child characteristics (e.g. age, sex, IQ), a short medical history, and comorbid disorders were screened. Fifteen children had a comorbid disorder, i.e. 9 children were diagnosed as having Attention Deficit Hyperactivity Disorder, 3 children were diagnosed as having Autism Spectrum Disorders, and 3 children were diagnosed with both. The children's mean intelligence quotient was 84.2 (SD 11.0; range 60–109).

To determine the performance level of children with LD, 253 typically developing peers (125 boys and 112 girls), attending two mainstream schools in the same region, were included in the present study to provide reference values. The age range of the children was 7–11 years (mean age 9.5 years; SD 1.2) and children's grade level was appropriate to their age, indicating that their ability on academic performance was in the normal range (i.e. the expected level in relation to their learning experiences).

[1] Children with learning disorders are defined here as children with problems in academic skills like reading and mathematics that attend Dutch special-needs primary schools.

Table 1
Number of children with learning disorders per measurement per age group.

Age	Number of participants			
	T1	T2	T3	Total
7 years	10	0	0	10
8 years	14	17	0	31
9 years	20	13	12	45
10 years	2	22	12	36
11 years	0	1	19	20
Total	46	53	43	142

Informed consent was obtained for all children and all procedures were approved by the institutional Ethics Committee of the Center for Human Movement Sciences, University Medical Center Groningen, University of Groningen, as being in accordance with the ethical guidelines of the American Psychological Association.

2.2. Assessment of motor skills

The Test of Gross Motor Development-2 (TGMD-2; Ulrich, 2000) was used to measure motor skill performance. The TGMD-2 is a qualitative, process-orientated measure (i.e. evaluates movement based on the demonstration of performance criteria which provided information of how the movement was performed) to assess 12 gross motor skills. The gross motor skills are divided into 6 locomotor skills (run, gallop, hop, leap, jump, and slide) and 6 ball skills (two-hand strike, stationary bounce, catch, kick, overhand throw, and underhand roll). Each skill is executed twice and evaluated based on the presence (success; score 1) or absence (failure; score 0) of three to five qualitative performance criteria. The highest total raw score for both subtests is 48. The higher the (total) score, the better the performance. The TGMD-2 was individually administered at their school gym by specially trained test administrators.

The TGMD-2 has good psychometric qualities to assess gross motor skill performance of typically developing children, according to the test manual (Ulrich, 2000). The internal consistency, the test–retest, and the interrater reliability varied between .85 and .98 for both subtests and the total TGMD-2. The construct validity, measured with a confirmatory factor analysis, was good (χ^2 = 280.3; GFI = .96; AGFI = .95) (Ulrich, 2000). Reliability and validity studies of the TGMD-2 in children with mild intellectual disabilities and learning disabilities showed similar values as reported by Ulrich (Simons et al., 2008; Zhang, 2001).

2.3. Data-analysis

Multilevel modeling (MLwiN 2.23) was used to investigate the longitudinal changes in gross motor skills in children with LD. In multilevel models, longitudinal data, which are not independent and nested within children, can be analyzed. The advantage of multilevel models is that the amount of measurements may vary per child, as MLwiN assumes data is missing at random (Snijders & Bosker, 2011). Multilevel models were created for the locomotor skills and the ball skills, whereby Level 1 values are the repeated measures *within* individual children and Level 2 values are the differences *between* individual children. To examine the developmental changes in locomotor skills and ball skills, age (i.e. linear) and age^2 (i.e. quadratic) were considered as possible predictors. Both age and age^2 were entered in the model to find the best model fit. That is, to examine if the best model fit was a linear or quadratic curve, or a combination of both. Age 7 is used as the reference age to create simple models, whereby the intercept shows the predicted score for 7-year olds. Value one represented age 8, value two represented age 9, value three represented age 10, and value four represented age 11.

Additionally, sex and the possible interactions between age and sex were entered in the model. Random intercepts were considered allowing a unique intercept for each individual child (Snijders & Bosker, 2011). Also, random slopes were entered into the model to properly account for correlations amongst repeated measures in individuals (Snijders & Bosker, 2011). All models were adjusted for comorbid disorders and IQ. The possible predictors (i.e. age, age^2, and sex) were entered separately into the initial model. During each step, goodness of fit was evaluated by comparing the −2*Log Likelihood (IGLS deviance) of the previous model with the most recent model. Variables that did not contribute significantly to the model ($p > .05$) were removed from further analysis. Predictions were calculated based on the final models.

To determine the between-group differences in children with LD and typically developing children at each age, the gross motor skill scores of children with LD were compared with typically developing peers using ANCOVAs with sex as the covariate (SPSS version 20.0). The ANCOVAs were conducted separately per age. To determine the meaningfulness of group effects, correlational effect sizes were calculated in accordance with Rosnow, Rosenthal, and Rubin (2000). An effect size correlation of r = 10 was defined as small, r = 30 as moderate, and an effect size of r = 50 as large (Field, 2005). An alpha of .05 was adopted for all tests of significance.

3. Results

3.1. Locomotor skill development

Table 2 lists the estimated model of the locomotor skills. The predictors age ($p = .50$), age^2 ($p = .55$), sex ($p = .34$), comorbid disorder ($p = .43$), and IQ ($p = .36$) did not significantly contribute to the locomotor skill model and were therefore not included in the final model. The interaction between age and sex was not significant ($p = .50$) indicating that the developmental trajectory of the locomotor skills was not different for boys and girls. Random slopes did not improve the model fit ($p > .05$). The predicted curve for the locomotor skills is plotted in Fig. 1. The graph shows that the locomotor skills did not improve between ages 7 and 11.

3.2. Ball skill development

For the ball skill model, age, age^2, and sex significantly improved the model. Comorbid disorder ($p = .28$) and IQ ($p = .92$) did not improve the model fit and were therefore not included in the final model. The interaction between age and sex was not significant ($p = .82$) indicating parallel developmental trajectories for boys and girls. Also, random slopes did not improve the model fit ($p > .05$). The final estimated ball skill model including age, age^2, and sex as significant predictors, is presented in Table 3. The following equations were derived from this ball skill model:

Ball skill performance for boys = $28.334 + 5.777^{*}\text{age} - 0.802^{*}\text{age}^2$
Ball skill performance for girls = $24.362 + 5.777^{*}\text{age} - 0.802^{*}\text{age}^2$

In these equations, age 7 is the reference age and represented as zero, value one represented age 8, value two represented age 9, value three represented age 10, and value four represented age 11. For instance, it is predicted that boys at age 9 will score $28.334 + 5.777^{*}2 - 0.802^{*}2^2 = 36.68$ on the ball skills.

Table 2
Multilevel model for the locomotor skills.

Fixed effects	Coefficient	Standard error	p
Intercept (constant)	36.991	0.590	<0.001
Random effects	**Variance**	**Standard error**	**p**
Level 2 random effects			
Intercept variance	14.685	3.734	<0.001
Level 1 variance			
Residual variance	11.329	1.723	
Deviance	827.821		
Deviance empty model, $p < .05$	866.503		

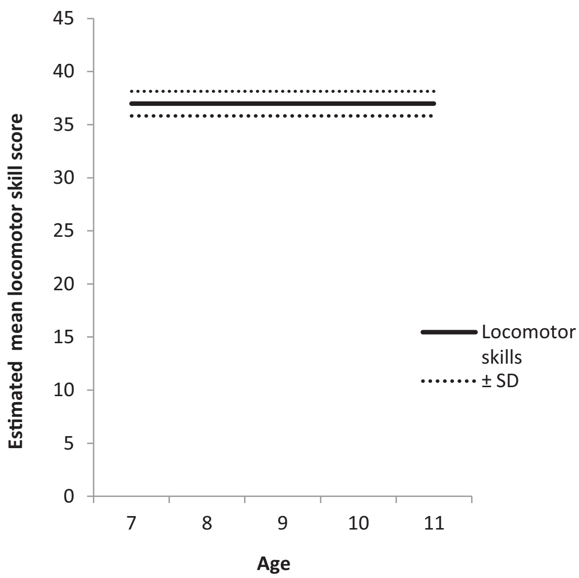

Fig. 1. Locomotor skill development from age 7 to age 11.

Table 3
Multilevel model for the ball skills.

Fixed effects	Coefficient	Standard error	p
Intercept (constant)	28.334	1.228	<0.001
Age	5.777	1.022	<0.001
Age^2	−0.802	.219	<0.001
Boy	0	0	
Girl	−3.972	1.199	0.002
Random effects	**Variance**	**Standard error**	**p**
Level 2 random effects			
Intercept variance	11.724	3.236	<0.001
Level 1 variance			
Residual variance	12.197	1.860	
Deviance	826.160		
Deviance empty model, $p < .05$	907.327		

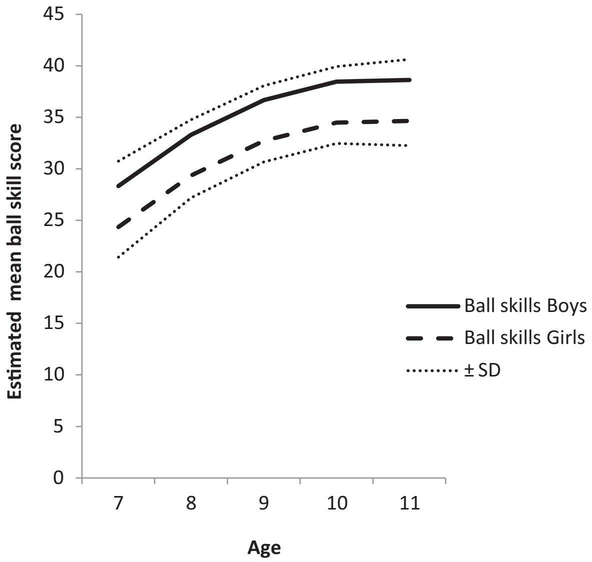

Fig. 2. Ball skill development from age 7 to age 11 for boys and girls. Standard deviations (SD) are only illustrated in one direction for clarity, in reality SD's should be illustrated both ways.

The predicted ball skill curves for boys and girls are plotted in Fig. 2. The observed quadratic age effect indicates an accelerated development between 7 and 9 years with a plateau around 10 years of age for boys as well as for girls. Children were estimated to improve the most from age 7 to 8 (almost 5 points), followed by age 8 to 9 (3.4 points).

3.3. Age-related between-group differences on gross motor skills

Table 4 shows the estimated mean gross motor skill scores for the children with LD and typically developing children presented by age. The between-group analyses showed that the typically developing children significantly outperformed the

Table 4
Estimated mean gross motor skill scores for children with learning disorders and typically developing children presented by age.

Age	Locomotor skills						p	ES	Ball skills						p	ES
	Children with LD			TD children					Children with LD			TD children				
	n	M[a]	SE	n	M[a]	SE			n	M[a]	SE	n	M[a]	SE		
7 years	10	39.3	.98	11	39.6	.94	.805	.06	10	26.2	1.7	11	37.1	1.6	<.001	.74
8 years	31	35.9	.70	42	41.5	.60	<.001	.59	31	32.0	.74	42	39.1	.63	<.001	.65
9 years	45	37.4	.65	53	40.8	.60	<.001	.36	45	35.4	.64	53	39.5	.59	<.001	.43
10 years	36	37.9	.74	74	41.0	.52	.001	.31	36	36.3	.75	74	39.6	.52	<.001	.33
11 years	20	36.6	.84	57	41.2	.50	<.001	.48	20	37.5	1.0	57	40.3	.62	.021	.24

Note: LD, learning disorders; TD, typically developing; ES, effect sizes.
[a] Estimated mean score, statistically adjusted for sex.

children with LD on the locomotor skills and ball skills at all ages, except on the locomotor skills at age 7. For the locomotor skills, at age 8 the effect sizes was large and at age 9, 10, and 11 moderate effect sizes were found. For the ball skills, large effect sizes were found at age 7 and 8, moderate effect sizes at age 9 and 10, and a small effect size was found at age 11. This indicates that the gap in locomotor skills between children with LD and typically developing children varied across the ages and the gap in ball skills between both groups decreased with increasing age.

4. Discussion

The aim of this longitudinal study was to chart the developmental trajectory of gross motor skills (i.e. locomotor skills and ball skills), and sex-differences therein, in 7- to 11-year-old children with LD and to compare the results with typically developing children to determine the performance level of children with LD.

The results of the present study showed that the ball skills of children with LD improved during ages 7–11, but no improvement was found for the locomotor skills. The observed quadratic age effect in the development of ball skills indicates an accelerated development between 7 and 9 years with a plateau around 10 years of age. In typically developing children, the preschool and the early primary school years are recognized as the critical timeframe to develop proficiency in gross motor skills (Gabbard, 2008; Ulrich, 2000). The scores of the typically developing children presented here, showed a similar pattern with little improvement after 7 years of age. Notable is the large ball skill difference between both groups at age 7 years, while the difference between both groups at age 11 is much smaller. Therefore, we might conclude that children with LD develop their ball skills later in the primary school-period compared to their typically developing peers. However, at the end of the primary school period there is still a gap between both groups of children. Eleven-year-old children with LD perform under the level of the 8 year-old typically developing children, indicating a lag in ball skills of at least three years.

No age-related developmental changes were found for the locomotor skills in children with LD. A possible explanation for this finding might be that this study is conducted in primary-school-age children between 7 and 11 years of age and not in younger children. In typically developing children, locomotor skills develop rapidly before 7 years of age (Gabbard, 2008). It might be that children with LD also show the most improvement in locomotor skills before 7 years of age. However, the between-group comparisons showed that children with LD scored lower than the typically developing children at all ages, except at age 7. At the end of the primary school period children with LD did not achieve the performance level of 7 year-old typically developing children indicating a lag in locomotor skills of at least four years.

The between-group performance lag for both the locomotor skills and ball skills persisted over the years. In the present study, gross motor skills were assessed in a relatively static setting that required competence in basic skills (Wall, 2004). If children's skills were evaluated in more complex and open environments (e.g. sport settings), the results would probably have reflected a growing age-related lag in the performance of the LD group. Smyth and Anderson (2000) suggested that this performance lag could negatively affect the children's active participation in games on the playground and they indeed found children with less proficient motor skills to spend more time alone and to participate less in playground games than the more competent children. Poor motor performance may also affect the pleasure children with LD experience in sports and games as playing with typically developing peers, because in the Netherlands in many organized sports children are mainly divided in groups based on their age rather than on their performance level.

Our results showed sex differences in ball skill performance, boys had higher scores than girls, but no sex differences were found on the locomotor skills. No significant interaction effects were found between age and sex indicating that the developmental patterns were not different for boys and girls and that these trajectories were parallel over time. The sex differences in gross motor skill performance in children with LD are comparable with studies in typically developing peers (Barnett et al., 2010; Butterfield et al., 2012). Butterfield et al. (2012) reported sex differences in ball skills in typically developing children favoring boys, but parallel growth curves for boys and girls.

The present study is the first longitudinal study investigating developmental changes in gross motor skills in children with LD. Insight is given into the gross motor skill development during a large part of the primary school period. However, the development trajectory before 7 years of age is still unknown. Therefore, future studies interested in gross motor skill development should focus on children younger than 7 years old. Second, the present study included a relatively small sample of 7-year-old children, which might have resulted in relatively high locomotor skills scores at age 7 compared to the other ages due to some high individual scores. Furthermore, the study population included some children with comorbid disorders, which may have influenced the data. However, the results showed that both comorbidity and IQ did not significantly influence the locomotor skill and the ball skill model. This indicated that the developmental trajectory of gross motor skills was not different for children with a comorbid disorder and children without a comorbid disorder and for children with a below average IQ and children with an IQ in the normal range. The results can be, therefore, generalized to all children with LD in Dutch special-needs primary schools.

The present study has some practical implications. First, this study stresses the importance of providing interventions for children with LD to help them develop and maintain adequate levels of gross motor proficiency. Second, there was a wide range in gross motor skill scores suggesting a variety in gross motor performance between children with LD. Motor interventions in children with LD should take into account this variability by using different skill levels in the exercises in the intervention sessions in order to challenge individual children at their own motor skill level. Finally, as motor skills and cognitive skills are related (Cameron et al., 2012; Diamond, 2000), early detection of motor skill problems is recommended and might be useful in the identification of problems with later school performance.

5. Conclusion

The present study showed that the ball skills of children with LD developed between 7 and 11 years of age, but the locomotor skills did not improve. Children with LD developed their ball skills later in the primary school years compared to typically developing peers, however, the development pattern was similar. Furthermore, for the ball skills sex differences were revealed, boys scored higher than girls, and parallel growth trajectories for boys and girls were found. At all ages typically developing children outperformed children with LD highlighting the need for motor interventions in children with LD to minimize the delay in motor development and thus possibly in other areas such as their sports participation and school performance.

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