

Gross motor skill performance in children with and without visual impairments—Research to practice

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ABSTRACT

The aim of this study was to provide an empirical basis for teaching gross motor skills in children with visual impairments. For this purpose, gross motor skill performance of 23, 6–12 year old, boys and girls who are blind (ICD 10 H54.0) and 28 sighted controls with comparable age and gender characteristics was compared on six locomotor and six object control tasks using the Test of Gross Motor Development Second Edition. Results indicate that children who are blind perform significantly ($p < .05$) worse in all assessed locomotor and object control skills, whereby running, leaping, kicking and catching are the most affected skills, and corresponding differences are related to most running, leaping, kicking and catching component. Practical implications are provided.

Keywords:

Gross motor skill performance
Visual impairments
Children who are blind
Test of Gross Motor Development-Second Edition
Whole-part-whole method

1. Introduction

1.1. Background and significance

The development of fundamental motor skills during childhood is a critical component in the overall development of an individual. A child with fundamental motor skill proficiency and thus a higher motor skill competency will likely participate in more physical activities (Cantell, Crawford, & Doyle Baker, 2008; Cawley & Spiess, 2008; Hands, 2008; Hands & Larkin, 2006) which provides many secondary health benefits, including both fitness and metabolic indices (Cantell et al., 2008; Sallis, Prochaska, & Taylor, 2000; Yang, Telama, Viikari, & Raitakari, 2006). Conversely, a child with low motor skill competence can be expected to be at increased risk for sedentary behaviors (e.g. Jarous, Lourie Gelberg, Engel Yeger, & Bart, 2011; Magalhães, Cardoso, & Missiuna, 2011; Smyth & Anderson, 2000) and subsequent secondary health deficits. This evidence is particularly critical for children with visual impairments as previous research has revealed that these children are typically behind in motor skill competence (e.g. Houwen, Hartman, & Visscher, 2008; Houwen, Visscher, Hartman, & Lemmnik, 2007; Schneekloth, 1989) and selected, corresponding motor activities (Brambring, 2001) when compared to their sighted peers (a comprehensive review of recent research is provided in Section 1.2).

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1.2. Empirical evidence and desideratum

In their comprehensive review, [Houwen, Visscher, Lemmink, and Hartman \(2009\)](#) identified a total of 17 studies focusing on the comparison of motor skill performances between children with and without visual impairments. Twelve studies show broad agreement that children with visual impairments perform worse on static and/or dynamic balance ([Bouchard & Tetreault, 2000](#); [Gipsman, 1981](#); [Häkkinen, Holopainen, Kautiainen, Sillanpää, & Häkkinen, 2006](#); [Johnson Kramer, Sherwood, French, & Canabal, 1992](#); [Leonard, 1969](#); [Pereira, 1990](#); [Ribadi, Rider, & Toole, 1987](#); [Wyver & Livesey, 2003](#)) as well as on fine motor skill/manual dexterity tasks ([Caputo et al., 2007](#); [Ittyerah, 2000](#); [Reimer, Smits Engelsman, & Siemonsma Boom, 1999](#); [Webber, Wood, Gole, & Brown, 2008](#)). However, only one study ([Houwen, Visscher, Lemmink, & Hartman, 2008](#)) was regarded as having high methodological standard and thus, will be described in detail below.

[Houwen, Visscher, et al. \(2008\)](#) aimed to examine motor skill performance of children with visual impairments using the Movement Assessment Battery for Children – Second edition, age band 2, 3 ([Henderson, Sugden, & Barnett, 2007](#)), which provides eight subtests on manual dexterity, aiming and catching as well as on balance. Therefore, performance of 48 children with visual impairments aged between 7 and 10 years and 48 sighted children was compared. When compared to the sighted controls, children with visual impairments showed the poorest performance on unimanual speed, eye hand coordination, catching, static balance, and dynamic balance while moving slowly. These are important information because if a child cannot maintain their balance or catch a ball, their chances for active participation in physical activity, play, and associated socialization processes ([Kremer Sadlik & Kim, 2007](#)) dramatically decrease. Possible adaptations to balance problems were shown in a recent study by [Hallemans, Ortibus, Truijten, and Meire \(2011\)](#); their results revealed that children and adults with visual impairments have slower walking speed, a shorter stride length, prolonged duration of stance and double support in comparison to age related individuals with normal vision.

Reduced gross motor skill competency in children with visual impairments can partly be assumed due to a more sedentary lifestyle (e.g. [Houwen, Hartman, et al., 2008](#)) which in turn might be caused by reduced opportunities to participate in physical activities ([Lieberman & MacVicar, 2003](#)). Often, this results from a lack of knowledge on the part of physical educators on how to appropriately modify curriculum for the specific needs of this population ([Lieberman, Houston Wilson, & Kozub, 2002](#)). In this regard, [Houwen, Visscher, et al. \(2008\)](#) suggest to reduce the complexity of the task by teaching in a stable environment, allowing the learner extra instruction and practice time, and modifying the equipment by enhancing the visual cues as well as auditory input from balls, targets, and boundaries. The chances to progress with these measures are good, since children with visual impairments have been found to enjoy participating in movement activities such as baseball, football and basketball when there have been appropriate equipment, rule, and instructional modifications ([Conroy, 2012](#); [Lieberman, Robinson, & Rollheiser, 2006](#); [Perkins, Columna, Lieberman, & Bailey, 2013](#)). However, the removal of task specific constraints alone will not compensate for the fact that children with visual impairments never had or will have the chance to visually experience role models in performing gross motor skills. Therefore, it seems (even more) important to focus on how to actually teach a particular gross motor skill in this population. As a basis for developing appropriate curricula for children with visual impairments, gross motor deficits must be identified by comparing children with and without visual impairments on a variety of practically relevant tasks such as running, jumping, kicking, throwing or catching. However, comprehensive research on gross motor skill performance in this group is lacking to our knowledge.

1.3. Study aim and hypothesis

The aim of this study was to provide an empirical basis for teaching gross motor skills in children with visual impairments. Therefore, we basically questioned whether there are differences in gross motor skill performance between children with and without visual impairments. Considering the findings from the literature it was assumed, that children with visual impairments would show lower gross motor skill performances in comparison to their sighted peers. To identify the whole spectrum of potentially affected gross motor skills in children with visual impairments, performances of children who are blind and sighted are compared.

2. Methods

2.1. Participants and recruitment

A total of 23 boys ($N = 14$; mean age = 10.00 years; $SD = 1.62$ years) and girls ($N = 9$; mean age = 10.44 years; $SD = 1.51$ years) diagnosed as blind on the basis of the International Statistical Classification of Diseases and Related Health Deficits 10th Revision ([World Health Organisation, 2010](#); ICD 10, H54.0, no light perception) but no other disability, aged 6–12 years (mean age = 10.17 years; $SD = 1.56$ years) were included in this cross sectional study. Participants were recruited and tested at seven summer camps for children with visual impairments across the United States (AK, AZ, CA, CT, MD, and NY).

In addition, a total of 28 sighted controls (mean age = 9.36 years; $SD = 1.83$ years; boys: $N = 15$; mean age = 9.40 years; $SD = 2.03$ years; girls: $N = 13$; mean age = 9.31 years; $SD = 1.65$ years) were recruited from local schools. The study received institutional approval and each participant and their parent agreed to participate.

Table 1
TGMD-2 modifications and cues.

Item	Equipment/space modifications	Cues used
Run	Sound box 50 feet away	Run back and forth between sound sources
Gallop	Sound box 25feet away	Step hop, step hop forward
Hop		Tactile cue to lift leg
Leap	Fluorescent tape around bean bag	Jump forward with one foot and land on one foot
Jump		Jump as far as you can with two feet
Slide		Step side, together, step
Striking	Beep baseball from a tee	Shoulder to wall, step, swing
Dribble	Women's basketball	Push with fingertips waist level
Catch	Wiffle ball with bells inside	Hands out, palms up, catch
Kick	Beeping ball on top of bean bag	Run, step beside ball, kick with toe, follow through
Throw	Tennis ball, sound box	Step with opposite foot, throw, follow through
Roll	Softball, sound box	Step with opposite foot, bend front knee, roll

Children who are blind and sighted showed comparable age (Total: $T(49) = 1.70$; $p = .096$; boys: $T(27) = 0.88$; $p = .388$; girls: $T(20) = 1.64$; $p = .116$) and gender characteristics ($\chi^2(1, 51) = 0.27$; $p = .777$), wherefore a further statistical consideration of both potential confounders was disclaimed.

2.2. Measures

The Test of Gross Motor Development Second Edition (TGMD 2; Ulrich, 2000) was used to determine participants' gross motor skill performance in both study groups. The TGMD 2, which is validated for children with (Houwen, Hartman, Jonker, & Visscher, 2010) and without (Ulrich, 2000) visual impairments covers six locomotor (running, galloping, hopping, leaping, jumping, and sliding) as well as six object control skills (striking, dribbling, catching, kicking, throwing, and rolling). The TGMD 2 materials were slightly modified in order to enable the children who are blind to perform all tasks; corresponding modifications and cues are listed in Table 1.

Since the standardized administration of the TGMD 2 includes a demonstration of each skill, participants who were blind were given the opportunity to receive additional instruction and/or feel the movement prior to performing a gross motor skill. The order of the testing procedure followed the TGMD 2 manual for each child. The children were assessed outdoors by professors and graduate students with expertise in the areas of adapted physical education and motor development with a focus on visual impairment. Evaluations took approximately 15–20 min depending upon how much additional instruction was needed by each child.

2.3. Data analysis

All gross motor skill assessments were recorded with an HD flipvideo, and the video recordings were used to assess each participant's performance scores for all measures. The data of individual participants were stored anonymously, the video recordings and protocol sheets were deleted after the conclusion of data analysis; therefore, an assignment of the test results to individual participants was no longer possible. Performance was assessed based upon 3–5 qualitative performance criteria (process oriented components). Each criterion is evaluated as a 1, if that criterion is present, or a 0 if it is not. Each gross motor task is performed two times. Component scores are then totaled for each gross motor skill (see Table 2), and skill scores are totaled for the locomotor or object control total score, respectively.

TGMD 2 raw data are based on observations; thus, total, skill, and component scores will be presented as medians with corresponding ranges and analyzed with non-parametric Mann-Whitney U tests (one-tailed) using SPSS 21.0. To reduce the likelihood of a type I error, resulting p values (a priori $\alpha = .05$) for total (level 1), skill (level 2) and component (level 3) comparisons are adjusted level-wise using Bonferroni-Holm method (Holm, 1979). Corresponding effects are considered as small ($\phi > .01$), moderate ($\phi > .03$) or large ($\phi > .05$), respectively (see Cohen, 1988), and post hoc power ($1 - \beta$) will be reported for the discussion of non-significant comparisons (Onwuegbuzie & Leech, 2004).

Table 2
TGMD-2 scoring using the example of running.

Skill	Performance criteria	Trial 1	Trial 2	Trial score
Run				
1	Arms in opposition to legs, elbow bent	0	<u>1</u>	2
2	Brief period where both feet are off the ground	<u>0</u>	0	1
3	Narrow foot placement landing on heel or toe	0	<u>1</u>	1
4	Nonsupport leg bent approximately 90°	<u>0</u>	0	0
	Skill score		1	4

Note: 0 = criterion is not present; 1 = criterion is present.

Table 3
Comparison of locomotor total, skill and (selected) component scores between children who are blind and sighted.

	Blind (<i>N</i> = 23)		Sighted (<i>N</i> = 28)		<i>z</i>	<i>p</i>	adj. <i>p</i>	ϕ	1 - β
	Median	Range	Median	Range					
Locomotor	21.00	10.00–33.00	42.00	35.00–48.00	6.10	.000	.025	.85	.83
Run	2.00	0.00–8.00	8.00	7.00–8.00	6.37	.000	.004	.89	.64
Run 1	0.00	0.00–2.00	2.00	1.00–2.00	4.52	.000	.013	.63	.46
Run 2	0.00	0.00–2.00	2.00	2.00–2.00	4.77	.000	.006	.67	.40
Run 3	0.00	0.00–2.00	2.00	2.00–2.00	5.49	.000	.003	.77	.43
Run 4	0.00	0.00–2.00	2.00	2.00–2.00	6.49	.000	.004	.91	.65
Gallop	4.00	0.00–8.00	7.00	4.00–8.00	5.00	.000	.008	.70	.48
Hop	4.00	0.00–6.00	8.00	4.00–10.00	5.22	.000	.005	.74	.45
Leap	0.00	0.00–4.00	6.00	3.00–6.00	6.18	.000	.006	.87	.65
Leap 1	0.00	0.00–2.00	2.00	1.00–2.00	5.63	.000	.004	.80	.51
Leap 2	0.00	0.00–2.00	2.00	2.00–2.00	4.78	.000	.013	.68	.52
Leap 3	0.00	0.00–1.00	2.00	0.00–2.00	6.01	.000	.006	.85	.64
Jump	4.00	2.00–6.00	7.50	3.00–8.00	4.90	.000	.013	.69	.53
Slide	7.00	0.00–8.00	8.00	2.00–8.00	2.46	.007	.025	.34	.22

Notes: Run 1 = arms in opposition to legs, elbow bent; Run 2 = brief period where both feet are off the ground; Run 3 = narrow foot placement landing on heel or toe (i.e., not flat footed); Run 4 = nonsupport leg bent approximately 90° (i.e., close to buttocks); Leap 1 = take off one foot and land on the opposite foot; Leap 2 = a period where both feet are off the ground longer than running; and Leap 3 = forward reach with the arm opposite the lead foot.

3. Results

Description and interpretation of results will be provided in Section 3.1 (locomotor performance) or Section 3.2 (object control performance), respectively.

3.1. Locomotor performance

Locomotor performances in children who are blind and sighted are listed in Table 3.

Children who are blind show a significantly lower locomotor total score in comparison to their sighted peers; the difference found, reflects a large effect.

Results of subsequent skill analysis indicate, that children who are blind perform significantly worse in running, galloping, hopping, leaping, jumping and sliding. A moderate effect can be found in the slide; all other significant differences reflect large effects whereby running and leaping are the most affected skills and thus, will be analyzed in detail below.

A detailed analysis of corresponding component scores makes it clear that,

- (i) running differences are related to run component 1 (arms in opposition to legs, elbow bent), run component 2 (brief period where both feet are off the ground), run component 3 (narrow foot placement landing on heel or toe), and run component 4 (nonsupport leg bent approximately 90°); all significant differences reflect large effects.
- (ii) leaping differences are related to leap component 1 (take off one foot and land on the opposite foot), leap component 2 (a period where both feet are off the ground longer than running) and leap component 3 (forward reach with the arm opposite the lead foot); all significant differences reflect large effects.

3.2. Object control performance

Object control performances in children who are blind and sighted are listed in Table 4.

Children who are blind show a significantly lower object control total score in comparison to their sighted peers; the difference found, reflects a large effect.

Results of subsequent skill analysis indicate, that children who are blind perform significantly worse in striking, dribbling, catching, kicking, throwing and rolling. Moderate effects can be found in dribbling and rolling; all other significant differences reflect large effects, whereby kicking and catching are the most affected skills and thus, will be analyzed in detail below.

A detailed analysis of corresponding component scores makes it clear that,

- (i) kicking differences are related to kick component 1 (Rapid continuous toward the ball), kick component 2 (An elongated stride or leap immediately prior to ball contact), kick component 3 (Non kicking foot placed even with or slightly in back of the ball) and kick component 4 (Kick the ball with the instep of preferred foot (shoelaces) or toe); a moderate effect can be found in kick component 3, whereas significant differences in kick components 1, 2 and 4 reflect large effects.
- (ii) Catching differences are related to catch component 2 (Arms extend while reaching for the ball as it arrives) and catch component 3 (Ball is caught by the hands only); small but non significant effects were also observed in catch component 1 (Preparation phase where hands are in front of the body and elbows are flexed; all significant differences reflect large effects.

Table 4
Comparison of object control total, skill and (selected) component scores between children who are blind and sighted.

	Blind (N=23)		Sighted (N=28)		z	p	adj. p	ϕ	1 - β
	Median	Range	Median	Range					
Object control	20.00	12.00–38.00	38.50	26.00–47.00	5.69	.000	.050	.80	.86
Strike	6.00	4.00–9.00	9.00	5.00–10.00	4.67	.000	.006	.65	.38
Dribble	2.00	0.00–8.00	6.00	0.00–8.00	3.34	.000	.013	.47	.25
Catch	2.00	0.00–4.00	6.00	0.00–6.00	5.45	.000	.004	.76	.47
Catch 1	2.00	0.00–2.00	2.00	0.00–2.00	1.07	.143	.013	.15	.04
Catch 2	0.00	0.00–2.00	2.00	0.00–2.00	4.77	.000	.006	.67	.40
Catch 3	0.00	0.00–1.00	2.00	0.00–2.00	5.94	.000	.004	.83	.56
Kick	4.00	0.00–7.00	8.00	7.00–8.00	6.55	.000	.005	.92	.69
Kick 1	0.00	0.00–2.00	2.00	1.00–2.00	5.34	.000	.003	.75	.40
Kick 2	0.00	0.00–2.00	2.00	2.00–2.00	6.71	.000	.004	.94	.69
Kick 3	2.00	0.00–2.00	2.00	2.00–2.00	2.84	.002	.013	.40	.19
Kick 4	1.00	0.00–2.00	2.00	2.00–2.00	4.29	.000	.006	.60	.32
Throw	3.00	0.00–8.00	6.00	0.00–8.00	3.85	.000	.008	.54	.28
Roll	4.00	0.00–8.00	6.00	2.00–8.00	3.32	.000	.025	.47	.35

Notes: Kick 1 = rapid continuous toward the ball; Kick 2 = an elongated stride or leap immediately prior to ball contact; Kick 3 = non-kicking foot placed even with or slightly in back of the ball; Kick 4 = kick the ball with the instep of preferred foot (shoelaces) or toe; Catch 1 = preparation phase where hands are in front of the body and elbows are flexed; Catch 2 = arms extend while reaching for the ball as it arrives; and Catch 3 = ball is caught by the hands only.

4. Discussion

4.1. Summary and progress of knowledge

In this study, gross motor skill performance of 23 boys and girls who are blind (ICD 10 H54.0) aged 6–12 years and 28 sighted controls with comparable age and gender characteristics was compared on six locomotor and six object control tasks. Results further confirm the general findings that children with visual impairments do have significant deficits in performing locomotor and object control skills (e.g. Houwen, Hartman, et al., 2008) when comparing to their sighted peers. However, the present results also provide a threefold deepening of our current knowledge. That is, that (i) children who are blind perform significantly worse in a variety of gross motor skills, whereby (ii) running, leaping, kicking and catching are the most affected skills, and (iii) corresponding differences are related to almost every movement component. This is essential information in terms of subsequent practical implications, not only for children who are blind but also for children with moderate or severe visual impairment. This break down to lower levels of visual impairment is feasible when considering the following two aspects. First, children with moderate or severe visual impairment cannot be expected to exceed the spectrum of gross motor skill deficits as shown in this study, even though the relationship between the degree of visual and motor impairment is not entirely clear, yet (in overview Houwen et al., 2009). Second, even in the case of a particular gross motor skill not affected in children with moderate or severe visual impairment, it is clear that the more one experiences that skill, the better that individual will likely perform in it (Pica, 2008; Rink, 2010; Smith & Biddle, 2008).

4.2. Practical implications

Instructors must start with teaching the entire skill first through the whole-part-whole method. In the case of a child with residual vision, the teacher should begin by demonstrating the whole skill in the child's field of vision while explaining the motions verbally. Another option is to have a young peer demonstrate the skill while the teacher describes the movement (for the significance of peer involvement see also Ayvazoglu, Oh, & Kozub, 2006). For example, if the motor skill is a run, the peer performs the movement and the teacher says, "swing arms forward and back, back leg bent and step with heel toe with a time when both feet are off the ground" (Lieberman & Haibach, in press).

Once the skill is generally understood the teacher should break the skill down into its components and teach each part of the skill using either physical guidance (move the child through the motions), and/or tactile modeling (the child feels the teacher or a peer doing the motions; i.e., co-active movement). For example, a child does not understand the concept of the weight transfer in the kick. The instructor can have the child feel a peer (tactile modeling) going through the motion of weight transfer several times until the skill can be executed correctly. Tactile modeling and physical guidance are two instructional techniques also used to teach children with visual impairments who may not be able to see a demonstration. Both of these techniques would be coupled with clear verbal explanation and cues such as "approach the ball, step beside the ball, kick with the instep of the foot and follow through" in case of the kick or "hands out, palms up, catch, and grip" in case of the catch. (Lieberman & Haibach, in press; O'Connell, Lieberman, & Petersen, 2006).

Once the child has practiced the whole skill and then refined it by executing each part, then they can put the parts together to perform the whole skill. This can also be accompanied by the cues for each step.

Finally, it is important to keep in mind that children with visual impairments can perform gross motor skills as well as their peers with sight (Blessing, McCrimmon, Stovall, & Williford, 1993; Singh & Singh, 1993), but they just need to be given the opportunity and time (Lieberman & Haibach, in press; Lieberman, Ponchillia, & Ponchillia, 2013).

4.3. Limitations and future perspectives

Within this study, almost all significant differences (total, skill and component scores) in gross motor skill performance between children with (blind) and without (sighted) visual impairments reflected large effects ($\phi \geq .50$)¹ which underlines the clinical relevance of the findings; this even more so when considering, that this data was collected at summer camps for children with visual impairments and that many of the children assessed were at camps focusing upon athletics. Although not every child was athletic, their perceived motor competence may be higher and, therefore, they would likely perform significantly better than a child who does not attend sports camps (Shapiro, Moffett, Lieberman, & Dummer, 2005). For this reason, it is likely that the significance found in this study would be even greater for the general population of children with visual impairments. Therefore, a replication of the findings is one central task for future research, this even more so when considering that the present study was more or less underpowered, which for example is one rival explanation of the statistically non significant findings in catch component 1. However, the realization of an appropriate sample size seems challenging due to the low incidence and geographic dispersion of this population. Subsequent analysis should also focus upon the effects of age, gender, and level of visual impairments on gross motor skill performance in children with visual impairments as there is insufficient research in this area (Houwen et al., 2009).

5. Conclusion

Developing fundamental motor skills during childhood is an important component of motor skill competence which can have lifelong effects upon physical activity participation, fitness levels, and overall health and well being. Results of the present study make it clear that children who are blind are behind their sighted peers in the development of locomotor and object control skills such as running, leaping, kicking and catching. An analysis of the underlying process oriented components enabled a detailed understanding of the specific areas of weakness for the identified gross motor skills. These results provide benchmarks for an appropriate curriculum to be designed for children with visual impairments in general in the effort to decrease the motor skill gap.

Conflict of interest

The authors declare that there is no actual or potential conflict of interest.

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¹ It is possible that the comparatively low differentiation between children with and without visual impairments for the locomotor skill, sliding, may be due to the fact that children were able to achieve a high score on the slide without a flight phase even though there typically is a flight phase in proficient sliding.

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