Bilateral Coordination of Children who are Blind

Izabela Rutkowska
Department of Disability Sport, Józef Piłsudski University of Physical Education in Warsaw, Warsaw, Poland

Lauren J. Lieberman
The College at Brockport, State University of New York, USA

Grzegorz Bednarczuk, Bartosz Molik, Kalina Kazimierska-Kowalewska, and Jolanta Marszałek
Department of Disability Sport, Józef Piłsudski University of Physical Education in Warsaw, Warsaw, Poland

Miguel-Ángel Gómez-Ruano
Faculty of Physical Activity and Sport Sciences, Technical University of Madrid, Spain

Abstract
The purpose of this study was to evaluate the bilateral coordination in children and adolescents with visual impairments aged 7 to 18 years in comparison to their sighted peers. An additional objective was to identify the influence of sex and age on bilateral coordination. Seventy-five individuals with congenital severe visual impairment (40 girls and 35 boys) comprised the visually impaired group. The Sighted group comprised 139 youth without visual impairment. Subtest 4 of the Bruininks-Oseretsky Test of Motor Proficiency was administered to test bilateral coordination. To analyze the effect of the independent variables in the results obtained in the Subtest 4, four linear regression models were applied according to group and sex. The results indicated that severe visual impairment and lack of visual sensation had a negative effect on the development of participants' bilateral coordination, which however did not depend on sex or age.
Keywords
disability, balance, coordination, physical activity

Introduction
Visual impairment has a negative effect on children’s motor development and learning of complex motor skills (Atasavun Uysal & Dulge, 2011; Bouchard & Tetreault, 2000; Brambring, 2006, 2007; Reimer, Smits-Engelsman, & Siemonsma-Boom, 1999; Żyka, Lach, & Rutkowska, 2013). Motor skills mastered by the child indirectly reflect the development of neuromuscular coordination. Lack of bilateral coordination, the ability to use the right and left sides of the body in an integrated and agile manner (Navarro, Fukujima, Fontes, Andra de Matas, & Prado, 2004), manifests itself in poor coordination of both sides of the body, avoiding crossing the midline, production of ipsilateral instead of bilateral movements, difficulties in performing sequencing tasks, and an undetermined laterality (ambidexterity). Individuals with severe visual impairment exhibit delays in reaching the midline of the body, resulting in a low body awareness, deficits in the manual operations, and deficits in the two-hand object manipulation (Brambring, 2007; Jan, Sykand, & Groenveld, 1990). Houwen, Visscher, Lemmnik, and Hartman (2009) pointed out that strong evidence of the existence of deficits in development of small and gross motor skills, including bilateral coordination, has been observed only in studies evaluating the motor development during childhood (i.e., infancy and preschool from 1 to 6 years old) (Brambring, 2006, 2007). Intensive development of bilateral coordination in able-bodied people occurs in late childhood and early school years and should be fully developed at about 10 to 12 years of age (Bruininks & Bruininks, 2005; Cardoso & Magalhaes, 2009). The literature lacks accurate information about how visual impairment affects individuals with severe visual impairment in relation to bilateral coordination, and how this skill develops in children with blindness in comparison to their sighted peers. Therefore, the evaluation of bilateral coordination in children and adolescents with visual impairments is an important issue.

Limited functional abilities of blind children to perform daily tasks and poorer fitness decrease opportunities to learn and/or to improve motor skills (Lieberman, Byrne, Mattern, Watt, & Fernandez-Vivo, 2010; Żyka et al., 2013). Some researchers have suggested that early detection of developmental delays and appropriate intervention programs could reduce or even prevent serious deficits in the development of motor skills in children with visual impairment (Brambring, 2006, 2007; Fazzi, Signorini, Bova, Ondei, & Bianchi, 2005; Jan et al., 1990). The proper assessment of the bilateral coordination is essential to creating programs to improve motor development in the specific case of children with severe visual impairment. The analysis of motor skills and the diagnosis of
children with visual impairment, especially of children with blindness, are more complex than for their sighted peers; thus, the available research on this topic is limited. Some studies have indicated that the level of motor skills in children and young people who are blind and visually impaired is lower than in their sighted peers (Atasavun Uysal & Dulge, 2011; Bouchard & Tetrault, 2000; Brambring, 2007; Houwen, Visscher, Lemmnik, & Hartman, 2008; Reimer et al., 1999). However, other studies have indicated that the development of compensatory mechanisms in children with visual impairment allowed children with partial sight and blindness to achieve outcomes on some coordination tests similar to those of their able-bodied peers (Navarro et al., 2004). Due to equivocal results for bilateral coordination of children with visual impairment, further research in this area is necessary.

Identification of factors influencing the development of motor coordination and motor skills of children and adolescents with visual impairment is very important. Houwen et al. (2009) determined the term of motor skills performance of children with visual impairment on the basis of the theoretical framework of the International Classifications of Functioning, Disabilities and Health, and also researched on variables explaining the motor skills performance of children with visual impairment and literature on motor development of children. Motor skills performance is influenced by the child’s predisposition and impairments, environmental opportunities, barriers to movement, and the task characteristics; groups of variables explain the motor skills performance of children with visual impairment, personal and specific for visual impairment variables, environment, and task. The most important of the personal variables are age, sex, height and body mass, physical fitness, and the child’s personality. Houwen et al. (2009) pointed out that as sighted children grew older, their motor skill performance improved because of maturation, experience, and age. A few studies have indicated that performance of some motor skills improves with age, but most of the observations concern childhood. Ungar, Blades, and Spencer (1995) stated it is the strategies used by children with congenital blindness and partial sight in learning new skills, rather than visual status or chronological age, that accounts for differences in performance between children with visual impairment. There is insufficient evidence as yet to characterize the effects of age on motor skill performance of children with visual impairment (Houwen et al., 2009).

Sex differences in motor skills performance for children and youth in general may exist due to differences in body composition during growth and maturation and also social influences regarding physical activity. Houwen et al. (2009) stated that for children and adolescents with visual impairment, there is weak evidence for a relationship between sex and motor skill performance but only in static balance. Generally, the magnitude of differences in motor performance between able-bodied boys and girls is low to moderate during childhood, but this changes quite markedly after puberty, when boys tend to outperform girls.
In order to assess the influence of age and sex on bilateral coordination, it is necessary to evaluate the development of abilities in children and adolescents with visual impairment from early school years to postpubertal adolescence. The purpose of this study was to evaluate the bilateral coordination in children and adolescents with visual impairment aged 7 to 18 years in comparison to their sighted peers. An additional objective was to characterize the influence of sex and age on bilateral coordination.

**Hypothesis.** The bilateral coordination in children and adolescents with visual impairment will be mainly influenced by vision status and age but not sex.

**Method**

**Participants**

Participants were 75 individuals with severe congenital visual impairment (VI group; 40 girls and 35 boys; aged 7 to 18 years) attending an Educational Centre for Blind Children in Poland. The inclusion criteria for this group was in accordance with the World Health Organization (WHO) classification of blindness (categories 4 and 5) which is defined as visual acuity less than 1/60 in the better eye with the best possible correction (World Health Organization, 2010). The children participated in group physical education classes two to three times per week; the duration of each class was 45 min. The control group consisted of 139 able-bodied individuals (65 girls and 74 boys; aged 7 to 18 years) who were students of a primary school, a gymnasium, and a high school in Warsaw. Both the Sighted and VI groups participated in physical education classes two to three times per week, and that represented most of their physical activity. The exclusion criteria for participation in the study were nervous system disorders, structural changes within the musculoskeletal system, and intellectual limitations. These limitations were determined on the basis of an interview and medical records. All participants had written consent from their parents or legal guardians to participate in the study, and students with visual impairment additionally assented to access of their medical records for research purposes. The participants were also free to withdraw from the study at any time. The tests were conducted in January 2015. The study was approved by the Senate Ethics Committee of the Józef Piłsudski University of Physical Education in Warsaw.

**Procedure**

Subtest 4 “Bilateral Coordination” of the Bruininks-Oseretsky Test of Motor Proficiency (BOT-2) was administered to all participants. The BOT-2 is an individually administered test that includes goal-directed activities to measure a wide
range of motor skills in individuals aged 4 to 21 (Bruininks & Bruininks, 2005). It can identify motor skills deficits in individuals with mild to moderate motor control problems. The authors claimed that BOT-2 could be used to support clinical diagnoses for some clinical groups: individuals with developmental coordination disorders, visual and hearing impairments, mild to moderate mental retardation, and Asperger’s. Bruininks and Bruininks (2005) presented evidence for the validity of test in the Manual, and also specifically for Subtest 4, identifying motor performance deficits in individuals with disabilities. The BOT-2 test was selected due to its validity in participants with disabilities and sighted participants of both sexes, per the available research. The BOT-2 is a valid measure of the motor proficiency of any given children on a specific day. The test–retest reliability coefficients obtained by the previous studies were >.60 in disabled children and >.75 in sighted children (Butler & Koschtial, 1994; Cardoso & Magalhaes, 2009; Melograno & Loovis, 1991; Siegel, Marchetti, & Tecklin, 1991).

In the present study, to assess the validity and reliability of Subtest 4 of BOT-2 in this sample, Pearson’s correlation coefficients were calculated as test–retest reliability, and the mean results obtained for all the subtests was high, \( r = .89, p < .001; 95\% \text{ CI} = .86, .92 \). In addition, the split-half reliability using Spearman–Brown correlations indicated high internal consistency reliability, \( r = .94, 95\% \text{ CI} = .91, .97 \).

The tests were conducted in a school gym in accordance with the BOT-2 instructions (Bruininks & Bruininks, 2005). Adaptations for the participants included the use of physical guidance, for example, to set the participant up in the starting position and methodically show participants the sequence of movements. Then the participant executed the task, with the help of a researcher or alone. The trials started when the researcher was sure that each child understood the next task and was ready for it. Participants performed seven tasks:

1. Touching Nose with Index Fingers—Eyes Closed (point score: 0–4 pt).
2. Jumping Jacks (point score: 0–3 pt).
3. Jumping in Place—Same Sides Synchronized (point score: 0–3 pt).
4. Jumping in Place—Opposite Sides (point score: 0–3 pt).
5. Pivoting Thumbs and Index Fingers (point score: 0–3 pt).
6. Tapping Feet and Fingers—Same Sides Synchronized (point score: 0–4 pt).
7. Tapping Feet and Fingers—Opposite Sides (point score: 0–4 pt).

The raw score for each item was converted into a score rated on a scale of 0 to 3, or 4 selection points, in accordance to the study protocol, and the standardization of the test described in the manual of the BOT-2 (Bruininks & Bruininks, 2005). The sum of raw scores from all the seven items ranged from 0 to 24 points. The scale score was used to describe the examinee’s proficiency on Subtest 4. The score expressed how far an examinee’s score was from the...
The mean score of sighted examinees of the same age, taking into account the standard deviation (SD) of scores in the population sampled.

The level of bilateral coordination was assessed by comparison with the BOT-2 norms represented by the descriptive category (Above Average, Average, Below Average, or Well-Below Average). This expressed in words the approximate distance of the group’s score range from the age group mean. Each category corresponded to a range of scores defined by the SD with the Average category corresponding to the range from 1 SD below the mean to 1 SD above. Above Average/Below Average corresponded to scores from 1 to 2 SD above/below the mean, and the Well-Below Average corresponded to scores more than 2 SD below the mean.

The standard anthropometric measures, accurate to 0.1 cm and 0.1 kg, were used for height and body mass, respectively. Additionally, the body mass index (BMI) was calculated. The tests were conducted by two specialists in Adapted Physical Activity, physiotherapy, occupational therapy, and by two physical education teachers working in the Educational Center. All examiners had more than 10 years of experience working with students with disabilities.

**Statistical analysis**

First, the Kolmogorov–Smirnov test was used to test data normality assumptions. All the variables showed a normal distribution ($p < .05$), so parametric statistical analyses were applied to the data. Second, descriptive analyses (means and SDs) of the data for general characteristics and measures of the BOT-2 battery were run for each group and sex. Third, in order to analyze the effect of age, body height, body mass, and BMI in the sum of points obtained for the seven tasks of the BOT-2 battery, four linear regression models were applied according to group and sex. Visual status was the dependent variable (total points); $\beta_0$ was the intercept; and $\beta_1$, $\beta_2$, and $\beta_3$ indicated the effect of each predictor variable on the independent variables. Finally, $\varepsilon_i$ was the disturbance term. The model is as follows:

$$DV = \beta_0 + \beta_1 \times \text{age} + \beta_2 \times \text{height} + \beta_3 \times \text{body mass} + \beta_3 \times \text{BMI} + \varepsilon_i$$

Finally, a two-way analysis of variance was applied to identify the main effects and interactions of group and sex on the seven items of the BOT-2 battery and the total points obtained. Bonferroni post-hoc tests were carried out for comparisons between groups. The effect size estimations were partial eta-squared ($\eta^2_p$), and their interpretation was based on the following criteria: 0.01 is a small effect, 0.06 a medium effect, and 0.14 a large effect (Cohen, 1988). The statistical analyses were performed using IBM SPSS statistics for Windows, version 20.0 (SPSS Inc., Chicago, IL), and statistical significance was set at $p < .05$. 
Results

The descriptive results about demographic information were presented in Table 1 according to group and sex of the participants. Table 2 shows the results for each item’s score and the total sum of points of the battery BOT-2 for each group and sex. The smallest number of points was obtained by the VI group for Item 4 (Jumping in Place—Opposite Sides Synchronized). The VI group, similarly to the Sighted group, obtained the highest results on Items 1 and 6, Nose Touching with Index Finger and Tapping Feet and Fingers—unilateral leg work.

Table 1. Demographic information about Sighted and VI groups by sex.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sighted Boys (n = 74)</th>
<th>Sighted Girls (n = 65)</th>
<th>Visual impairment Boys (n = 40)</th>
<th>Visual impairment Girls (n = 35)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>M: 11.78 SD: 2.10</td>
<td>M: 11.95 SD: 2.09</td>
<td>M: 11.70 SD: 2.69</td>
<td>M: 12.14 SD: 3.12</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>M: 46.35 SD: 14.53</td>
<td>M: 42.68 SD: 13.68</td>
<td>M: 38.05 SD: 12.74</td>
<td>M: 43.80 SD: 16.18</td>
</tr>
<tr>
<td>Body mass index</td>
<td>M: 0.30 SD: 0.07</td>
<td>M: 0.28 SD: 0.07</td>
<td>M: 0.25 SD: 0.06</td>
<td>M: 0.29 SD: 0.08</td>
</tr>
</tbody>
</table>

Table 2. Descriptive statistics for sum of points of the battery of BOT-2 and the seven items analyzed according to group (sighted and blind children) and sex (boys and girls).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Sighted Boys</th>
<th>Sighted Girls</th>
<th>Visual impairment Boys</th>
<th>Visual impairment Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Item 1</td>
<td>3.97</td>
<td>0.16</td>
<td>3.97</td>
<td>0.25</td>
</tr>
<tr>
<td>Item 2</td>
<td>2.91</td>
<td>0.44</td>
<td>3.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Item 3</td>
<td>2.86</td>
<td>0.60</td>
<td>2.98</td>
<td>0.12</td>
</tr>
<tr>
<td>Item 4</td>
<td>2.55</td>
<td>0.97</td>
<td>2.42</td>
<td>1.13</td>
</tr>
<tr>
<td>Item 5</td>
<td>2.82</td>
<td>0.51</td>
<td>2.86</td>
<td>0.46</td>
</tr>
<tr>
<td>Item 6</td>
<td>3.97</td>
<td>0.16</td>
<td>3.98</td>
<td>0.12</td>
</tr>
<tr>
<td>Item 7</td>
<td>3.36</td>
<td>0.92</td>
<td>3.15</td>
<td>1.02</td>
</tr>
<tr>
<td>Total points</td>
<td>22.46</td>
<td>2.71</td>
<td>22.37</td>
<td>2.02</td>
</tr>
</tbody>
</table>

Note. Item 1: Touching Nose with Index Fingers—Eyes Closed; Item 2: Jumping Jacks; Item 3: Jumping in Place—Same Sides Synchronized; Item 4: Jumping in Place—Opposite Sides Synchronized; Item 5: Pivoting Thumbs and Index Fingers; Item 6: Tapping Feet and Fingers—Same Sides Synchronized; Item 7: Tapping Feet and Fingers—Opposite Sides Synchronized.
The effects of the three independent variables (age, height, body mass, and BMI) on the total points obtained on the BOT-2 battery are displayed in Table 3. The results showed that the four linear regression models were statistically significant ($p < .05$). However, neither the intercept nor the independent variables were statistically significant (total points obtained were not directly affected by age, height, body mass, and BMI).

Table 4 shows the results of the two-way analysis of variance. The group main effect was significant for total points and Items 2, 3, 4, 5, and 6, with higher values for the Sighted than the VI group. The main effect of sex was not significant, with no effect on the total points and the seven items. Interactions between group and sex were not statistically significant for any of the variables (total points and the seven items).

According to the BOT-2 norms, although about half of the VI group achieved results at the Average level, the other half of scores were Below and Well-Below Average (Figure 1).

**Discussion**

The main purpose of this study was to evaluate bilateral coordination of children and adolescents with visual impairment. Therefore, the results obtained by people with visual impairment in the BOT-2 bilateral coordination subtest were compared with the results achieved by sighted peers and with the BOT-2 norms.
for healthy peers. The level of motor skills mastered by the child indirectly reflects the development of neuromuscular coordination. Therefore, specific reference was made to the results of studies in which such motor skills were evaluated in individuals with severe visual impairment.

In this study, the sum of points on Subtest 4 of BOT-2 characterizing the level of bilateral coordination of the VI group was significantly lower than that of the

| Table 4. Results of the effect of group (sighted and blind children) and sex (boys and girls) and their interactions on the items of the battery of BOT-2 and the sum of points. |
|---|---|---|---|---|---|---|
| Factors | Variables | SS | df | MS | F | P |
| Group | Item 1 | 0.27 | 1 | 0.27 | 1.97 | 0.16 | 0.01 |
| | Item 2 | 8.80 | 1 | 8.80 | 24.87 | 0.01** | 0.11 |
| | Item 3 | 24.98 | 1 | 24.98 | 41.11 | 0.01** | 0.16 |
| | Item 4 | 50.33 | 1 | 50.33 | 35.62 | 0.01** | 0.15 |
| | Item 5 | 35.64 | 1 | 35.64 | 50.22 | 0.01** | 0.19 |
| | Item 6 | 1.17 | 1 | 1.17 | 4.98 | 0.03* | 0.02 |
| | Item 7 | 5.66 | 1 | 5.66 | 4.00 | 0.05 | 0.02 |
| | Total points | 630.49 | 1 | 630.49 | 41.41 | 0.01** | 0.16 |
| Sex | Item 1 | 0.10 | 1 | 0.10 | 0.70 | 0.40 | 0.00 |
| | Item 2 | 1.08 | 1 | 1.08 | 3.05 | 0.08 | 0.01 |
| | Item 3 | 0.05 | 1 | 0.05 | 0.09 | 0.77 | 0.00 |
| | Item 4 | 0.30 | 1 | 0.30 | 0.21 | 0.65 | 0.00 |
| | Item 5 | 1.86 | 1 | 1.86 | 2.62 | 0.11 | 0.01 |
| | Item 6 | 0.10 | 1 | 0.10 | 0.43 | 0.51 | 0.00 |
| | Item 7 | 0.92 | 1 | 0.92 | 0.65 | 0.42 | 0.00 |
| | Total points | 4.70 | 1 | 4.70 | 0.31 | 0.58 | 0.00 |
| Group × Gender | Item 1 | 0.11 | 1 | 0.11 | 0.82 | 0.37 | 0.00 |
| | Item 2 | 0.14 | 1 | 0.14 | 0.41 | 0.52 | 0.00 |
| | Item 3 | 1.13 | 1 | 1.13 | 1.86 | 0.17 | 0.01 |
| | Item 4 | 0.18 | 1 | 0.18 | 0.13 | 0.72 | 0.00 |
| | Item 5 | 2.63 | 1 | 2.63 | 3.71 | 0.06 | 0.02 |
| | Item 6 | 0.16 | 1 | 0.16 | 0.68 | 0.41 | 0.00 |
| | Item 7 | 0.26 | 1 | 0.26 | 0.18 | 0.67 | 0.00 |
| | Total points | 2.37 | 1 | 2.37 | 0.16 | 0.69 | 0.00 |

Note. Item 1: Touching Nose with Index Fingers—Eyes Closed; Item 2: Jumping Jacks; Item 3: Jumping in Place—Same Sides Synchronized; Item 4: Jumping in Place—Opposite Sides Synchronized; Item 5: Pivoting Thumbs and Index Fingers; Item 6: Tapping Feet and Fingers—Same Sides Synchronized; Item 7: Tapping Feet and Fingers—Opposite Sides Synchronized.
* *p < .05; ** *p < .01.
Sighted group. Only in two out of seven tasks (Touching Nose with Index Fingers—Eyes Closed and Tapping Feet and Fingers—opposite sides) were the mastery of the two groups similar. Touching Nose with Index Fingers—Eyes Closed is one of tests used in clinical practice to assess ataxia, i.e., irregular and uncoordinated movement. Results of the task obtained in this study confirmed the research inclusion criteria—children and adolescents with visual impairment had substantial ataxia (i.e., disorders in the neurological area).

The lower bilateral coordination in the group with severe visual impairment in comparison to the Sighted group was surprising. Taking into consideration that bilateral coordination in able-bodied people should be fully developed at about 10 to 12 years of age (Bruininks & Bruininks, 2005; Cardoso & Magalhaes, 2009), it was assumed that age would be a significant factor influencing the assessment of this skill in people with visual impairment aged 7 to 18 years and that this effect would reduce the differences from their sighted peers. Maturation of musculoskeletal and nervous systems, development of compensatory mechanisms, and gaining movement experience could have significant influence. Despite bilateral coordination increasing with age, almost half of

![Figure 1. Comparison of bilateral coordination in blind and sighted participants, assessed in the descriptive category, against standards of BOT-2. Each category corresponds to a range of scores defined by the standard deviation (SD) with the Average category corresponding to the range from 1 SD below the mean to 1 SD above. Above Average/Below Average corresponds to scores from 1 to 2 SD above/below the mean, and the Well-Below Average corresponds to scores more than 2 SD below the mean.](image-url)
children and adolescents with visual impairment showed a level of bilateral coordination Below Average or Well-Below Average according to the norms of the BOT-2. This means that the VI group had deficits in the ability to use the left and right sides of the body in an integrated and skillful way. The cause of these deficits could be different among children with visual impairment than in their sighted peers, as eye-motor coordination in blindness is replaced by auditory-motor coordination. Compensation processes play a huge role (Fazzi et al., 2005). Noordzij, Zuidhoek, and Postma (2007) found that for visual imagery, people use the channels currently available (haptic for the blind; visual for the sighted). In their spatial-imagery task, the reliance on haptic processing did not seem to suffice and people benefited from visual experience and ability. Vision played an important role in representing and updating spatial information encoded through touch and has important implications for the role of vision in the development of neuronal areas involved in spatial cognition (Pasqualotto & Newell, 2007). The role of visual processing mechanisms and visual experience in haptic spatial tasks was discussed in detail (Postma, Zuidhoek, Noordzij, & Kappers, 2008).

Some studies have tried to explain the deficits in the bilateral coordination of individuals with severe visual impairment as a consequence of the delays in motor development in early childhood. Children who are sighted make clear connections between their hands and their bodies, subsequently reaching to and often crossing midline at a young age, indicating cognition of the two symmetrical sides of the body. Infants who are blind do not see their own hands and therefore often show delays in crossing the midline of their bodies. This delay often results in low body awareness, deficits in manual operations, as well as deficits in the two-handed object manipulation (Brambring, 2007; Jan et al., 1990). Problems in the area of bilateral coordination can have an important influence on mastering more complex motor skills (Brambring, 2007; Houwen, Visscher, Hartman, & Lemmink, 2007; Houwen et al., 2008; Reimer et al., 1999). Bouchard and Tetreault (2000) found that children with severe visual impairment mastered motor skills later than sighted children. Tasks requiring fine motor skills were better performed by the people with visual impairment than tasks requiring gross motor skills, in comparison with their sighted peers (Bouchard & Tetreault, 2000). Atasavun Uysal and Dulge (2011) found that children with low vision, compared to those with total or near blindness, had better scores on running, balance, coordination of upper extremities, response speed, abilities of upper extremity, and total motor point results. According to the test scores, children with normal sight attained the highest scores on all the tasks. Particularly, Houwen et al. (2009) stated that children with partial vision, in comparison to sighted peers, had worse results in tasks assessing one-hand speed, eye-hand coordination, and catching, static and dynamic balance. Children with mild and moderate visual impairment had better bilateral coordination and eye-hand coordination than children with severe visual impairment.
In the present study, an attempt was made to determine whether there is a sex effect on bilateral coordination. There is not sufficient evidence to establish the relationship between sex and motor skill performance of children with visual impairment (Houwen et al., 2009). In general populations, there is a low to moderate sex effect in motor performance during childhood, but this effect is much larger after puberty, when boys tended to outperform girls. Results of this study as well as other studies (Bouchard & Tetreault, 2000; Houwen et al., 2009) showed that among children with severe visual impairment, there is no relationship between sex and motor skill performance on coordination tasks over the observed age range (7 to 18 years). Intervention programs with the goal of improving ability to use the right and left sides of the body can be used for either sex.

An additional objective was to identify the tasks in which the individuals with severe visual impairment had the greatest difficulties. The key problem in testing the coordination in this group was the selection of the appropriate tests/tasks to identify deficits in coordination. The structure of motor tasks that are included in the BOT-2’s Bilateral Coordination subtest is quite simple and no adaptations or previous experience from the participants was required in the case of the individuals with severe visual impairment. In the present study, all the items were discussed with physical education teachers and physiotherapists from the Educational Centre for the individuals with severe visual impairment before the tests.

The most difficult test for all participants with visual impairment was the Jumping in Place—Opposite Sides Synchronized. None of the younger participants (aged 7 to 9 years) performed this item properly. Jumps were not a problem for them, but the alternate-sided movement using the arms and legs was difficult. It was easier for these children to perform the same task with unilateral limb movements (Jumping in Place—Same Sides Synchronized). Another task problematic for participants was Tapping Feet and Fingers—Opposite Sides Synchronized. The results showed that the most difficult tasks for children and adolescents with visual impairment were the movements requiring the use of the contralateral body parts (limbs). As a result, intervention programs for the individuals with severe visual impairment should contain exercises with alternate-sided movements (upper and lower limbs) to use the left and right side of the body at the same time in an integrated and agile way. Improving basic skills in this area may be an important factor for learning more complex motor skills. Some authors emphasize that early detection of developmental delays and appropriate intervention programs can reduce or even prevent serious deficits in the development of motor skills in youth with severe visual impairment (Brambring, 2006, 2007; Fazzi et al., 2005; Jan et al., 1990). Lieberman, Ponchillia, and Ponchillia (2013) suggested that children with visual impairment should participate in movement activities with changing conditions (open skills) as well as activities that are more constant (closed skills) in
order to experience performing different kinds of motor skills. Studies have shown that the individuals with severe visual impairment who were engaged in intervention programs as opposed to just regular physical activities may improve their motor skills and fitness to a level similar to their sighted peers (Brambring, 2006, 2007; Houwen et al., 2009; Lieberman et al., 2013).

Limitations and conclusion

The present study has some limitations, such as a lack of children under 7 years of age. Based on the literature, this is an especially relevant period, as it is sensitive to the development of bilateral coordination. Other variables that affect bilateral coordination should be also studied, especially the extent and cause of vision loss, the level of visual-motor integration, and opportunities for movement experiences.

Based on the present findings and on the available researches, it can be concluded that severe visual impairment and lack of visual sensation have a negative effect on the development of bilateral coordination of youth aged 7 to 18 years. The bilateral coordination task performances were not affected by sex and age. Despite coordination abilities increasing with age, almost half of youth with visual impairment showed deficits in the ability to use the left and right sides of the body.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was supported by a grant DS-127 from the Ministry of Science and Higher Education.

References


**Author Biographies**

**Izabela Rutkowska**, PhD, is an associate professor at the Jozef Pilsudski University of Physical Education in Warsaw (Poland), Faculty of Rehabilitation. She is focused on adapted physical education, especially children with sensory impairments.

**Lauren J. Lieberman**, PhD, is a professor at the College of Brockport (USA), Department of Kinesiology, Sport Studies, and Physical Education. She is focused on adapted physical education, especially children with sensory impairments.

**Grzegorz Bednarczuk**, PhD, is a lecturer at the Jozef Pilsudski University of Physical Education in Warsaw (Poland), Faculty of Rehabilitation. He is focused on balance and performance analyses of persons with disabilities.

**Bartosz Molik**, PhD, is an associate professor at the Jozef Pilsudski University of Physical Education in Warsaw (Poland), Faculty of Rehabilitation. He is focused on performance analysis and classification problems of persons with disabilities in Paralympic sport.

**Kalina Kazimierska-Kowalewska** is an assistant at the Jozef Pilsudski University of Physical Education in Warsaw (Poland), Faculty of Rehabilitation. She is focused on gross motor function analysis of children and youth with and without disabilities.

**Jolanta Marszałek** is an assistant at the Jozef Pilsudski University of Physical Education in Warsaw (Poland), Faculty of Rehabilitation. She is focused on performance analysis and classification problems of persons with disabilities in Paralympic sport.

**Miguel-Ángel Gómez-Ruano**, PhD, is a lecturer at the Faculty of Physical Activity and Sport Sciences (Spain, Madrid), Technical University of Madrid. He is focused on researching performance analysis in sport and teaching physical activity.