Temporal spatial parameters analysis of the gait in children with vision impairment

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This study compared the linear parameters between children who are blind and children with low vision. Six children who are blind and five children with low vision, aged between five and seven years (mean = 5.9 years old) were analysed by three-dimensional gait analysis and linear parameters of gait: velocity, cadence, stride length, and step width from 12 gait cycles. The comparison of the numerical variable was made using the Mann-Whitney Test. The only significant difference was found in stride length. The results suggested that an adapted gait provided stability which, in turn, improved balance. This finding seems to indicate the importance of commencing orientation and mobility (O&M) training as soon as possible to improve gait, balance, and movement with children who are blind or have low vision.

INTRODUCTION

According to the World Health Organization, vision impairment relates to people who are blind or have low vision. Those considered blind present visual acuity of less than 3/60 with the best possible correction, and those with low vision present visual acuity of less than 6/18 but equal or better than 3/60 in the better eye with the best possible correction (WHO, 2009).

Vision plays an important role in locomotion. For example, vision is essential in the development of anticipation strategies, to promote the necessary physical adjustment needed for moving across varying surface types, and to plan routes to reach desired destinations (Kuyk, et al., 2004).

In the absence or lack of vision, other remaining and intact systems will be responsible for capturing sensory information from around an individual's environment (Navarro, Fukujima, Fontes, Matas, & Prado, 2004). However, these systems have limitations and the information obtained by them cannot be as precise as the visual system (Patla, 1997). Thus, one of the greatest challenges for children with vision impairment is to move around safely and independently in various types of environments. The total or partial absence of vision can alter the biomechanics of gait in three ways including: (i) alteration in step length, (ii) deficit of balance, and (iii) protective reactions (Aust, 1987).

In addition, children with low vision present an alteration of the functional capacity of their vision which is caused by several isolated or associated factors such as low visual acuity, a significant reduction of visual field, cortical and/or sensitivity to alterations of contrast (Bruno & Mota, 2001). Therefore, these children need to learn to use their residual vision and other intact senses to make their daily life and school activities accessible and easier (Albert, 2010; Sánchez, 1994). The use of residual vision in children with low vision could be improved by orientation and mobility (O&M) training that might positively impact locomotion and motor performance.

In the past, little importance was given to the need for psychomotricity stimulation in children with low vision. Unlike children who are blind, children with low vision had residual vision, and therefore, it was believed that they would not experience problems in their psychomotor development (Sánchez, 1994). However, after several studies suggested that psychomotor problems impeded development, psychomotor stimulation was included in the rehabilitation process of people with low vision through O&M (Bruno & Mota, 2001; Revuelta & López, 2004; Sánchez, 1994). Initially, psychomotor stimulation was used only for adults and adolescents (Sánchez, 1994). Today, the importance of psychomotor stimulation via O&M for children with vision impairment is well known and should commence as early as possible to encourage important motor patterns like independent gait. Some authors reported a delay in acquisition of gait in children with vision impairment (Revuelta & López, 2004; Sánchez, 1994) and described their gait as a "shuffling gait" with short steps, limited rotation of the trunk and pelvis, an absence of arm swing, with a flexion of the knees and a wide step width (Aust, 1987; Sankako, Lucareli, de Carvalho, & Braccialli, 2014).

Knowledge of the gait characteristics in children with vision impairment and of the influence that residual vision can bring to the variables of the gait can assist with a planned rehabilitation process to improve locomotion. However, no studies have been identified that analysed the gait in children with vision impairment, or which have compared the gait of individuals who are blind or have low vision by kinematics.

This study aims to compare the linear parameters of gait in children who are blind to those with low vision. This study was submitted to the Research Ethics Committee of the Faculdade de Filosofia e Ciências, UNESP, in Marília, São Paulo state, Brazil, and approved through protocol # 2777/2007.

METHOD

Participants

The researchers contacted a rehabilitation centre where people with vision impairment attend. At the time of contact, 20 children with vision impairment had been undertaking long-term (many years) rehabilitation at the centre that also included mobility training. The mobility training involved the children learning to use their vision effectively while walking safely through environments. With parental signed consent all 20 children were considered for participation in the study.

The participation inclusion criteria were: to have an independent gait pattern, and an absence of other neuromuscular or musculoskeletal disorders that altered gait pattern. All children were evaluated by a physiotherapist and 11 children met the inclusion criteria.

Of the 11 children, six were blind and had a mean age of 6.17 ± 0.75 years (4 males and 2 females), and a mean height of 1.23 ± 0.07 metres. These children commenced O&M training at a mean age of $21.5 \pm 09/13$ months. The five children with low vision had a mean age of 5.6 ± 0.8 years (1 male and 4 females), and a mean height of 1.14 ± 0.06 metres. These children commenced O&M training at a mean age of 41.8 ± 20.52 months (Table 1).

Instruments and materials

These included eight cameras with optoelectric motion capture systems (Motion Analysis Corporation, Santa Rosa CA), a computer with a specialised board for movement analysis – MIDAS (Motion Analysis Corporation, Santa Rosa, CA) – DATASTATION, computer Intel Core Duo – WORKSTATION, *Evart*® 5.0 and *Orthotrack* 6.2® – (Motion Analysis Corporation, Santa Rosa, CA), reflective markers, and a toy piano.

Table 1. Characteristics of participants.

Participants	Vision impairment	Age (years)	Height (metres)	Gender	Age at the beginning of O&M training
P1	Blind	7	1.31	Male	19 months
P2	Blind	5	1.12	Male	10 months
P3	Blind	6	1.25	Female	14 months
P4	Blind	6	1.28	Male	21 months
P5	Blind	7	1.20	Male	47 months
P6	Blind	6	1.20	Female	18 months
P7	Low Vision	5	1.08	Female	17 months
P8	Low Vision	5	1.10	Male	49 months
P9	Low Vision	6	1.18	Female	71 months
P10	Low Vision	7	1.22	Female	29 months
P11	Low Vision	5	1.10	Female	43 months

Experimental protocol

The participants were barefoot and wearing swimsuits. A total of 29 reflective markers were placed on specific anatomical landmarks according to the Helen Hayes Marker set (Davis, Õunpuu, Tiburski, & Gage, 1991).

The dimensions of the area designated for testing participants' gait was 5.0 × 7.0 metres. Around the testing area, eight cameras were attached to the walls so that the entire area could be monitored. Before each data collection period the gait analysis system was calibrated (static and dynamic) in accordance with the manufacturer's instruction. Data collection did not begin until the error for finding the centre of each marker was inferior to 1 millimetre in accordance with the protocol for gait analysis (Sankako, Lucareli, de Carvalho, & Braccialli, 2014).

Participants were informed about the data collecting procedures. Then orientation training occurred so that participants were able to walk in a reasonably straight line through the testing area. To assist straight line walking an audio track (music) was played that participants followed from the start of the testing area to the end (Brasil, 2003).

At the commencement of data collection, each participant was positioned half a metre behind the start area designated for performing the gait so that the 'usual stride' could be measured once data collection began. During testing participants did not use a cane or

any other aid to assist their gait. Participants were directed to walk in their usual manner, to start walking when the music started, and to stop only when the researcher said "stop", which occurred at the end of the testing area. This procedure was repeated per participant for a total of 12 gait cycles. There was silence during data collection so that participants could follow the audio track.

DATA ANALYSIS

The recording and three-dimensional reconstruction was made by the software *Evart®*. Based on the biomechanical model employed in the software *Orthotrack®* it was possible to obtain kinematical parameters for analysis (Davis, Õunpuu, Tiburski, & Gage, 1991).

The mean values, standard deviation, minimum value, median, and maximum value of temporal spatial parameters of the gait: velocity, cadence, stride length, and step width were exported to the ASCII archives by the *Orthotrack®* software and calculated in the SPSS 13.0 for each group, i.e., children who were blind or had low vision. A total of 12 gait cycles were used. The comparison between the numerical variables according to the group (blind x low vision) was performed by the Mann-Whitney test (Armitage & Berry, 1997). For all the tests $p < 0.05$ level for significance was used.

RESULTS

Table 2 presents the values of mean, standard deviation (DS), median, minimum, and maximum values of the velocity (m/s), cadence (steps/minute), stride length (m), and step width (m) for each group analysed, and the comparison between the groups in each variable, using the Mann-Whitney statistical test.

Significant differences were found only in the stride length between the children who were blind or had low vision. The children who were blind exhibited a narrower stride length than the children with low vision.

DISCUSSION

This study compared the temporal spatial parameters of the gait in children who were either blind or had low vision. The results indicated that there was a significant difference only in stride length.

One factor that appears to influence stride length is that of the individual's height, so the taller the individual, the wider the stride length (Inman, Ralston, & Todd, 1998). However, in this study, even though the mean height of the children who were blind was greater

than that of the children with low vision, the children who were blind obtained a narrower stride length than the children with low vision. This finding might suggest that children who have residual vision are more confident when walking, influencing a longer stride.

Table 2. Data of velocity, cadence, stride length, step width, and comparison between groups (blind and low vision LV) by Mann-Whitney test (p).

Variable	Group	n	Mean	DS	Minimum	Median	Maximum	p
Velocity (m/s)	Blind	6	0.388	0.176	0.1	0.379	0.6	0.273
	LV	5	0.489	0.102	0.3	0.516	0.6	
	Total	11						
Cadence (step/minute)	Blind	6	114.767	21.142	92.4	112.200	139.6	0.855
	LV	5	107.780	12.601	97.8	100.00	121.8	
	Total	11						
Stride length (m)	Blind	6	0.397	0.149	0.1	0.440	0.5	0.045*
	LV	5	0.548	0.079	0.4	0.578	0.6	
	Total	11						
Step width (m)	Blind	6	0.133	0.025	0.1	0.131	0.17	0.272
	LV	5	0.116	0.018	0.1	0.121	0.12	
	Total	11						

$p < 0.05$

No studies were found that had analysed the gait of children with vision impairment by kinematics. However, when the results of this study were compared with those of the Hernandéz, Reyes, Urióstegui, Carrera, and Sanpablo (2010) study it suggests that the participant's (children) vision impairment influenced the velocity linear parameter values of cadence and stride length. The Hernandéz et al. study (2010) analysed the linear parameters of the gait in children with sight without motor disorders, aged between six and seven years (a similar age to the children in this study), and the values of velocity, cadence, and stride length were higher than those found in this study.

Although no significant differences were found between the two participant groups across the other variables, i.e., velocity, cadence, and step width, the results of this research are similar to that of other studies which reported individuals' locomotion with vision impairment had been characterised by low velocity and cadence, small stride length, and step width (Aust, 1987).

Aust (1987) described the locomotion in individuals with vision impairment as a shuffling gait with the purpose of improving balance by increasing the time of foot contact with the ground and exploring the environment, resulting in small steps and lower velocity.

Low velocity and guarded walking in individuals with vision impairment could be ways of adjusting to improve stability. For example, vision impairment can delay the postural adjustment necessary to maintain balance when confronted with an obstacle on one's path (Nakamura, 1997).

To walk with low velocity causes a decrease in joint movement, especially in the sagittal plane; in other words, a flexion/extension or anterior/posterior tilt (Kirkwood, Gomes, Sampaio, Culham, & Costigan, 2007). According to Aust (1987) alterations in this plane, such as flexion of the knee and a tilt of the trunk, are typical characteristics of the posture in an individual with vision impairment (Aust, 1987).

England and Granata (2007) emphasised the potential effect of velocity for improved stability during locomotion. According to the authors, the walking velocity interferes in the kinematics, double support time, stride length, and other variables related to improved stability. A high velocity of locomotion implies an increase in the segmental momentum and, consequently, the need for greater neural control to minimise these kinematical alterations. Short steps limit the neuromuscular system to compensate for the mechanical changes or to correct errors.

The low values of temporal spatial parameters obtained by children in this study might be explained as a way of trying to minimise the effects of instability during gait, probably caused by the lack of visual feedback from the environment.

Step width is the reflection of the relation of pelvic width upon the opening of the ankles. The width of the pelvis refers to the body width at the level of the anterior superior iliac spine, and the opening of the ankle refers to the distance between the centres of right and left ankles during the double support phase (Inman, Ralston, & Todd, 1998). Step width should be from 0.05 to 0.10 metres during locomotion in individuals with sight without motor disorders (Lippert, 2003).

Both participant groups in this study presented a mean step width of over 0.10 metres. According to Kendall, Mccreary, Provance, Romani, and Rodgers (2005), the wider step width provides better balance, and could explain the higher values for this variable during these children's locomotion.

The impact of visual deprivation on gait is apparently related to the important role of vision on postural control. This was observed by Hallermans et al. (2009) that compared the linear parameters in children with sight (between three and 11 years) without motor disorders, and in adults with sight without motor disorders under two conditions: eyes open and eyes closed. Both the adults and children with eyes closed obtained low values of velocity, cadence and stride length, and a wide step width. However, the authors observed that children were more affected by deprivation of visual information than were the adults.

This conclusion, according to these authors, could be explained by the children relying more heavily on visual information during locomotion or because the other sensory systems had not yet fully developed to take postural control.

The characteristics of gait presented by the children in this study were similar to those in children who were starting to walk, which aligns with the report by Sánchez (1994). Sánchez continues to emphasise the importance of correcting gait pattern, as well as all other postures that are acquired before gait, as soon as possible so that this pattern does not remain throughout children's lives.

There seems to be a difference between the neuropsychomotor development in children with vision impairment and that of children with sight. Neuropsychomotor development is a dynamic process of interaction with the environment on the maturation of sensorimotor structures occurring through the continuous exchange between stimulus and response (Figueira, 2000). However, with the deprivation of the visual sense comes the slowing of the process because it is necessary to make adaptations in the use of residual vision and other remaining senses (Levtzion-Korach, Tennenbaum, Schnitzer, & Ornoy, 2000).

Among the possible causes that can affect neuropsychomotor development in children are: the lack of vision as a motivation to execute movement; a lack of motor experience due to protective parents and their anxiety about the way they touch or handle their children; fear of the unknown environment, and stimulation activities provided at an older age and late phase of neuropsychomotor development (Sánchez, 1994).

One of the ways to stimulate the psychomotor development in children with vision impairment is through O&M training. Orientation and mobility training should commence at an early age at the onset of children's first spontaneous and intentional body movements (Bruno & Mota, 2001; Skellenger & Sapp, 2010). Participants in this study had received O&M training though at a later stage in development. For example, the children who are blind began O&M intervention at about 10 months, and for children with low vision at about 17 months of age. At these stages children with vision impairment should be starting to sit without support and make their first independent steps (Revuelta & López, 2004). The late start in O&M might have contributed to the gait characteristics demonstrated by the children in this study.

CONCLUSION

The study identified little difference between the gait of children who are blind and those with low vision. Perhaps the low number of participants and the late commencement of O&M could have influenced the results. Despite this, the study revealed the presence

of adaptations in gait of children with vision impairment including wide step width, low velocity, cadence and stride length, which seems to have improved their balance. These adaptations in gait might be the result of an absence or lack of vision which has an important role in locomotion. The findings suggest the importance of commencing O&M training at an early age, when children with vision impairment first experience movement so that inadequate posture and movements are corrected. This might assist these children to acquire a gait similar to that of their sighted peers.

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