Context-Dependency of Mobility in Children and Adolescents With Cerebral Palsy: Optimal and Natural Environments

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Introduction

The International Classification of Functioning, Disability and Health (ICF) (World Health Organization, 2001) states that the functional and disability processes in individuals with spastic cerebral palsy (SCP) are strongly influenced by the contexts in which they conduct their daily lives. However, much of the available evidence about movement and mobility in this patient population focuses on the components of body structure and function that contribute to and/or influence functional activities. Appropriate attention has not been paid to the contextual factors affecting mobility (Palisano, 2006).

Individuals with SCP must adapt to environmental features to meet the locomotion demands within that particular setting. Moreover, functional activities during the development and growth of children with SCP influence their body structure and function by shaping posture and movement patterns (Cosgrove, Corry, & Graham, 1994; Graham, 2001; Palisano, 2006). As the children grow, there are changes in the muscle fiber morphology, muscle mass shortening, increases in stiffness, restrictions in the range of motion of joints, and changes in connective tissue. Such changes may impose demands on the bones and tissues of children with SCP, altering their mobility and performance (Koman, Mooney, Smith, Goodman, & Mulvaney, 1993; Moreu, Teefey, & Damiano, 2009; Ohata, Tsuboyama, Haruta, Ichihashi, & Nakamura, 2009).

Contracture in children with SCP is compounded by the disparity between muscle and bone growth because bones often outgrow muscles. Voluntary muscle activity in weight-bearing limbs, which is the key muscle growth stimulus, is reduced in children with SCP primarily due to muscle weakness (Graham, 2001). The relationship between skeletal muscle and motor function in individuals with SCP is variable and unpredictable. It is affected by worsening of the symptoms over time and by the positive (i.e., facilitator) or negative (i.e., barrier) influences that the environment exerts. Thus, it is important to investigate the functional mobility of individuals with SCP in different environments and to analyze their health status (e.g., unilateral vs. bilateral impairment) and personal factors (e.g., children vs. adolescents).

Usually the ability to walk, from a biomechanical point of view, is evaluated with gait analysis (GA). The term GA refers to the method of quantitative multifactorial and three-dimensional computerized evaluation of walking (Perry & Burnfield, 2010). This process is facilitated through the use of technology such as specialized, computer-interfaced video cameras to measure patient motion, electrodes placed on the surface of the skin to appreciate muscle activity, and force platforms imbedded in a walkway to monitor the forces and torques produced between the ambulatory patient and the ground (Perry & Burnfield,

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TABLE 1
Sample features: Means and standard deviations for age (years), body mass (kg), and height (cm) groups by SCP type and age

Groups	n	Age	Body mass	Height
Children with bilateral SCP	8	8,2 ± 2,2	25,5 ± 12	130,3 ± 9,01
Children with unilateral SCP	8	8,13 ± 2,5	27,6 ± 9,7	129,7 ± 16,6
Adolescents with bilateral SCP	10	13,2 ± 1,3	41,7 ± 6,8	146,1 ± 12,4
Adolescents with unilateral SCP	5	14 ± 1,6	51,7 ± 14	160,2 ± 8,2
Bilateral SCP	18	11 ± 3,07	34,5 ± 12	139,1 ± 13,4
Unilateral SCP	13	10,4 ± 3,6	37 ± 16,5	141,5 ± 20,4
Children	16	8,2 ± 2,3	26,6 ± 10	130 ± 12,9
Adolescents	15	13,5 ± 1,4	45,1 ± 10	150,8 ± 12,8
Total	31	10,7 ± 3,3	35,5 ± 14	140,1 ± 16,5

Legend: n = number of participants.

2010). The GA is an important method to quantify the walking providing information that allows understanding the etiology of gait abnormalities and in treatment decision-making, but understanding the cerebral palsy locomotion in an ecological context is also needed to reach more effective rehabilitation goals (Perry & Burnfield, 2010). GA for its nature is done in a motion analysis laboratory avoiding the evaluation of the children in an ecological context. The exam is held in an optimized environment (e.g., flat surface), and the patients need to wear electrodes and anatomical markers to perform the walking. Moreover, this method does not evidence the ability of the subject to walk over irregular surfaces and long distances.

This observational study aimed to analyze and compare the functional mobility of individuals with SCP during locomotion over different distances (5, 50, and 500 m) in natural and optimized environments, taking into account the degree of impairment (unilateral vs. bilateral) and age (child vs. adolescent). In this study, the optimized environment was composed of regular, flat surfaces, making it an ideal setting for performing movement. The natural environment represented places that were normally traversed in participants' daily lives, such as their home, school, or neighborhood. These places may have irregular surfaces and often contain obstacles, such as furniture and holes, which require immediate strategies to avoid collisions, slips, and falls. The comparison between optimal vs. natural environments is important for the rehabilitation field because it provides better understanding for the health professionals about the real strategies adopted by children with SCP in their day-by-day locomotion activities.

Methods

Participants

Thirty-one individuals with SCP between the ages of 5 and 16 years were divided into two age groups (children = 5 to 11 years old and adolescents = 12 to 16 years old) and into two impairment types (bilateral = diplegic and quadriplegic and unilateral = hemiplegic). The study included individuals who had independent mobility and could understand the tasks. Table 1 shows the group distribution according to impairment type and age. The participants of this study were recruited from rehabilitation centers located in the cities of Rio Claro, Araras, and Limeira in the state of Sao Paolo, Brazil. This work was submitted and approved by the Ethics Review Committee from the Biosciences Institute of the Universidade Estadual Paulista, CEP-IB-UNESP (process number 70 2497/07), and all experimental procedures followed the Declaration of Helsinki.

Procedure

Before the start of data collection, the parents and guardians were informed of the study's procedures and asked to sign a consent form, which included detailed information about the study. The consent was obtained for all participants. The participants' anthropometric data (body mass, weight, and height) were also collected.

To obtain functional mobility data in an optimized environment, each participant was asked to walk three distances (5, 50, and 500 m) along an unobstructed path (i.e., corridors and sports' courts). Three observers evaluated each participant's performance. One observer followed the participant along each path, while the others observed from the beginning and the end of the path. The natural-environment data collection was conducted using an analog camera (Panasonic model NV - M9000PN S - VHS) to record each child's locomotion. The participants walked with and without support devices through areas containing curves, obstacles, and objects in the middle of the route.

The 5-m walking evaluation was conducted in each participant's own residence and involved moving from the bedroom to the living room. The 50-m test was conducted at the participant's school, institution, and/or rehabilitation center, and it required him/her to travel from the classroom to the courtyard, change directions and use ramps. For the 500-m distance, each individual was recorded near his/her residence, walking on sidewalks, and/or unpaved roads. The camera recorded the locomotion during each task. The data collection occurred in numerous locations, which necessitated a mobile camera. In both the natural and optimized environments, the distances were measured by tape-measure within millimeters and marked with tape.

The risks of participation in this study were minimal. During each trial, an evaluator remained close to the participant to prevent possible falls. Adequate rest time between each walking trial was provided according to the needs of each participant. Similarly, rest breaks that did not involve sitting were allowed whenever requested by a participant during a trial.

The outcome variables measured were the functional mobility and time required to walk the distances. The functional mobility was classified by the Functional Mobility Scale (Graham, Harvey, Rodda, Nattrass, & Pirpiris, 2004; Harvey, Graham, Morris, Baker, & Wolfe, 2007 – Appendix 1). After all of a participant's data had been collected in the optimized environment, the observers came to a consensus about the ratings to be assigned for the scales. The interobserver agreement for the optimized environment was 100%. In the natural environment, an observer assigned a score immediately after witnessing the trials. The other two observers watched the film twice, with 15 days between viewings, and coded the performance according to the Functional Mobility Scale classification. The intraobserver concordance was 95.1%, and the interobserver concordance was 83%.

The times spent to traverse the distances in both environments were expressed in seconds (s) and were documented by a digital timer (SONY) that was accurate to one hundredth of a second. The walking time in a particular environment is an important factor in characterizing the functional mobility of children with SCP. For example, walking with another person requires individuals to be able to keep pace with their partner.

Statistical Analysis

The data were initially analyzed by descriptive statistics (means and standard deviations). The ordinal data (the Functional Mobility Scale classification) were analyzed by nonparametric statistics. The Wilcoxon test was used for the following comparisons: (1) between environments (optimized vs. natural), considering each distance (5, 50, and 500 m) separately; (2) between environments (optimized vs. natural), considering each type of cerebral palsy and each distance (5, 50, and 500 m) separately; (3) between environments (optimized vs. natural), considering the age groups (children and adolescents) and each distance (5, 50, and 500 m) separately; (4) between the environment (natural vs. optimized) for the children only, considering each SCP type (unilateral and bilateral) and each distance (5, 50, and 500 m) separately; and (5) between the environment (natural vs. optimized) for the adolescents only, considering each SCP type (unilateral and bilateral) and each distance (5, 50, and 500 m) separately. The Mann–Whitney test for independent samples was used for the following comparisons: (1) between the SCP types (unilateral vs. bilateral), considering each environment (optimized and natural) and each distance (5, 50, and 500 m) separately; (2) between the age groups (children vs. adolescents), considering each environment (optimized and natural) and each distance (5, 50, and 500 m) separately; (3) between the SCP types (unilateral vs. bilateral) among the children, considering each

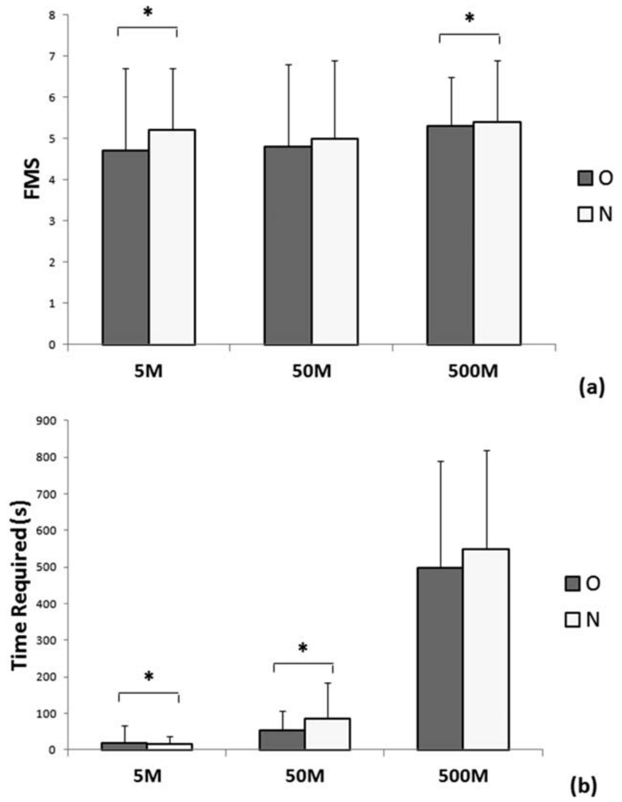

FIGURE 1

Comparisons of Optimized (O) and Natural (N) environments in terms of mean and standard deviation for FMS scores (a) and time required (b). Legend: * = $p < 0.05$.

environment (optimized and natural) and each distance (5, 50, and 500 m) separately; (4) between the SCP types (unilateral vs. bilateral) among the adolescents, considering each environment (optimized and natural) and 142 each distance (5, 50, and 500 m) separately. To minimize the chance of type I errors, the significance level (α) was adjusted for the number of comparisons in many analyses, ranging from $\alpha = 0.05$ to $\alpha = 0.0125$.

Because the data for time to walk each distance was not normally distributed and homogeneous by the Shapiro–Wilk and Levene tests, it was logarithmically transformed (log10). A three-way ($2 \times 2 \times 2$) analysis of variance (ANOVA) was used for the inferential analysis of the time required to cover the three distances (5, 50, and 500 m). We also tested the interaction effects with $\alpha = 0.05$.

Results

The participants' mobility, as assessed by the Functional Mobility Scale, had higher scores in the natural environments than in the optimized environment for 5 m ($t = -2.658$, $p = 0.008$ – Figure 1a) and 500 m ($t = -1.933$, $p = 0.05$ – Figure 1a) trials. When the Functional Mobility Scale values were compared

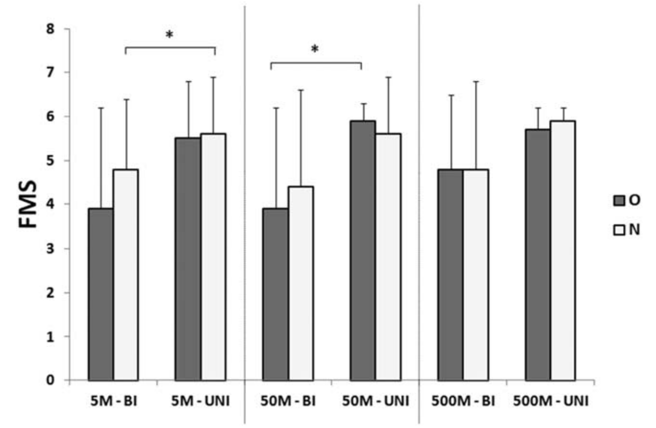

FIGURE 2

Comparisons between the types of SCP (unilateral and bilateral) for Optimized (O) and Natural (N) environments in terms of mean and standard deviation for FMS scores. Legend: * = $p < 0.05$.

between the types of SCP (unilateral and bilateral), separated by environment (optimized and natural), a significant difference was revealed for the 50-m trial in the optimized environment ($U = -2.683$, $p = 0.019$ – Figure 2). Individuals with bilateral SCP were also more dependent on mobility devices in the 50-m distance. Significant differences in the functional mobility of the participants with bilateral SCP were found only in the 5-m trial ($t = -2.724$, $p = 0.006$ – Figure 2), with higher scores in the natural environment.

The ANOVA revealed that the environment had the most significant effect on the time required to walk 5 m ($F1, 27 = 20.036$, $p = 0.001$ – Figure 1b) and 50 m ($F1, 24 = 22.574$, $p = 0.001$ – Figure 1b). The time individuals with SCP required to walk 5 m was shorter than the time to walk 50 m in an optimized environment.

Interactions between the environment and the age group for the walking time required were seen at 5 m ($F1, 27 = 4.146$, $p = 0.05$ – Figure 3a) and at 500 m ($F1, 18 = 9.629$, $p = 0.006$ – Figure 3b). The post hoc tests revealed that in the optimized environment, the adolescents with SCP walked faster the 5 m distance than the children, although these groups required similar times to cover this distance in the natural environment (Figure 3a). For the long-distance path in the natural environment, the adolescents with SCP spent more time walking 500 m than did the children, but the groups were similar in the optimized environment (Figure 3b).

Discussion

The aim of this study was to analyze the functional mobility of individuals with SCP in different environments (optimized and natural). This analysis compared individuals with SCP by type of impairment (unilateral and bilateral) and age group (children and adolescents).

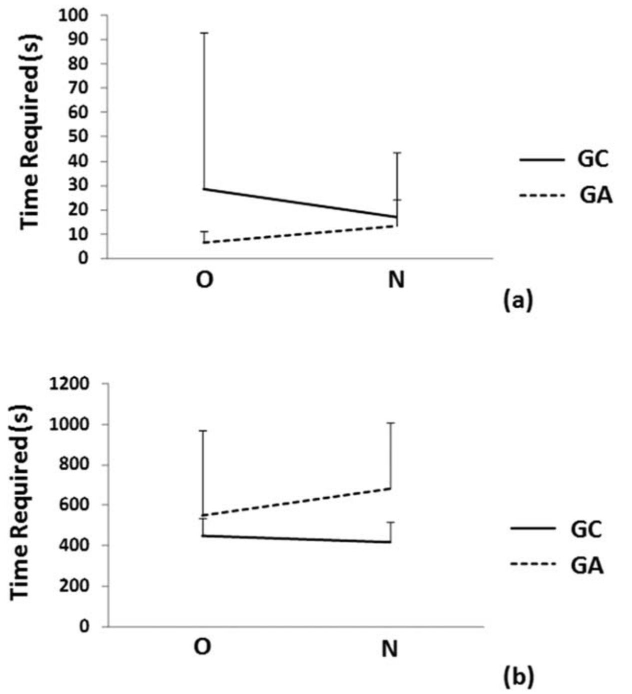

FIGURE 3

Interaction between time required and the environment (optimized - O and natural - N) for age groups (Children Group – CG and Adults Group – AG) in 5 m (a) and 500 m (b).

Differences were observed in functional mobility and time required to traverse different distances by impairment type and age group in both the optimized and natural environments. After analyzing functional mobility, the results showed that supportive equipment was needed more often to walk distances of 5 and 500 m in the optimized environments. Most authors (Berry, McLaurin, & Sparling, 1996; Lepage, Noreau, & Bernard, 1998; Østensjø, Carlberg, & Vøllestad, 2003; Palisano et al., 2003) have not specifically compared the mobility of individuals with SCP in the contexts of their environments. There have, however, been discussions of how people with SCP travel in different ways in their homes compared with places with a significant amount of social interaction (i.e., schools and neighborhoods). These authors have also found a positive relationship between the distance traveled and the need to use assistive mobility devices in children with SCP. In this study, more specific aspects of this relationship were revealed. The apparent linear association between distance traveled, mobility devices, and time required walking that has been suggested in the literature was shown to be mediated by personal (age) and environmental (optimized or natural) factors.

This study also found no difference between the natural and optimized environments for the 50-m distance (school and institutional environments). However, differences were found in the time required to walk 50 m. This fact can be explained by the features of the natural environments. Even institutions that have been adapted to be accessible to this population have curves, ramps, and steps, features not found in the optimized environments.

The time required to walk specific distances also showed differences at 5 m but did not show significant differences at 500 m. The environmental features were the main factor in the time required; the time required for the 5-m and 50-m trials in the optimized environment was shorter than in the natural environments. It was also expected that participants could complete the 500-m distance in a shorter time in the optimized environment than in the natural. Regardless of the environment, walking this distance requires great energy expenditure and, consequently, may increase muscle fatigue and demand better cardiorespiratory fitness. Spastic muscles fatigue quickly because of muscle weakness and other abnormalities in upper motor neurons (Damiano, Dodd, & Taylor, 2002; Østensjø et al., 2003). Given this result, we speculate that the negative signs of spasticity, especially muscle weakness, may have influenced the distance covered by a person with SCP because no difference was found between environment types.

Because of the weakness, it was expected that differences would be found in the children's mobility (both for the Functional Mobility Scale and time required) according to impairment type. However, no difference was observed. Gorter et al. (2004) did not detect differences between unilateral and bilateral impairments in the Gross Motor Function Classification System rankings. Perhaps these results were influenced by sample size and by the majority of the participants presented being able to independently ambulate. The locomotion differences between the impairment types, as evidenced in the literature, showed differences in the need to use equipment (Kleiner et al., 2008) and in spatial and temporal gait variables (Damiano & Abel, 1998; Damiano, Laws, Carmines, & Abel, 2006).

When the age groups were compared, no differences were found in the Functional Mobility Scale classification. It was expected that differences would be found in the need for equipment due to progressive neurological and musculoskeletal deformities (Moreu et al., 2009; Ohata et al., 2009). These deformities result from upper motor neuron syndromes, which affect motor function over time (Cosgrove et al., 1994; Graham, 2001; Love et al., 2001).

Interactions occurred between the environment and age group for the time required to cover 5 and 500 m. At 5 m, the adolescents covered the optimal environment in less time than they needed for the natural environment. In the children, the opposite occurred. Nevertheless, the adolescents traversed the optimal environment in less time than the children, and no difference was found between the groups for the natural environment. The results showed that the natural environment's irregular nature (i.e., curves, steps, and furniture) imposed different difficulties on each age group. The adolescents were more cautious about walking 5 m in the natural environment than in the optimal, perhaps to avoid falling or bumping into objects; while the children used the environmental features as facilitators for performing the task.

For the 500-m distance, the children took less time to go through the natural environment than the adolescents, and no difference was found between these groups at this distance in the optimized environment. However, the children showed no difference in the time required to cover 500 m in the two environments, and the adolescents moved through the natural environment in a similar time. These results show that the children used the same strategies and/or auxiliary equipment in both environments. Once again, however, the adolescents had poor conditioning for confronting the irregularities of the natural environment. Perhaps these more cautious strategies adopted by adolescents in the natural environment resulted from their greater functional impairment brought on by aging (Johnson, Damiano, & Abel, 1997; Moreu et al., 2009; Norlin and Odenrick, 1986).

These arguments can only be applied to the 5-m and 500-m distances. The age groups and environmental features appear not to have influenced the time required to cover 50 m. This study demonstrated the participants' performance and their ability to move in environments with different surfaces. This compensatory ability was due to their locomotive performance in the environments that were part of their daily lives, and their locomotive ability (potential function) in optimized, irregularity-free environments. The ICF activity component, an individual capacity and performance assessment, offers distinct information about a particular functional task, such as mobility (which was discussed in this study).

This study has some limitations, such as the small sample size, which may have influenced some results. Moreover, because the natural environment was different for each participant, one place may have presented more challenges to locomotion than another. Much remains to be investigated and explored concerning the locomotion of individuals with SCP in different environmental contexts.

In particular, observational studies of daily locomotion tasks are needed. They should use specific scales and have greater sample control, including the participants' severity level and more homogeneity, for example. The observation of the individuals' movement within its context is likely to assist with rehabilitation programs, giving the therapist the opportunity to ascertain the real needs of these individuals' for achieving adequate locomotion.

Finally, there were three major results from this study. First, the environment influenced the functional mobility of individuals with SCP. When the environments were compared, regardless of the impairment type or age group, significant functional mobility differences were found at 5 and 500 m. In the natural environment, the individuals with SCP were less dependent on assistive equipment. In the optimized environment, the participants walked 5 and 50 m in a less time. Second, the impairment type was associated with functional mobility differences only for the 50-m trial in the optimized environment. The time required did not indicate any environmental difference. Last, the age of individuals with cerebral palsy in this study influenced the time required to walk 5 and 500 m.

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Appendix 1

TABLE A1
Functional mobility scale classifications (Harvey et al., 2007; Graham et al., 2004)

Functional mobility scale	
Classification	**Description**
1	Uses a wheelchair, motorized wheelchair or cart: can stand up and can walk assisted by another person or using a walker/wheelchair, and so forth.
2	Uses a walker: without another person's assistance.
3	Use two crutches: without another person's assistance.
4	Uses a crutch or two sticks: without another person's assistance.
5	Regardless the surface type: do not use any accessory to walk or need another person's assistance. If he/she uses as a mobile support, walls, fences in front of stores, use the item 4 as the most appropriate description.
6	Independent in all areas: does not use any accessory to walk or need some help from another person when he/she walks, runs, climbs stairs, and ladders.