Using the Edinburgh Visual Gait Score to Compare Ankle-Foot Orthoses, Sensorimotor Orthoses and Barefoot on Gait Pattern in Children with Cerebral Palsy: A Cross-Sectional Cohort Study

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Abstract

Background: Gait analysis is one of the important aspects of evaluation in ambulatory children with cerebral palsy (CP). Typically prescribed for children with CP, ankle-foot orthoses (AFOs) improve gait and alignment through providing support and stability to the ankle complex. An alternative and under-researched orthosis being used in this population is the Sensomotoric orthotic (SMotO), which uses a different approach to correct alignment and improve gait. The Edinburgh Visual Gait Score (EVGS) is a valid, robust, reliable and easy-to-use observational gait analysis scale to measure of gait quality in CP. Improvements to gait could then be attributed to intervention, or regression of gait could be attributed to poor intervention or physical changes. Therefore, the aim of this study was to use the EVGS to determine the effect of SMotOs, AFOs and barefoot on gait pattern in children with CP. Methods: This cross-sectional cohort study investigated the differences in gait quality in children with CP between wearing SMotOs and AFOs through using the EVGS. Video imagery was taken when walking barefoot (where appropriate), in SMotOs and in AFOs for at least 5m at a self-directed pace. Individual scores and averages across the population were recorded. Data was analysed through SPSS statistics software (Version 20) and the Microsoft Office Excel 2007. A one-way ANOVA and post hoc Bonferroni were completed to identify significant differences with the alpha level set at $p<.05$. Results: One-way ANOVA analyses revealed significant differences between total left ($p=0.011$) and right ($p=0.014$) scores between SMotO and AFOs. Overall, results demonstrate improved gait in favour of SMotO vs AFO and that there are no significant differences between being barefoot and wearing AFOs. Conclusions: SMotOs are a viable orthotic option to improve gait in children with CP, but due to small yield of participants, a larger scale, blinded study should be performed to further determine results.

Background

Cerebral Palsy (CP) is a neurodevelopmental condition well recognised to begin at birth or early childhood and persisting through the lifespan (Rosenbaum P. , Paneth, Leviton, Goldstein, & Bax, 2006). It has been defined as a group of permanent disorders of the development of movement and postures, causing activity limitation and are often accompanied by disturbances of sensation, perception, cognition, communication, and behaviour, by epilepsy and by secondary musculoskeletal problems (Rosenbaum, et al., 2006) such as muscle spasticity (Romkes & Brunner, 2002). A potential (or common) activity limitation is the ability and coordination for walking (gait), with control of movements and postures being affected.

According to the Cerebral Palsy Alliance, NSW (CPA, 2019), there are three types of CP; quadriplegia (where all four limbs are affected, as well as muscles in the trunk, face and mouth often affected), diplegia (where both legs are affected), and hemiplegia (where one arm and leg on the same side are affected).

The description and severity of the topographical of CP description can be further added to by including motor type as well as severity (mild, moderate, severe) as well as further classification into presentation

(Cans, et al., 2007). These are; spastic (damage in the motor cortex affecting 70-80% of individuals and the most common form, increased tone and spasticity with pathological reflexes), dyskinetic (damage in the basal ganglia affecting 6% of individuals, demonstrated by uncontrolled, involuntary, recurring movements with primitive reflex patters and varying muscle tone), ataxic (damage in the cerebellum affecting 6% of individuals and is characterised by shaky movements due to the loss of orderly muscle co-ordination, compromising balance and proprioception with a predominance of low tone), and mixed, which is a combination of the damages described above.

Gross Motor Function Classification System (GMFCS) classifies the child's movements such as sitting, walking, and use of mobility devices and provides a standardised system that has been found to be valid and reliable (Oeffinger, et al., 2004). The GMFCS describes the function of a child through self-initiated movement and the use of assistive mobility devices. It has a simple five-level grading system that is used to describe the function of the child with CP, starting at GMFCS-I being able to walk without limitations to GMFCS-V requiring full assistance in a wheelchair.

As ambulation is the usual method for mobilising, many children with CP strive to achieve any form of walking possible, whether it's with or without an assistive device. Gait analysis is one of the important aspects of evaluation in ambulatory children with CP (Gupta & Raja, 2012; del Pilar Duque Orozco, et al., 2016). In order to improve a child with CP's gait and to be able to quantify the outcomes of intervention, it is essential to perform an analysis before and after the intervention (Bella, Rodrigues, Valenciano, Silva, & Souza, 2012). Access to the gold standard assessment tools such as three-dimensional, kinetic or kinematic gait analysis (Bella, et al., 2012) may not always be readily available or feasible in a clinical setting (Read, Hazlewood, Hillman, Prescott, & Robb, 2003; Gupta & Raja, 2012). For this reason, many valid and reliable observational gait analysis scales have been devised to clinically evaluate gait without the use of such technologies.

Read et al., (2003) developed the Edinburgh Visual Gait Score (EVGS), a scale for observational gait analysis, which comprises of 17 parameters for each lower limb and evaluates across six sites (trunk, pelvis, hip, knee, ankle and foot). Each gait phase is analysed in the frontal, sagittal and transverse planes and the anatomical sites are evaluated for movement through video observation (Bella et al., 2012). Scoring uses a 3-point ordinal scale, with scores ranging from 2, 1, 0, 1, and 2, the highest score being 34. When the segment is marked 0, it determines a normal score. When there is a 1, it means a moderate deviation from normal in either direction (appropriate to the plane e.g. left or right, flexion or extension), and 2 relates to a marked deviation, therefore a higher score relates to a more severe deviation or abnormality of gait.

The EVGS is a valid, robust, reliable and easy-to-use observational gait analysis scale to measure of gait quality in CP (Read, Hazlewood, Hillman, Prescott, & Robb, 2003; Robinson L. W., Clement, Herman, & Gaston, 2017) and is a quick and easy gait assessment tool to use in a clinical setting where gait laboratories are not accessible (Thomai & Gita, 2017). The EVGS is shown to correlate with the Gait Profile Score and the GMFCS (Robinson L. W., et al., 2015), two relevant and valid measures relating to

CP. The scale has stringent instructions to ensure reliability. Its agreement and validity with three-dimensional gait analysis have been documented (del Pilar Duque Orozco, et al., 2016) and was noted to be 52-73%. The developers of EVGS reported a score reduction of 4 on each limb (compared to pre-intervention score) as an improvement and as the minimum change in score required that would be indicative of change, not merely related to observer variation (Read et al., 2003).

The essential properties of an observation scale are validity, reliability, and ability to detect change (Gupta & Raja, 2012). Responsiveness is the ability of a tools detection of change due to an intervention or over time. Thomai and Gita (2017) found the EVGS to be sensitive enough to note changes in gait after two months of physiotherapy intervention in children with CP. Due to the nature of spasticity and the effect it has on gait in children with CP, the ability to consciously and continuously differ or correct gait pattern is severely reduced, resulting in a nonchanging pattern of gait. Improvements to gait could then be attributed to intervention, or regression of gait could be attributed to poor intervention or physical changes.

Ankle-foot orthotics (AFOs) are the typical prescription of lower extremity orthoses for the management of lower limb deformities that often occur with CP. AFOs are found to; support normal joint alignment and mechanics, provide variable range of motion (ROM) when appropriate, facilitate function (Brodke, et al., 1989; Knutson & Clark, 1991; White, Jenkins, Neace, Tylkowski, & Walker, 2002), stabilise the ankle / foot complex (Buckon, Jakobson-Huston, Moor, Sussman, & Aiona, 2004), enable a continuous Achilles / gastrocnemius stretch (Boyd, Pliatsios, Starr, Wolfe, & Kerr Graham, 2000), and prevent contractures of the Achilles / gastrocnemius from developing (Morris, 2002; Hainsworth, Harrison, Sheldon, & Roussounis, 2007). Along with joint alignment, other improvements that may be seen through the use of AFOs are the improvement in walking efficiency (Rethlefsen, Kay, Dennis, Forstein, & Tolo, 1999), and improvement in gait function (Westberry, et al., 2007).

Sensomotoric orthotics (SMotO) provide a different approach to the management of gait and spasticity in children with CP. The SMotOs are created to ‘activate and deactivate’ muscles by increasing or decreasing individually placed point specific pressure on musculotendinous structures in the foot, meaning the information that is transmitted by the sensors for the control of muscle activity is changed (Ohlendorf, 2013). Depending on these individual pressure bumps’ height and placement, the muscles can be activated or restricted by making use of the regulation circuit (Ohlendorf, 2013). It has been proposed that information is sent by afferent feedback pathways in order to reduce the activity of over-active muscles through inhibition, which in turn facilitates an increase in the activity of weaker muscles (Ludwig, Quadflieg, & Koch, 2013). Given the physiology of ascending muscle chains, the reaction will not only affect the single muscle targeted, but influence the complete chain of movement and positively impact malposition (Ohlendorf, 2013).

Due to the paucity of literature on the direct impact of the SMotO on the neurologically affected sensorimotor system, the proposal of muscle activity and inhibition may only be demonstrated through clinical evidence and supposition. Because of the nature of spasticity and the effect it has on gait in children with CP, the ability to consciously and continuously differ or correct gait pattern is severely reduced, resulting in a nonchanging pattern of gait. Therefore, this cross-sectional cohort study aims to compare the effect of wearing SMotO to AFOs and to barefoot, on gait pattern in children with CP by using the EVGS.

Methods

Participants were children with CP aged between three to 13 years who were recruited and assessed through two private paediatric therapy practices in Sydney (Therapies for Kids and NAPA Centre). The participant inclusion criteria were: a) a diagnosis of CP, b) no surgery in past six weeks, and c) currently using both AFOs and SMotO and d) able to mobilise (with or without a device). Participants brought their own SMotOs and AFOs to the data collection sessions and any GMFCS level was included. The AFOs were all made from polypropylene with Velcro straps holding the foot in place. The SMotOs were custom made for each child from EVA and had been assessed by a podiatrist or pedorthists who were both experts in this design type of orthosis.

The participant was asked to walk barefoot (where appropriate due to ability to mobilise without any type of foot support), in SMotOs and in AFOs for at least 5m at a self-directed pace. To provide randomisation and non-bias from the researcher as well as motivation, the participant was able to choose the order in which they wore the orthoses. Video imagery was taken with a handheld device (Apple iPhone 7s) in anterior, posterior and lateral views. Videos were taken in a well-lit environment, with the child being allowed the comfort of a break between walks if needed.

Ethical approval was obtained through the Bond University Research and Ethics Committee (Approval RO-1835). Consent was gained from Clinic Directors in both private practice settings. Participants and their caregivers were given an explanatory statement and consent form, both of which were read and completed before data collection took place.

Data Analysis:

Frame by frame analysis was performed to score the gait using the EVGS with all analysis performed by the principal researcher, a physiotherapist who works with the children and had 6 years of experience using this tool. This analysis took place after all face-to-face data collection had been completed, thereby minimising time pressures on the families and their child.

A summated score of each limb was used for data analysis for this study. Thus, the score for the EVGS ranges from 0 to 34 on left (L) or right (R). SPSS statistics software (Version 20) and the Microsoft Office Excel 2007 were used for the data entry and analysis. Descriptive statistics were used to profile the data: the median difference of the total EVGS scores and the mean difference of the average walking score, before and after the intervention, were calculated. The data for the barefoot condition and both orthoses was then statistically analysed through a one-way ANOVA to determine significance, and post hoc Bonferroni to outline further comparison significance. Alpha levels were set at 0.05 *a priori.*

Results

From 13 viable participants, two were excluded in the final comparative data analyses between SMotO and AFOs as they did not wear AFOs anymore (but were included in comparisons, yield and participation). Of the 11 participants, seven were able to walk barefoot and therefore had barefoot data collection recorded. There were five participants with spastic diplegia, six with spastic quadriplegia and two with spastic dystonic quadriplegia. GMFCS levels were; three level I, four level II, four level III, two level IV. Six participants used assistive devices for EVGS. One participant had ethyl vinyl acetate (EVA) heel wedges on their solid AFO to encourage weight through heel, mimicking heel strike.

The total scores for (L) and (R) barefoot (where applicable) and with each orthosis and are described in Table 1. When barefoot was assessed, the scores across participants demonstrated a poorer score than both AFO and SMotO except for one participant, who demonstrated poorer results when wearing AFOs compared to barefoot and SMotO. There were six participants who required the use of ambulatory aids, displaying a varied range of gait ability.

Table 1 Total (L) & (R) EVGS for participants

The descriptive statistics of EVGS is provided in Table 2 outlining the mean and standard deviation (SD) for total (L) and (R) scores for barefoot, AFO and SMotO intervention.

Table 2 Data descriptors for total (L) and (R)

One-way ANOVA analyses revealed significant differences between total (L) ($p=0.011$) and (R) ($p=0.014$) scores between SMotO and AFOs (Table 3). There were significant differences on the (L) lower limb between barefoot and SMotO ($p=0.032$), and AFO and SMotO ($p=0.027$). On the (R) lower limb, there were significant differences between AFO and SMotO ($p=0.028$), and minimal differences between SMotO and barefoot ($p=0.052$).

Table 3 Bonferroni Comparison between the three conditions

Discussion

The aim of this study was to investigate the effect two types of orthoses (SMotOs and AFOs) had on gait pattern in children with CP as derived through the EVGS. All the participants were in GMFCS levels II-IV and used orthoses to walk, both SMotOs and AFOs. Barring a couple of participants, the general trend indicated that SMotO had the lower scores, which correlates to the EVGS score line, indicating a more aligned gait pattern than that of AFOs or barefoot.

The total raw scores of each participant demonstrated more desirable gait patterns were observed when wearing SMotO. This was resultant across 11 participants by a lower total score when wearing SMotOs on both left (7.46) and right (7.77) compared to when wearing AFOs on left (14.00) and right (14.36) and barefoot left (14.22) and right (14.11). One participant demonstrated a worse score on the (L) foot when wearing SMotO compared to AFO due to poor foot and knee alignment. The one-way ANOVA confirmed that there was a significant difference in EVGS scores between the use of SMotO and AFO. Subsequently, a significant difference on the left lower limb was found when participants wore SMotOs compared to barefoot or AFOs, but not the right lower limb. The right lower extremity score of p=0.052 was very close to being significant when comparing SMotO to barefoot or AFOs, but may need a larger yield study to determine its significance and if it is a usual trend. Interestingly, there was no significant difference between the AFO and barefoot scores.

A retrospective study by Brehm (Brehm, Harlaar, & Schwartz, 2008) compared the effect of AFOs on walking efficiency and gait in a group of 172 children with CP (hemiplegia, quadriplegia and diplegia), to the same population walking barefoot. They found the use of an AFO significantly decreased (p=0.007) the energy cost of walking in those with quadriplegic CP vs barefoot, but energy cost remained unchanged for those with hemiplegia and diplegia whether in AFO or barefoot. Although their study investigated the effect AFOs had on energy expenditure, the findings demonstrate similar outcomes where AFOs did not make a significant difference to walking in children with CP when compared to walking barefoot. There were no other papers noted to directly compare gait in children with CP when walking with AFOs vs SMotOs and barefoot.

The results of this study suggest an improved gait when participants with CP (quadriplegic or diplegic) were wearing SMotOs compared to barefoot or when wearing AFOs. The implications of this research may lead to validating SMotOs as another form of orthotic therapy for children with many types of CP.

Limitations of the Study: Limitations to this research include a final small yield of participants available to collect the full range of data, mainly due to the limitations uncovered such as comprehension of task, ability to follow direction, and ability to attend data collection. This may affect the strength of the results, although papers within the literature demonstrate a range of participant numbers whilst using the EVGS, from 7 (Bella et al., 2012) to 151 (Robinson et al., 2017). With a longer recruitment period and implementation of this as ‘usual practice’ in prescription of SMotOs, a larger group could be assessed for continuation of these research findings.

Conclusion

This study suggests that the SMotO is a more effective orthosis intervention to improve gait in children with CP compared to that of an AFO or walking barefoot. These results encourage further investigation into the longevity of SMotO use in children with CP or to further specify the areas of benefit of the SMotO alongside AFO in relation to this population, their gait function and level of disability. Clinically, this creates an alternate orthoses prescription possibility for children with CP, especially for those wishing to improve gait.

Abbreviations

(L): Left

(R): Right

AFO: Ankle foot orthoses

CP: Cerebral palsy

EVA: Ethyl vinyl acetate

EVGS: The Edinburgh Visual Gait Score

SD: Standard deviation

SMotO: Sensomotoric orthoses

Declarations

ETHICAL APPROVAL AND CONSENT TO PARTICIPATE: Ethical approval was obtained through the Bond University Research and Ethics Committee (Approval RO-1835). Consent was gained from Clinic Directors in both private practice settings. Participants and their caregivers were given an explanatory statement (Appendix 1) and consent form (Appendix 2), both of which were read and completed before data collection took place.

CONSENT FOR PUBLICATION: Not applicable

AVAILABILITY OF DATA AND MATERIALS: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

COMPETING INTERESTS: CM acknowledges a working relationship with the manufacturers (podiatrist and pedorthists) of the SMotO. Due to the nature of CMs work and the lack of research into the orthoses, creating a research paper surrounding the selected population and intervention was beneficial to therapists, family and the children with CP. WH and RO have no competing interests.

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AUTHORS’ CONTRIBUTIONS: CM created and designed the research study, recruited appropriate participants from two private practice locations, collected EVGS data at noted locations, created datasets, assisted with data analyses, data interpretations and completed manuscript. WH assisted with study design, led data analyses and analyses, supported manuscript review and editing. RO assisted with data analyses, data interpretation, manuscript review and editing. All authors read and approved the final manuscript.

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Supplementary Files

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- EVGSDataSet.xlsx
- Tables.docx