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Development and Test Efficacy of a Novel Walker on Gait Parameters and Energy Expenditure in Children with Spastic Diplegic Cerebral Palsy

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ABSTRACT

Background: A walker is an assistive device used to provide stability and relieve full or partial weight bearing on a lower extremity. These are frequently prescribed to children with Cerebral Palsy (CP) to provide additional stability during ambulation. Traditionally, anterior and posterior walkers have been used as walking aids but the information about the use of these walkers in terms of gait and energy consumption is lacking.

Aim: The purpose of this study is to compare the efficacy of a novel walker with the traditional posterior walker in terms of gait parameters and energy expenditure in subjects with spastic diplegic CP.

Methods: A novel walker consists of two rigid square frames attached with four wheels and a handle with height adjustment features is constructed. A seat is attached to the upper square frame for sitting provision and reducing fatigue. 30 spastic diplegic CP children (mean age: 6.6 ±1.4 years) with poor trunk control were subjected to a 10-meter walk test for measuring gait parameters (step length, stride length, velocity, cadence, and walking width) and energy expenditure in the form of physiological cost index. The post-test comparison was performed between both walkers and the data was analyzed through an Independent Students t-test with a significance level (α) set at 0.05.

Results: The subjects walked with significantly higher velocity (18%) and improved PCI (58%) using a novel walker compared to the posterior walker ($p<0.05$). However, other temporal-spatial gait parameters did not show any statistical difference ($p>0.05$), although these were improved with the use of novel walker compared to the posterior walker.

Conclusion: The novel walker improves the gait parameters and energy expenditure, and therefore, its use may be encouraged as an adjunct to physical and orthotic therapy in subjects with spastic diplegic CP.

Keywords: Cerebral palsy; efficacy; energy; gait; novel; posterior; walker

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INTRODUCTION

Cerebral palsy (CP) is primarily a disorder of movement and posture. It is a group of non-progressive, but often changing, motor impairment syndromes secondary to lesions or anomalies of the brain arising in the early stages of its development [1]. It is referred to as a static encephalopathy because, despite the constant primary lesion, the clinical pattern of presentation may change over time due to growth and developmental spasticity, and central nervous system maturation [2]. Spasticity primarily impairs voluntary movements but can occasionally be beneficial for weight bearing or support. Extensor tone in the limbs aids in standing and maintains muscle bulk and bone density [3]. Most of the children with CP have difficulty while walking independently because of impaired postural control, abnormal muscle tone and pathological muscular coordination [4]. Different types of walking aids and assistive devices are often prescribed for assisting and providing the stability necessary for ambulation. Assisted walking may not only improve the growing child mobility but also make a difference in their ability to explore the environment and interact with their peers [5]. However, extremely high heart rates and slow walking speed were recorded in the children with CP during ambulation with walking aids [6].

Walkers are frequently prescribed to children with CP to provide additional stability required for ambulation. Traditionally, an anterior walker has been used as a walking aid. However, a child using an anterior walker tends to lean forward while pushing the walker. The Posterior Walker is sparely used and it is designed to be positioned behind the child because it facilitates a more upright posture [6]. However, it can also be very difficult to collapse and adjust. In the past, studies have been conducted on the comparison of the anterior walker and posterior walkers. Most of the studies have focused on gait analysis, energy consumption, and kinetics and kinematics of the upper extremity in children with spastic diplegic cerebral palsy, however, the information about the use of these walkers is heterogeneous and controversial [7,8]. In systematic reviews, researchers have compared the use of anterior and posterior walkers by children with cerebral palsy to determine which type of walker is preferable. *Poole et al. (2017)* has studied the outcomes including velocity, pelvic tilt, hip flexion, knee flexion, step length, stride length, cadence, double stance time, oxygen cost and participant/parental preference and found heterogeneity and low quality of existing evidence that prevented the recommendation of one walker type [7]. *Tao et al. (2020)* in another review found similar gait parameters and upper extremity functions in both types of walkers, but they concluded that the posterior walker was preferable due to its relatively low oxygen cost [8]. Furthermore, there have been conflicting results in the literature regarding gait parameters and energy expenditure between anterior and posterior walkers. The novel approach of designing walkers for maintaining an upright posture, reducing energy expenditure, and improving gait parameters in people with cerebral palsy has not been thoroughly investigated. An attempt was made in this study to design and develop a novel walker to address issues of height provision, assist the user in walking with proper posture, and improve biomechanical efficiency. Therefore, this study intends to establish the biomechanical efficacy of the novel walker and compare it with the standard posterior walker. This research will help to plan appropriate

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ambulatory devices for CP children, reducing energy expenditure and improving gait parameters.

MATERIALS AND METHODS

2.1 Subject characteristics

- Sample size: Thirty subjects with spastic diplegic CP with age range 4-10 years
- Inclusion criteria: The subjects with poor trunk control with good hand grip power. They were able to understand the command and able to walk independently with a walker. None had undergone orthopaedic or neurosurgical intervention before being enrolled in this study.
- Exclusion criteria: The subjects with poor neck and sitting balance or with profound developmental retardation, multiple disabilities and COVID positive test findings during screening were excluded.
- Ethical approval and Consent: The study was approved by the Institutional Ethics Board of SVNIRTAR, DA/MPO/08/2019 on March 03, 2020. All patients signed an informed consent form and were informed about the purpose of the study with their parents. The CTRI registry number is CTRI/2022/01/039642.

2.2 Description of Walkers

Basically, the posterior walker is designed to be used by individuals who can fully support their own weight and are able to take steps. Posterior walker design neglects the rapid growth and typical activities of young children. In contrast, the novel walker designed and developed in this study has taken the basic functional requirements of children with spastic diplegic CP into consideration. This has been a modified approach ensuring the advantages of different variants of walkers available in the global market. The features of the walkers used for comparison in this study are elaborated below.

Fig. 1 Walkers used (a) Posterior and (b) Novel in the study

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Posterior Walker	Novel Walker
• It is positioned behind the child allowing an upright position. • It has four wheels, two handles, and wraps around the back of the user to ensure proper posture (Fig. 1a). • It has no provision for height adjustment. Its height is 23 inches.	• It is designed to be used with a square frame outside the patient trunk. • It consists of two square frames and four wheel attached to the corners for increasing the base of support, with a handle. • The height adjustment facility with telescopic bars is available that can adjusted to match the measurement of the patient (i.e. greater trochanter to floor). • There are 3 vertical bars out of which two are proximally connected with smaller square frame and distally connected with the base square frame. The front vertical bar is proximally attached to handle and distally attached to the base square frame (Fig. 1b). • A seat is attached to the upper smaller square frame for provide sitting facility and reduce fatigue during ambulation. • The seat height can be adjusted from 16 to 22 inches and the handle height can be raised from 22 to 26 inches.

2.3 Study tools and Parameters

A 10-meter walk test [9] was used for measuring gait parameters. The energy expenditure was measured by using Physiological Cost Index (PCI) by using an oxymeter. Parameters such as step length, stride length, velocity, cadence, width of walking base were measured by using stop watch and measuring tape.

2.4 Study procedure

Following the initial screening, assessment, and evaluation, demographic data such as age, gender, height, and weight were collected. The patients were divided into two groups at random. Group A (n=15) subjects were tested with the posterior walker, while Group B (n=15) subjects were tested with the novel walker. The posterior walker was prefabricated whereas the novel walker was height adjusted to the subject's needs. The handle height was positioned at elbow 15 degree flexion for the individual subject. The training on their use during gait was provided for one month prior to the evaluation so that they were familiar with both types of walkers. The subjects were told to walk on a 10-meter walk test paper using a modified walker or a posterior walker (Fig. 2). An oxymeter was used to measure energy expenditure before and after each experiment. A stop watch and measuring tape were also used to measure step length, stride length, velocity, cadence, and the width of the walking base. The standard COVID protocol was maintained during data collection.

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2.5. Data analysis and statistics

All data were managed in a Microsoft Excel spread sheet. The statistical analyses were conducted using SPSS v. 21.0 (SPSS Inc, Chicago, Illinios). Independent student t-test was performed to analyze the difference between posterior and novel walker. The tests were applied at 95% confidence interval and a *p*-value less than or equal to 0.05 was considered statistically significant.

Fig. 2 Performance of subjects using (a) Posterior and (b) Novel Walkers in 10-meter walk test

RESULTS

The demographic data of included subjects is presented in Table 1. There were 70% boys and 30% girls. There was no significant difference between group A and B for all demographic parameters.

Study Group	Number	Age (year)	Height (cm)	Weight (kg)	BMI (kg/m2)
A	15 (Boys = 12, Girls = 03)	6.6 ± 1.4	117.9 ± 3.7	21.2 ± 3.5	15.3 ± 1.7
B	15 (Boys = 10, Girls = 05)	6.8 ± 1.7	116.8 ± 3.5	20.1 ± 3.6	14.7 ± 1.5

Table 1 Demographic information of subjects

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The results of gait parameters and energy expenditure are presented in Table 2. It show that the mean values of step length, stride length, cadence and velocity is more whereas width of walking base and PCI is less in novel walker than that with posterior walker. However, the results show significant improvement only in terms of velocity and PCI with novel walker ($p<0.05$).

The reduction in walking base and PCI indicate improved gait efficiency. It was observed that the subject walked with 18% higher velocity using novel walker compared to posterior walker and the PCI value indicates that novel walker is 58% more energy efficient compared to posterior walker. However, other parameter like step length, stride length, cadence and velocity did not show any statistical difference between novel walker and posterior walker ($p>0.05$).

Parameters	**Posterior Walker**	**Novel Walker**	**P value**
Step Length (cm)	21.2±2.7	22.8±2.8	p>0.05
Stride Length (cm)	43.0±5.2	45.4±5.1	p>0.05
Cadence (steps/min)	63.8±6.8	68.2±7.6	p>0.05
Velocity (m/min)	7.3±1.7	8.7±1.6	p<0.05
Walking Width (cm)	15.1±2.4	13.2±1.8	p>0.05
PCI (beats/min)	2.48±0.54	1.03±0.32	p<0.05

Table 2 Comparison of Results between Posterior and Novel walker

DISCUSSION

This study intended to compare the effect of the novel walker and posterior walker use on gait parameters and energy expenditure in subjects with spastic diplegic cerebral palsy. Their upper extremities were good functionally and the grade of spasticity in their upper extremities was less than grade 1+ on the modified Ashworth scale. To avoid the learning effect, the children were familiarized with both types of walkers for a period of 1 month. To satisfy the objective, the comparison was made between group A and B with regard to temporal-spatial parameters (step length, - stride length, cadence, velocity, and width of walking base) and energy expenditure measured by PCI. The link between gait parameters and energetic cost shows how variations in step length, cadence, step width, and step variability affect the mechanical work and metabolic cost involved in gait.

The results of our study indicate that the gait parameters such as step length, stride length, cadence, and velocity with a novel walker (22.8±2.8; 45.4±5.1; 68.2±7.6 and 8.7±1.6) are higher than posterior walker (21.2±2.7; 43.0±5.2; 63.8±6.8 and 7.3±1.7) showing improvement. However, except velocity ($p<0.05$), the other gait parameters did not show any statistical significance ($p>0.05$) between both groups. The width of the walking base and PCI were decreased with the use of a novel walker (13.2±1.8; and 1.03±0.32) compared to a posterior walker (15.1±2.4; and 2.48±0.54) that indicate improved energy efficiency. An earlier study has reported differences in gait parameters between different variants of a walker. However, there have been inconsistencies in previous reports. *Levangie et al. (1990) and Logan et al. (1989)* showed higher step lengths using a posterior walker compared to the anterior walker ($p<0.05$) [10, 11]. *Chandra Kumar et al. (2019)* showed higher stride length while walking with a posterior walker than the anterior walker ($p<0.05$) [3]. In contrast, the research work performed by *Greiner et al. (1993)* showed no significant difference in step length between the two variants of the walker ($p>0.05$) [12]. *Poole et al. (2017)* observed no significant difference in cadence between the two variants of the walker ($p>0.05$) [7]. In contrast, *Baker et al. (2008)* reported increased steps with the use of an anterior walker ($p<0.05$) [13]. Concerning velocity, the study conducted by *Logan et al. (1990), Strifling et al. (2008), and Konop et al. (2009)* resulted in lower velocity by using a posterior walker [10, 14, 15], however, *Mattsson and Andersson (1997)* and *Poole et al. (2017)* found that the posterior walker was faster than the anterior walker [4, 7]. In contrast, *Park et al. (2001)* and *Chandra Kumar et al. (2019)* found no significant difference in velocity by using an anterior walker and posterior walker ($p>0.05$) [3, 6]. In the same study [3], the authors reported a decrease in step width with the use of the posterior walker ($p< 0.05$) and *Park et al (2001)* observed lesser energy consumption with the posterior walker compared to the anterior walker ($p<0.05$) [6]. In similar reports, the authors employed the heart rate method to calculate the energy expenditure index and found that posterior walker users consumed less energy [14, 15]. However, only one study using perceived exertion obtained a higher energy cost in posterior walker users [4]. These evidence-based narratives synthesized reports indicate the controversial results between different variants of walker use in terms of gait and energy analysis in subjects with CP.

It was observed that the CP subjects acquired a more upright posture with better trunk alignment with the use of the novel walker. The increased step and stride length with the use of a novel walker could be because the usage of a novel walker leads to the position of the center of mass falling inside the base of support. This may cause co-contraction of trunk and knee muscles as well as activation of hip extensors, resulting in a better hip-knee angle and correct foot contact. As gait parameters increase, causing the locomotion approaches normal and the child uses less energy while walking. *Mockford and Caulton* [16] addressed how increasing stride length may imply improve walking stability in children with CP. *Logan et al.* [10] corroborate this hypothesis and discovered a considerable increase in stride length with the posterior walker and a significant decrease in double stance time indicating improved stability. It is important to remember that ambulation with walking aids must be integrated into daily life. Reduced energy expenditure is desirable to encourage the walker to use for longer durations. As a result, while selecting a walking aid, energy conservation is critical. Since one of the goals of intervention for children with CP is their capacity to walk, the use of a walker can help these non-ambulant subjects with impairments to take their first steps toward independence and improve their mobility, autonomy, involvement, and social function.

Some of the major limitations of the study include the use of non-instrumental gait analysis which could have provided more insight into the kinematic and kinetic analysis and comparison between novel and posterior used by the authors. Secondly, the acclimatization time for both walkers was one month, which can be considered less time for CP subjects. Lastly, the comparison of gender specific differences for temporal-spatial gait parameters was not undertaken in this study. Therefore, future studies are indicated to check the long-term efficacy with a large number of samples to generalize the findings.

CONCLUSION

The novel walker improved the gait parameters and energy expenditure compared to the posterior walker in subjects with spastic diplegic cerebral palsy. The subjects using the novel walker acquired more upright posture with better trunk alignment. The use of novel walker encourages involvement and improved the physical activity of users with parental satisfaction. Therefore, the use of this novel walker should be encouraged as a part of rehabilitation with physical and orthotic therapy in subjects with cerebral palsy.

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Declarations

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Conflict of interests

The authors declare that there is no conflict of interest.

Ethics approval

This research followed guidelines of the Declaration of Helsinki and was approved by the Institutional Review Board of Swami Vivekanand National Institute of Rehabilitation Training and Research (SVNIRTAR), India.

Consent to participate

The well-informed written consent was obtained from the individuals or their parents prior to their participation in this study.

Written Consent for publication

Not applicable.

Availability of data and material

The authors declare that they have written entirely original work, and if the authors have used the work and/or words of others, then this has been appropriately cited or quoted. All data and materials will be furnished upon request.

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