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Effect of Ankle Foot Orthosis (AFO) on kinematics in Children with Cerebral Palsy (CP)

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Abstract

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Conclusion: FRAFO is more effective than SAFO.

Keywords: Cerebral palsy (CP), Solid ankle foot orthosis, Kinematics, Swing, Stance, SAFO, Children

Authors:

Tayyaba Pervaiz: (Corresponding author)

MS Scholar, Rehabilitation Sciences (Orthotics & Prosthetics) -Superior University Lahore, Punjab, Pakistan.

(Email: tayyabap336@gmail.com)

Saad Saleem: Senior Lecturer, Superior University Lahore, Punjab, Pakistan.

Laraib: MS Scholar, Rehabilitation Sciences (Orthotics & Prosthetics) -Superior University Lahore/ Central Incharge- Accessibility beyond limitations, Pakistan.

Sana Pervaiz: PhD Scholar, Government College University Faisalabad, Punjab, Pakistan.

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Authors:

Tayyaba Pervaiz: (Corresponding author)

MS Scholar, Rehabilitation Sciences (Orthotics & Prosthetics) -Superior University Lahore, Punjab, Pakistan.

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Introduction

Spastic cerebral palsy is a widespread condition encountered in all societies. Approximately 12,000 are bothered by this Condition every 12 months. The majority of children with cerebral palsy have the spastic physiologic condition. Approximately 85% of these kids wore an orthosis. The most usual orthosis used in spastic cerebral palsy is the ankle foot orthosis (AFO),

which is available in a variety of designs. (Lucareli et al., [2007](#))

Children with cerebral palsy (CP) frequently wear ankle-foot orthoses (AFOs), however, conventional solutions cannot handle the diversity and changing needs of CP patients. (Novak et al., [2017](#))

A chronic condition caused by a variety of prenatal and postnatal circumstances, cerebral palsy (CP) affects posture, and mobility, and the results harm to a



developing mind. Poor motor control is frequently the result of this type of neurological injury. The symptoms of cerebral palsy (CP) include stiffness, sensory loss, and muscle weakness. These neuro-musculoskeletal problems impact walking ability, balance, and upright posture. As a result, such children's total gait performance is less than that of typical children, which makes it difficult for them to execute daily tasks. (Kim & Son, [2014](#))

Children who have cerebral palsy (CP) exhibit poor postural control, which leads to unstable walking and performance. A very common sign of inadequate postural control in kids with cerebral palsy is the crouching pattern. This function is caused by insufficient plantar flexion/knee extension and manifests as increased knee and hip flexion and ankle dorsiflexion. Children who adopt the crouching position may also experience prolonged muscle weakness and a decrease in postural control. By altering the floor response pressure (GRF) in the sagittal plane, a floor reaction ankle foot orthosis (FRAFO) will promote external knee extension. With CP, it might also restrict ankle dorsiflexion.

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An ankle-foot orthosis is prescribed for spastic CP patients. Common designs which might be prescribed for spastic CP patients who walk with excessive knee flexion all through the stance are SAFO (solid ankle foot orthosis) and FRAFO (floor response ankle foot orthosis). (Morris et al., [2011](#)), (Kerkum et al., [2013](#)), (Kerkum et al., [2015](#)) The function and mechanism of both designs is that they manipulate the position of the foot which does not directly help the knee joint and hip joint. (Arellano-Martínez, et al [2013](#)) (Majewska et al., [2017](#)) Furthermore, floor reaction orthosis has an anterior overlaying simply below the knee joint and the principle of ground reaction is a planter flexion knee extension mechanism that creates knee extension

movement in stance via transferring floor reaction force anterior to the knee by its planter flexed position at the ankle. Floor reaction orthosis reduces knee flexion at mid-stance because of planter flexion knee extension coupling.

The lower limb movements at a certain time in gait can be quantitatively described using the existing three-dimensional gait evaluation approaches. The biomechanics of normal human gait are thus better understood, which makes it possible to more accurately identify the issues and, as a result, conduct objective research on them. Because one of the goals of treatment for CP is to improve the gait cycle of those children, this analysis has been crucial in both evaluating the results of treatments and making decisions about medical treatment.

Children's gait improvement and capacity issues are frequently evaluated using spatiotemporal characteristics. In addition to assessing abnormal gait variables, the examination of those characteristics evaluates post-surgical development or conservative treatment. However, it has to be found to make evidence-based judgments on the treatment of individuals with gait abnormalities. (Kim & Son, [2014](#)).

Nowadays, symmetry is a crucial gait feature that is regularly studied and reported, particularly in hemiplegic patients and single-leg amputees, in which one limb is primarily afflicted. However, asymmetrical lower limb behavior is not limited to hemiplegics; healthy individuals can also exhibit it. Gait asymmetry is important from a clinical standpoint since it may be linked to certain adverse consequences. (Bahramizadeh et al., [2011](#)).

Spastic hemiparesis affects the intermediate postural section "swing" that is manifested in posture, balance, and gait with decreased speed and stride period and benefits an extra contact of the foot with the floor. In hemiplegic sufferers, the involved limb stance is reduced to everyday step length, and the stride additionally differs from normal. (Majewska et al., [2017](#)).

The study's primary goals were to assess the efficacy of solid ankle foot orthoses and floor reaction orthoses on CP patients and to examine the gait of CP patients by monitoring temporospatial metrics with these orthoses.

Material and Methods

Over six months, the quasi-experimental investigation was carried out at the Gait Lab at PIPOS, Peshawar. Using non-probability convenient sampling, 15 patients

with mild spastic hemiplegia, ages 6 to 10, were chosen. Patients with modest spasticity (Ashworth Scale I, +1), the capacity to walk on their own and adhere to directions, and a history of using orthoses for longer than three months were all required for inclusion. Individuals with a history of trauma or comorbidities were not included.

A 10-meter pathway was used for 2D digital gait analysis data collecting. The patients completed three walking tasks: one with a floor reaction ankle foot orthosis (FRAFO), one without an orthosis, and one with a solid ankle foot orthosis (SAFO). Cameras and a stopwatch were used to monitor stride length, step length, cadence, stride time, and walking speed, while spherical markers were positioned at anatomical landmarks. Standard methods based on the foot traffic count method were used to derive temporal characteristics.

After the collection of data through this method temporal parameter was calculated by using the following standard formulas.

The time it took a person to walk a predetermined distance was recorded to calculate speed:

$$\text{Walking Speed } \left(\frac{m}{s}\right) = \frac{\text{Distance}(m)}{\text{Time}(s)}$$

Using a stopwatch, cadence was calculated by counting how many steps a subject took in a predetermined amount of time:

$$\text{Cadence } \left(\frac{\text{footfalls}}{\text{min}}\right) = \frac{\text{Footfalls counter} \times 60(s)}{\text{time}(s)}$$

Partial footfalls are not taken as factors in this method, which uses an integer value for the number of footfalls taken.

Stride time was measured with stride length measured by walking speed calculated:

$$\text{Stride Time } (s) = \frac{\text{Stride length } (m)}{\text{Walking speed } \left(\frac{m}{s}\right)}$$

To identify any significant changes between walking with and without orthoses, repeated measures ANOVA was used in SPSS, and descriptive statistics were created using Microsoft Excel. The significant level considered was $\alpha = 0.05$.

Results & Analysis

Table I

Outcome measures compared with normal

| Spatiotemporal parameter | Normal | Without AFO | With Solid AFO | With FRAFO | Deviation from normal | Improvement with Solid AFO | Improvement with FRAFO |
|--------------------------|---------------|---------------|----------------|---------------|-----------------------|----------------------------|------------------------|
| | | (Avg) | (Avg) | (Avg) | % | % | % |
| Cadence | 120 steps/min | 108 steps/min | 106 steps/min | 113 steps/min | 10 | - 1.86 | 4.62 |
| Velocity | 1.4 m/s | 0.95 m/s | 0.9 m/s | 1.1 m/s | 3.14 | 5.2 | 15 |
| Stride time | 1.42 sec | 1.4 sec | 1.5 sec | 1.28 sec | 1.4 | 6.6 | 8.5 |
| Stride length | 1.41 meter(m) | 1.41 meter(m) | 1.41 meter(m) | 1.41 meter(m) | 0 | 0 | 0 |
| Step length | 0.71 meter(m) | 0.71 meter(m) | 0.71 meter(m) | 0.71 meter(m) | 0 | 0 | 0 |
| Stance phase | 60 % | 63 | 65 | 56 | 5 | 3.17 | - 11.1 |
| Swing phase | 40 % | 37 | 35 | 44 | 7.5 | - 8.1 | 18.91 |

The gait metrics of patients walking barefoot, with SAFO, and with FRAFO are compared to normal values in the table. The % improvements with SAFO and FRAFO were computed after the percentage departures from normal for barefoot walking. The

results indicate that SAFO significantly improves the situation, whereas FRAFO improves it much more.

Separate graphs of some parameters are explained below;

Figure 1
CADENCE

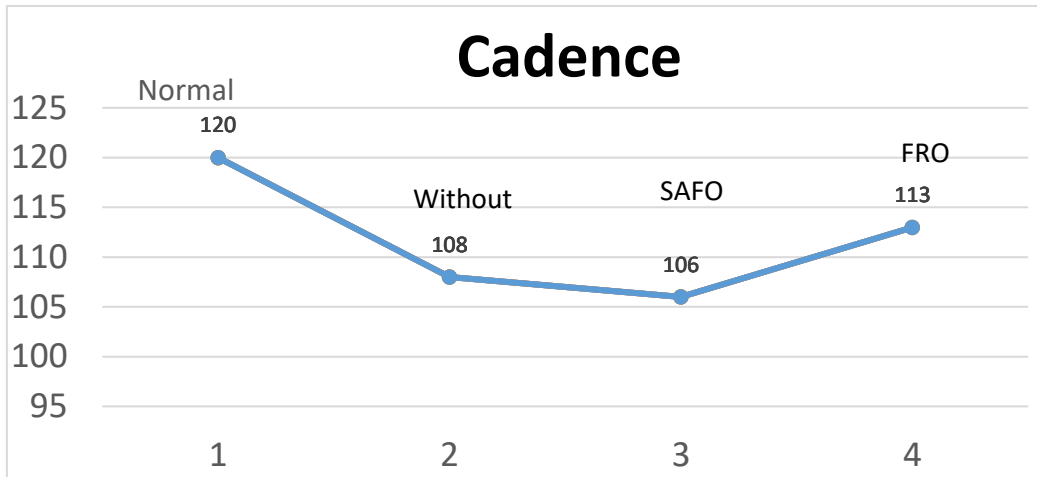


Figure 2
VELOCITY

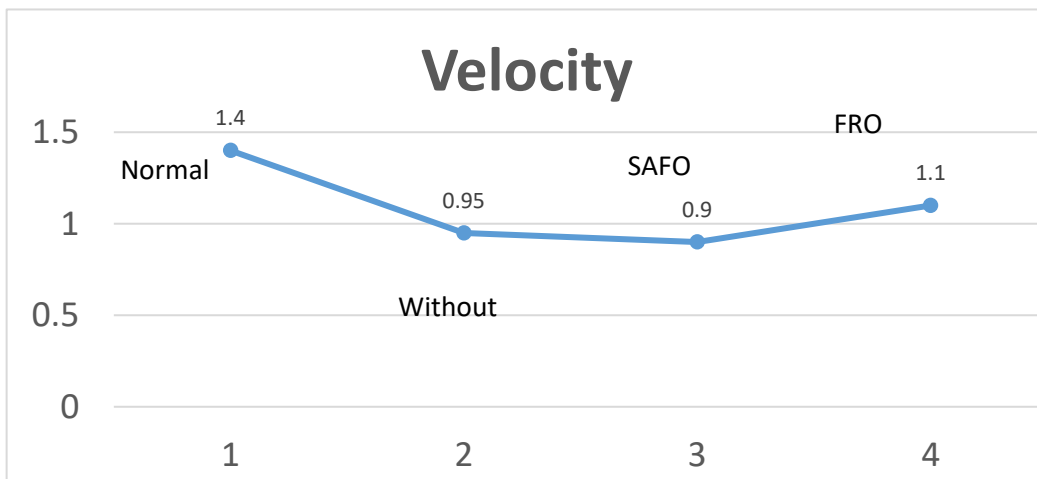


Figure 3
STRIDE TIME

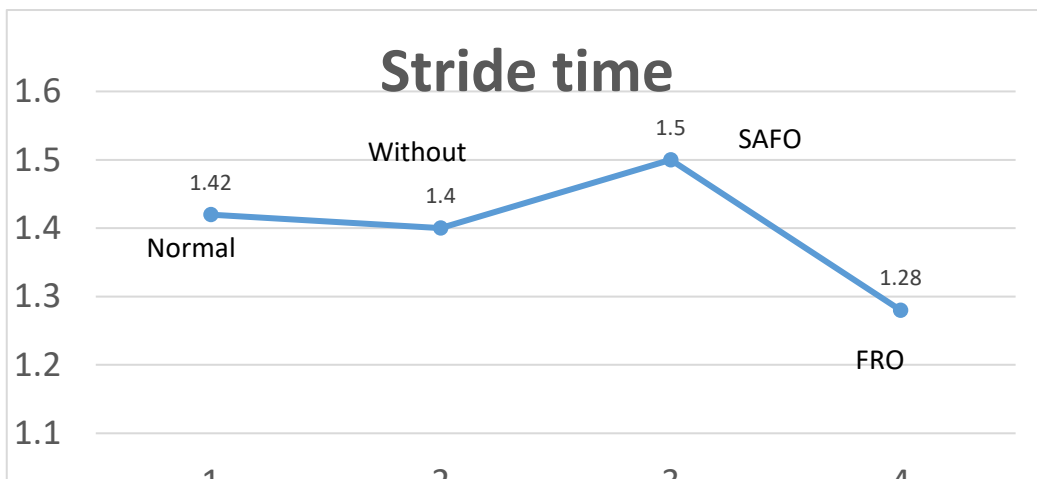


Figure 4

SWING PHASE

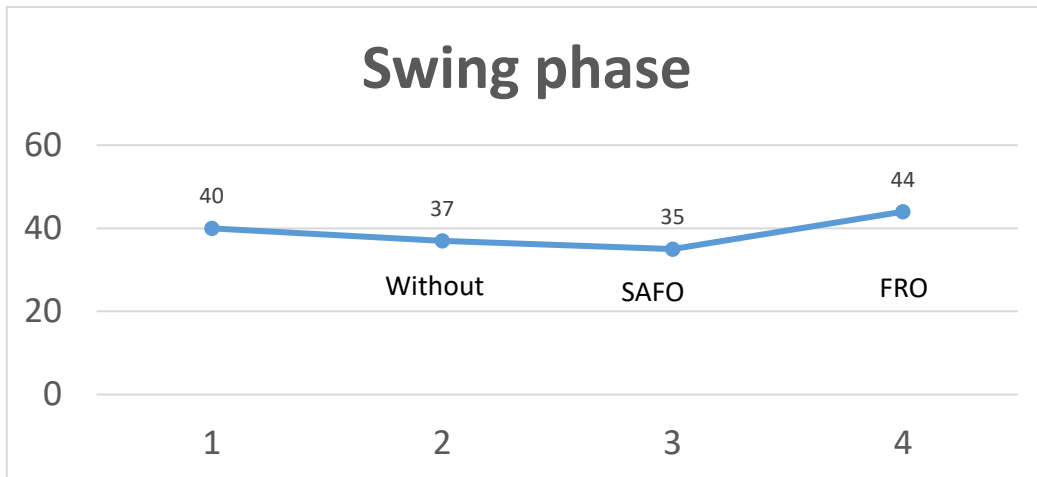


Figure 5

STANCE PHASE

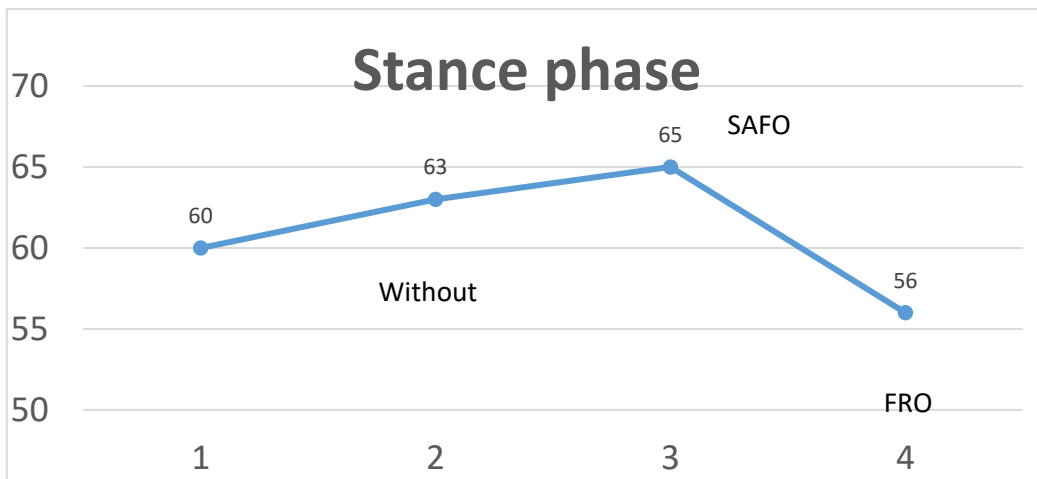


Table 2

Dynamic data sagittal plane (HIP)

| | Normal Values | Hip (Flex+ /Ext-) Without Orthosis | Hip (Flex+ /Ext-) With SAFO | Hip (Flex+ /Ext-) With FRAFO |
|------------------|---------------|------------------------------------|-----------------------------|------------------------------|
| Initial Contact | 20 | 23.12 | 36.03 | 26.74 |
| Loading Response | 20 | 24.6 | 34.66 | 24.56 |
| Mid Stance | 0 | 7.94 | 8.77 | -4.46 |
| Terminal Stance | -20 | -2.22 | -9.8 | -14.71 |
| Pre-Swing | -10 | 4.13 | -4.05 | -10.71 |

The above table illustrates the mean values of hip angles compared with normal angles. The positive sign

shows flexion of the hip and the negative sign shows the extension of the hip.

Table 3*Dynamic data Sagittal plane knee*

| | Normal Values | Knee (Flex+ /Ext-) Without Orthosis | Knee (Flex+ /Ext-) With SAFO | Knee (Flex+ /Ext-) With FRAFO |
|------------------|---------------|-------------------------------------|------------------------------|-------------------------------|
| Initial Contact | 0 | 20.77 | 36.22 | 18.97 |
| Loading Response | 20 | 31.37 | 39.19 | 29.31 |
| Mid Stance | 0 | 18.62 | 17.4 | 8 |
| Terminal Stance | 0 | 24.47 | 8.99 | 1.25 |
| Pre-Swing | 40 | 38.2 | 31.58 | 36.02 |

Normal values of knee angles in the gait cycle (stance phase) at IC, LR, MD, TS, and PS are 0, 20, 0, 0, and 40 respectively. These angles in patients without orthosis are 20.77, 31.37, 18.62, 24.47, and 38.2 which are much higher than normal values. The angle values obtained with SAFO are 36.22, 39.19, 17.4, 8.99 and 31.58. Angle values obtained with FRAFO are 18.97,

29.31, 8, 1.25, and 36.02 these values are better than SAFO values.

The marked reduction in knee angle at mid-stance is achieved with FRAFO (8°) as compared with SAFO (17.4°) and without orthosis (18.62°) which brings the patient toward stability.

The test results are illustrated below.

Figure 6

| ANOVA | | | | | | |
|-----------|----------------|----------------|----|-------------|--------|------|
| | | Sum of Squares | df | Mean Square | F | Sig. |
| With FRO | Between Groups | 11016.660 | 4 | 2754.165 | 76.238 | .013 |
| | Within Groups | 72.252 | 2 | 36.126 | | |
| | Total | 11088.912 | 6 | | | |
| With SAFO | Between Groups | 9910.649 | 4 | 2477.662 | 11.006 | .085 |
| | Within Groups | 450.252 | 2 | 225.126 | | |
| | Total | 10360.901 | 6 | | | |

Discussion

The purpose of this study was to assess how children with hemiplegic cerebral palsy (CP) responded to floor reaction ankle foot orthoses (FRAFO) and solid ankle foot orthoses (SAFO) in terms of temporospatial gait metrics. The main conclusions showed that both orthoses greatly enhanced phase distribution (stance and swing phases), cadence, velocity, and stride time. Particularly, FRAFO outperformed SAFO in terms of improvement, demonstrating its higher efficacy in improving gait dynamics.

Many aspects of movement in kids with cerebral palsy have been examined in earlier research

investigations. In order to compare the sagittal kinematics of the affected limb with the less affected limb, Choi and collaborators investigated barefoot walking in children with hemiplegic cerebral palsy on various slopes. They came to the conclusion that the adaption patterns of affected and less affected limbs differed.

Our research confirmed that FRAFO improved cadence by 4.62%, bringing it towards the standard cadence of 120 steps in keeping per minute. This is consistent with the findings of Bahramizadeh et al., who observed that changed FRAFO notably progressed cadence, stride period, and velocity in children with cerebral palsy. Following prolonged usage of FRAFO, Bahramizadeh has a look at additionally located an improvement in knee joint variety of motion (ROM)

and a decrease in ankle ROM, indicating that FRAFO successfully tackles critical biomechanical restrictions in CP patients. These findings are supported by using our statistics, which showed that cadence extended from 108 steps per minute without orthosis to 113 steps per minute with FRAFO. Another essential measure, velocity, increased by 15% with FRAFO to at least one.1 m/s, which is close to the standard value of 1.5 m/s. This improvement is consistent with research by Pauk et al., who found that CP sufferers who used AFOs had a higher velocity than individuals who did not. Our studies support the belief that FRAFO improves dynamic manipulation and propulsion during gait, increasing on-foot speed in children with hemiplegic cerebral.

FRAFO has also proven an improvement in stride time, stance phase, and swing phase. While stance and swing phases increased by way of 7.1% and 13%, respectively, stride time increased by 85%. These findings are consistent with those of Harrington et al., who determined that anterior FRAFO progressed normal gait balance by using foot velocity, step duration, and single assist length. Additionally, Romes' 2006 has a look at backs using AFOs, mainly FRAFO, to improve hip and knee flexion angles. Notwithstanding those encouraging results, the modern-day study has boundaries. The consequences' generalizability is restrained by the small sample size of 15 members. Furthermore, because the trial lasted six months, it may not have fully captured the long-time period impacts of orthotic treatment. To assess the lengthy-term advantages of SAFO and FRAFO, future studies must focus on larger sample sizes and longer observe-ups. Furthermore, investigating the consequences of

extra gait metrics including joint kinematics and energy expenditure may additionally provide a greater thorough comprehension of these orthoses' efficacy.

Conclusion

In conclusion, orthosis had a substantial influence on the temporospatial and kinematic gait parameters in children with cerebral palsy. The findings of our study revealed that the orthotic intervention had a positive impact on not only temporospatial aspects but also on joint kinematics. This as a result led to better gait stability for the patients and allowed them to walk better.

In the end, orthosis had an extensive impact on the temporospatial and kinematic gait parameters in children with cerebral palsy. The findings have revealed that the orthotic intervention had an effective effect on not only temporospatial factors but also on joint kinematics. This as a result brought about increased gait balance for the sufferers and allowed them to walk better. Based on the outcomes of our research one of the main characteristics has been concluded. First of all, a significantly greater difference was noticed in patients with and without AFO so orthotics contributed towards an effective outcome. Final results become noticed with FRAFO compared to Solid ankle AFO primarily based on each temporospatial and kinematics measure. The difference among stance and swing phase, hip flexion at the terminal swing, and knee flexion at the midstance also tested big final results with the application of orthotics and comparatively higher with FRAFO.

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