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Original Research Article

The effect of hinged supracondylar knee ankle foot orthosis on gait parameters in children with spastic cerebral palsy having knee hyperextension and ankle equinus

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ABSTRACT

Background: In cerebral palsy, importance must be given on effective and efficient walking. 30 subjects; 16 males and 14 females (mean age 6.5 year) of spastic cerebral palsy with knee hyperextension and ankle equines were included in this study and were fitted with bilateral moldedhinged SKAFO with pair of shoes.
Methods: Observational gait analysis by video recording was performed and gait parameters by 10 m walk test and knee angle at mid stance using goniometer in standing position were recorded in bracing and non-bracing conditions.
Results: The orthosis controlled knee hyperextension by not restricting normal flexion and extension moment with smooth transition of ankle motion. There was significant improvement in step length; stride length as well as knee angle at midstance (with orthosis) but velocity and cadence were reduced as compared to bare foot walking.
Conclusions: A stable, natural and controlled knee hyperextension gait pattern was found.

Keywords: Cerebral palsy, Hyperextension, spastic, Supracondylar, Hinged SKAFO

INTRODUCTION

In spasticity, there is increased muscle tone which results in stiff muscles which can make movement difficult including gait. There are 4 common gait abnormalities of the knee in cerebral palsy such as crouch knee, jump knee, stiff knee, and recurvatum knee.[1] Knee hyperextension in mid-stance of the gait cycle is a common disorder of the knee function in children with spastic cerebral palsy (CP) which is described by Simon and Becher.[2,3] Ankle equinusis also most common which cause the line of action of the ground reaction force to pass well in front of the knee and hip joints, causing an excessive external knee extension moment, and a flexion moment around the hip.[4] The causes of genu recurvatum described in the literature are triceps surae spasticity or weakness, contracture of tendo Achilles, quadriceps spasticity, anterior lean of the trunk, bony deformities of the proximal tibia, ligament or capsular laxity at the knee, weakness of hamstrings, or distal lengthening of the hamstrings.[2,5-7] Energy consumption is increased due to interruption of the smooth transfer of potential energy to kinetic energy in genu recurvatum.[1,8] There are two different groups of the knee recurvatumi. Early recurvatum and late recurvatum based on the results of kinematic analysis of children with CP.[2] In early recurvatum, recurvation occurred within the first half of the stance phase and the late recurvatum occurred in the second half of stance phase. In order to measure the knee extensor torque, the timing of peak recurvation has been shown to be an important predictor. In one comparison study, it is found that the late stance knee recurvatum patients have significantly lower extensor torque.[9] Early hyperextenders have a relatively tighter soleus than late hyperextenders described by Hullin.[10] Early knee recurvation that is caused by a dynamic equinus deformity, and late knee recurvation is linked to the fixed equinus deformity. Both Rigid AFO and hinged AFO are prescribed in current practice. Middleton found that hinged ankle-foot orthosis is more effective than the rigid ankle foot orthosis with more natural ankle motion during stance phase.[11] Hinged ankle-foot orthosis (hinged AFO) is used to stabilize the foot and ankle which will promote functional gait and assist in dorsiflexion which will reduce spasticity in the triceps surae muscle and stretch the Achilles tendon.[12,13] For mild degrees of genu recurvatum, AFO is indicated to prevent excessive ankle plantar-flexion in stance phase, subsequently controlling knee recurvatum.[14] Hyperextension angle in moderate recurvatum is 5° to 15° and severe recurvatum is more than 15°.[15] However very few studies are available on gait parameters in mild to moderate category of knee hyper extension. But no study was found on quantification of the knee angle at midstance in spastic CP having knee hyperextension in our knowledge. This study was conducted to determine the effect of hinged SKAFO on gait parameters, and knee angle at mid stance compared to barefoot walking in children with spastic Cerebral palsy.

METHODS

Thirty individuals of (mean age 6.5 years) diagnosed as spastic diplegic cerebral palsy having knee hyperextension with ankle equines during mid-stance in SVNIRTAR hospital from Dec-2016 to Dec-2018were studied to check the effectiveness of SKAFO with oklahoma ankle joints. A pre-post experimental study was done to analyze the result. All individuals showed delayed developmental milestones and were selected as per modified GMFCS I and II criteria. Individuals with previous history of surgery, free from limitations in the range of movement of the ankle, knee or hip were excluded for our study. Modified Ashworth scale (MAS) score two or less and individuals with poor to fair cognitive abilities was set as an inclusion criteria.

Orthosis design

In order to achieve triplanar control and stance phase support with unrestricted ankle motion of affected limb, an orthotic design was proposed, fabricated and fitted to check the effectiveness. Oklahoma ankle joints were added to make it hinged design which facilitates smooth ankle dorsiflexion and stops plantar flexion. Working principle was based on a couple force systems in which one posterior directed force is applied from the superior border of the patella and countered by one anterior directed force from the postero-superior trimline near to popliteal fossa (Figure 1). To achieve the sitting cosmesis, the anterior-superior trim lineis kept just one inch superior to upper edge of patella. Optimum height of posterior calf is kept to apply the counter force and also for interfering in knee flexion while sitting.

Figure 1: Orthosis design.

Parameters and instrumentation

Observational gait analysis (OGA) was done by video recording and a 10 m walk test was performed to measure temporal-spatial gait parameters.[16] A stop watch was used to calculate time for evaluation of velocity and cadence, a standard measuring tape was used to measure the length and a goniometer was used to measure the knee angle.

Procedure

The subjects were explained about the study procedure. The informed consent was obtained from the individual prior to the study participation. The demographic data like age, gender were taken. Baseline data like temporal spatial gait parameters of each patient was taken on the 1st day of reporting. Post data was taken after the immediate fitment of the orthoses. Step length, stride length, cadence, velocity and knee angle at mid stance were assessed by 10 meter walk way test in bracing and non bracing conditions. Average of the three trials was calculated for every parameter.

Statistics

SPSS statistical software version 25 was used for data analysis**.** Statistically the results were analysed using the t-test. Sample paired t-test was used to compare the gait parameters between without orthosis and with orthosis data. The significance level of $p<0.05$ was fixed.

RESULTS

From the observational gait analysis it was found that the orthosis controlled the knee hyper extension with mediolateral stability but allowed normal knee joint flexion and extension with smooth ankle motion from neutral to dorsiflexion. All the patients were fitted with bilateral hinged SKAFO (Figure 2-3).

Figure 2: Study patient.

Figure 3: Patients fitted with bilateral hinged SKAFO.

Table 1: Comparisons of demographic data.

Baseline characteristics	Description
No. of subjects (N)	30
Sex (male/female)	16/14
Age range(years)	4-9 (mean±SD=6.533±1.382)
GMFCS	I, II

Comparisons of demographic data, distribution of mean step length, stride length, cadence, velocity and knee angle at mid-stance were shown in the (Table 1-2). The comparisons of all the means of step length, stride length, cadence, velocity and knee angle at mid-stance shown in (Figure 4-8) respectively. The mean without orthosis step length (mean±SD) was 24.50± 2.20 and the mean with orthosis step length (mean±SD) was 30.13±2.94. There was statistically significant difference between without orthosis step-length and with orthosis step length (p=0.00).The mean without orthosis stride length (mean± SD) was 49.23±5.22 and the mean with orthosis stride length was 55.90±5.56. There was statistically significant difference between without orthosis stride length and with orthosis stride length (p=0.00).The mean without orthosis cadence (mean± SD) was 86.63±10.10 and the mean with orthosis cadence was 61.73±3.64. There was statistically significant difference between without orthosis cadence and with orthosis cadence (p=0.00).The mean without orthosis velocity (mean±SD) was 0.57±0.11 and the mean with orthosis velocity was 0.3107±0.03. There was statistically significant difference between without orthosis velocity and with orthosis velocity (p=0.00).The mean without orthosis knee angle at mid-stance (mean± SD) was 17.80±2.51 and the mean with orthosis knee angle at mid-stance was 2.83±1.28. There was statistically significant difference between without orthosis knee angle and with orthosis knee angle at mid-stance (p=0.00).

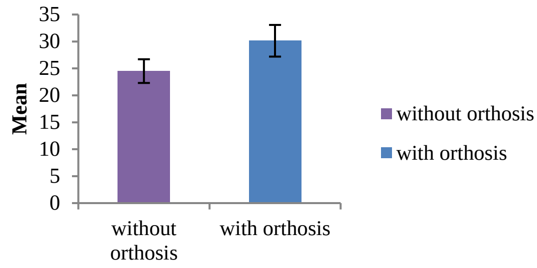

Figure 4: Without orthosis and with orthosis step length.

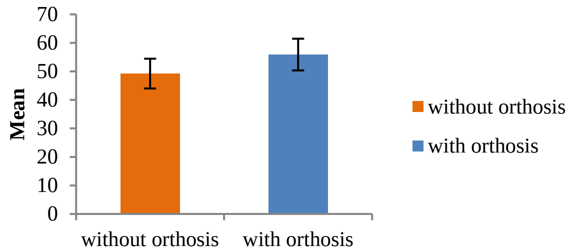

Figure 5: Without orthosis and with orthosis stride length.

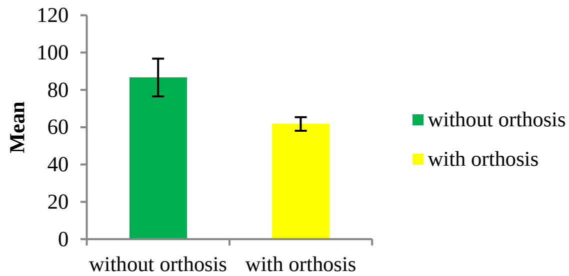

Figure 6: Without orthosis and with orthosis cadence.

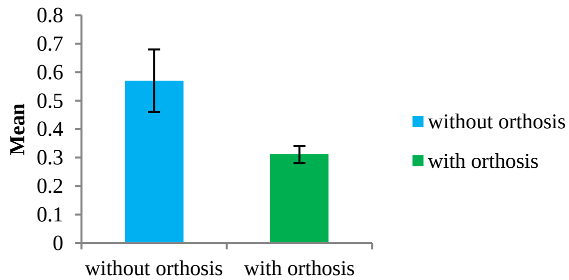

Figure 7: Without orthosis and with orthosis velocity.

DISCUSSION

From the results, it was observed that there was significant difference in mean step length, stride length, cadence, velocity and knee angle at midstance in subjects with bare foot condition (without brace) and with brace as t=-16.06 and p=0.00, t=-18.86 and p=0.00, t=13.74 and p=0.00, t=12.19 and p=0.00, t=31.45 and p=0.00.

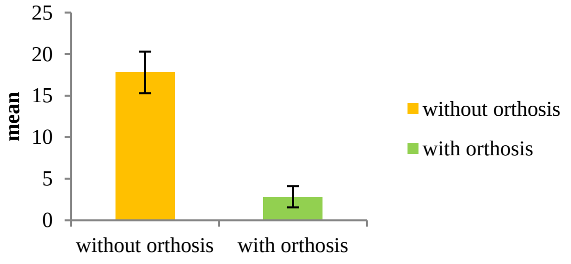

Figure 8: Without orthosis and with orthosis knee angle at midstance.

It was observed that hinged SKAFO was effective in controlling knee hyperextension may be due to the fact that control of excessive hyperextension requires more time for the individuals to bring their limb from hyperextension of knee in mid-stance to flexion required during pre-swing. Rosenthal et al also support the findings of present study which revealed that the genu recurvatum was well controlled and gait was improved by a fixed-ankle below-the-knee orthosis for the management of genu recurvatum in spastic cerebral palsy.[17] The present study also agreed with another study by Buckon et al. which showed that preventing plantar-flexion through the use of orthosis has been found to improve walking efficiency in children with spastic diplegic cerebral palsy.[18,19] Mohanty et al also supports some of the findings of the present study which revealed that genu recurvatum was controlled with improved gait parameters and energy expenditure by a solid SKAFO in which ankle was fixed in neutral position.[20] In a systematic review, Figueiredo et al found that stride and step length and gait velocity did not show any single trend with the use of different designs of AFO which was contradictory to the present findings.[21] The result of the present study also showed that velocity and cadence were markedly reduced and almost found same in every case after using the orthosis. This may be due to the fact that velocity of patients walking with barefoot was increased as they were GMFCS I, II category but the gait was not natural. Some patients were walking with dragging foots and some were walking with excessive heel rise. After using the orthosis the gait was symmetric and found heel to toe gait pattern. Mohanty et al does not support the present findings which showed that there was increased in velocity and cadence with the use of solid SKAFO in which ankle was fixed in neutral position.[20] Figueiredo et al also agreed with the results of present findings which showed that cadence was decreased with different AFO designs when compared with no AFO.[21] It is difficult to generalize the results due to less sample size. As 10 meter walk test was used for the collection of data; always there are chances of errors. As immediate effects of orthosis data were collected, It is not cleared that the deformity will be corrected completely (measuring the knee angle without bracing) after using this orthosis for a particular period of time.

Table 2: Distribution of parameters.

Parameters	Without/with	Total Subject (N)	Mean (N)	SD	T-value	P-value
Step length (cm)	Without orthosis	30	24.50	2.20	-16.06	0.00
	With orthosis	30	30.13	2.94		
Stride length (cm)	Without orthosis	30	49.23	5.22	-18.86	0.00
	With orthosis	30	55.90	5.56		
Cadence (step/min)	Without orthosis	30	86.63	10.10	13.74	0.00
	With orthosis	30	61.73	3.64		
Velocity (m/s)	Without orthosis	30	0.57	0.11	12.19	0.00
	With orthosis	30	0.31	0.03		
Knee angle at mid-stance (degree)	Without orthosis	30	17.80	2.51	31.45	0.00
	With orthosis	30	2.83	1.28		

CONCLUSION

Molded hinged SKAFO showed positive results on gait parameters and knee joint angulation simultaneously controlling gait deviations and abnormal movements in individuals with spastic Cerebral palsy. Therefore, it is recommended that in the future, high quality gait lab studies on similar case seriesto investigate how hinged SKAFO influence the gait ability and knee angle (before and after using the orthosis) in spastic cerebral palsy.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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