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Gait Initiation in a Patient With Spastic Hemiplegia Cerebral Palsy With and Without a Dynamic Ankle Foot Orthosis: A Pilot Study

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국문요약

강직성 편측 뇌성마비 환자의 보행 기시에 미치는 동적 단하지 보조기의 효과: 사전연구

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본 연구는 강직성 편측 뇌성마비 환자의 보행 기시(gait initiation)의 특성을 파악하고, 동적 단하지 보조기(dynamic ankle foot orthosis: DAFO)가 이런 환자들의 보행 기시에 미치는 영향을 알아보기 위하여 실시하였다. 연구대상자는 19세 선천성 강직성 우측 뇌성마비를 가진 여자 대학생이었다. 연구대상자는 4개의 다른 보행 기시 조건에서 각 조건당 7회의 보행 기시를 하였는데, 각각의 보행 기시 조건은: 1) 보조기 없이 좌측 하지로 보행 기시; 2) 우측 하지 보조기 착용 상태에서 좌측하지로 보행 기시; 3) 보조기 없이 우측 하지로 보행 기시; 4) 우측 하지 보조기 착용 상태에서 우측 하지로 보행 기시였다. 두개의 힘 판(force plate) 위에서 본인이 선택한 가장 편안한 방법과 속도로 2 m를 걷도록 하였다. 연구대상자가 보행 기시를 하는 동안 양쪽 가자미근과 앞정강근에 부착된 4개의 표면 전극으로부터 근 전도 신호와 보행 기시를 하는 연구 대상의 양 발 아래 놓인 두개의 힘 판의 자료를 분석하여 체중(body weight: BW)으로 정량화 하였다. 실험결과는 각 조건마다 7회 실시된 측정값들의 평균을 이용하였다. 본 사전연구의 결과는 다음과 같다. 1. 보행 기시 전 양다리로 선 상태에서 환측보다 건측으로 많은 체중지지를 하였으나(환측 42.57%BW, 건측 58.03%BW) 보조기의 착용이 환측으로의 체중지지를 향상시켰다(환측 44.46%BW, 건측 55.54%BW). 2. 보행 기시 중 가자미근과 앞정강근의 동시수축(coactivation)이 계속되었는데 이러한 양상은 보조기의 착용 유무에 따라 크게 달라지지 않았다. 3. 힘 판에서 들어온 지면 반발력(ground reaction force)의 수직 분력(vertical element, Fz)과 전후 분력(anterior-posterior element, Fx)을 분석한 결과, 건측 다리로 보행 기시를 할 때 보조기 착용은 가속을 촉진시켜 역학적으로 유리하였다.

이상의 연구 결과는 보조기의 착용이 건측 다리로 보행 기시를 할 때 미치는 신경학적, 역학적 장점들에 대한 구체적 연구의 필요성 및 근거를 제시하고, 환자들의 보행 훈련 접근에 보다 효율적인 보행방법을 소개하는데 이용될 수 있다.

핵심단어: 뇌성마비; 보행기시; 동적 단하지 보조기.

Introduction

Walking is the most essential function of human being. And difficulty in walking causes significant limitations in daily life. Gait initiation (GI) is defined as the transition from the standing to walking. GI is characterized in the normal population (Brunt et al, 1991; Elble et al, 1994; Nissan and Whittle, 1990). During standing, in normals, the tonic calf muscle contraction maintains steady standing. GI begins with inhibition of tonic soleus (SL) activity followed by tibialis anterior (TA) activation to move the center of gravity forward to initiate a step. Which means contraction of the TA flexes the ankle upward and pulls the shine over the fixed foot. It is believed that the interaction of initial SL inhibition and TA activation is centrally programed.

The details of normal GI is characterized by the center of pressure (COP) moving backward and toward the swing limb and then laterally toward the stance limb. Just before swing occurs there is a quieting of gastroc-soleus activity in the stance limb and simultaneous bilateral activity in the TA. This TA activity is responsible for the posterior movement of COP toward the swing limb. The center of mass (COM) moves anterior and toward the stance limb (Brunt et al, 1991; Brunt et al, 1995; Ellie et al, 1994; Nissan and Whittle, 1990). A weight shift to the stance limb precedes rapid acceleration of the COM. The stance limb controls momentum once the swing limb is unloaded.

Control parameters and limb loading during GI in persons suffering stroke is also documented (Brunt et al, 1991). In stroke patients it was demonstrated that there was decreased loading over the involved limb with resultant decreased forces to generate forward momentum in GI. This appears related to decreased TA activity contributing to the acceleration of the COM. There was also an increase in GI activity of the non-involved limb helping to control forward momentum in preparation for swing heel strike (Brunt et al, 1995).

GI has been studied in young normal children but little is known about GI in spastic cerebral palsy (CP) patients (Breniere, 1989; Ledebt et al, 1998). During GI in children with less than 200 days of independent walking there is an inconsistent progression of the COP backward toward the heels (Breniere, 1989). This may relate to their postural instability or the lack of anticipatory movements related to programming of gait (Ledebt et al, 1998). There is an increase in anticipatory displacements of the COP as the child ages. Accurate tuning of feedforward control has been observed in children between 4 and 6 years old (Breniere, 1989). An immature and inconsistent pattern of GI is observed in young children less than 4 years of age. Development of a mature pattern of GI is dependent on maturation of the nervous system, experience, and practice (Berger et al, 1985).

There have been several articles written concerning gait analysis involving CP patients, however, nothing specific to GI in this population is written (Lee et al, 1992; Skrotzky, 1983). Gait in children with spastic CP has demonstrated a pattern similar to children learning to walk. This pattern is characterized by coactivation of antagonistic muscles during stance and decreased magnitude in gastroc-soleus electromyography (EMG) activity that is poorly modulated and tonic. Large reflex potentials at the beginning of stance with short latencies have also been noted. EMG recordings show no active dorsiflexion during swing by tibialis anterior (Berger, 1998; Berger et al, 1984). Coactivation in young children appears to relate to poor control of equilibrium. It has been observed clinically that persons with cerebral palsy have poor control of equilibrium. In children less than 4 years old, there is a synchronized pattern in the hip, knee, and ankle joints. Disas- sociation of these joints occurs in children 4 years and older. This allows for heel strike, forward placement of the leg at the end of swing phase and a rolling over the foot for propulsion at the end of stance phase. Children with spastic CP do not demonstrate isolated control of lower extremity joints in gait. Lacking is a maturation of spinal mechanisms due to supraspinal center damage in this population.

Braces have been used with the cerebral palsy population in attempts to improve gait parameters and prevent loss of joint motion. There is ambiguous data on the benefits of wearing orthotics. Studies have shown that subjects with spastic CP wearing AFO have improved stride length, decreased cadence, increased velocity, increased percent single-limb support and reduced excessive ankle plantar flexion when compared to no orthosis. No differences in temporal distance gait characteristics, joint motions, muscle timing, or effects on proximal joint alignment were noted in these studies (Abel et al, 1998; Radtka et al, 1997). A study on the effects of AFO on balance skills of a child with a learning disability demonstrated improved balance skills when abnormal lower extremity alignment and biomechanics existed (Orner, 1994).

The purpose of this study is to look at gait initiation in a patient with spastic hemiplegia CP, with and without the use of her brace on the involved lower extremity.

Research hypotheses were; 1) Compared to normal GI, the subject will demonstrate coactivation in the TA and SL on the involved side. 2) SL will remain firing on the non-involved stance limb during GI. 3) Compared to normal GI, limb loading over the involved limb will be less during quiet stance. 4) Limb loading over the involved limb will be less during quiet stance without the brace compared to with the brace. 5) There will be a correlation between limb loading and the ground reaction forces on the involved limb during GI. As limb loading is decreased over the involved limb there will be a decrease in the peak anterior-posterior element of ground reaction force (peak Fx) and the peak vertical element of ground reaction force (peak Fz). This will be compared with and without the brace. This will be compared during swing and stance on the involved limb.

Methods

A 19 years old female volunteered as a participant for this study. Subjects is diagnosed with spastic right hemiparesis CP. She wears DAFO type orthosis in her involved leg for daily ambulation. Subject is an independent functional ambulator who is actively involved in college. She showed moderately increased spasticity (grade 2 in Modified Ashworth Scale) for clinical testing.

Two force plates were mounted under the walkway to measure ground reaction forces of both low extremities during GI. Muscle activities from TA and SL muscle during the GI were recorded bilaterally by using four silver chloride surface EMG electrodes. A ground electrode was placed on the medial aspect of the right tibia. An electrogoniometer was placed on the stance limb to measure the position changes of ankle joint, and an electrical heel switch was placed under the swing limb heel to determine the moment of the heel strike of the swing limb respectively. In addition one foot switch was placed under the stance foot to determine the time of heel off of the stance limb. Processed EMG and amplified force plate signals were sampled online at a rate of 1,000 Hz by using BIOTAC system (Goleta, CA).

On the purpose of kinematic analysis, subjects performance was videotaped from her right lateral view during the whole test session (the kinematic data is not shown in this paper). A right side plastic DAFO (patient owns) was used to compare the effect of the orthosis on the GI.

Subject stood on the predetermined positions of the force plates with bare foot for each trial of all testing conditions. She was instructed to start walk with normal self-selected speed when a light switch on.

The subject was tested under 4 different conditions: 1) Left leg swing without brace, 2) Left leg swing with brace, 3) Right leg swing with brace, and 4) Right leg swing without brace. Subject had 3 4 practice trials before the test trials for each condition. The swing limb represents a leg which start to take a step forward and the stance limb refers a leg which maintained on the ground. The subject performed 7 trials for each condition. The randomized order of testing conditions was A-C-D-B.

Analog data signals from EMG electrodes and force plates were stored and digized by using Acknowledge software. Independent variables were; 1) the use of DAFO (with and without brace conditions) and 2) gait initiation pattern (whether right or left limb for swing). The dependent variables were EMG activity from bilateral TA and SL, and force plate data (Fx and Fz).

Results

For this paper the results were reporting the mean value of dependent variables for all four conditions. The experiment tested based only one subject therefore; no causal relationships between independent and dependent variable from the data by using statistical methods.

The subject demonstrated coactivation of the TA and SL on her right ride. There was bilateral coactivation of the TA and SL in all conditions. The high peak of the TA EMG activity during swing phase is consistent with the pattern of normal gait EMG. The use of brace showed no significant effect on the activity of the SL during the experiment. The bilateral activity of the SL continued to fire as during the entire GI.

During quiet stance weight bearing, the subjects bears more weight on the left limb versus the right limb for all four testing conditions (Fig. 1). As demonstrated in figure 1, the mean value of Fz (vertical force) during quiet standing before GI for condition A was 58.03% of body weight (%BW) for the left and 42.57%BW for the involved right limb. This data clearly supports the hypothesis that limb loading during quiet stance will be asymmetrical with less weight beared on the involved side.

The brace in relationship to quiet stance weight bearing had a positive effect. When wearing an orthotic on the right limb, the subject was able to load more weight compared to conditions when the brace was not worn (Fig. 1). The mean values of Fz confirmed this finding. When the brace was on during quiet stance, the mean value for right limb loading in condition B increased to 44.46%BW from 42.57%BW that the mean without the brace for the same condition.

Figure 2 shows the effect of the brace on the stance limb peak Fz1. The event is looking at swing limb toe off and maximum vertical loading of stance limb. The data illustrates when the brace is worn. the right limb is able to load a higher percentage of BW (mean= 108.24%BW). When the right limb is in swing, the brace has no effect on the mean loading values which are 104.82%BW without the brace and 104.97%BW with the brace.

Figure 3, which illustrates the maximum value of peak swing leg Fx, shows the maximum loading of the COP toward swing limb just prior to the start of the swing phase. The data conclude that there were poor acceleration forces on the right (involved) limb when right leg was used as a swing limb. In this condition, the brace offered no improvement. However, when the right limb was in stance limb, there was a significant increase in the amount of loading. Wearing the brace as the right limb was a stance limb offered more efficient loading than without. The

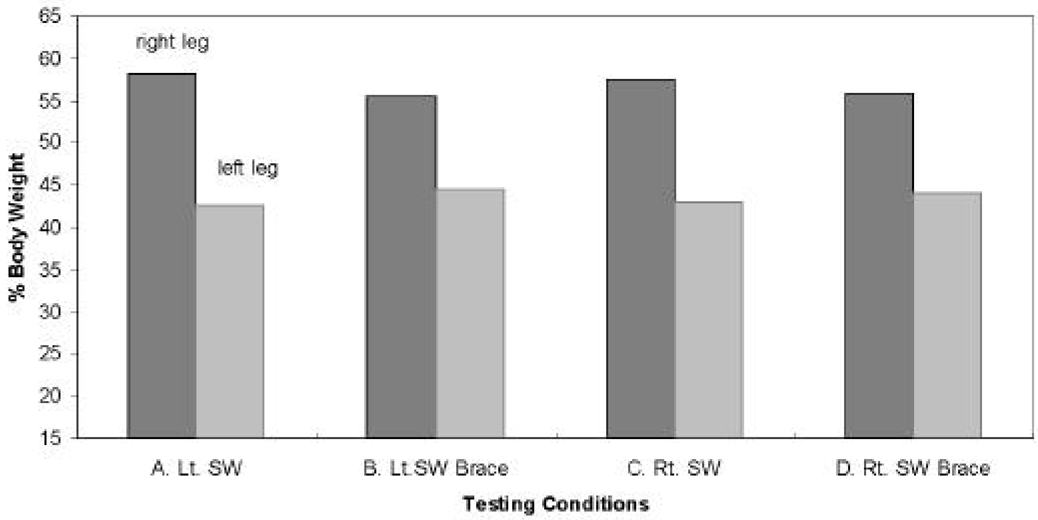

Figure 1. Quite standing weight bearing (Fz)

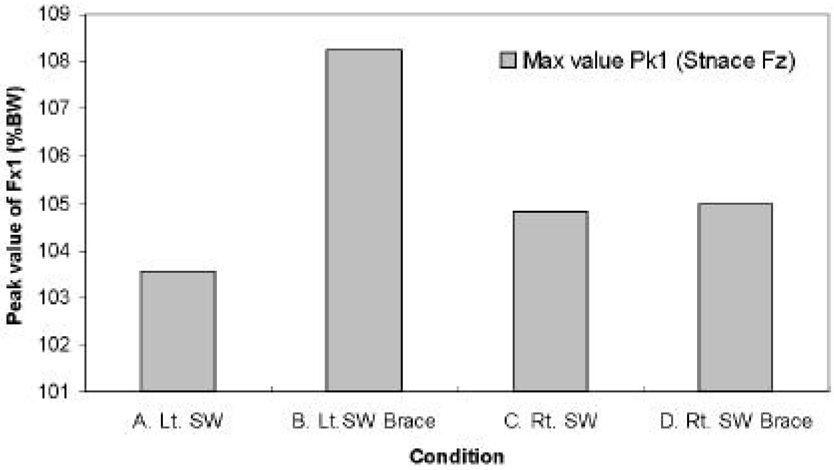

Figure 2. The effect of brace on stance limb Pk Fz1

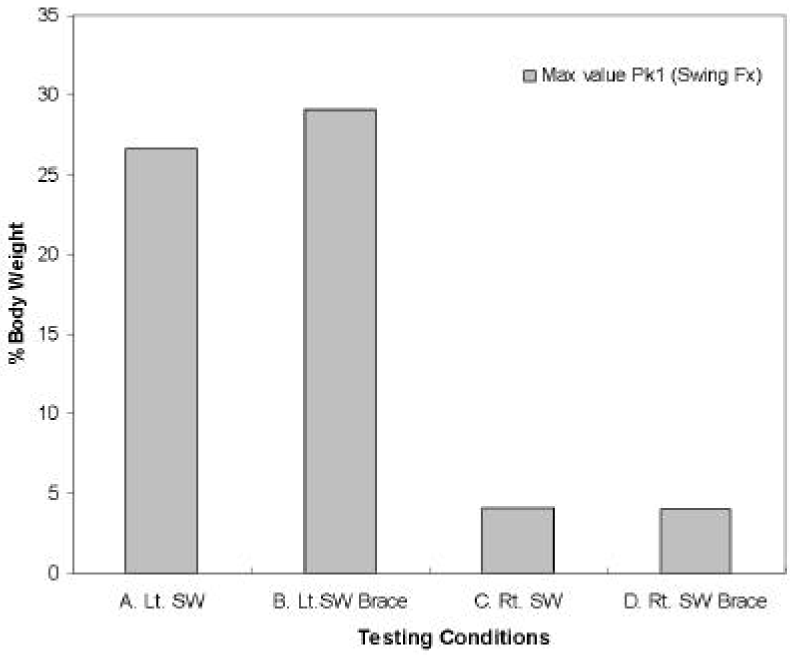

Figure 3. Swing P Limb Pk Fx1

mean value for the four conditions are as follows: A. Lt. SW (26.16%BW); B. Lt. SW with brace (29.10%BW); C. Rt. SW (4.01%BW); and D. Rt. SW with brace (3.99%BW)

The stance peak Fx1 (Stance limb) value was measured and corresponded with the swing toe-off phase with the gait cycle. The data showed that when the right limb was in stance phase with the brace and left limb was in swing the subject exhibits a more efficient mean loading percentage (49.37%BW) compared to 40.56%BW when not wearing the brace. The subject reached her maximum loading when gait was initiated with the right limb while wearing the brace (mean=49.53%BW). The condition where the subject used her left limb to initiate gait without the brace demonstrated the poorest acceleration forces.

For the vertical forces measured as Fz during the swing phase, the data shows that maximum loading of the swing limb prior to toe-off was achieved when the involved limb was wearing the brace (mean=84.79%BW). Without the brace the loading percentage decreased slightly to report a mean of 81.38%BW. However, when the involved limb was used to initiate gait there was a marked decline in the ability to load the limb prior to toe-off. Even with the brace the mean loading percentage was 63.04%BW. The mean percentage dropped to 60.03%BW when the brace was not worn.

The stance limb peak Fz2 and peak Fx2 data were an illustration at the point of double limb stance phase of gait. The swing limb was approaching heel strike whereas the stance limb was preparing for toe off. When the right stance limb was moving toward toe off, the acceleration forces were improved while wearing the brace. The mean values of peak Fx2 were 77.60%BW without the brace and 87.90% BW with the brace. The peak Fz2 graph clearly shows that the brace has no significant effect on the vertical forces. The mean value calculated for Fz2 were 94.47%BW without the brace and 92.55% BW while wearing the brace.

Discussion

The subject, while in quiet stance, exhibited asymmetrical loading with more weight placed on the non-involved limb. This is an expected event with spastic hemiplegia. When the brace was introduced the subject gained more stability and was able to load more efficiently on the involved side causing a shift of weight to the right. Overall, the weight was still primarily shifted to the non-involved side.

The SL EMG activity never quiets during entire GI. This is abnormal because there should be a typical inactivation of the posterior leg muscles during the swing phase of GI. This kind of coactivation pattern was expected from the subject due to her diagnosis. Research has suggested that this occurs from poor control of equilibrium. The result of this pilot study showed that the brace did not have any significant effect on decrease of abnormal SL activity during swing.

This paper reported that while the subject used her involved limb for stance, she was able to lead more body weight on the involved limb. This finding supports the conventional instructions for gait training that therapist have used in the clinical setting. Therapists have encouraged patient with asymmetries to initiate gait with their non-involved limb because then they will load more on the involved side. The use of the brace was most effective in improving the maximum amount limb loaded and also increasing the acceleration force while the involved limb was maintained in the stance phase. The data, however, does not show any significant evidence that it improved loading or increased peak ground reaction forces when the involved limb was used as a swing limb.

It appears the wearing the brace improves gait efficiency. The subject was able to establish greater stability while in stance. Without the brace, the left leg must shift to the load phase quickly because the involved limb lacks the ability to bear the weight without orthotic support. This pilot study provides the necessity of further well structured clinical research to explain the details of possible mechanical and neuro-physiological advantages of use of brace in GI of person with spastic hemiplegia CP.

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