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ORIGINAL ARTICLE

Effect of ankle-foot orthoses on functional performance and physiological cost index in children with cerebral palsy

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Purpose: This study was designed to evaluate the effectiveness of ankle foot orthoses (AFO) on functional performance and physiological cost index in children with cerebral palsy (CP).
Methods: A convenience sample of 30 children with CP (14 hemiplegics, 16 diplegics) with a mean age of 10±3 years were the subjects of the study. The children were in the first and second level of Gross Motor Functional Classification System and had been using their appropriate and comfortable AFOs regularly for at least three weeks. All of these children were properly rehabilitated by pediatric physiotherapists in rehabilitation centers at least two days in a week. The children were tested with and without AFOs by using timed up and go test, timed up and down stairs test, timed one legged stance test, one minute walk test and functional reach test. Physiological Cost Index was used to assess energy cost during the one minute walk test.
Results: A statistically significant difference was observed in favor of the AFO condition in all of the measured parameters ($p<0.05$) except functional reach test ($p>0.05$).
Conclusion: The results indicated that AFOs with correct biomechanical features improve postural control, functional performance, and physiologic cost of gait in children with CP. However if we applied a longer walking test instead of one minute walk test, results could be more valuable.
Keywords: Orthosis, Cerebral palsy, Fatigue.

Serebral palsili çocuklarda ayak-ayak bileği ortezinin fonksiyonel performans ve fizyolojik tüketim indeksine etkisi

Amaç: Bu çalışma, serebral palsili (SP) çocuklarda ayak-ayak bileği ortezinin (AFO) fonksiyonel performans ve fizyolojik tüketim indeksine etkisini değerlendirmek amacıyla planlandı.
Yöntem: Çalışmaya yaş ortalaması 10±3 yıl olan ve uygun özelliklere sahip, 14'ü hemiplejik, 16'sı diplejik 30 SP'li çocuk dahil edildi. Tüm çocuklar Kaba Motor Fonksiyonel Sınıflama Sistemine göre 1 ve 2. seviyedeydi ve kendileri için yapılan uygun AFO'ları en az üç haftadır kullanıyorlardı. Çocuklar pediatrik alanda çalışan fizyoterapistler tarafından haftada en az iki seans fizyoterapi programına alınıyorlardı. Çocuklara postüral denge ve fonksiyonel performansı değerlendirmek amacıyla, süreli kalk-yürü testi, süreli merdiven inip-çıkma testi, süreli tek ayak üzerinde durma testi, 1 dk yürüme testi ve fonksiyonel uzanma testi uygulandı. Modifiye Borg skalası, süreli merdiven inip-çıkma testi ve 1 dk yürüme testinde yorgunluğu belirlemek amacıyla kullanıldı. Fizyolojik harcama indeksi 1 dk yürüme testinden hesaplandı. Testler AFO'lu ve AFO'suz olmak üzere iki kez uygulandı.
Bulgular: AFO'lu ölçümlerde AFO'suz ölçümlere göre, fonksiyonel uzanma testi dışında ($p>0.05$) tüm testlerde daha iyi sonuçlar elde edildi ($p<0.05$).
Sonuç: Bu çalışma, SP'li çocuklarda AFO'nun postüral kontrol, fonksiyonel performans ve fizyolojik tüketim indeksinde olumlu etkileri olduğunu gösterdi. Yürüme testlerinin bir dakika yerine daha uzun tutulmasının daha uygun sonuçlar vereceği düşünüldü.
Anahtar kelimeler: Ortez, Serebral palsi, Yorgunluk.

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Cerebral palsy (CP) is characterized by activity limitations that are formed by several movement and postural disorders which are related to non-progressive brain damages.[1,2] Lesion that occurs in central nervous system of children with CP, blocks normal performance of postural control mechanism. Hereby, ambulation abilities such as stabilization and sitting, standing up, walking, claiming up and down stairs are affected.[3,4] Hemiplegic and diplegic CPs are the most frequent and orthoses applied these group.

In diplegia, lower extremities are affected more than upper extremities. It is the most common form of CP. Almost 32% of the CP population is diplegia. Most frequent gait problems are crouch gait, scissoring gait, jump knee gait, stiff knee gait and toe-heel gait in this form of CP.[3] In hemiplegia, ipsilateral upper and lower extremity of the body are affected. Functional prognosis is better than other forms. Nearly all of the hemiplegic children walk at the age of three. Walking potential of this group is high. However, equinus deformity is the most common gait problem. In this problem foot clearance gets hard. Equinus gate is frequent in both diplegics and hemiplegics.

Ankle foot orthosis (AFO) is advised to these children with the aim of preventing the formation and progression of equinus deformity and eliminating the negative effects on gait. In every gait problems one of the most important problems is abnormal energy consumption. This is a factor which decreases physical activity level of these children.[5-8]

The aims of prescribing orthosis to these children are diminishing the spasticity, increasing the stability in stance phase, preparing the foot to heel strike phase, preventing the foot contact in swing phase of gait and supporting the functionality. Additionally the orthosis should be designed personally to these children. It is very important to produce the most suitable orthosis for every children.[8,9] This study was designed to evaluate the effectiveness of AFO on children CP by functional ambulation tests.

METHODS

Subjects who were involved in this study were diagnosed as hemiplegic and diplegic CP, according to Gross Motor Functional Classification System (GMFCS) they were at level 1 and 2, aged between 5-15 years, had equines deformity which required AFO usage, by extension: (a) they were using AFO regularly, without any complaint for minimum 3 weeks, (b) they could walk independently, (c) they were mentally available to understand the given commands throughout the tests, (d) they had not been applied any botulinum toxin or surgical intervention within six months.

Thirty children with CP (aged 10±3 years; height 130.3±16.6 cm; weight 33±11 kg) participated in our study. Four of these children had the diagnosis of right hemiplegic CP. Ten of these children were left hemiplegic CP, and sixteen of these children were diplegic CP. The children who were in the first and the second level of GMFCS, took place in this study. Nineteen of the participants were using articulated AFO, eight of them were using unarticulated and three of them were using dynamic ankle foot orthosis (DAFO). Timed up and go test (TUG), timed up and down stairs test (TUDS), timed one legged stance test (TOLS), one minute walk test (1MWT) and functional reach test (FR) were applied to all participants. The Modified Borg Scale was measured during timed up and down stairs test and one minute walk test. Physiological Cost Index (PCI) was calculated during the 1MWT. All of these tests were assessed both 'with AFOs' and 'without AFOs' conditions.

Children were tested twice for both two conditions and the means of the results were used. Subjects were relaxed by sitting for five minutes before the tests. Throughout the tests, patients were encouraged verbally.

During TUG, subjects were asked to stand up with "start" command, to walk three meters at a set point, to turn around the reference point, to walk back to the starting point and to sit down. Duration was recorded as seconds. The test was repeated if the subject ran.[10]

During TUDS, the subject was asked to ascend the upper step of the 14 stepped stairs and from there, the subject was requested to descend at once. The duration was recorded from the "Go" command until two feet descended the last step. After the test, the subjects were asked to identify their best suitable fatigue level by using The Modified Borg Scale.[11]

The 1MWT, was practiced at a silent, 20×45 meter hallway. Markers were adhered to the both two starting points of a 30 meters long distance. The subject was asked to walk in the stated area within one minute with his/her fastest capacity without running. The heart rate value of the subject was recorded before and after the test by using Polar heart rate measurement device. Besides, his/her walking speed was identified and PCI of the subject was calculated and fatigue level of the subject was identified by the Modified Borg Scale.[12]

During the FR test, the subject stood lean in the way that his/her arms were contactless by the wall and a measuring tape was adhered to the wall according to his/her shoulder height. The subject was wanted to hold their arms at 90° flexion without extending forward. Then, the subject was asked to extend his/her arms to the front as much as he/she can. Firstly, the distance between acromion and middle finger's (3^{rd} finger) tip was measured (position 1). Then, the maximum distance that the subject can extend his/her arms horizontally was measured (position 2). The difference between two positions was calculated as centimeters. While diplegic subjects extended with dominant side, hemiplegic subjects extended with unaffected part. The tests' of subjects who have touched the wall, stepped to the front and the ones who have excessive rotational movements were cancelled and repeated.[13]

During TOLS test, the subject was positioned 60 cm away from the wall and the wall had a visual target (smiley face) in the eye level. The subject was asked to start with start command when he/she felt ready and was requested to raise the tested foot by focusing on the visual target. Then the duration of the standing position was recorded. Both two sides of diplegic patients and unaffected parts of hemiplegic patients were tested.[14]

The PCI was calculated with the aim of determining the energy consumption levels of the subjects. The data which was obtained by Polar heart rate measurement device was calculated according to the formula given below:

PCI = (Heart rate during walking) – (Heart rate during rest) / Walking Speed.[15]

Patients' fatigue level was measured using the Modified Borg scale which was specifically used for children.[16]

The GMFCS is formed by five levels:

Level I: Walking without any limitations

Level II: Walking with some limitations

Level III: Walking with aid.

Level IV: Mobility can only achieved by motorized walking aids.

Level V: Patient is moved by wheelchair.[17]

Our study was approved by Hacettepe University Ethics Committee on January 30, 2009 by LUT 08/51 registration number.

Statistical analysis

The t-test was applied for dependent samples. Data was analyzed using SPSS-16 program (SPSS Inc, Chicago, USA). Data was calculated as arithmetic mean ± standard deviation (mean ± SD). Paired *t* test was used at comparisons of with and without AFO. A *p* value was received as 0.05.

Throughout the power analysis, timed up and go test was accepted as the primary method of the measurements. The duration value of timed up and go test was displayed as seconds and it is a sensitive test. Therefore we decided to include 30 cases to the study with a type 1 error of 5% and power with 80%.

RESULTS

There were significant differences in favor of AFO during TUG, TUDS, TOLS, 1MWT, PCI, walking speed and Borg scale which were performed with and without AFO ($p<0.05$) (Table 1) (Figure 1). There was not any meaningful difference after FR test with and without AFO ($p>0.05$) (Table 1).

DISCUSSION

Within the treatment of CP, therapists are primarily aimed to bring functional and energetic effective walking pattern to children with CP. The AFO is an effective treatment method that promotes this aim given above.

There are numerous studies in the literature which searched for investigating the effectiveness of AFO. A major part of those

Table 1. Comparisons of Timed up and go test, Timed up and down stairs test, Modified Borg Scale for Timed up and down stairs test, Timed one legged stance test, 1 minute walk test, Modified Borg Scale for 1 minute walk test, Functional reach test, and Physiological Cost Index with and without ankle foot orthosis (AFO) (N=30).

	With AFO X±SD	Without AFO X±SD	p
Timed up and go test (sec)	11.83±3.00	12.58±3.23	<0.001
Timed up and down stairs test (sec)	24.44±14.81	38.58±21.47	<0.001
Modified Borg Scale (Timed up and down stairs test)	1.41±0.72	2.45±1.12	<0.001
Timed one legged stance test (sec)			
Right	22.05±19.33	12.53±12.76	0.008*
Left	11.94±10.33	6.53±10.09	0.005*
Functional reach test (cm)	9.60±3.10	9.28±3.15	0.141
One minute walk test (m)	75.48±12.94	66.65±13.09	<0.001
Modified Borg Scale (1 minute walk test)	3.98±1.19	5.13±1.23	<0.001
Physiological Cost Index (pulse/meter)	0.63±0.29	1.66±0.73	<0.001

* p<0.05.

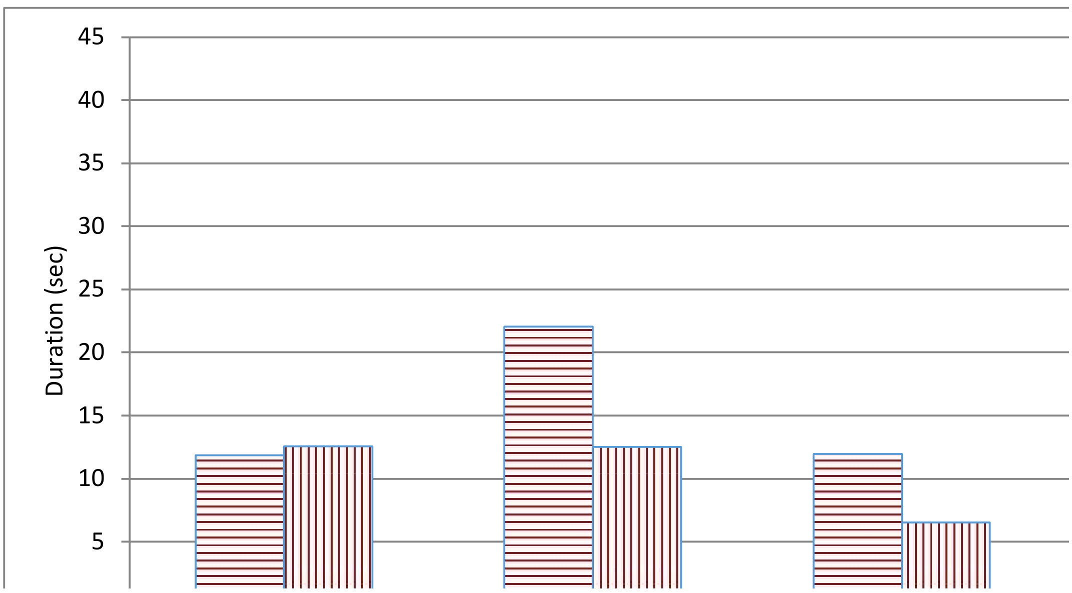

Figure 1. Comparisons of timed up and go test, timed one legged stance test and timed up and downstairs test results with and without ankle foot orthosis (AFO).

studies were conducted in laboratory environment and kinetic and kinematic analysis methods were used in those studies. In the course of time, with the development of technology, those studies provided clear numeric data.

Throughout the study, equipments such as reflective markers for placing the participants, three dimensional analysis systems, oxygen masks for measuring energy consumption, walking platform and treadmills were used. Participants' short-ranged performances were put into account within the laboratory environment.[18-24]

Even though the data that were retrieved from those studies were valuable, the used equipments' limitations on the CP children are still argumentative. On the other hand, the correlation between the study environment and the children's real life environment is low. Equipments and study environment could create discomfort on CP children. As a matter of fact, children with CP are following their coevals back in the social environment and this kind of testing environment could be a reason for children not to display their actual performance.

Katz-Leurer et al found similar results to our study. Ten children with CP (aged 7-13 years) participated in their study. After six weeks of exercises, there was a mean 1.6 sec decline in TUG test, a 3 cm progress in FR test and 10 m increase in two minutes walk test in study group. There was not a significant progress in energy consumption after the exercise period.[25] In our study, there was a 0.75 sec mean decline in TUG test, 0.32 cm mean increase in FR test and 9 meters mean increase in 1MWT with AFO. Distinctly, we reached significant progress in terms of the PCI.

Scholtes et al applied a functional strengthening program to fifty-one children with CP (mean age 10 years, GMFCS levels I-III) for 12 months. The TOLS test was applied before and after the treatment. There was a little progress in that test but it was not significant.[26] In our study, TOLS durations increased significantly with AFO. Ijzerman et al designed a study on 12 children with CP (8 hemiplegic and 4 diplegic) and calculated PCI after 8 minutes walking test. In that study AFO and barefoot conditions were compared. However, that study eventuated against AFO as distinct from our study.[27] In a study, 20 children (aged 5-15 years) with CP (hemiplegic and diplegic) and 20 healthy subjects (aged 4-11 years) were applied a 250 meters walk test with bare foot condition and PCI was calculated. In that study average PCI value was 0.61 pulse/meter comparably in our study we found 0.63 pulse/meter.[6]

When we searched the literature; we found that the designs of many studies were before and after exercise or surgery. We defined AFO as an effective treatment method and we compared two different conditions in our study. Our aim was emphasizing the importance of AFO in the rehabilitation of children with CP.

There are many different levels in CP. Therefore, when designing a study about this issue, there is a need to have to homogenize groups. One of the most important critera about this process is GMFCS. We chose the children who were in the first and the second level of GMFCS; because in these levels sufficient functional capacity is important for performance tests. Therefore we generated a group which has a higher level of walking potential. We did not generalized about CP on the contrary we focused on a homogenous group. Furthermore performance tests which we applied in this study reflected daily life movements of these children. Our study contains two important issues: functional performance and energy.

We did not directly measure energy consumption but we used modified Borg scale and calculated PCI. These are practical tests and do not disturb these special children.

One of the strongest side of our study was the sensibility about selecting cases. We especially include children who adopt his/her orthosis and use it properly. Another important criterion was the characteristic of orthosis. Selection and design of the orthosis was the other important issue. The orthosis must permit the maximum walking performance of a child with CP.

On the other hand all of our subjects were treated properly in physiotherapy and rehabilitation centers at least two days per week by pediatric physiotherapists. Not only orthosis or physiotherapy is enough. The combining of these two methods is most effective selection.

Limitations

The weakest point of our study was practicing the walking test within a short time period which was one minute. More reliable results could be obtained if the walking period was applied in a longer time. The energy consumption of this population was far more than normal children. If the walking duration gets longer, the fatigue amount would be increased; hereby longer walking duration would support more reliable results by reflecting the fatigue amount more realistic.

Conclusion

As a result of the study, CP subjects who were using AFO were tested with functional performance tests and consequently when subjects with AFO compared with subject without AFO, the ones who were using AFO seemed to be more favored than the others.

According to the PCI results of 1MWT, energy consumption with AFO could be considered less than without AFO. During timed up and down stairs test and 1MWT, fatigue amount was measured with the Modified Borg Scale and the results show that, subjects have more amount of fatigue without AFO. During functional reach test, we sentimentalized a lot, so the results are lower when compared with the ones in the literature. Finally, we performed our study in a routine clinical. Because sophisticated conditions may change normal physical performance of these children.

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