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Effects of a stabilizer sock in balance in patients with different neurologic diseases

Efectos en el equilibrio y confort de un calcetín estabilizador en pacientes con diferentes alteraciones neurológicas

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Keywords:

Sock, cerebral palsy, equilibrium, postural balance, postural control, comfort, gait.

Abstract

Background: There are different neurological pathologies such as cerebral palsy, myopathies, neurological pes planus foot and cognitive deficits that cause different gait and equilibrium abnormalities (like motor clumsiness), which can cause falls, stumbles and insecurity.

Patients and methods: With a sample of 13 patients aged between 3 to 18 years with different neurological affections, we conducted a study with a commercial standard sock that presents tensing bands in the ankle. Two months after the sock delivery, we carry out the balance analysis with a force platform (Instituto de Biomecánica de Valencia, IBV), both with the experimental sock and without it. In addition, we conducted a survey of legal guardians to assess the comfort of socks in patients.

Results: The mean deviation of the center of pressure when performing the tests of Romberg with open eyes (ROA) was 6,473 with tensions socks and 9,061 with socks control and the test of Romberg with closed eyes (ROC) was 5,867 with tensions socks and 6,603 control socks. The Wilcoxon test determined that there were significant differences in 10 cases with decreased mean deviation in the center of pressure in the tensors socks respect the control in the tests of ROA ($p = 0.010$) and ROC ($p = 0.041$). In relation to comfort, the 13 subjects continued to use the socks, referring to a greater safety and attachment to ankle joint.

Conclusion: The socks with tensing bands help the subjects to maintain a greater balance, provided comfort, safety and stability in the foot, facilitating their gait and avoiding at the same time that they can suffer falls or stumbles.

Palabras clave:

Calcetín, parálisis cerebral, equilibrio, balance postural, control postural, confort, marcha.

Resumen

Introducción: Existen diferentes patologías neurológicas como la parálisis cerebral, las miopatías, el pie plano laxo neurológico y los déficits cognitivos, que provocan diferentes anomalías en la marcha y el equilibrio, las cuales pueden ocasionar torpeza motora, caídas, tropiezos e inseguridad.

Pacientes y métodos: Con una muestra de 13 pacientes con edades comprendidas entre los 3 y 18 años con diferentes afectaciones neurológicas, realizamos un estudio con un calcetín comercial estándar que presenta bandas tensoras en el tobillo. Dos meses después de la entrega del calcetín, llevamos a cabo el análisis del equilibrio con la plataforma de fuerza (Instituto de Biomecánica de Valencia, IBV), tanto con el calcetín experimental como sin él. Además, realizamos una encuesta a los tutores legales para evaluar el confort de los calcetines en los pacientes.

Resultados: La desviación media del centro de gravedad al realizar las pruebas de Romberg con ojos abiertos (ROA) fue de 6,473 mm con los calcetines tensores y de 9,061 mm con los calcetines control, y en Romberg con ojos cerrados (ROC) fue de 5,867 mm con los calcetines tensores y 6,603 mm con los calcetines control. La prueba de Wilcoxon determinó que había diferencias significativas en 10 casos, con una disminución de la desviación media del recorrido del centro de gravedad en los calcetines tensores que respecto a los controles, en las pruebas de ROA ($p = 0.010$) y ROC ($p = 0.041$). En relación con el confort, los 13 sujetos seguían utilizando los calcetines, refiriendo que presentan una mayor seguridad y sujeción de la articulación tibioperoneoastragalina.

Conclusiones: Los calcetines con bandas tensoras ayudan a los sujetos a mantener un mayor equilibrio, proporcionado confort, seguridad y estabilidad en el pie, facilitando así su marcha y evitando al mismo tiempo que sufran caídas o tropiezos.

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INTRODUCTION

Certain childhood neurological, degenerative, cognitive, systemic syndrome disorders, can cause anomalies in gait, especially insecurity, falls, instability, or slowness[1] which are related to abnormal muscle tone[2,3].

Cerebral palsy (CP), is the most common cause of motor disability in childhood[4]. It is known as an alteration of movement development and posture, responsible for a restriction of activity, which are attributed to a non-progressive aggression on a developing brain, in the fetal or early years[5,6].

Its prevalence is estimated between 2 and 3.5 cases per 1,000 new-borns. It is classified into three main groups: 1) spastic CP: characterized by an increase in muscle tone that may not be constant with hyperreflexia and/or signs of pyramidalis, such as clonus or Babinski (80 % of the total); 2) Dyskinetic CP: characterized by involuntary movements (10-15 % of the total) and 3) ataxic CP: characterized by a loss of muscle coordination. It usually presents with hypotonia and poor stability to maintain a posture (5-10 % of the total).

However, the clinical forms of CP presentation are not so pure and offer mixed presentations. In these cases it is recommended to classify according to the predominant motor disorder. In most cases hypotonia, spasticity, motor control deficit and deformities in the lower extremities are observed.

The phases of the march will be altered, being very marked in the period of support an insufficient dorsal flexion and in the period of taking off and rolling a very marked plantar flexion, in many cases dragging the tip of the foot on the ground. Spastic cerebral palsy is the most common form of presentation, which we can classify in[7]: Spastic tetraplegia (more severe) affecting all four limbs and with greater involvement in upper extremities (5, 7, 8), spastic diplegia (more frequent) which predominantly affects lower limbs[5,7,8] and paresis spastic hemiplegia which affects only the extremities on one side[5,7,8].

Myopathies, on the other hand, are affections that cause problems in contraction and skeletal muscle tone to perform voluntary movements. Due to that present alterations such as weakness, pain, cramps, stiffness, or fatigue[9,10].

The lax flat foot secondary to neurological affections is certainly the most common and is usually asymptomatic to physical examination. A good longitudinal plantar arch can be observed when the patient is at the sites, and when shitting it flattens to disappear. Different degrees of forefoot abduction and valgus rearfoot can also be observed. This type of foot is usually associated with generalized ligament laxity. In most cases the flexible flat foot is asymptomatic, but may cause pain in some cases due to alteration of the foot mechanics[11,12]. It implies an excessive mobility of the subtalar joint and therefore presents a lot of instability in the gait[6].

Cognitive deficits are an affectation defined by an incomplete mental development that is accompanied by significant limitations, such as motor skills, language, social skills and cognitive functions[13,14].

There are various devices available to help improve the affections that arise in gait. These include commercial splints, custom splints (Ankle Foot Orthosis AFO, Distal Ankle Foot Orthosis DAFO), anti-equine splints (Boxia), leggings, and socks. These devices are placed around the ankle joint, and provide support and stability to the weakened muscles, allowing adequate limb control. Custom made devices are the most used because the support they provide is more secure. Since DAFOs limit joint movement less than do AFOs, they can help prevent muscle weakness and increase orthopædic comfort[15,16].

Proprioception is the ability of the body to perceive the relative position of contiguous body parts. Proprioceptors are very specialized sensory organs, they inform our brain when we are in motion or at rest. But for those with nervous system pathologies they may have problems with proprioception[7].

Some of these devices, such as the DAFO leggings and socks like those sold by the DM Orthotics® brand, are custom made. The leggings have a positive effect on gait, as well as allowing the individual to be more stable and to have better control of their gait. However, they have may disadvantages such as becoming too small very fast because of the child's growth and hence no longer fulfilling their function, their very high cost, and they are hot to wear and hard to put on[17].

Currently some models of commercial compression socks include compression elements that could be beneficial for these gait disturbances. These socks help to maintain balance through a compression band that surrounds the ankle joint and improves stability, thus helping to improve anomalies in gait[18]. There are, however, no scientific data available to support their use.

The objective of the present study was to verify the benefits of a commercial, standard, and non-specific commercial sock on the gait and comfort of patients with degenerative, neurological, pie planus, and cognitive disorders so that these children may gain in security and balance.

PATIENTS AND METHODS

Subjects

A sample of convenience was selected that presented some type of neurological involvement with abnormalities in its gait, but with the ability to perform the same independently. All subjects unable to perform any of the tests correctly were excluded. All patients and legal guardians of patients after oral and written explanation of the study content signed the informed consent. This document described the objectives of the study and the tests we would perform on each of them.

Contact socket with the tension socks

The socks used to test comfort and balance in this study were the Equilibrium® Vitalsox (Figure 1. Feetness Sl, Italy).

These socks are equipped with elastane tensioning bands. A bundle of tensor fibers surrounds the supramaleolar area and another bundle of fibers holds the midfoot, surrounding the bones of the proximal tarsus.

The patients were called to the Extremadura ASPACE (Asociación de Parálisis Cerebral, Cerebral Palsy Association), federation Plasencia, and were given the socks corresponding to their foot size. We helped them put the socks on, and asked them to walk for a few minutes to see if there were any discomfort and for them to tell us their first sensations. We explained to the family members the easiest way to put the socks on which is to turn them inside out, leaving a pocket for the toes, and then to pull them up. All the patients or their legal guardians signed their informed consent after the oral and written explanation of the study's content. This document described the objectives of the study and the tests that would be performed on each participant.

Figure 1. Equilibrium socks with tensor fibers (gray) around the ankle. From: https://vitalsox.com/equilibrium/.

Comfort questionnaire

To assess the comfort of the socks as perceived by the patients, a questionnaire (Annex 1) was given to their parents or legal guardians.

This survey had different types of questions:

1. Open questions: Answered with total freedom by the respondent, i.e., in their own words.
2. Closed questions: The respondent had to choose between specific options. The responses were either dichotomous (YES or NO) or on a Likert scale measuring various related variables instead of just one variable.

The data obtained from the survey were analysed after two months of using the compression socks.

The balance force platform study

This test was performed 2 months after the socks were delivered to the patients. For the balance study, we used the NedSVE/IBV force platform of the Valencia Biomechanical Institute. This is a software application for the study, rehabilitation, and monitoring of balance disorders, with graphic outputs that are easy to interpret. The test were based on the Dinascan/IBV P600 force platform which was designed for the efficacious assessment and reduction of balance disorders through comparisons with normality standards[19].

For the evaluation of static equilibrium, the Romberg test was performed, which is carried out to look for some motor coordination disorder, called sensory ataxia, which will be a lack of balance in the performance of the test. It consists of placing the patient in a bipedal position with the feet together, the arms stretched to both sides and the eyes open. It records the movements that it detects in the patient (balancing of hips, knees or whole body) and then asks him to close his eyes, comparing the stability that he presents at that time with that he had using vision. If done on a force platform, it can monitor the movement of the centre of pressure.

For this test, the patient first has to be weighed and the platform calibrated, To this end, the patient is told to stand on the platform with the arms down parallel to the body, looking straight ahead, and without moving. We performed Romberg open eyes (ROA) and Romberg closed eyes (ROC) with the compression socks and with the control socks 2 months after the patients were given the socks. To avoid the learning effect, the tests were performed randomly with the control socks first in half of the patients and the compression socks first in the other half. For the ROA, the patient is placed on the platform with the arms straight down at the side of the body, looking straight ahead during the whole test, and trying not to move. The ROC is performed in the same way, but with the eyes closed. For the performance of this test, they were deprived of their usual assistive devices.

Variables and statistical study

Mean deviation (mm). This is the mean of the total deviation from the centre of pressure in every direction. Maximum mediolateral and anteroposterior deviations (mm). These correspond to the furthest points on the mediolateral and anteroposterior axes to which the pressure centre moves during the recording time. Descriptive statistics (mean ± SD) were calculated for the mean deviation, and maximum mediolateral and anteroposterior deviations. Since the sample was small, the Wilcoxon nonparametric test was applied for the pre-post balance comparison. This subtracts the tests without the compression socks from those with these socks. This test also provides the sum of ranks, and the negative (less deviation), positive (more

ANNEX 1. Questionnaire: Comfort of EQUILIBIRUM® socks

Sex: M ☐ F ☐

Age:

1. What date did the socks begin to be worn? _____
2. How did you learn of the existence of the socks to improve your child's motor activity?

   _____

   _____
3. Are the socks still being used?: Yes ☐ No ☐
4. Are the socks worn daily?: Yes ☐ No ☐
5. If not daily, what is the reason?: _____

   _____
6. Have you noticed any improvement?:
   1. No improvement ☐
   2. Slight improvement ☐
   3. Improvement ☐
   4. Much improvement ☐
7. Walking (security)
   1. Slower ☐
   2. Same ☐
   3. Faster ☐
   4. Safer ☐
8. What does the child feel?:
   1. Uncomfortable ☐
   2. Same (feels nothing) ☐
   3. Safer ☐
   4. Increased mobility ☐
9. What changes have you noticed in the child?: _____

   _____

   _____
10. Complications (sweat, chafing, too much compression,...):

    No ☐

    Yes ☐ IIn this case, indicate which.
11. Is putting the socks on worth it, due to the evident improvement?:

    Yes ☐

    No ☐

deviation), and tied cases. Calculations were performed using the SPSS software package (v.22.0, UEX Campus licence). The significance level was set at 5 % ($p<0.05$).

RESULTS

The sample consisted of 13 patients (5 male and 7 female) between 3 and 18 years of age (mean age 11.1 ± 4.4), all of them with some alteration in their gait cycle. The average weight of patients in the study is 42.2 ± 17.1 kilograms and the average height is 137.5 ± 20.1 centimeters. Four patients had hemiplegia, five flat foot lax secondary to neurological alterations and four gait alterations due to rare syndromes. Nine of the 13 patients wore assistive devices (splints, dictus) or other orthotic treatments on a daily basis.

The maximum anteroposterior deviation in the Romberg test with open eyes without the experimental socks was 20.091 ± 31 mm, while in the Romberg test with closed eyes it was 18.291 ± 35.69 mm. With the compression socks, the mean deviation was 11,425 ± 22.23 mm with open eyes, and 15,767 ± 28.46 mm with closed eyes. The mean deviation and maximum mediolateral deviation are given in Tables I and II.

Pre-post comparison

The mean deviation in the Romberg test with open eyes (Experimental-Control) with the compression socks was negative in 10 of the cases, and positive in 3 of them ($p = 0.010$). In the Romberg test with closed eyes, the result was 10 negative ranges, 2 positive ranges, and 1 tie ($p = 0.041$). In both Romberg tests, the maximum mediolateral and anteroposterior deviations showed between 9 and 10 negative ranges, 2 and 4 positive ranges, and 0 and 2 ties ($p>0.05$, Table III).

Comfort survey

The 13 patients or their legal guardians completed the compression socks comfort survey questionnaire. Of these 13 cases who used the socks during the two months, two subjects did it daily and 11 alternately or occasionally. Of the 11 who did it occasionally, 5 do not use it daily because they only had a pair of socks at that time. Of the 13 patients, 7.14 % did not have any improvement with the experimental socks, 21.43 % presented a slight improvement, 55.14 % had improvement, and 14.29 % had much improvement

9 of the patients explained that they walked safer, 1 faster and 3 walked the same as before using experimental socks. After the two months, 9 of the patients indicated that they felt safer and with more support on the feet, 3 indicated that they walked with straighter feet, and 1 stated that they had greater dorsal flexion in their gait.

DISCUSSION

In light of the results, it can be inferred that the compression socks provided greater balance to this sample of patients. There was a smaller deviation from the centre of pressure in both the mean deviation and the maximum anteroposterior and mediolateral deviations when the tests were performed with the compression socks.

One observes (Tables II and III) that the greatest variation in the Romberg tests corresponded to the mediolateral balance test, with an evident improvement when wearing the experimental socks. This indicates that, when the patient was wearing the compression socks, there were fewer lateral oscillations from the centre of pressure.

In some patients, no changes were observed in the measurements performed with and without the compression socks. However, at a visual level, one can establish a certain decrease in the range of movement of the centre of pressure with the experimental socks (Figures 2 and 3).

In other cases, on the other hand, the improvement in the lower medialateral and anteroposterior path of the centre of pressure was very evident (Figures 4 and 5), resulting in patients who showed greater comfort and adaptation to the tensor sock.

We found no studies in the literature that report similar balance tests with compression socks. Wheat et al.[20] conducted a

Table I. Descriptive statistics with the control sock.

	N	Mean	SD
Desv. Media ROA	13	15.54	9.061
Desv. Max. MLROA	13	31.46	28.756
Desv. Max. APROA	13	31.00	20.091
Desv. Media ROC	13	13.46	6.603
Desv. Max. MLROC	13	39.38	45.747
Desv. Max. APROC	13	35.69	18.291
N valid (as listed)	13		

Table II. Descriptive statistics with the experimental sock.

	N	Mean	SD
Desv. Media ROACON	13	8.31	6.473
Desv. Max. MLROACON	13	19.23	9.435
Desv. Max. APROACON	13	22.23	11.425
Desv. Media ROCCON	13	8.38	5.867
Desv. Max. MLROCCON	13	26.46	19.160
Desv. Max. APROCCON	13	28.46	15.767
N valid (as listed)	13		

Table III. Pre-post comparison.

		N	Mean rank	Rank sum	p
Desv. Media ROACON Desv. Media ROA	Negative ranges	10	8.25	82.50	**0.010**
	Positive ranges	3	2.83	8.50	
	Ties	0			
Desv. Max. MLROACON Desv. Max. MLROA	Negative ranges	9	6.78	61.00	**0.013**
	Positive ranges	2	2.50	5.00	
	Ties	2			
Desv. Max. APROACON Desv. Max. APROA	Negative ranges	9	8.22	74.00	**0.046**
	Positive ranges	4	4.25	17.00	
	Ties	0			
Desv. Media ROCCON Desv. Media ROC	Negative ranges	10	6.50	65.00	**0.041**
	Positive ranges	2	6.50	13.00	
	Ties	1			
Desv. Max. MLROCCON Desv. Max. MLROC	Negative ranges	10	6.90	69.00	**0.018**
	Positive ranges	2	4.50	9.00	
	Ties	1			
Desv. Max. APROCCON Desv. Max. APROC	Negative ranges	10	6.70	67.00	**0.028**
	Positive ranges	2	5.50	11.00	
	Ties	1			

study with another type of sock that textured with pompoms of different thicknesses and in different arrangements, to determine the balance in healthy young adults standing in single-leg stance. The study concluded that, for both the open- and closed-eyes tests, the socks with pompoms on the sides led to improved balance in the mediolateral deviations. These results are not extrapolatable since that study's sample comprised healthy adults and no therapeutic effect was expected from the socks.

The brand Silvert's (Silvert's Holdings Ltd, Ontario) markets a sock for cerebral palsy patients that has grip options on the plantar part to prevent falls and slips[21]. Similarly, the brand Eurocat (Centro Tecnológico de Cataluña, Cataluña, España)[22] has brought out a prototype of a smart sock which, through

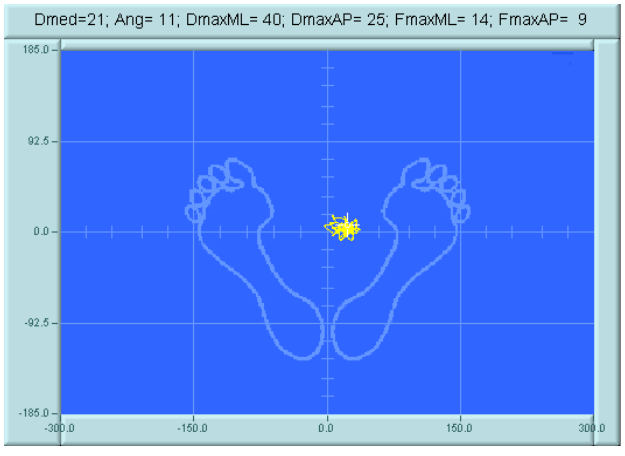

Figure 2. Romberg Open Eyes with control socks.

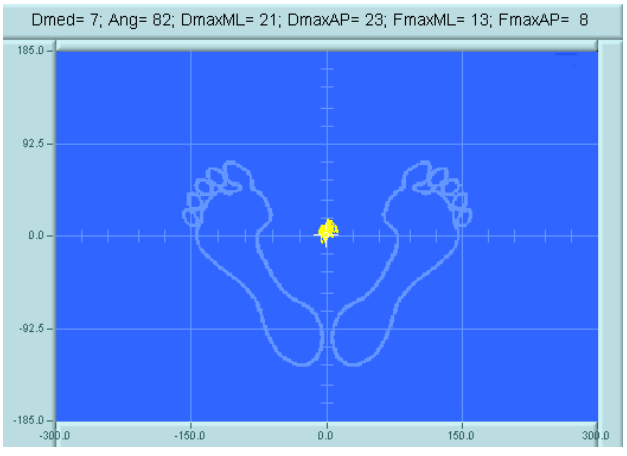

Figure 3. Romberg Open Eyes with tensor socks.

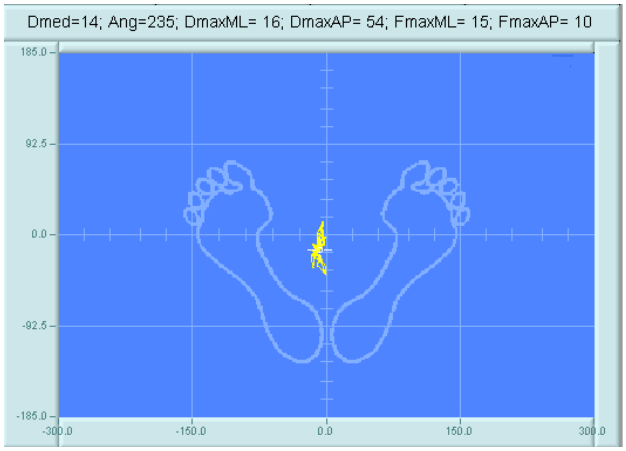

Figure 4. Romberg Closed Eyes with control socks.

Figure 5. Romberg Closed Eyes with tensor socks.

a mobile phone application, is able to monitor the patient's gait in order to control balance and prevent falls. These socks still have not been the subject of any type of scientific study that can lend support to their aiding balance in patients with neurological disorders.

There is clearly therefore a lacuna in the literature regarding this topic since patients with balance difficulties that have consequences for their gait could be helped by using commercial compression socks.

With regard to comfort, 90 % of the patients continued to wear the socks when going about their everyday activities. 28.6 % of the legal guardians indicated that they noticed either just a slight improvement or no improvement in the patients, but we would indicate that, within this percentage, 75 % of the patients felt safer when walking wearing the Equilibrium® compression socks. This fact could be related to greater stability of the ankle joint due to the compression bands in the socks have which help support the ankle. The result is fewer of the sprains, stumbles, and falls that the patients are prone to due to the muscle hypotonia and ankle instability they suffer from[1-3].

Hemiplegia is a type of affection within cerebral palsy in which only the limbs on one side are affected[16]. The gait of this type of patient is characterized by a rhythmic sound due to the outer edge and tip of the foot rubbing against the ground, which increases the risk of falls and the wear of the toe of the shoes[1]. One of the patients (who was affected by hemiplegia) reported less wear of the toes of their shoes since using the compression socks. The improvement in this patient could be due to the use of these socks since the foot performs greater dorsal flexion, thus reducing the contact of the tip and the outer edge of the foot with the ground, which makes falling less likely.

The present study represents the basis for further investigations of improvement in gait in patients with neurological conditions through the sock Equilbrium® of the brand Feetness.

The use of these socks would be a complete aid in your treatments. The sock with tensioning bands being the lower limb device prescribed. Chosen for its positive effects on balance, stability and comfort in driving, and also add for its economic cost, much lower than the other devices, and its easy handling when putting and removing. For all of the above, our patients with the application of these socks will obtain both physical and emotional benefits, which will improve their quality of life. This objective is one of the most important in its multidisciplinary treatments.

It can be concluded that the patient's mediolateral and anteroposterior balance of the centre of pressure improves markedly with the use of the compression socks. Patients feel safer and more stable with the compression socks, which in turn could help to reduce the number of falls. Compression ant tensor socks could be part of the everyday life of these patients, becoming a small additional help to the orthopædic devices they have to wear, and thus enhance their quality of life.

CONFLICT OF INTEREST

The authors state that they do not have any conflict of interest related to this article Funding.

FINANCIAL DISCLOSURE

The socks were delivered by the company Vitalsox (Feetness SI, Italy) to the researchers and permanently donated to the patients. Each patient was given the socks they wore on the day of the test and at least 2 or 3 more pairs at the end of the study. The research group states that apart from the donation of the socks there has been no other study funding from the donor company neither from any other company.

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