Orthotic Devices with Out-toeing Wedge as Treatment for In-toed Gait in Children

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Background: Orthotic devices are used to help children progressively acquire a more physiologic walking pattern.

Methods: To determine the effect of an orthotic device with an out-toeing wedge along with a physiologic shoe as treatment for in-toed gait, angle of gait was measured in 48 children aged 3 to 14 years with in-toed gait. The following comparisons were made: angle of gait in children unshod versus children shod without treatment, angle of gait in children shod without treatment versus children shod plus orthoses, and angle of gait in children unshod versus children shod plus orthoses.

Results: Using a correctly fitting shoe increased the angle of gait in a nonsignificant manner, but a significant increase was revealed in the comparison of the angle of gait in children unshod versus children under treatment. The results showed that the behavior in boys and girls was similar to that in the total sample. Regarding side, the corrective effect of the orthotic device was similar in the two feet. However, the data showed a greater corrective effect of the shoe in the right foot.

Conclusions: Orthotic devices with out-toeing wedge combined with correctly fitting shoes, as well as shoes alone, are useful tools in the treatment of in-toed gait in children.
(J Am Podiatr Med Assoc 100(6): 472-478, 2010)

The effect of in-toed gait on the biomechanical behavior of the lower limbs gives rise to a series of compensatory consequences that can lead to acquired deformities that are difficult to resolve in adulthood, including arthrosis of the hip,[1] patello-femoral abnormality,[2, 3] patellar instability,[4] and alterations of the foot associated with abnormal subtalar pronation.[5]

Although the effect of bad postural habits on the development of the torsional morphotype of the child's lower limbs seems undeniable, in many cases, postural treatment is insufficient to resolve the associated torsional abnormality, and it is then that orthotic treatments are used. The use of orthotic and shoe therapy for in-toed gait is an ongoing topic of discussion; some authors maintain that they are completely ineffective,[6-8] and others defend their indication and usefulness in this alteration, above all when there are associated alterations in the foot.[9-11]

Some types of orthoses and elements added to the shoe, elongated to the external level of the foot ("gait plates"), are sometimes indicated for the treatment of in-toed gait in children.[11, 12] The earliest reference is from 1967, when Shuster[12] published an article on the effect of a rigid element added inside the shoe and overshooting the fourth and fifth metatarsals for the treatment of in-toed gait. More recently, in 2000, Redmond[11] conducted a study on the effect of gait plate orthotic devices in the treatment of in-toeing in children. He claimed that in 14 of 18 cases, the devices significantly reduced the number of falls by the child.

In the present study, an orthotic device was used with the aim of helping the child progressively acquire a more physiologic walking pattern. This orthotic device is characterized by an out-toeing wedge consisting of a distal extension of the material of the orthotic device that selectively overshoots the metatarsophalangeal articular line

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of the external rays and ends in a point in the subdigital space of the fifth toe. This device is similar to a gait plate but is combined with a custom-made functional orthosis. The main aim of this work was to ascertain whether this treatment produced any favorable alteration in the angle of gait of the child at the moment it was applied. We also wanted to establish whether the physiologic shoe, that is, a correctly fitting, sensible-style shoe, could by itself alter the angle of gait. The null hypothesis was that this type of treatment does not increase the angle of gait at the moment it is applied.

Materials and Methods

This study was performed between January 2005, and December 2007. The sample consisted of 48 children (96 feet) aged 3 to 14 years (mean ± SD age, 6.88 ± 3.25 years) with in-toed gait. The participants were residents of Seville attending either the Clinical Podiatric Service at the University of Seville (n = 39) or a private podiatric clinic in Mairena del Alcor, Seville (n = 9) who presented with in-toeing. The nature and aims of the study were explained to the parents, and all who agreed to participate provided written consent. The study was approved by the Experimentation Ethics Committee of the University of Seville.

All of the children who presented with an in-toed gait were considered for inclusion in the study. Participants were excluded from the study if 1) they suffered or had suffered from motor alterations or serious deformities in the lower limb that would affect gait, such as infantile cerebral paralysis, neuromotor alterations in the lower limb, osteochondrosis with serious sequelae, congenital luxation of the hip, equinus foot, rocker-bottom foot, congenital convex flatfoot, clubfoot, and serious varus forefoot; 2) had been surgically treated in the lower limb (bone surgery, osteoarticular surgery, or surgery of the neuromuscular tissue); or 3) presented with in-toeing requiring surgical treatment.

The independent variables in this study were the orthotic treatment and the correctly fitting shoe. Unlike the soft or semisoft orthoses used in a previous study,[11] the orthoses applied in this study were made of a semirigid, 3-mm-thick polypropylene. Moreover, in this case, the distal edge of the out-toeing wedge ended just beneath the fifth toe, that is, the fifth toe had to be resting on the elongation of the orthotic device to the level of the lateral surface of the forefoot. The main dependent variable in the study was the angle of gait measurement. This was taken for each child when unshod (AG1), shod but without orthoses (AG2), and shod with orthoses (AG3).

The method used to measure the angle of gait was the same as that used earlier by other authors.[13, 14] This method consisted of recording the footprint with a 2-mm-thick latex sheet, 1.20 m long and 50 cm wide. This sheet, inked on the lower face, was placed on a longer strip of 60-cm-wide porous paper, which received the footprint of the walking participant (Fig. 1). The porous paper was placed parallel to a longitudinal straight line representing the line of advance of the gait, that is, the direction that the child had to follow in walking. Thus, the direction of gait was identified by the longitudinal edge of the paper strip.[9] With this system, at least one complete step was recorded. Finally, the angle of gait of each foot was determined as the angle formed by the longitudinal axis of the foot and the line representing the direction of gait (Fig. 2). The angle of gait was quantified in degrees, being positive if the angle was external and negative if it was internal. The measurement was performed twice consecutively, and the definitive value was taken as the mean of the two measurements. The process of obtaining the plantar print and the determination of the angle of gait were always performed by the same observer (J.M.C.).

Each orthosis was constructed using the following method. With the child in the standing position, the subtalar joint was placed in a neutral position by

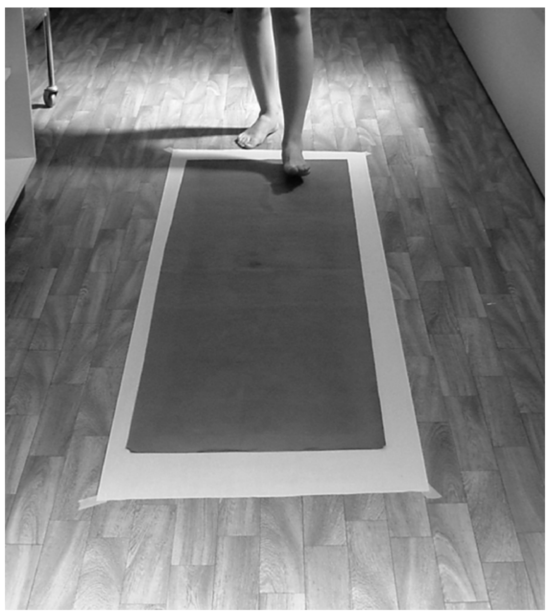

Figure 1. Procedure used to obtain the footprint to measure the angle of gait.

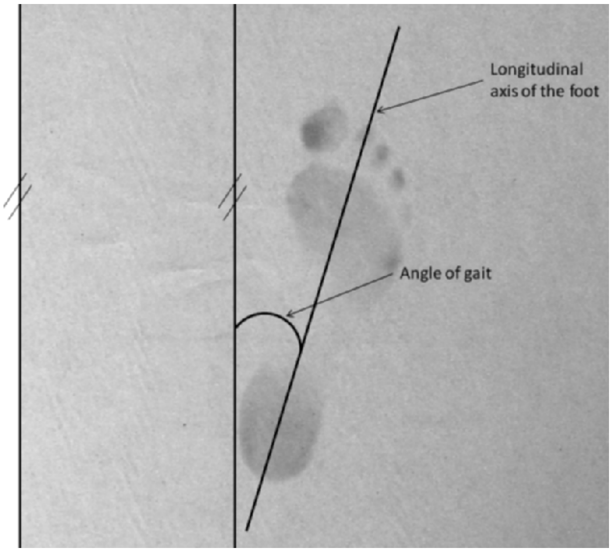

Figure 2. Measurement of the angle of gait.

manipulating the distal third of the leg (external rotation/internal rotation) until the talus head was centered, that is, with equal prominence on the medial and lateral faces of the foot, and a foot cast was made with phenolic foam.[15] The orthoses were made with 3-mm-thick polypropylene on the positive casts obtained. The part corresponding to the distal edge of the orthotic device had the form of a straight line joining the zone just behind the head of the first metatarsal and the zone corresponding to the subdigital space of the fifth toe (Fig. 3).

The shoe used for the measurements of the angle of gait had to be of physiologic type, that is, it had to fulfill the following requirements[16]: 1) the shoe must perfectly fit the morphologic and physiologic features of the foot; 2) the shoe must respect the perimeter of the foot in the inframalleolar zone, midfoot, metatarsophalangeal joints, and toes; 3) the maximum height of the counterfort must not overshoot the subastragaline joint; 4) the vamp must have a fastening system (laces, straps, or hook and loop fasteners [Velcro; Velcro USA Inc, Manchester, New Hampshire]); 5) the vamp must respect the direction of the longitudinal axis of the foot; 6) the sole must be made of natural or treated rubber, be resistant but not too rigid, and have a maximum heel height of 25 mm; and 7) the shoe must not have corrective orthopedic elements. If the child's own shoes did not fulfill these criteria, footwear was prescribed (this prescription was made in 21 children). The aim was that all of the children wore normal shoes similar in characteristics.

The estimated minimum sample size, based on a pilot sample with a standard deviation of 4, a maximum imprecision of ±1.5, and a confidence level of 0.95, was 28 feet (14 participants). This calculation was made with statistical software (CTM 1.1; Glaxo Wellcome SA, Madrid, Spain). The statistical analysis of the variables consisted of a descriptive assessment of the total sample, of boys and girls separately, and of the left and right feet separately. Normal distribution of the data was confirmed with the Shapiro-Wilk test, and parametric analysis was used for further analysis of the data. Comparisons made were AG1 versus AG2, AG2 versus AG3, and AG1 versus AG3. The t test for paired samples was used to compare the three measurements of the angle of gait (AG1, AG2, and AG3) in the total sample. The t test was also used for independent samples in the comparisons of the angle of gait between the sexes and between the left and right feet. Values of $P < .05$ were considered significant. In the case of obtaining significant differences, 95% confidence intervals for the difference of the means are provided. Data analysis was

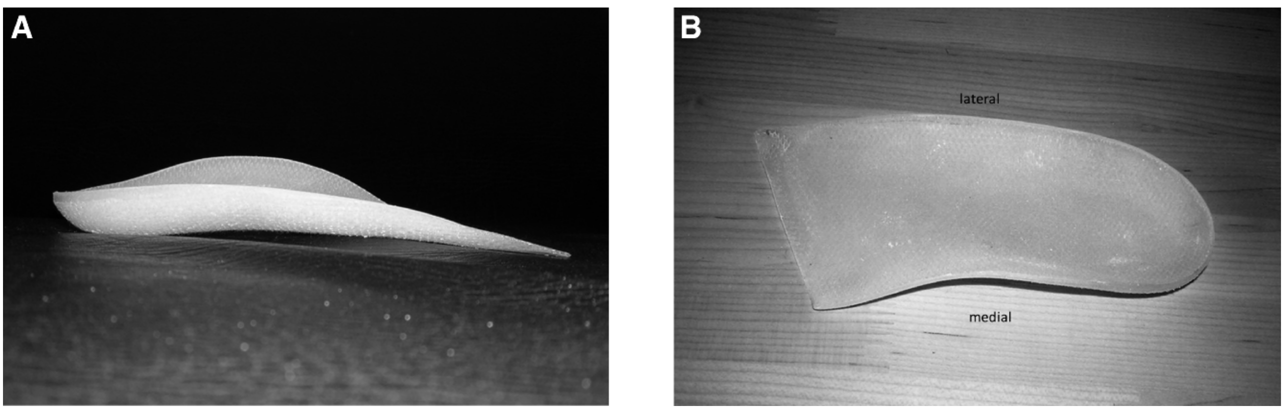

Figure 3. Lateral (A) and dorsal (B) views of an orthotic device with an out-toeing wedge.

performed with a statistical software package (SPSS 15.0 for Windows; (SPSS Inc, Chicago, Illinois).

Results

This study examined 48 children—22 boys (45.8%) and 26 girls (54.2%)—with a mean ± SD age of 6.88 ± 3.25 years. The distribution by side was symmetrical (96 feet [48 left and 48 right]). The results of the angle of gait measurements in the three modalities (AG1, AG2, and AG3) and the results of the comparisons between the different measurements in the whole sample are given in Table 1. A significant improvement in angle of gait was seen when using the recommended footwear (AG1–AG2), but a greater increase was revealed when using the footwear with orthoses (AG1–AG3).

Regarding sex, the results showed that when boys and girls were considered as separate groups, the change was similar to that in the total sample; that is, in all of the comparisons, boys showed generally greater changes in the angle of gait than did girls. But the difference between the sexes reached statistical significance only for the comparisons of AG1 to AG2 and AG1 to AG3. The changes between shod and shod plus orthosis was not statistically significantly different between boys and girls (Table 2).

Regarding side, the right foot generally showed a greater change in angle of gait compared with the left. The difference between left and right reached statistical significance only for the comparison of unshod with shod (AG1–AG2) (Table 3). The values obtained from each measurement of the angle of gait in all of the participants are given in Table 4.

Table 1. Descriptive Analysis of the Angle of Gait in the Total Sample

Measurement	Value (°)
Angle of gait (mean ± SD)	
AG1	−2.32 ± 3.43
AG2	−0.67 ± 3.23
AG3	2.98 ± 2.89
Angle of gait comparisons (mean [95% CI])[a]	
AG1–AG2	1.66 (1.33–1.98)
AG1–AG3	5.30 (4.87–5.74)
AG2–AG3	3.60 (3.18–4.11)

Abbreviations: AG1, unshod; AG2, shod but without orthoses; AG3, shod with orthoses; CI, confidence interval.

[a] $P < .001$ for all.

Table 2. Descriptive Analysis of the Angle of Gait in Boys and Girls Separately

Measurement	Boys	Girls
Angle of gait (mean ± SD [°])		
AG1	−2.73 ± 3.24	−1.98 ± 3.58
AG2	−0.70 ± 3.06	−0.63 ± 3.39
AG3	3.11 ± 1.91	2.87 ± 2.90
Angle of gait comparisons of the differences obtained between boys and girls (mean [°])		
AG1–AG2	2.03	1.35
AG1–AG3	5.84	4.85
AG2–AG3	3.82	3.42
Angle of gait difference (mean [95% CI] [°])		
AG1–AG2	0.67 (0.04–1.31)[a]	
AG1–AG3	1.01 (0.13–1.85)[a]	
AG2–AG3	0.40[b]	

Abbreviations: AG1, unshod; AG2, shod but without orthoses; AG3, shod with orthoses; CI, confidence interval.

[a] $P < .05$.

[b] $P = .4$.

Table 3. Descriptive Analysis of the Angle of Gait in Right and Left Feet Separately

Measurement	Left Foot	Right Foot
Angle of gait (mean ± SD [°])		
AG1	−1.50 ± 3.09	−3.15 ± 3.59
AG2	−0.21 ± 2.77	−1.13 ± 3.59
AG3	3.44 ± 2.52	2.52 ± 3.19
Angle of gait comparisons of the differences obtained between right and left feet (mean [°])		
AG1–AG2	1.29	2.02
AG1–AG3	4.94	5.67
AG2–AG3	3.56	3.65
Angle of gait difference (mean [95% CI] [°])		
AG1–AG2	0.73 (0.09–1.35)[a]	
AG1–AG3	0.73[b]	
AG2–AG3	0.09[c]	

Abbreviations: AG1, unshod; AG2, shod but without orthoses; AG3, shod with orthoses; CI, confidence interval.

[a] $P < .05$.

[b] $P = .097$.

[c] $P = .859$.

Table 4. Raw Data for All of the Participants: Unshod, Shod, and Shod Plus Orthoses

Unshod			Shod Without Orthoses			Shod Plus Orthoses		
Angle of Gait (°)	Feet (No. [%])	Gathered Percentage	Angle of Gait (°)	Feet (No. [%])	Gathered Percentage	Angle of Gait (°)	Feet (No. [%])	Gathered Percentage
−15	1 (1.0)	1.0	−12	1 (1.0)	1.0	−5	1 (1.0)	1.0
−10	2 (2.1)	3.1	−8	1 (1.0)	2.1	−4	1 (1.0)	2.1
−9	1 (1.0)	4.2	−7	3 (3.1)	5.2	−3	3 (3.1)	5.2
−8	4 (4.2)	8.3	−6	2 (2.1)	7.3	−2	1 (1.0)	6.3
−7	4 (4.2)	12.5	−5	4 (4.2)	11.5	−1	4 (4.2)	10.4
−6	3 (3.1)	15.6	−4	9 (9.4)	20.8	0	11 (11.5)	21.9
−5	7 (7.3)	22.9	−3	7 (7.3)	28.1	1	5 (5.2)	27.1
−4	9 (9.4)	32.3	−2	10 (10.4)	38.5	2	13 (13.5)	40.6
−3	9 (9.4)	41.7	−1	5 (5.2)	43.8	3	13 (13.5)	54.2
−2	15 (15.6)	57.3	0	13 (13.5)	57.3	4	15 (15.6)	69.8
−1	8 (8.3)	65.6	1	13 (13.5)	70.8	5	12 (12.5)	82.3
0	19 (19.8)	85.4	2	14 (14.6)	85.4	6	4 (4.2)	86.5
1	3 (3.1)	88.5	3	7 (7.3)	92.7	7	9 (9.4)	95.8
2	4 (4.2)	92.7	4	6 (6.3)	99.0	8	3 (3.1)	99.0
3	5 (5.2)	97.9	5	1(1.0)	100.0	9	1 (1.0)	100.0
4	1 (1.0)	99.0	Total	96 (100.0)		Total	96 (100.0)	
5	1 (1.0)	100.0						
Total	96 (100.0)							

Discussion

The aim of the present work was to determine to what extent a treatment we frequently used in cases of in-toeing gait in children was effective at the moment it was applied. After analyzing the results of this study, the null hypothesis can be rejected because the orthotic devices proposed, in association with the physiologic shoe, produced an increase in the angle of gait in children with in-toed gait. The reduction of in-toeing between unshod and shod plus orthotic device (AG1 to AG3) was 5.30°, and between shod and shod with treatment (AG2 to AG3) was 3.60°. Moreover, it is considered that the shoe also contributed to the improvement observed because it obtained a variation between the angle of gait unshod and shod (AG1 to AG2) of 1.66°.

There was generally a greater effect in boys than in girls and on the right side compared with the left. Regarding sex, the changes were significantly greater in boys than in girls between the angle of gait unshod and shod and between unshod and shod with treatment ($P < .05$). Regarding side, the changes were significantly greater on the right side for the unshod and shod comparison ($P < .05$). The change in angle of gait when shod compared with shod plus orthotic device was not affected by sex or side, whereas the use of a physiologic shoe exerted greater correction in this type of gait in right feet and in boys. Lafuente et al,[13] Morton,[17] Murray et al,[18, 19] and Seber et al[20] observed that the angle of gait is greater in the right foot than that in the left foot and in boys than in girls. The participants examined in the present study showed that boys were more in-toed than were girls (AG1) and that the right foot was more in-toed than was the left. Therefore, these data are not in concordance with those of the previously mentioned studies. However, the results obtained when comparing AG1 and AG2 suggest that a greater correction on the right side in boys could be achieved.

Other treatments using the elongation of the orthosis to the fifth ray for the treatment of in-toed gait in children have been investigated previously. Shuster,[12] in 1967, studied the out-toeing effect of a rigid element fitted inside the shoe and overshooting the metatarsophalangeal joints of the external rays. Taking the footprint of the individual as reference and using a system to study the angle of gait similar to the one used in the present work, Shuster[12] found that the angle of gait of the moving foot increased from 5° to 20° with that treatment. Redmond,[11] in 2000, conducted a study with premolded gait plate orthotic devices and found that in 14 of 18 cases treated, the in-toeing was reduced significantly. Unlike in the two previously mentioned studies, the orthoses applied in this work were custom-made orthoses with out-toeing wedge. We consider that besides producing an out-toeing effect, this type of treatment helps control biomechanical alterations in the subject's foot. This could be an advantage because the orthosis may help control the resultant propulsive period of pronation that may take place in the foot because of this type of orthosis.[10]

The effect by which this type of orthotic device increases the angle of gait is still unknown. It was hypothesized that the alteration produced by this element in the normal sequence of load distribution on the forefoot during push-off contributes to producing external rotation. Under normal conditions, the external metatarsals are the first to lose contact with the ground in push-off, starting with the fifth ray, followed by the fourth, the third, and so on. The elongation of the orthotic device to the level of the lateral surface of the forefoot might generate certain instability of the foot at push-off, and this instability might be corrected by seeking support from the medial surface of the forefoot with an external rotation of the lower limb. Such external rotational moment exerted on the whole lower limb by continued use of the orthotic devices with out-toeing wedge, before the child has acquired the definitive torsional and rotational parameters, could contribute to the acquiring of a new, more physiologic walking pattern and, thereby, help resolve the internal torsional alterations. However, this is only speculation, and further research is necessary to determine the exact effect of this type of plantar orthosis.

The main limitation of this study may be the use of porous paper to measure the angle of gait. More modern systems, such as electronic pressure mats, could have provided more accurate values. Also, having a control group and comparing the results of both groups across time, and not only at the moment of applying the treatment, could have given more validity to the study. It could be the interest of a future study.

Conclusions

The results of this study show that the orthotic devices with out-toeing wedge, in association with a normal shoe, increased the angle of gait in children 3 to 14 years old who presented with in-toed gait. Moreover, it has been observed that just using a physiologic shoe, without the addition of orthoses, significantly reduces adduction in the study participants' feet, with this effect being greater in boys than in girls and in the right foot than in the left foot. Although further work is necessary to determine the reason the orthotic devices produce this effect, this seems to be an effective treatment. Use of these devices could help the child develop a more physiologic walking pattern during growth, with little risk to the patient.

Financial Disclosure: None reported.
Conflict of Interest: None reported.

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