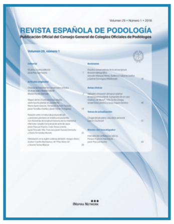

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Effectiveness of conservative orthotic treatment in flexible pediatric flatfoot

Eficacia del tratamiento conservador ortésico en el pie plano flexible infantil

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Palabras clave:

Pie plano flexible infantil, pie plano infantil, tratamiento conservador, eficacia, ortesis plantar, ortesis invertida, análisis de la marcha, cinemática.

Resumen

Introducción: Existe gran controversia respecto a la eficacia del tratamiento conservador mediante plantillas del pie plano flexible infantil (PPFI). El presente estudio trata de investigar el efecto de diferentes tipos de ortesis en la cinemática de las articulaciones de tarso y coxofemoral durante la marcha.

Pacientes y métodos: Se valoraron 167 escolares de 9 a 11 años, de los que se seleccionaron 24 niños con PPFI (índice de postura del pie de 9,81 ± 1,24). Se realizó un análisis esterofotogramétrico mediante 9 cámaras infrarrojas Optitrack, con un diseño mixto aleatorizado y autocontrolado. Se midió el efecto de las ortesis tipo Lelièvre, ortesis de resina y ortesis invertida sobre las articulaciones subtalar (AST) y mediotarsiana (AMT) en plano frontal y coxofemoral en plano frontal y transverso. Se analizó el efecto del calzado, grado de afección, sexo, y miembro considerado.

Resultados: El calzado y la ortesis redujeron significativamente la máxima eversión de AMT ($p < 0{,}001$), pero solo la ortesis la redujo sobre la AST ($p < 0{,}001$). La ortesis invertida y de Lelièvre redujeron significativamente la máxima eversión de retropié respecto de la ortesis de resina ($p = 0{,}005$) y ($p = 0{,}003$). Las ortesis de Lelièvre y de resina redujeron significativamente la máxima eversión de mediopié respecto de la ortesis invertida ($p = 0{,}011$) y ($p = 0{,}010$).

Conclusión: Las ortesis plantares han demostrado cambios en la cinemática de las articulaciones del tarso del PPFI, pero no sobre el muslo, con una posible interferencia del tejido blando.

Keywords:

Flexible pediatric flatfoot deformity, pediatric flatfoot, conservative treatment, effectiveness, foot orthoses, inverted orthoses, gait analysis, kinematics.

Abstract

Introduction: There is controversy regarding the effectiveness of conservative treatment by means of foot orthoses for the flexible pediatric flatfoot deformity condition. The present study aims to investigate the effect of different types of orthoses in the kinematics of tarsal joints and hip joint during gait.

Patients and methods: A total of 167 pediatric students between 9 and 11 years were initially evaluated and 24 subjects with flexible pediatric flatfoot deformity were finally selected (foot posture index 9.81 ± 1.24). Gait analysis was performed by means of 9 infrared Optitrack cameras with a randomized and controlled type design of the study. The effect of three different orthoses (Lelièvre orthoses, Polyester resin orthoses and polypropylene inverted orthoses) on subtalar-rearfoot (STJ) and midtarsal (MTJ) joints in the frontal plane and coxofemoral joint in the frontal and transverse plane were evaluated. The effect of shoe, deformity, sex and limb were also analyzed.

Results: Both shoe and orthoses reduced maximal pronation of MTJ ($p < 0.001$) but only orthoses reduced maximal pronation on STJ ($p < 0.001$). Inverted orthoses and Lelièvre orthoses reduced maximal eversion of rearfoot compared to resin orthoses ($p = 0.005$ and $p = 0.003$). Lelièvre orthoses and resin orthoses reduced maximal eversion of midfoot compared to polypropylene inverted orthoses ($p = 0.011$ and $p = 0.010$).

Conclusions: Foot orthoses have shown changes in kinematics parameters in tarsal joints in patients with flexible pediatric flatfoot deformity but not in hip joint with possible interference of soft tissues around the thigh.

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INTRODUCTION

Kevin A. Kirby[1] has defined pediatric flexible flatfoot deformity as a deformity with four characteristic elements: excessive pronation of subtalar and midtarsal joint, decrease of medial longitudinal arch and increased ligament laxity. Several terms have used to define the deformity such us flatfoot, valgus foot, pes planus, pronated feet, flexible flatfoot deformity or hypermobile flatfoot deformity[2]. In a systematic review, Evans & Rome reported a prevalence of pediatric flexible flatfoot deformity between 0.6 % and 77.9 %, attributing that variability to the different methods of evaluation used in the studies and diversity of age and ethnic groups presented[2]. Rao & Joseph[3] in a study with 2300 pediatric patients showed a prevalence of 14.9 % in children less than 6 years and 2.5 % in children less than 13 years. Jerosch et al. reported a prevalence rate of 19.1 % in a group of 345 children from Germany between 10 and 13 years of age[4]. García-Rodríguez et al.[5], in a study of 1181 children from Spain reported a prevalence of 2.7 % in children from 4 to 13 years of age. Bordin et al. reported a prevalence rate of 16.4 % in a group of 243 Italian children (8-10 years)[6]. Pfeiffer et al.[7] observed prevalence rates of 54 % at 3 years and 24 % at 6 years in a sample of 835 children from USA. Homayouni et al.[8] in a study of 290 girls from Iran showed a prevalence of 48.1 % at 6 years and 15.6 % at 11 years.

Ligament laxity related to the flexible pediatric flatfoot deformity in associated with a decrease in resistance force of the plantar fascia, ligaments and plantar tendons to ground reaction forces, triceps sural tension and weight of the subjects. In that condition, stability of plantar arch would be jeopardized the efficiency of the propulsive phase. Decrease of stiffness of these structures would also decrease the storage of potential energy needed for inversion of STJ and plantarflexion of the forefoot during propulsive phase with a decrease in the medial longitudinal arch[9,10]. Medial deviation of the axis of STJ axis creates an increase in pronation moments and a decrease in supination moments from ground reaction forces and from muscular actions[9-12].

One of the objectives of the orthotic treatment of pediatric flexible flatfoot deformity is to correct foot posture by means of different types of foot orthoses that can vary en their materials, design and fabrication processes. Lelièvre orthoses are a non-custom orthotics described in 1970 that consists of a plane leather layer in which several elements of latex or foam are glued. For flatfoot treatment, those elements usually are: rearfoot supination wedge, forefoot pronation wedge, arch support and metatarsal pad[13]. In 1994, Adelina Dorca and Tomás Céspedes introduced in Spain the Direct Adaptation Technique described in France by Dr. Claustre. A layer of polyester resin is directly applied on the foot (heated to 60-80° Celsius degrees) with a direct assisted vacuum[14]. In middle eighties Dr. Richard Blake[15] invented the inverted orthoses made of polypropylene from a positive cast of the patient who is inverted 15-25°. Kirby in 1992 described the Medial Heel Skive technique that can be used in conjunction with the inverted orthoses for the treatment of pediatric flatfoot deformity[16].

The objective of the present study consists in the evaluation of the effect of these 3 types of orthoses (Lelièvre, resin and inverted orthoses) in the kinematic parameters of STJ and MTJ in the frontal plane and in the coxofemoral joint in the frontal and transverse plane during gait in children with pediatric flexible flatfoot deformity. Influence of sex, limb, shoe and degree relaxed calcaneal stance position (RCSP) were also evaluated.

PATIENTS AND METHODS

After the acceptance of the Ethics Committee of clinical investigation of Aragon (CEICA), 167 children born between 2003 and 2004 (9-11 years old) from two local Schools in Zaragoza (Spain) were evaluated. After obtaining parents consent, 53 children were initially selected for a second evaluation from whom only 28 turned into a posterior visit to the office of the author of the paper. From these 28 children only 15 children were finally selected. Nine children selected from the podiatric office of the main investigator were also added to the sample of the study (Figure 1). Inclusion criteria were: being born between January 2003 and December 2004, Resting Calcaneal Stance Position (RCSP) between 6 and 10 degrees, decrease in medial longitudinal arch contacting the floor in weightbearing, Foot Posture Index (FPI-6) between 6 and 12 points, medially deviated subtalar joint axis, and being bellow of 95 percentiles in Body Mass Index for their age. Exclusion criteria were: positive jack test, positive Single Heel Rise Test or Double Heel Rise test, Beighton test superior to 4, sagittal plane mobility greater than 10 mm of the first ray, absence of pain and the presence of previous surgeries in lower extremities.

Instrumentation

A computerized gait analysis was performed in the biomechanics laboratory of engineering investigation of Aragon (i3A). A walking treadmill was used for the study in which subjects initially walked in a warmup period not inferior to 5 minutes[17-19]. Nine Infrared Optitrack cameras were used to record reflective markers attached to the patient that were posteriorly processed with the software Motive® (Natural Point Inc.,). A multisegment foot model with two elements, forefoot and rearfoot, was constructed with the use of a plate similar of that used by Leardini et al.[20] allowing introducing the foot inside shoes and capturing the markers with no interferences (Figures 2 and 3). Thigh segment required a specific marker attached to the skin.

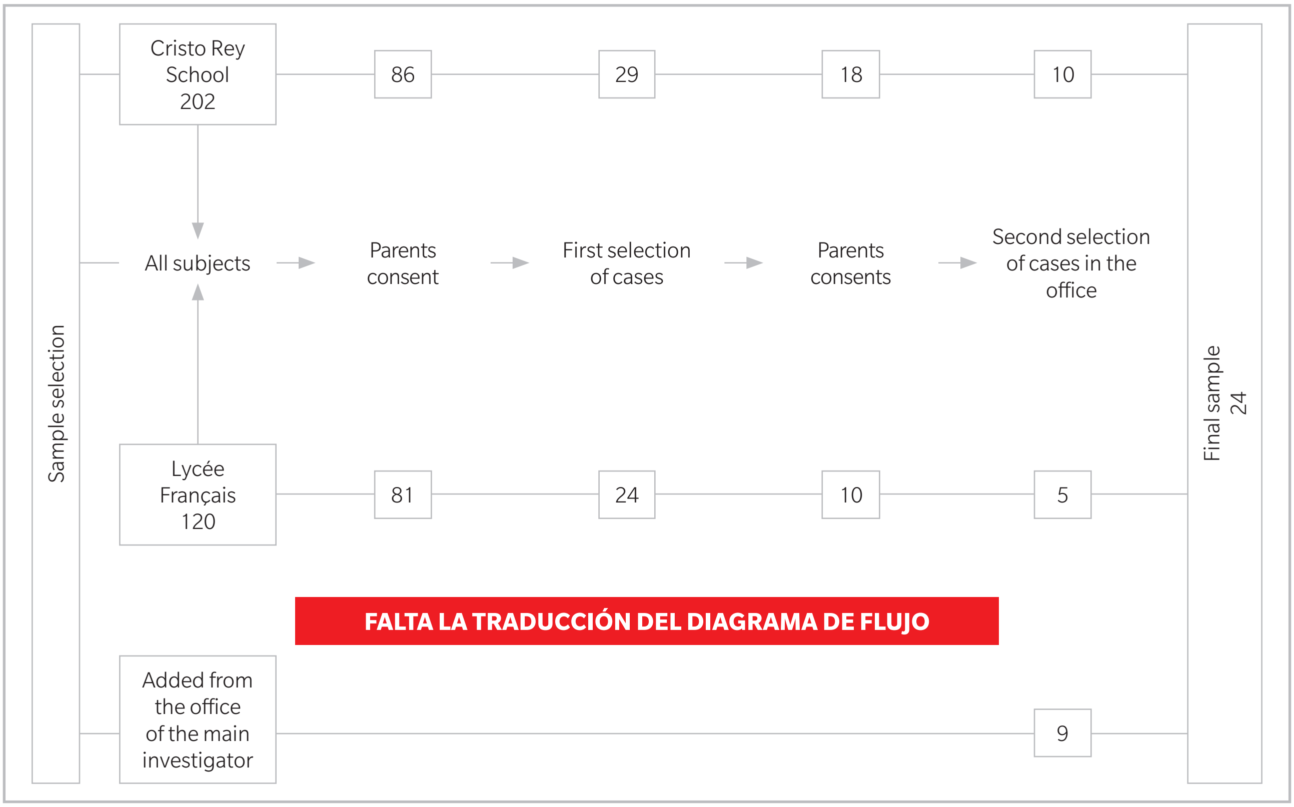

Figure 1. Flow Chart of Study Population.

Figure 2. Posterior view of rearfoot marker unshod and shod.

Figure 3. Posteromedial view of foot marker unshod and shod.

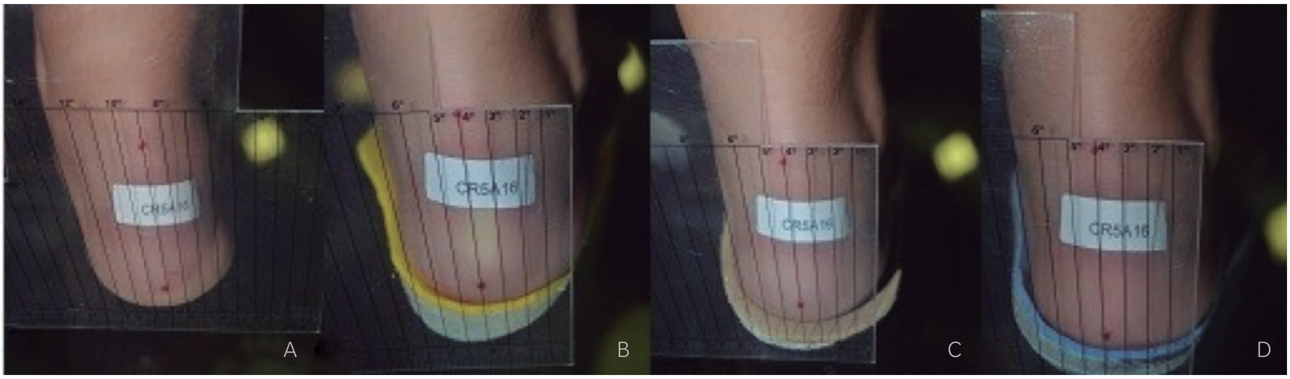

Figure 4. RCSP of a right foot of 9º that is reduced 5º with all the orthoses.

Orthoses shoes

Lelièvre orthoses or element-type orthoses (OE) consisted of a plane leather layer of 2 mm thickness in which a 5 mm rearfoot wedge (70-75° Shore and 1.25 gr/cm^3 density); and a medial longitudinal arch (30-35° Shore and 0.95 gr/cm^3 density) were glued.

Resin orthoses (OR) were constructed by fusion of HERFLEX® of 1.9 mm and TF FLUX Antracita® of 1.3 mm, (Herbitas, Spain) using the direct adaptation technique directly on the patient foot. During that process, inversion of the foot was performed manually without extrinsic wedges. All resin orthoses were stabilized with the use of neutral post of rearfoot of high density EVA.

Inverted orthoses made of polypropylene (OP) were constructed form a positive cast taken with controlled or partial weigthbearing of the patient in a phenolic foam box. During the casting foot position was controlled to avoid hyper o under correction of the deformity. They were posteriorly constructed by a orthotic laboratory (PERPEDES TECNOINSOLE®, Alicante, Spain) in polypropylene with a Medial Heel Skive of 5 mm and 5º-6º of inversion. All orthoses and casting were performed by the main investigator.

Two types of shoes were used. Sport shoes with a thin layer in the upper cover and minimal resistance to lateral forces exerted by the foot (ZAP) and running shoes composed of several layers in the upper cover (leather, synthetic materials and foam) and with a rigid counterheel to resist lateral forces exerted by the foot (DEP). Both had dorsal strap adjustment and closure.

Study Protocol

The three orthoses were previously tested on the children and they should have corrected the same amount of degrees of RCSP during static stance prior to its application in the study. All that measurements were made by the main investigator.

After a warmup period of 5-10 minutes walking on the treadmill in a constant velocity of 2.9 km/hour, ten similar gait cycles were selected of each condition of each patient. The conditions studied were always tested in the same order as follows: Barefoot (DES), with sport shoes without orthoses, with running shoes without orthoses, with sport shoes and OE, with running shoes and OP, with sport shoes and OR, with running shoes and OE, with sport shoes and OP and with running shoes and OR. A static trial with the child in RCSP was initially captured as the reference position for the measurement of the kinematics parameters. This position was called "zero rotations".

Variables

An initial visual inspection of all captured trials was made and atypical trials were eliminated to decrease variability[21,22] when a temporal disagreement was observed. All selected trials of each condition of each subject were finally mixed into a final graph that represented the mean graph for that condition for each subject[23-25]. Values of walking barefoot trials (DES) of each subject were used as a control to avoid bias derived from marker placement. Independent variables used were: sex, foot (right/left), type of shoe (sport shoes / running shoes), grade of deformity of RCSP (5-6° / 7-8° / 9-10°); orthoses (barefoot/shod without orthoses/ OE/OP/OR).

Two dependent variables were studied. The first was the maximum value of rotation for the 8 conditions tested compared to barefoot (DES) during the stance phase of the gait cycle. The second was the range of rotation between a superior and inferior limits occurred during the stance phase of the gait cycle. Exactly those variables were: "RTP_RzΔ" (increase of rotation of rearfoot segment); "RTP_RzD" (maximal rotation of rearfoot segment); "PIE_RzΔ" (increase of rotation of midfoot segment); "PIE_RzD" (maximal rotation of midfoot segment); "MUSLO_RzΔ" (increase of rotation of thigh segment in the frontal plane); "MUSLO_RzD" (maximal rotation of thigh segment in the frontal plane), "MUSLO_RyΔ" (increase of rotation of thigh segment in the transverse plane); "ZAN" (step length) y "ZAN_MI" (number of steps per minute).

Data analysis

A cross-over design of repeated measures was used because dependent variables were compared with the same subject in different conditions. SPSS 19.0 software program (SPSS, Chicago, IL) was used for calculations. Both limbs were used for analysis for comparison between them. Shapiro-Wilk test was used to test normality of the variables. One factor ANOVA was used for anthropometric data; repeated measures ANOVA was used for comparison of the kinematic variables of the different segments; multivariant ANOVA for independent samples was used to test the order effect as has been recommended[26]. Hypothesis testing with a cut-off value of equal or less than 0.05 was used in all these tests. Also a 95 % confidence interval and size effect was calculated in all cases.

RESULTS

The final sample was formed by 14 girls and 10 boys, 12 feet had a RCSP of 6°, 31 feet had a RCSP between 7 and 8° and 5 feet had a RCSP between 9 and 10°. The real prevalence of flexible pediatric flatfoot deformity was 8.98 % (15/167) and the estimated prevalence was 16.76 %. Table I shows anthropometric data of the sample of the study.

Table II shows the results of the hypothesis tests in the dependent and independent variables of the study. The variable of range of motion of the frontal plane in the rearfoot showed a mean rotation of rearfoot in the frontal plane of 4.09° ± 1.70. A statistical significance decrease in eversion range of rearfoot (less than 1º) was obtained with OE and OP compared to OR (p = 0.007 and p = 0.044 respectively). Walking without orthoses and OR increased the eversion range compared to DES. The size effect attributable to orthoses was 4,3 % (0.043). Orthoses (not shoe) significantly reduced maximal eversion of rearfoot (p < 0.001). Greater reduction was obtained with OE followed by OP, both with a statistical significant reduction compared to OR (p = 0.003 and p = 0.005 respectively). Size effect attributable to orthoses was 46.0 % (0.460).

The mean rotation range in MTJ was 7.27° ± 2.56. Shoe effect reduced eversion range of MTJ compared to barefoot (p < 0.001). No differences were found in all shod conditions. This reduction was bigger in boys (p = 0.013), with running shoes (p = 0.050) and with a RCSP of 5-6° compared to RCSP of 7-8°. Effect size of the orthoses was 22.1 % (0.221). Maximal eversion of MTJ in the frontal plane was reduced with shoe compared to barefoot (p < 0.001) and with orthoses compared to shoe without orthoses condition. There were no differences between OE and OR (p > 1.000) and both reduced maximal eversion of MTJ compared to OP (p = 0.011 and p = 0.010 respectively). Reduction was bigger in boys (p = 0.016) and with running shoes (p = 0.048). Effect size attributable to orthoses was 58.1 % (0.581).

Regarding coxofemoral joint, the mean range of adduction was 3.72° ± 1. The OE orthoses reduced femoral adduction compared to the rest of situations: DES, shod without orthoses, OR and OP (p < 0.001). Inverted Orthoses (OP) also reduced femoral adduction compared to barefoot (p = 0.021). The right limb showed greater reduction femoral adduction range and in the femoral maximal adduction compared to the left limb (p < 0.001). Differences were less than 1°. Effect size of the orthoses was 15.2 % (0.152), and effect size of the limb was 28 % (0.280).

No differences were detected regarding femoral frontal plane variables (range and maximal value of rotation). The mean range of femoral internal rotation was 15.13° ± 5.18°.

Table III shows the results of the hypothesis of the dependent variable regarding variable orthoses.

Table I. Anthropometric data of the sample

	General (n = 24)	Boys (n = 10)	Girls (n = 14)	*p* Value
Age	10,45 ± 0,58	10,40 ± 0,49	10,50 ± 0,63	0,691*
Weight	36,87 ± 8,05	37,49 ± 10,20	36,44 ± 6,50	0,761*
Height	141,08 ± 9,70	141,80 ± 12,83	140,57 ± 7,18	0,767*
BMI	18,78 ± 4,09	19,16 ± 4,40	18,51 ± 4,00	0,713*
RCSP	7,39 ± 1,06	7,33 ± 0,84	7,42 ± 1,19	0,771*
FPI-6	9,81 ± 1,24	9,8 ± 1,22	9,82 ± 1,26	0,934 *
RCSP Grade	**PCRA 5-6°**	**PCRA 7-8°**	**PCRA 9-10°**	***p* Value**
FPI-6	9,25 ± 0,94	9,87 ± 1,29	10,67 ± 0,98	0,004**
BMI	16,67 ± 1,88	19,03 ± 4,31	22,34 ± 3,67	0,023**

* One factor ANOVA **Posthoc Bonferroni. BMI: Body Mass Index. FPI: Foot Posture Index. RCSP: Resting Calcaneal Stance Position.

Table II. Results of dependent and independent variables

Variable	μ ± σ	CV	*p* value	η2	sex	limb	shoe	degree
RTP_RzΔ	4,09° ± 1,70°	0,41	p = 0,009	0,043	-	-	-	-
RTP_RzD	-	-	p < 0,001	0,46	-	-	-	-
PIE_RzΔ	7,27° ± 2,56°	0,35	p < 0,001	0,221	p = 0,013	-	p = 0,05	p = 0,012
PIE_RzD	-	-	p < 0,001	0,581	p = 0,016	-	p = 0,048	-
MUz_Δ	3,72° ± 1,15°	0,31	p < 0,001	0,152	-	p < 0,001	-	-
MUz_D	-	-	p = 0,164	0,021	-	p < 0,001	-	-
MUy_Δ	15,13 ± 5,18°	0,34	p = 0,883	0,004	-	-	-	-
ZAN	80,791 ± 4,658 cm	0,058	p < 0,001	0,272	p < 0,001	-	-	p = 0,030
ZAN_MI	54,505 z' *	0,047	p < 0,001	0,321	p < 0,001	-	-	p = 0,036

RTP_RzΔ: range of eversion of rearfoot segment. RTP_RzD: maximal eversion of rearfoot segment. PIE_RzΔ: range of eversion of midfoot segment. PIE_RzD: maximal eversion of midfoot segment. MUz_Δ: range of coxofemoral joint in frontal plante.; MUz_D: maximal value of coxofemoral joint in the frontal plane. MUy_Δ: range of coxofemoral joint in the transverse plane. ZAN MI: steps per minute. ZAN: Step length.

DISCUSSION

In the present study, a kinematic analysis was performed on the effect of different types of orthoses and shoes on the range and maximal values of eversion of rearfoot and midfoot joints and on the coxofemoral joint in children with flexible pediatric flatfoot deformity between 9 and 11 years of age. If all initially preselected children would have come to a posterior evaluation, the estimated prevalence of flexible pediatric flatfoot deformity would have been 16.76 %. This data is closed to those reported by Bordin et al. (16.4 %)[6], Jerosch et al. (19.1 %)[4] and Homayouni (15.6 %)[8]. However, it would be different from the 2.5 % and 14.9 % reported by Rao & Joseph in 1992[3], and from the 2,7% that showed García-Rodríguez et al. in 1999[5]. Evans & Rome[2] attributed those differences to the diversity of ethnic groups and the different evaluation meth-

Table III. Results of the dependent variable orthoses

RTP_RzΔ	Mean	DES	CS	OE	OP	OR
DES	0	-				
CS	-0,243	-	-			
OE	0,516	-	-	-		p = 0,007
OP	0,403	-	-	-	-	p = 0,044
OR	-0,041	-	-	-	-	-
RTP_RzD	**Mean**	**DES**	**CS**	**OE**	**OP**	**OR**
DES	0	-		p < 0,001	p < 0,001	p < 0,001
CS	0,87	-	-	p < 0,001	p < 0,001	p < 0,001
OE	4,275	-	-	-		p = 0,003
OP	3,921	-	-	-	-	p = 0,005
OR	3,453	-	-	-	-	-
PIE_RzΔ	**Mean**	**DES**	**CS**	**OE**	**OP**	**OR**
DES	0	-	p < 0,001	p < 0,001	p < 0,001	p < 0,001
CS	2,342	-	-			
OE	2,804	-	-	-		
OP	2,729	-	-	-	-	
OR	2,855	-	-	-	-	-

(Continue in the next page)

Table III. Results of the dependent variable orthoses (Cont.)

PIE_RzD	Mean	DES	CS	OE	OP	OR
DES	0	-	p < 0,001	p < 0,001	p < 0,001	p < 0,001
CS	4,956	-	-	p < 0,001	p < 0,001	p < 0,001
OE	7,305	-	-	-	p = 0,011	
OP	6,469	-	-	-	-	p = 0,010
OR	7,045	-	-	-	-	-
MUz_Δ	**Mean**	**DES**	**CS**	**OE**	**OP**	**OR**
DES	0	-		p < 0,001	p = 0,021	
CS	0,195	-	-	p < 0,001		
OE	0,733	-	-	-	p = 0,001	p < 0,001
OP	0,438	-	-	-	-	
OR	0,326	-	-	-	-	-
MUz_D	**Mean**	**DES**	**CS**	**OE**	**OP**	**OR**
DES	0	-				
CS	0,068	-	-			
OE	0,494	-	-	-		
OP	0,294	-	-	-	-	
OR	0,246	-	-	-	-	-
MUy_Δ	**Mean**	**DES**	**CS**	**OE**	**OP**	**OR**
DES	0	-				
CS	-0,032	-	-			
OE	-1,004	-	-	-		
OP	-0,503	-	-	-	-	
OR	-0,484	-	-	-	-	-
ZAN_	**Centimeters**	**DES**	**CS**	**OE**	**OP**	**OR**
DES	80,791	-	p < 0,001	p < 0,001	p < 0,001	p < 0,001
CS	84,708	-	-		p = 0,010	p = 0,012
OE	85,638	-	-	-		
OP	86,694	-	-	-	-	
OR	86,139	-	-	-	-	-
ZAN MI	**Steps per minute**	**DES**	**CS**	**OE**	**OP**	**OR**
DES	54,505	-	p < 0,001	p < 0,001	p < 0,001	p < 0,001
CS	51,527	-	-		p = 0,012	
OE	51,073	-	-	-		
OP	50,728	-	-	-	-	
OR	50,898	-	-	-	-	-

RTP_RzΔ: range of eversion of rearfoot segment. RTP_RzD: maximal eversion of rearfoot segment. PIE_RzΔ: range of eversion of midfoot segment. PIE_RzD: maximal eversion of midfoot segment. MUz_Δ: range of coxofemoral joint in frontal plante. MUz_D: maximal value of coxofemoral joint in the frontal plane. MUy_Δ: range of coxofemoral joint in the transverse plane. ZAN MI: steps per minute. ZAN: step length. DES: barefoot. CS: shod without orthoses. OE: lelièvre orthoses. OP: inverted orthoses. OR: resin orthoses.

ods used to assess the prevalence of this deformity. Because the longitudinal arch remains quite stable at 6 years[2] the age of the participants of the present study (9-11 years) should not have influenced that estimation.

At the same time, of the children who accepted to participate in the present study there were more girls (69.23 %) than boys (35.51 %) which probably conditioned the sample of the study which is in contrast with the bigger prevalence of flat-foot deformity reported in boys in several studies[2,7,27,28], and that has been related to several factors such us overweight, ligament laxity or sedentarism[2,7,27-29]. The absent of statistical significant differences in age, weight, height, RCSP and PFI-6 associated to sex in the present study can be interpreted as a sign of adequate homogeneity of the sample. As was expected, FPI-6 and RCSP were related (p = 0.004). However, regarding FPI-6 there is no clear consensus of their reliability with some studies showing a low reliability[30,31], while other have showed a very acceptable reliability[32,33]. In this study, the

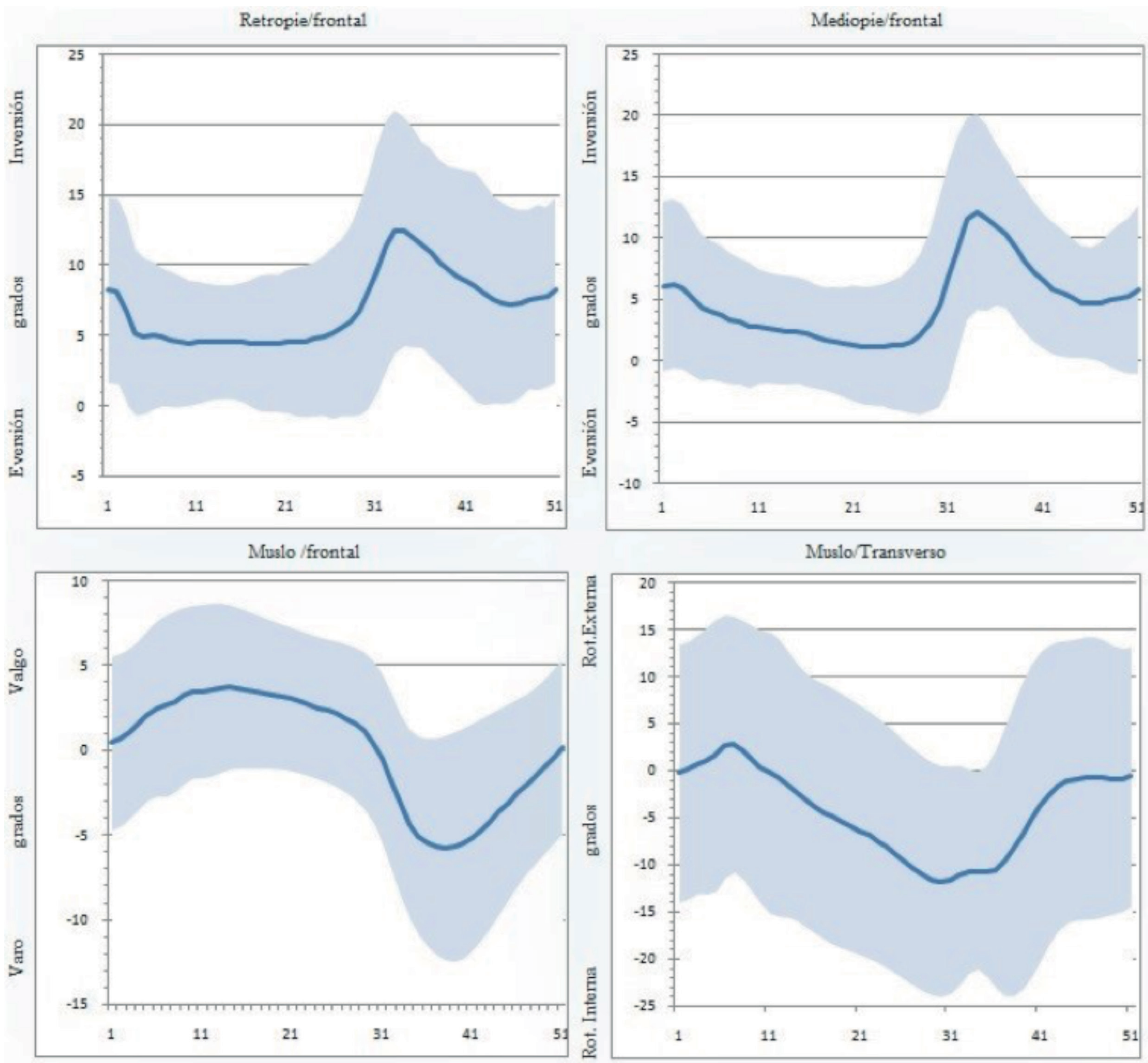

Figure 5. Mean values observed of flexible pediatric flatfoot deformity in the children of the study (24 right feet). Upper left shows rearfoot rotation in the frontal plane. Upper right shows midfoot rotation in the frontal plane. Lower left shows femoral rotation in the frontal plane (femoral abduction/adduction) and lower right shows femoral rotation in the transverse plane.

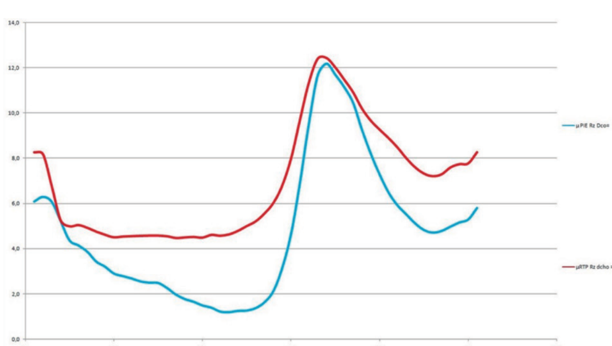

Figure 6. Mean values of rearfoot (red) and midfoot (blue) observed (24 right feet). Horizontal line represents the percentage of the gait cycle.

assessment of FPI-6 was made by the same investigator who is a podiatrist with more than 20 years of experience.

The present study showed a range of pronation of the rearfoot complex in the frontal plane of 4.09° ± 1.7°, which is inferior to the 10° referred by Root[34], 10.7° showed by Leardini et al. using a similar marker set used in the present study[20], the 10.8° ± 2.2 showed by Stebbins et al. in children[35] and the 7°, 8.9° and 10° reported by Westblad et al., Arndt et al. and Reinschmidt et al., using intracortical pins[36-38]. These differences could be explained by the sample of the present study who was formed by children with flatfoot deformity whose mean RCSP was 7.39°.

Although observed differences between orthoses were small, the differences founded between OP and OE regarding OR could be related to the design of an inclined plane exerted by the supination wedge in the OE and by the Medial Heel

Skive in the OP (Figure 7). That configuration would offer more stability at heel strike than the more curved one observed in the OR or in the case of walking shod without orthoses which generated an inversed effect (increased pronation).

Statistical significant reduction of maximal eversion of STJ was 4º for both OE and OP, and 3.4° for OR compared to walking barefoot. These data are similar to those obtained by McCulloch et al. (3°-4°)[39] and bigger to the 2.3° reported by Mündermann et al.[40], to the 2,2° reported by Genova & Gross[41], to the 1-3° reported by Eng & Pierrynowsky[42], to the 1,59° reported by Williams et al.[43] and to the 1,5° reported by Nigg et al.[44]. The auto-controlled design of the study (subjects compared with themselves) could have influenced these results compared to other studies. The absence of reduction of maximal pronation values with the use of shoes without orthesis could be indicative of the limited effect of shoes for the control of pronation at heel strike. The three orthoses reduced maximal eversion of rearfoot compared to barefoot and shoes without orthoses. The design of the OE and OP could be the reason of bigger reduction of this orthoses compared to the curved heel of OR.

The MTJ showed a mean eversion range of 7.27° ± 2.56. This value is smaller compared with the values reported by Lundberg et al. (20.30°)[45], by Ouzoniam et al. (17.70°)[46], and by Arndt et al. using intracortical pins (13.5 ± 4.1°)[37]. Leardini et al. and McWlliams et al.[20,47], reported 2.8° and 2.5° of MTJ eversion respected to calcaneus that also had an eversion movement of 10°[20,47]. In the present study, absolute values were reported to a reference global system and that is the reason that the values of this study are more similar to those reported by Arndt et al.[37]. The inferior value could be related to the initial reference position that was quite close to that of maximum pronation. Shoes significantly reduced eversion range of MTJ during midstance ($p < 0.001$) and no differences could be drawn between shoes without orthoses, OE, OP, and OR. Running shoe decreased eversion range compared to sport shoe ($p = 0.050$).

The use of the shoe and the posterior addition of foot orthoses generated a reduction in the maximal eversion of MTJ ($p < 0.001$), which agrees with the results of the studies of Moraleda & Mubarak, Sinha et al. and Boks et al.[48-50]. This reduction was bigger in OE and OR compared to OP probably because of the conservative prescription of only 5-6 degrees of inversion of the inverted orthoses. Again, running shoes reduced maximal eversion of MTJ compared to sport shoes only ($p = 0.048$). Rao & Joseph and Sachithanandam & Joseph[3,51] tried to stablish a relationship between the use shoes in early childhood and the prevalence of flexible pediatric flatfoot deformity, supporting the hypothesis that strengthening of intrinsic muscles and soft tissues would be better in children that do not use shoes. However, Gould et al. found a faster development of medial arch in children that regularly used shoes during the first 2 years of age[52]. Important to note that in all these studies, the effect of shoe wearing was not taken into consideration which could negate or even create an opposite effect of control of the shoe. Pronation control exerted by the shoe that has been found in this study would not exclude a physical program to strengthen intrinsic plantar muscles. Control of pronation of MTJ could be beneficial in the evolution of MTJ arthrosis as Thomas et al., Menz et al. and Allen & Glasoe have pointed out[53-55]. Excess of pronation has been related to an increase of internal tibial torsion that could be associated to injury of anterior cruciate ligament[55,56], tendon problems of tibialis posterior or os tibiale externum[57,58].

Lelièvre orthoses significantly reduced range of coxofemoral adduction and also decrease non-significantly the maximal adduction angle but these reductions were quite small (1º and 0.5º respectively). From data obtained in this study it is quite possible that the thigh values obtained were influenced by movement of soft tissues around the marker which would have influenced the results. Although some authors have pointed the effect of orthoses in the adduction of the knee[43,59], others such us Reinschmidt et al.[38], Karlsson et al.[60], and Hold-

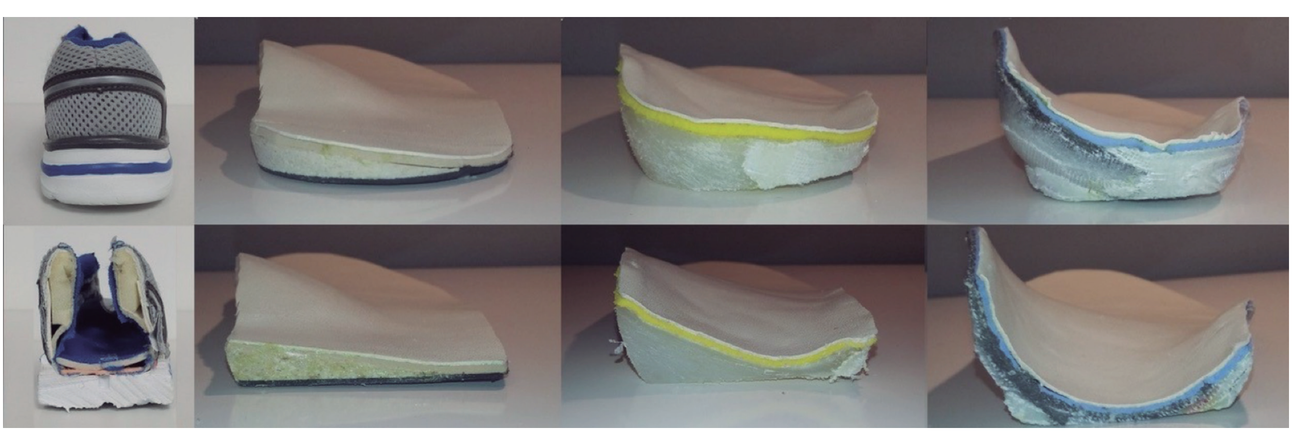

Figure 7. Posterior view of the orthoses used in the study. From left to right running shoe, Leliévre orthoses (OE), polypropylene inverted orthoses (OP) and polyethylene resin orthoses (OR).

en et al.[61], advise about the possible effect that movement of soft tissues around the markers in that results, especially in the frontal and transverse plane.

Thickness of the shoes used and the insoles would have elevated the length of the extremity which could have some influence in step length[62]. Girls showed increased step length which could be related to a greater degree of RSCP. Inversely, virtually increased length with the shoes and the orthoses significantly reduced number of steps in the present study.

The order used for testing did not show any influence in the results of the study and observed difference could be explained by other factors.

Although just purely descriptive, it is interesting to note the similarities founded in the kinematics graphs of STJ and MTJ in the frontal plane during the stance phase of gait. For the first 10-12 % of the cycle, both graphs pronate and MTJ continues pronation till its maximal eversion position which is close to the 68 % of the gait cycle. This value is 10 % more that the reported by Simon et al. in normal feet[63].

The present study has several limitations and its results should be interpreted cautiously. The main limitation associated to the study was the small sample size which was conditioned by the availability of the lab and the response of parents and children to the initial evaluation. The design of some markers could be seen as a potential limitation and also soft tissue movement around the thigh marker could have influenced the results obtained.

In conclusion, the present study has found that the shoe and the orthoses reduced maximal eversion of STJ and MTJ and that orthoses design in its posterior portion could be related with its effectiveness of motion control in the subtalar and midtarsal joints.

CONFLICTS OF INTERESTS

The author declares no conflicts of interests.

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