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Comparing the efficacy of exercise, internal and external shoe modification in pes planus: A clinical and pedobarographic study

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Abstract. Pes planus is a condition that can cause pain along the innerfoot due to the absence or abnormal depression of the longitudinal arch. There are few studies available that compare therapy modalities used in these patients. In our study, those treated with conservative therapies – internal and external shoe modifications and pes planus exercises – were compared clinically and pedobarographyically. 60 pes planus patients were included in the study. In the first group; internal modification was performed by placing a medial longitudinal arch support inside the shoe. In the second group, external shoe modification was performed using the Thomas heel. In the third group of patients however, only an exercise program was executed. The patients' foot pain levels, functional asssessment, satisfaction and quality of life were recorded. Pedobarography was used in measuring both static and dynamic plantar pressure. Assessments were carried out at baseline and at the end of the first and third months respectively where intra- and inter- group comparisons were performed. Each group was composed of 20 subjects. While improvement in terms of foot pain, foot function index and quality of life was observed in all the study groups ($p < 0.05$), the most improvement was observed in the group of patients treated with internal modification ($p < 0.016$). This was followed by the external modification and the exercise groups respectively. No difference was observed between the internal and external modification groups in terms of patient satisfaction. Cross-sectionally; clinical assessments, pedobarographic analysis were correlated. The changes observed after static and dynamic pedobarographic studies were not significantly different between the study groups. At the end of the study it was observed that internal modification yielded the most significant clinical improvement. In the literature, there are limited publications comparing the conservative treatments with each other. In this study we aimed to compare the conservative treatments for flatfoot.

Keywords: ???

1. Introduction

Pes planus is the absence or depression of the longitudinal arch while standing [1]. Frequency of pes planus among adolescents and adults is reported in a wide range of 1.1–43.2% [2]. There are three different types of pes planus namely; flexible pes planus, short achille tendon-flexible pes planus and peroneal spastic or rigid pes planus. Flexible pes planus forms two thirds of all pes planus cases [3]. Diagnosis was confirmed by direct radiograpgy in pes planus suspected

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patients who referred to Pyhsical Therapy Rehabilitation outpatient unit with foot problems. Pes planus diagnosis was concluded in direct radiography by evaluation of calcaneal inclination angle. Calcaneal inclination angle is the most suitable because it provides the most reliable diagnosis and is the most sensitive in showing structural changes [4]. However, in assessing the dynamic and static pressure changes forming along the medial longitudinal arch (MLA) pedobarography is the most widely used modality [5]. Pes planus can be treated either conservatively or through surgery. Exercise and shoe modification are the most important components of conservative management. Shoe modification; this is achieved by placing a longitudinal arch support inside the shoe [internal modification] or by the use of the Thomas heel [external modification] [6]. In our study we aimed to determine pre- and post therapy plantar pressure changes and the effects of using internal, external shoe modification and exercise on foot pain, disability and consequently function and quality of life in pes planus patients.

2. Methods

Sixty patients presenting with pes planus to the Physical Therapy and Rehabilitation Department Outpatient Clinics of Trakya University Faculty of Medicine Hospital between February 2011 and July 2011 were included in the study. The study was approved by the local ethical committee.

Exclusion Criteria: Pes planus patients with the following features were excluded from the study; history of foot surgery, those aged under 15 and over 65 years, those with a foot affected by a systemic, inflammatory and or infectious disease, those with a neurologic disease affecting gait, pregnancy and those who refused to participate in the study.

Inclusion Criteria: The cases with flatfoot were included in our study. In clinical examination; navicular height were measured. The prominent navicular bone generally represents the highest point of the medial longitudinal arch and a ruler may be used to measure the distance between this point and the supporting surface [7]. The foot was defined as normal if the navicular height was normal during standing. Moderately and total loss of the medial longitudinal arch or convexity of the medial aspect of the foot with the precense of talar head on medial plantar side was categorized as flatfoot. The diagnosis was supported by X-ray imaging in these patients. Having the calcaneal inclination angle less than 20 degree on the lateral weight-bearing radiography of the foot is considered as the inclusion criteria. Many studies have used the method in our article as a criterion for flatfoot. The patients with bilateral pes planus were included in our study. Pes planus types were bilaterally identical. Measurements were performed on both feet. In addition to this, the left-right comparison was not made in the result section. It was investigated that how generally the patients' complaints were changed. The comparison between the right and left was not also performed in Pedobarographic analysis, because it was considered that this comparison was not the main starting point of our research. For this reason, we do not have the data analysis of whether there is a difference between right and left [8–10].

Group Formation: Pes planus patients were categorised into three groups according to the conservative therapy used thus: In the first group internal shoe modification was used, in the second and third groups however external shoe modification and exercise respectively were used. We could not randomize our three groups. Our local ethics committee requires the disclosure of all treatment options to patients in diseases without a definite form of treatment. The rule requires the active participation of the patient when choosing a treatment option in the situation where there is more than one treatment option, and where each of these treatment options is not acquired superiority over each other certainly. In the conservative treatment of pes planus more than one type of treatment is available, and the superiority of these treatments over each is not clearly known. Therefore, we explained all treatment options to our patient and have included them in the stage of treatment decision. After 20 patients included in a group no other patient was recruited. The reason for this decision was to form groups with homogenous number of patients.

Assessment: Patients' demographic features and body mass indices (BMI) were recorded. All foot pathologies established after clinical and radiologic assessment were recorded. In pes planus clinical assessment pes planus types (flexible and rigid) were determined according to thumb dorsiflexion test (toe raising test/jack test) results [11]. In radiologic assessment the presence of epin calcanei and pes planus was determined. Patients were assessed thrice as follows; before the commencement of therapy and at the end of the first and third months of therapy. In these assessments the following were analysed; foot pain index, foot function index, quality of life, patient satisfaction and pe-

dobarographic foot pressure. The foot pain index was determined using a questionnaire designed by Garrow et al. [12]. While a low score showed good health, a high score reflected poor health. In order to determine the amount of foot pain and disability the foot function index which is a questionnaire designed by Mak et al. [13] was used. The index consists of three subgroups namely; pain, disability and activity limitations. While a low score showed good health, a high score reflected poor health. The foot pain index and foot function index were determined at baseline and at the end of the first and third months. The Short Form-36 (SF-36) was used to assess the quality of life of the participating patients. Using this form physical and mental health were determined: low and high scores reflected poor and good health respectively [14]. SF-36 was determined at baseline and at the end of the third month. Patient satisfaction was determined on a scale of 0–5 using the Likert Scale in patient groups that used internal and external shoe modifications. In this scale 0 score meant dissatisfaction and a score of 5 meant high satisfaction. Patient satisfaction was determined during follow-up done at the end of the third month. Pedobarographic assesment was conducted using the Mini-Emed pedobarogram device before the commencement of treatment and during follow-up at 3 months. With this system both static and dynamic plantar pressures were measured. The device's pressure measuring platform (650 $\times$ 290 $\times$ 25 mm) contains a sensoring area of 360 $\times$ 180 mm consisting of three sensors in each cm^2. The sampling rate was 14 frames/sec, storage range 20 frames, resolution 1 N/cm^2, accuracy related to foot 5% [15]. The patients were evaluated barefooted on Mini-Emed system, Pedobarography platform was in the form of settled into the floor. The first shot of the patient for the static measurement was performed as in the form of one foot placed on the platform of pedobarogram and the other foot on the lateral side (Fig. 1). As to dynamic measurement, the subjects were asked to walk continuously along a 30 m long area, for a few minutes before arriving at a wooden walking platform, which was 5 m long. They were instructed to put the foot on the platform during their normal walking rhythm [16] (Fig. 2).

The data on the monitor screen was fixed and recorded when the weight on a single foot was observed to be equal to 50% of the body weight. Analysis was performed separately for each foot [17]. In dynamic analysis maximum force (N/cm^2), maximum pressure exerted by the toes (N/cm^2), maximum pressure exerted by the inner part of the forefoot (N/cm^2), maximum pressure exerted by middle part of the forefoot (N/cm^2), maximum pressure exerted by the outer part of the forefoot (N/cm^2), maximum pressure exerted by middle part of the foot (N/cm^2), maximum pressure exerted by the heel (N/cm^2) and plantar surface area (cm^2) are analysed.

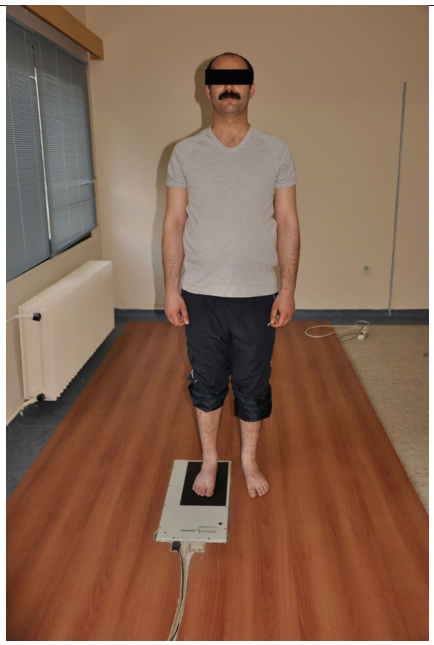

Fig. 1. The static measurement.

Fig. 2. The dynamic measurement.

Therapies Used: After diagnosis, all the pes planus patients were educated on the condition and its various modes of therapy. Internal modification, external modification and exercise programs were explained in detail and choice of therapy was left to the patient. In the first group of patients polyform material tougher as per the foot measurements, and transverse arch support were used. Because over-pronation not only affects the medial arch, it will also cause loss of the anterior and lateral longitudinal arches and, if excessive, the transverse arch can become rigid and somewhat flattened [18]. In order to reduce the stress on the sole to the minimum the sole plate surfaces were lined with smooth leatherette material. All insoles were made up by the same technician. The patients in the second group who preferred external shoe modification were required to bring circular tipped shoes that covered the whole foot and were comfortable enough for everyday use. The expression'Circular tipped heel shoes" is meant to shoes that Thomas heel will be applied are with large-tipped instead of narrow and pointed. It also desired not to be the type of sandal shoe. We did not tend the effect of a large-tipped shoe on flatfoot, but we tend in general that it should have priority in the choice of healthy shoes.

This type of shoe is generally preferred for the foot-health [19]. Shoes that were deemed fit were fitted with Thomas heel using a material derived from polyurethane and the patients were instructed to use these shoes for all their walking. The third group comprised of those patients who refused to use shoe modifications. These pes planus patients were managed using exercise programs. The exercise program included recommended home-based pes planus routines aimed at strenghtening of the foot inverters and intrinsic muscles and stretching of the gastrocnemius and evertors.

The Exercises for the treatment of flatfoot are:

1. Stretching: Stretch your gastrocnemius and soleus muscles. Lean forward until a strong but tolerable stretch was perceived in the calf muscles. Repeat it 3 times with the knee extended and 3 times with the knee slightly (hold it 30 seconds).
2. Toe clawing: Flex your toes as you can (hold it 10 seconds), and extend them fully (hold it 10 seconds).
3. Rise the medial border of the foot: The foot is slightly inverted (the internal arch is raised), but the sole is not turned upwards. The height of the arch is increased, whilst the toes are still gripping the ground (hold it 10 seconds).
4. Make a fist with your foot (hold it 10 seconds).
5. Small objects are picked by feet (of different sizes)
6. Stand on the lateral sides of the foot (hold it 10 seconds).

– The exercises was done 3 times daily, as 3 sets in each time by 10 repeats. There was 5 minutes rest period between each set.
– The patients were queried about the exercises during monthly outpatient controls and motivated.

At the end of the study the data was reviewed and entered into the computer. Statistical analysis was carried out using the SPSS 20.0 statistics program. One Sample Kolmogorov Smirnov Test was used to examine whether the values defined by the measurement fit the normal distribution. The comparison of the data which were found to fit the normal distribution was perfomed using single direction variance analysis and post-hoc Bonferroni Test. The comparison of the data which did not fit the normal distribution was performed using the Kruska Wallis variance analysis and Bonferroni-Corrected Mann Whitney U test. While paired t test and the *Wilcoxon two-sample paired* test were used when comparing patients within groups, the spearman rho correlation analysis was used in evaluation of variable correlations. Pearson χ^2 test was used in the analysis of qualitative data. Differences were considered as statistically significant at $p < 0.05$. Post hoc power analysis was done at the end of study based on Foot pain index baseline values. The power of this study was 93.2% with a minimum detectable difference (9.95) between groups, with a common standard deviation (8.33), with a type I error (5%), and $n = 20$ patients in each group.

3. Results

Sixty patients with pes planus were included in the study. Each of the three groups – internal modification group, external modification group and exercise group-consisted of 20 patients. The patients' ages, sex and body mass indices are given in Table 1 below.

The types of pes planus were similar in all the study groups ($p > 0.05$). When the foot pathologies (hallux valgus, epin calcanei, callus) of the patients taking part in the study were compared, the difference among the three groups was found to be statistically insignificant ($p > 0.05$). However, statistically significant differences were observed when the groups were compared in terms of FPI, FFIPS and FFIDS values recorded at baseline and during follow up ($p < 0.05$), (Table 2).

Table 1
Patients' demographic features

Variables	Internal modification group ($n = 20$)	External modification group ($n = 20$)	Exercise group ($n = 20$)	P
Age Mean ± SD	50.9 ± 10.4	48.7 ± 8.22†	52.3 ± 8.48*	> 0.05
Sex Female (n, %) Male (n, %)	15, %75 5, %25	15, %75 5, %25	15, %75 15, %25	> 0.05
BMI Mean ± SD	34.03 ± 6.48	34.46 ± 6.71	33.50 ± 7.28†	> 0.05

BMI: Body mass index, SD: Standard deviation, *: $p < 0.05$. †: When compared with the internal modification group $p < 0.05$.

Table 2
Comparison of study groups in terms of foot pain index,foot function index pain scale and foot function index disability scale at baseline and at the end of the first and third months

Evaluated parameters		Internal modification group ($n = 20$)	External modification group ($n = 20$)	Exercise group ($n = 20$)	P
FPI (Mean ± SD)	Baseline	41.30 ± 8.26*	30.35 ± 8.33†,*	23.25 ± 7.01	0.001
	1. Month	37.40 ± 8.80*	27.50 ± 6.97†,*	22.85 ± 6.72	0.001
	3. Month	32.05 ± 6.46*	26.65 ± 6.36†,*	22.00 ± 6.12	0.001
FFIPS (Mean ± SD)	Baseline	46.70 ± 12.28*	26.35 ± 15.78†,*	12.60 ± 14.15	0.001
	1. Month	38.35 ± 9.77*	22.10 ± 13.31†,*	11.35 ± 12.33	0.001
	3. Month	32.85 ± 9.39*	20.05 ± 6.36†,*	10.35 ± 10.92	0.001
FFIDS (Mean ± SD)	Baseline	67.40 ± 18.45*	27.50 ± 23.70†	13.50 ± 20.69	0.001
	1. Month	59.05 ± 17.27*	25.80 ± 21.67†	13.00 ± 19.33	0.001
	3. Month	53.10 ± 18.33*	25.25 ± 20.81†	12.60 ± 18.94	0.001

FPI: Foot pain index. FFIPS: Foot functional index pain scala. FFIDS: Foot functional index disability scala. Kruskal-wallis test, *: $p < 0.016$ When compared with the exercise group, †: $p < 0.016$ When compared with the internal modification group.

Table 3
Comparison of patient satisfaction between study groups

Degree of satisfaction	Internal modification group ($n = 20$)	External modification group ($n = 20$)	P
Little (n, %)	2, %10	2, %10	0.797
Some (n, %)	2, %10	3, %15	
Medium (n, %)	4, %20	5, %25	
Good (n, %)	7, %35	8, %40	
Very good (n, %)	5, %25	2, %10	

Pearson chi-square test.

Within each group FPI, FFIPS and FFIDS values recorded at baseline and at the end of the first and third months respectively were compared. In each group a statistically significant difference was observed in all parametres recorded at baseline and during follow up ($p = 0.001$). There was no significant difference observed between the evaluations done at 1 month and at 3 months in any of the groups ($p > 0.005$). Changes in the FPI, FFIPS and FFIDS values were mostly observed in the internal modification group (Bonferroni corrected Mann Whitney U test), ($p < 0.016$) (Fig. 3).

When changes in the quality of life were analysed; a statistically significant difference was observed only in the internal modification group (SF36-PCS baseline 28.05 ± 5.59, 3 months 32.65 ± 5.14 and $p = 0.001$). There was no significant difference observed in the groups treated with external modification and exercise in terms of quality of life ($p > 0.05$). No statistically significant difference was observed between patients treated with internal and external shoe modification in terms of patient satisfaction ($p > 0.05$), (Table 3).

Taking all the 60 patients into account, the presence of any cross-sectional correlation between clinical parametres and pedobarographic values was investigated. As a result of this investigation, all patients' clinical and pedobarographic measurements (static and dynamic) were analysed at baseline and at 3 months and consequently most parametres were found to be correlated (Table 4). FPI, FFIPS and FFIDS values were found to be higher in patients with higher sole (plantar) pressure but SF36-PCS was found to be lower. Static and dynamic pedobarographic measurements of both feet (left and right) taken at baseline and at the end of 3 months were compared with each other. Although no significant changes were observed in any of the measured parametres, changes in total plantar pressure were shown in all study groups ($p < 0.05$).

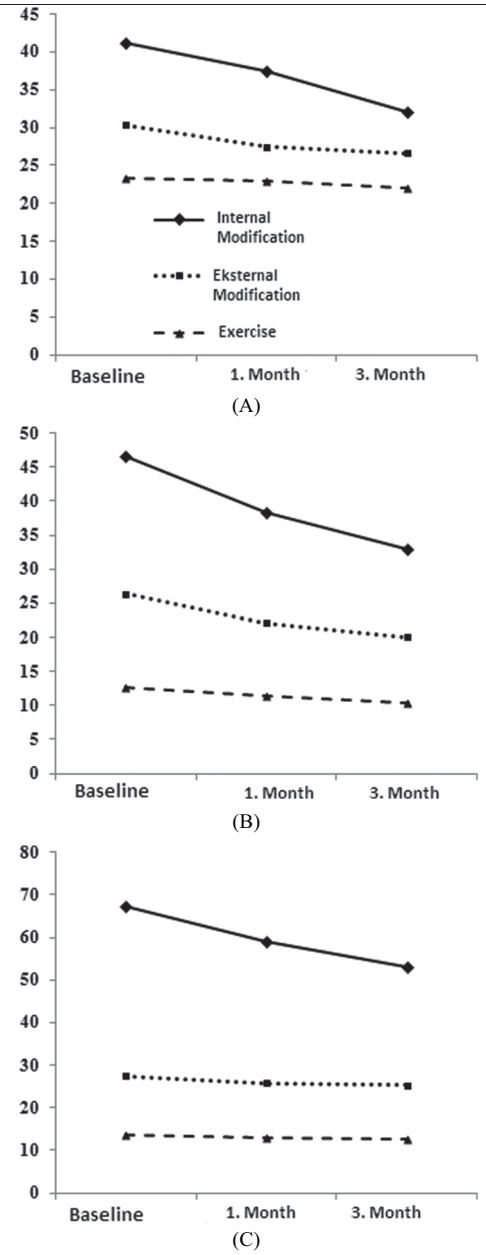

Fig. 3. Changes in terms of foot pain indices (A), foot function index pain scale (B) and foot function index disability scale (C) at baseline and at the end of months 1 and 3.

The extent of this change was similar in all the study groups ($p > 0.05$).

4. Discussion

Adult pes planus is usually a progression of paediatric foot problems namely the condition associated with partial or total absence of the medial longitudinal arch [17]. Studies on the conservative therapy of pes planus are unavailable in literature. However most of these studies are mostly on orthesis and exercise programs.

In our study we compared the efficacy of the various modes of orthesis namely; internal modification, external modification and conservative therapy (i.e. exercise). The number of publications definitely reporting the effectiveness of conservative treatment on flatfoot is limited. At the same time, the number of publications comparing the conservative treatments with each other is also limited. Additionally, the majority of flatfoot publications were reported at pediatric age group. There are few reports in adults. Overweight and high body mass index are accepted as etiologic factors in the development of pes planus in both children and adults [20]. However, studies are available that report the contrary [21]. Although limited, there is evidence that pes planus is familial and is seen more frequently in women, blacks and in African countries [22].

In our study 45 women (75%) and 15 men (25%) were included. According to our figures pes planus is thrice as frequent in women as it is in men. This is coherent with other reports in literature. While internal and external modification groups were in first degree obesity category, the exercise group was in the pre-obese (overweight category).

When assessing the types of pes planus, only two cases with rigid pes planus were discovered among those in the internal modification group. Considering the ages of the patients, the baseline assessment of internal modification group was found to be more advanced age than the other two groups. However, our results were showed greater improvement in several clinical parameters in this group. Although this situation is surprise for us, it was thought to be a sign of progression of the process in the young age groups. The table has been created for static and dynamic pedobarographic measurement values.

Generally, it was reported that internal modification achieved by changing the inner part of the shoe was not well tolerated due to the reduction of the internal shoe volume. In our clinical experience, we too discovered that patients were uncomfortable with the need to increase their shoe size necessary for the shoe modification. In addition, patients were uncomfortable with the turning and poor shape of the smooth material (silicon) used for internal shoe modification and therefore found the shoes difficult to use [6]. In order to overcome this problem, we used a material harder than silicon that

Table 4
The relationship between pedobarographic analysis and clinical parametres at baseline and 3 months

Parameter	FPI		FFIPS		FFIDS		SF-PCS	
	Baseline	3. Month	Baseline	3. Month	Baseline	3. Month	Baseline	3. Month
	P	p	p	p	P	P	p	P
Static left – the maximum pressure of the front foot	0.017*	0.010*	0.026*	0.001*	0.007*	0.001*	0.024*	0.003*
Static rigth – the maximum pressure of the front foot	0.050	0.028*	0.005*	0.001*	0.010*	0.001*	0.020*	0.007*
Static left – the maximum pressure in the rear foot	0.014*	0.020*	0.012*	0.006*	0.021*	0.008*	0.072	0.014*
Static on the right – the maximum pressure of the rear foot	0.066	0.068	0.024*	0.003*	0.019*	0.001*	0.036*	0.017*
Static left – maximum plantar pressure	0.845	0.746	0.002*	0.631	0.037*	0.654	0.852	0.638
Static on the right – the maximum plantar pressure	0.573	0.633	0.016*	0.392	0.003*	0.059	0.040*	0,861
Dynamic left – mid-foot maximum pressure	0.090	0.035*	0.001*	0.005*	0.094	0.028*	0.030*	0.003*
Dynamic right – mid-foot maximum pressure	0.001*	0.001*	0.047*	0.001*	0.001*	0.001*	0.001*	0.001*

FPI: Foot pain index. *FFIPS:* Foot functional index pain scala. *FFIDS:* Foot functional index disability scala. *SF 36-PCS:* Short form 36 physical component summary. Spearsman's rho correlationanalysis. *: $p < 0.05$.

was also tailored according to the patients' feet in the group where internal modification was used [24].

Interestingly, no significant difference was observed in terms of patient satisfaction between the external modification and internal modification groups in our study. Due to the fact that the choice of therapy was left to the patient, differences in basal values were present between the different patient groups. With an aim to get rid of this counfounding factor and to determine the modality of therapy that yielded the most clinical changes, all post-therapy changes in the various groups were calculated and compared with each other.

In conclusion, the most changes in clinical parametres were observed in the internal modification group. The external modification group changed in a manner not different from the exercise group only in terms of the foot function index. However, all the other parametres were better than those of the exercise group. This means that in terms of the clinical improvement internal modification was superior to external modification which was superior to exercise programs. When we take the baseline assessments into account; internal modification group consisted mostly of elderly patients with the worst clinical conditions. It is however interesting that the most clinical improvement was observed in this group of patients.

In our study, the other joints (knee and hip) were not investigated. Studies on the effects of shoe modification on the other joints are available in literature [24].

Foot pain is a condition correlated with functional limitation and disability. According to an earlier study, chronic and severe foot pain is a cause of difficulty in walking and affects the daily activities in women [25]. In one community-based study, pain was shown to be a cause of limitation in the daily activities [26]. However, there is no study available showing the relationship between disability and structural foot defect in the absence of pain. In a study by Woodburn et al. [27] 50 patients with rheumatoid arthritis-related foot pain were recruited. These patients were fitted with ortheses especially designed by podiatrists according to the specifications of the patients. 48 patients presenting to the outpatient clinic were also included in the study as a control group. The patients used ortheses for a period of 30 months. In the group of patients fitted with ortheses a rapid improvement in the FPI scores was recorded. This improvement peaked in 12 months. A decrease was observed in the FPI pain and disability scores. In a study by Jung et al. [28], pes planus patients were grouped into two. While in the first group of patients foot ortheses were used, both orthesis and an exercise program were used in the second group. It was observed that the combination of orthesis and exercise provided better results than the sole use of orthesis.

SF36-PCS changes in the internal modification group were more significant compared to the other groups. This is thought to show parallelism with the change in pain level. In a study by Kusumoto et al. [29] the effects of shoes and tailor-made sole plate on the qual-

ity of life in elderly women was investigated. A significant improvement in the quality of life (according to physical and mental scores) was observed in the patients using sole palates. Pressure changes emanating from biomechanical imbalance can lead to foot pain and disability. Very few studies in literature report on the relationship between sole pressure changes and the aforementioned symptoms [30].

In our study, we used pedobarographic equipment to analyse clinical and pedobarographic values in the same patient group. However, in both children and adults alike, normal pedobarographic values were difficult to determine [31]. The absence of normal values in pedobarographic analysis means that numeral values of the results of such analysis are of no significance when solely analysed. In pes planus patients the increased foot pressure reflects differently in pedobarography when different measurement areas are used. In our study, we investigated the presence of any relationship between clinical assessments and pedobarographic analysis. Interestingly, clinical results were correlated with the pressure increase (especially midfoot) in most of the areas measured using pedobarography at baseline and at the end of the third month. During follow up, pedobarographic assessments did not show any changes significant enough to reflect parallelism with the clinical improvement. However, the length of time necessary for the formation of changes in the pedobarographic analysis is unknown. In most of the studies where pedobarographic changes were observed, follow up lasted for at least one year [32]. Therefore, while 3 months of follow up in our study are enough for observation of clinical improvement, this period may not be long enough for the formation of observable pedobarographic changes. We are of the view that a long period of follow-up is necessary in these kind of studies. Viewed cross-sectionally, clinical and pedobarographic assessments were found to be correlated with each other. However, we are of the opinion that clinical and pedobarographic changes did not occur at the same time during follow up. During the last assessment carried out in our study radiographic analysis was not repeated and therefore the effects of our therapy methods on radiographic changes were not analysed. In a study where radiographic measurements were used, pes planus patients using tailored-made sole plates were investigated. In these patients radiographic improvements on the foot arch were shown [33].

5. Conclusion

It was found that internal modification yielded more clinical improvement than external shoe modification or solely executed exercise programs. Cross-sectional pes planus clinical and pedobarographic analysis are correlated.

Conflict of interest

Financial disclosure statements have been obtained, and no conflicts of interest have been reported by the authors or by any individuals in control of the content of this article.

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