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ORIGINAL RESEARCH REPORT

Effects of Short-Foot Exercises on Foot Posture, Pain, Disability, and Plantar Pressure in Pes Planus

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Context: Pes planus is a prevalent chronic condition that causes foot pain, disability, and impaired plantar load distribution. Short-foot exercises are often recommended to strengthen intrinsic foot muscles and to prevent excessive decrease of medial longitudinal arch height. ***Objective:*** To investigate the effects of short-foot exercises on navicular drop, foot posture, pain, disability, and plantar pressures in pes planus. ***Design:*** Quasi-experimental study. ***Setting:*** Biomechanics laboratory. ***Participants:*** A total of 41 participants with pes planus were assigned to the short-foot exercises group (n = 21) or the control group (n = 20). ***Intervention:*** Both groups were informed about pes planus, usual foot care, and appropriate footwear. Short-foot exercises group performed the exercises daily for 6 weeks. ***Main Outcome Measures:*** Navicular drop, Foot Posture Index, foot pain, disability, and plantar pressures were assessed at the baseline and at the end of 6 weeks. ***Results:*** Navicular drop, Foot Posture Index, pain, and disability scores were significantly decreased; maximum plantar force of midfoot was significantly increased in short-foot exercises group over 6 weeks ($P < .05$). No significant differences were determined between the baseline and the sixth week outcomes in control group ($P > .05$). ***Conclusions:*** Six-week short-foot exercises provided a reduction in navicular drop, foot pronation, foot pain, and disability and increment in plantar force of medial midfoot in pes planus.

Keywords: navicular drop, foot function, medial longitudinal arch, plantar force

Pes planus is a prevalent chronic condition with a reported incidence of 2% to 23% in the adult population and characterized by the lower medial longitudinal arch (MLA) with calcaneal eversion.[1–3] The most common problem associated with pes planus is excessive pronation during weight-bearing activities. Pes planus causes impaired plantar load distribution, excessive stress in the foot, ankle, and knee joints, and compensatory internal rotation of the hip joint. Common lower-limb pathologies such as hallux valgus, plantar fasciitis, tibialis posterior dysfunction, tarsal tunnel syndrome, and patellofemoral pain syndrome are also associated with pes planus.[4–7]

Excessive pronation in pes planus causes ground reaction forces to deviate medially during stance phase of the gait.[8] Thus, altered dynamic function and related foot deformities result in abnormal plantar pressure pattern in pes planus.[9] It has been reported that pes planus leads to higher pressure under the big toe, central forefoot, and the medial midfoot; with lower pressure in the medial and lateral forefoot compared with neutrally aligned feet.[9–11]

Integration of the active and passive structures of the foot support MLA and contribute dynamic foot control.[12] Extrinsic and intrinsic foot muscles act as the main components of foot function, and the intrinsic foot muscles are considered to have a more important role in dynamic foot control.[13] Evidence suggests that strengthening intrinsic muscles enhances dynamic support of MLA and foot stability.[14–16] Short-foot exercises (SFE), which are often recommended to strengthen intrinsic foot muscles, activate the abductor hallucis muscle and prevent excessive decrease of MLA height.[17] Previous research demonstrated that SFE is effective in increasing the cross-sectional area of the abductor hallucis muscle and the strength of flexor hallucis muscle in pes planus,[7] enhancing foot posture and function, reducing navicular drop (ND), and improving dynamic balance in healthy population.[14,15] However, there is a lack of research about the effects of SFE on dynamic plantar pressures in pes planus. The aim of this study is to investigate the effects of SFE on ND, foot posture, foot pain, disability, and dynamic plantar pressures in subjects with pes planus. We hypothesized that SFE would reduce ND, foot pronation, foot pain, and disability and further improve plantar pressure distribution in pes planus.

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Methods

Design

This was a nonrandomized controlled trial conducted in the biomechanics laboratory of the Zonguldak Bulent Ecevit University Faculty of Health Sciences. Before the study was conducted, the required permission was obtained from the Clinical Research Ethics Committee of Zonguldak Bulent Ecevit University. All participants were informed about the study, and an informed consent form was signed by each participant.

Participants

This study was conducted with 41 participants (25 females and 16 males) with pes planus. Inclusion criteria were age between 18 and 25 years and having bilateral pes planus according to ND[18] and the 6-item Foot Posture Index (FPI).[19] Pes planus was defined as ND exceeding 10 mm[18] and FPI score 6 to 12.[19] Exclusion criteria were having rigid pes planus, hallux valgus, hallux rigidus, epin calcanei, systemic, neurologic, or orthopedic problems that can affect the lower-extremity, and history of surgery on the lower-extremities.

Procedure

Demographic data of the participants were recorded, and the participants were assigned to short-foot exercise group (SFEG) or control group (CG) based on their willingness. Both groups were informed about pes planus, usual foot care, and appropriate footwear. SFEG performed short-foot exercises daily for 6 weeks. CG did not receive any intervention during the study.

Navicular drop, FPI, pain, disability, and dynamic plantar pressures were evaluated at baseline and the sixth week by the same physical therapist at the biomechanics laboratory. Group assignment and SFE training was conducted by the second physical therapist to provide blindness.

Outcome Measures

Navicular drop was measured as the navicular height difference between nonweight-bearing (sitting in a chair) with the subtalar joint neutral position and standing with a relaxed foot posture in millimeters.[18,20]

Foot Posture Index was conducted while the participants were in a standing position with relaxed foot posture. FPI is composed of 6 items to evaluate the forefoot and rearfoot. These items are talar head palpation, supra and infra lateral malleolar curvature, inversion/eversion of the calcaneus, prominence in the region of the talonavicular joint, height and congruence of the MLA, and abduction/ adduction of the forefoot on the rearfoot. Each of these criteria is evaluated on a scale from −2 to +2, and the total score is obtained. Positive scores indicate pronated foot, and negative scores indicate supinated foot.[19]

Pain and disability were assessed by pain and disability subscales (both include 9 items) of the Foot Function Index. The pain subscale measures the level of foot pain in a variety of situations. The disability subscale evaluates difficulty due to foot problems in performing daily activities. Each item is rated using a visual analog scale. Higher scores indicate more severe pain and disability.[21]

Dynamic pedobarographic analysis was conducted using a pressure platform (Zebris® FDM 2, 212.2 × 60.5 × 2.5 cm; Zebris Medical GmbH, Isny, Germany) located middle of an 8-m walk path. Participants walked through the path at a self-selected pace in the barefoot condition for the measurement. Three valid trials were recorded. Maximum force and maximum pressure of forefoot, midfoot, and heel were obtained from Zebris® FDM 2 software package.

Intervention

The short-foot exercise group performed the exercises for 6 weeks (2 d/wk under supervision, 5 d/wk home based) to strengthen the intrinsic foot muscles. To perform SFE, participants were requested to elevate the MLA, shorten the foot in the anterior–posterior line, and to approximate the first metatarsal head toward the heel without toe flexion. An elevated MLA position was maintained for 5 seconds in each repetition. Participants performed the SFE in 3 sets of 15 repetitions for each day and began in a sitting position (in first and second weeks), and progressed to a double-leg stance position (in third and fourth weeks), then single-leg stance position (in fifth and sixth weeks).

Statistical Analysis

Data were evaluated using the Statistical Package for Social Science 18 (SPSS Inc, Chicago, IL) program for Windows. The significance level was set to $P < .05$. Normality tests (visual and analytical) were conducted. Mann–Whitney *U* test was used to compare baseline data consisting age, body mass index, ND, FPI, pain, and disability scores and plantar pressures, which were not normally distributed between SFEG and CG. Chi-square test was used to compare the sex ratio between 2 groups. Intragroup comparisons were conducted with Wilcoxon test.

Results

This study included 41 subjects consisting of 25 females and 16 males. The participants' age, gender, body mass index, and baseline ND, FPI, pain, and disability results are presented in Table 1. Intergroup analysis indicated no significant differences in demographic background and baseline ND, FPI, and pain results ($P > .05$). The baseline disability score was higher in SFEG compared with CG ($P < .05$).

The comparison of baseline pedobarographic outcomes between SFEG and CG are presented in Table 2. There were no significant differences between 2 groups in terms of baseline maximum plantar force and plantar pressure data ($P > .05$).

Intragroup comparison of ND, FPI, pain, and disability scores revealed that these scores were significantly reduced in SFEG at the sixth week from baseline ($P < .05$). No significant change was determined in CG between ND, FPI, pain, and disability scores at baseline and the sixth week ($P > .05$; Table 3).

Table 4 presents intragroup comparison of maximum plantar forces and maximum plantar pressures. Maximum force was significantly increased in the midfoot of left side in SFEG (*P*

Table 1 Demographic Data and Baseline ND, FPI, Pain, and Disability Scores of the Participants

	SFEG (n = 21)	CG (n = 20)	*P*	*z*
Age	21.00 (1.00)	21.45 (1.73)	.54	−0.614
BMI	22.94 (3.30)	23.13 (1.92)	.92	−0.104
Gender (F/M)	16/5	9/11	.04*	
ND				
Left	17.38 (5.85)	16.30 (4.97)	.70	−0.392
Right	16.47 (5.45)	17.25 (5.31)	.49	−0.694
FPI				
Left	8.76 (1.84)	8.10 (1.61)	.22	−1.238
Right	8.95 (1.46)	8.40 (1.95)	.29	−1.060
Pain	12.23 (11.96)	7.20 (10.34)	.06	−1.886
Disability	7.80 (6.91)	4.05 (7.52)	.02*	−2.329

Abbreviations: BMI, body mass index; CG, control group; FPI, Foot Posture Index; ND, navicular drop; SFEG, short-foot exercise group. Note: Values are mean (SD). *$P < .05$.

< .05). There were no significant differences between the pedobarographic outcomes at baseline and the sixth week in CG.

Discussion

This study was conducted to determine the effects of SFE on ND, foot posture, foot pain, disability, and dynamic plantar pressures in subjects with pes planus. Six-week SFE was effective to decrease ND, enhancing foot posture, reducing foot pain and disability, and increasing plantar force in midfoot. However, ND, FPI, pain, disability, and maximum plantar force and pressure of CG did not change in 6 weeks.

Table 2 Comparison of Baseline Pedobarographic Outcomes Between SFEG and CG

	SFEG (n = 21)	CG (n = 20)	*P*	z
Maximum force, N				
Forefoot				
Left	604.77 (125.51)	573.48 (165.41)	.79	−0.261
Right	605.76 (125.78)	598.47 (109.88)	.92	−0.104
Midfoot				
Left	204.83 (85.64)	198.32 (89.97)	.81	−0.235
Right	200.42 (72.75)	212.18 (85.00)	.92	−0.104
Heel				
Left	432.23 (92.09)	432.77 (66.27)	.99	−0.012
Right	437.66 (89.15)	433.79 (63.93)	.66	−0.443
Maximum pressure, N/cm^2				
Forefoot				
Left	37.01 (7.88)	36.79 (7.10)	.85	−0.196
Right	38.81 (9.09)	36.75 (7.81)	.44	−0.770
Midfoot				
Left	16.26 (8.24)	15.52 (6.98)	.99	−0.013
Right	15.61 (6.01)	16.38 (5.01)	.37	−0.900
Heel				
Left	26.60 (6.22)	25.34 (3.91)	.46	−0.743
Right	26.30 (5.81)	25.47 (4.94)	.75	−0.313

Abbreviations: CG, control group; SFEG, short-foot exercise group. Note: Values are mean (SD).

Research revealed that intrinsic muscle activity provides support to maintenance of MLA.[15,17,22] Mulligan and Cook[15] demonstrated that 4-week SFE decreased ND and increased arch height index in subjects with neutrally aligned foot. There are also 2 studies indicating the beneficial effect of SFE on foot posture in healthy runners.[14,16] Studies which revealed that SFE is effective on supporting the MLA in pes planus had evaluated the MLA height solely during SFE.[17,23] The current study exhibited that 6-week SFE training had a positive impact on ND and foot posture in pes planus.

To our results, pain and disability scores were significantly reduced in subjects with pes planus after 6-week SFE, while no significant difference was observed in CG in this respect. There is limited evidence about the effect of exercise therapy on foot pain. Consistent with our results, Taspinar et al[24] demonstrated the improvement in terms of foot pain and disability in pes planus with 3-month exercise program including strengthening of the foot invertor and intrinsic muscles and stretching of the plantar flexors and evertors. The current study is significant in terms of revealing the positive effect of SFE on pain and disability in pes planus.

We found that maximum plantar force was significantly increased in the midfoot after 6-week SFE, while maximum force in the forefoot and rearfoot remained similar. Besides, no significant changes of maximum plantar pressure in the forefoot, midfoot, and rearfoot were identified after SFE. There are 2 studies with small sample size investigating the effects of ankle and intrinsic foot muscle strengthening on plantar pressure in pes planus.[25,26] One of those studies[25] revealed that plantar pressure of medial heel was reduced after 6-week tibialis posterior and foot intrinsic muscle strengthening, while the other[26] demonstrated that there were no significant differences in plantar pressures after an 8-week foot muscle training. On the other hand, it is known that pes planus leads to higher plantar pressure in medial midffoot.[9] From this point, our finding indicates that increasing effect of SFE on maximum plantar force in the midfoot seems to be disruptive on plantar loading in pes planus. However, the current study also demonstrated reduction in ND and FPI after SFE. This result indicated that SFE might prevent excessive pronation during gait. Therefore, plantar force of the lateral midfoot might be increased due to decreased pronation. Unfortunately, we could not obtain information about plantar pressures and forces in the subregion of the forefoot, midfoot, and rearfoot from the software we use, so it was not possible to determine the increment in plantar force was raised either in the medial or lateral midfoot. Further studies are needed to reveal the

Table 3 Intragroup Comparison of ND, FPI, Pain, and Disability in SFEG and CG

	SFEG (n = 21)				CG (n = 20)			
	Baseline	Sixth week	*P*	Z	Baseline	Sixth week	*P*	z
ND								
Left	17.38 (5.85)	11.57 (4.41)	<.001**	−3.588	16.30 (4.97)	16.45 (5.59)	.94	−0.080
Right	16.47 (5.45)	10.85 (5.92)	<.001**	−3.555	17.25 (5.31)	16.90 (5.90)	.06	−1.868
FPI								
Left	8.76 (1.84)	7.09 (2.44)	.002*	−3.051	8.10 (1.61)	8.25 (1.48)	.08	−1.732
Right	8.95 (1.46)	7.33 (2.15)	.001*	−3.446	8.40 (1.95)	8.50 (2.03)	.26	−1.134
Pain	12.23 (11.96)	7.85 (8.78)	<.001**	−3.521	7.20 (10.34)	5.00 (6.31)	.68	−0.406
Disability	7.80 (6.91)	3.95 (4.52)	<.001**	−3.526	4.05 (7.52)	3.55 (5.73)	.71	−0.378

Abbreviations: CG, control group; FPI, Foot Posture Index; ND, navicular drop; SFEG, short-foot exercise group. Note: Values are mean (SD).
$^*P < .05$. $^{**}P < .001$.

Table 4 Intragroup Comparison of Pedobarographic Outcomes in SFEG and CG

	SFEG (n = 21)				CG (n = 20)			
	Baseline	Sixth week	*P*	*Z*	Baseline	Sixth week	*P*	*z*
Maximum force, N								
Forefoot								
Left	604.77 (125.51)	577.22 (131.31)	.07	−1.790	573.48 (165.41)	603.13 (121.88)	.94	−0.075
Right	605.76 (125.78)	586.38 (127.57)	.14	−1.477	598.47 (109.88)	601.98 (131.60)	.94	−0.075
Midfoot								
Left	204.83 (85.64)	225.41 (99.34)	.02*	−2.381	198.32 (89.97)	204.64 (84.50)	.23	−1.195
Right	200.42 (72.75)	207.23 (87.20)	.61	−0.504	212.18 (85.00)	208.83 (85.63)	.60	−0.523
Heel								
Left	432.23 (92.09)	427.40 (87.53)	.39	−0.852	432.77 (66.27)	435.01 (71.42)	.63	−0.485
Right	437.66 (89.15)	427.63 (86.15)	.27	−1.095	433.79 (63.93)	439.78 (80.75)	.53	−0.635
Maximum pressure, N/cm^2								
Forefoot								
Left	37.01 (7.88)	36.51 (7.97)	.30	−1.043	36.79 (7.10)	36.35 (7.50)	.41	−0.821
Right	38.81 (9.09)	39.65 (9.59)	.63	−0.485	36.75 (7.81)	36.20 (8.44)	.46	−0.747
Midfoot								
Left	16.26 (8.24)	18.58 (11.45)	.16	−1.408	15.52 (6.98)	15.57 (6.25)	.94	−0.075
Right	15.61 (6.01)	16.88 (10.62)	.90	−0.122	16.38 (5.01)	15.39 (5.54)	.10	−1.662
Heel								
Left	26.60 (6.22)	26.44 (5.34)	.94	−0.075	25.34 (3.91)	25.13 (4.12)	.37	−0.896
Right	26.30 (5.81)	25.74 (5.28)	.49	−0.695	25.47 (4.94)	25.44 (4.65)	.99	−0.011

Abbreviations: CG, control group; SFEG, short-foot exercise group. Note: Values are mean (SD).
*$P < .05$.

effects of SFE on plantar pressures in the subregion of the forefoot, midfoot, and rearfoot with a detailed pedobarographic analysis.

The present study has some limitations. Disability score was higher in SFEG compared with CG at the baseline because the participants were not assigned randomly to the groups. Gender ratio of the groups was different, and this might affect the outcomes. However, the baseline outcomes of the groups were similar except disability score. So, one of the factors that causes higher disability scores in SFEG may be that there were more women in SFEG than in CG. Group assignment was conducted based on the willingness of the participants in order to increase the adherence to the exercises. Besides, long-term efficacy of SFE was not evaluated in this study. Finally, more accurate results about the effects of SFE on ND, FPI, pain, disability, and plantar pressures could be obtained if a larger number of participants were included.

Conclusions

Our main hypothesis was supported with the current results that indicated that 6-week SFE was effective on reducing ND, foot pronation, foot pain, and disability in pes planus. Increase in plantar force of the medial midfoot after SFE might arise from the increment in plantar loading of the lateral midfoot with decreased foot pronation.

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