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The impact of different exercise approaches on balance in people with pes planus

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Abstract

Introduction. Pes planus is caused by the extension of the intrinsic muscles in the medial arch of the foot, resulting in the arch approaching the ground or the sole of the foot touching the ground completely. The objective was to determine how exercise techniques affected patients with pes planus' ability to balance and to recommend the appropriate exercises.
Methods. In this study, 39 individuals with pes planus were allocated at random to either a stretching or stability and mobility exercise group. Star Excursion Balance Test, The Berg Balance Scale, The Functional Reach Test, and Weight Bearing Lunge, plantar flexion range of motion (ROM) assessments were performed before treatment and after treatment for a total of four weeks.
Results. The results demonstrated that both groups' balance and ROM during intragroup testing had improved ($p < 0.05$). Only the improvement in plantar flexion ROM in group 1 was found to be statistically higher than that in group 2 with group comparisons ($p < 0.05$).
Conclusions. Balance and ROM values were similarly affected by both 4-week pes planus exercise programs. We contend that the static and dynamic foot kinematics were successfully rectified with both of our treatment techniques.
Key words: flatfoot, foot, postural balance, exercise therapy

Introduction

Pes planus, often known as flat feet, is a common foot deformity defined by the forefoot being supinated in relation to the hindfoot, the forefoot bears weight in a valgus position, and a lack of the medial longitudinal arch in the midfoot [1]. This problem develops when the medial longitudinal arch of the foot is not as high as it should be physically [2].

According to various studies, people with pes planus experience significant postural instability due to the decreased medial longitudinal arch height. The balance of standing and walking is closely correlated with plantar pressure, the ligaments creating the foot arch, the intrinsic and extrinsic muscular tendons of the foot, sensory inputs from mechanoreceptors in the joint capsules, and flexibility and stability of the foot arches. Foot alignment alterations weaken postural stability by generating aberrant sensory input [3].

Exercise is one of the therapeutic modalities that is important in the recovery of pes planus. Exercise programs for individuals with pes planus support foot mechanics by increasing the strength and flexibility of the foot muscles and alleviating discomfort [4].

Stretching exercises are used on people with pes planus to increase the ROM in their ankles by making their muscles more flexible [5]. In this way, it will help to improve foot function by reducing foot biomechanical qualities and pressure on the foot arch.

According to recent studies, patients with pes planus ought to do stability exercises that improve their neuromuscular function, balance, and coordination, as well as strengthening and stretching activities [6].

Stability exercises help strengthen foot muscles and improve foot health. The short-foot exercises help to strengthen the intrinsic foot muscles that support the foot's posture and arch, making it one of the most frequently used stability exercises in the treatment of pes planus [7]. Short-foot exercises help people with pes planus balance and stabilise themselves by enhancing the foot's arch posture and dynamic stability and reducing pronation. The Short-Foot exercise is instrumental in aiding individuals with pes planus by improving their balance, stabilising foot arch posture, and reducing pronation. Commonly used in physiotherapy, this proprioceptive neuromuscular facilitation technique enhances foot muscle strength and dynamic stability. During the exercise, individuals sit or stand with their feet flat on the ground or on a stable surface. The objective is to contract the intrinsic foot muscles, such as the flexor digitorum brevis, abductor hallucis, and quadratus plantae, without curling the toes [8, 9].

Although the exercise approaches applied to individuals with pes planus are widely examined there is still no clear treatment approach. Therefore, we hypothesised that neuromuscular exercises, including stability and mobility exercises, would improve balance more effectively in individuals with pes planus compared to stretching exercises, supporting the need for an appropriate exercise program.

Subjects and methods

The study was conducted from September 2022 to January 2023. Random.org was used to distribute 39 participants who matched the inclusion requirements. Mobility and stability exercises were given to group 1 and stretching exercises were given to group 2. Exercises will be applied for 4 weeks. At the end of 4 weeks, the individuals were reevaluated and the effects of the exercise programs on the individuals were examined. This study was conducted at the laboratories of the Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Bahçeşehir University. The study

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was designed as a single-blind trial. Evaluation and treatment were administered by physiotherapists with 10 years of clinical experience each. Different physiotherapists conducted the evaluation and treatment.

After recording the demographic information of the participants, the Star Excursion Balance Test (SEBT), The Berg Balance Scale (BBS), The Functional Reach Test (FRT), and the Weight-bearing Lunge Test (WBLT) were applied before treatment and after four weeks of treatment.

Sample size calculation

The effect size value was calculated as 0.85, taking the result from the 'navicular drop test' as a reference. Using the G Power program (version 3.1.9.7), the number of cases needed for the study was calculated to be 18 with 80% power and 0.05 type 1 error. Twenty participants were included in each group, to account for any participant dropout.

Procedure

Participants in the study had to be between the ages of 18 and 40, have mild or moderate pes planus, foot posture index [10] of 19 and above, and have a navicular drop of more than 10 mm [11]. Each participant's dominant foot, which had experienced at least one inflammatory sign (pain, oedema, etc.), was checked to determine whether they had pes planus. The exclusion criteria included having had prior foot or ankle surgery, body mass index > 25, severe foot deformities like hallux valgus and crow's feet, and neuromuscular disorders. It was also necessary not to have any systemic, locomotor, or foot-related diseases, as well as sensory loss, diabetes, or peripheral neuropathy. All patients meeting the inclusion criteria signed written informed consent.

Assessments tools

The SEBT, which assesses the participant's capacity to move the farthest distance on the supporting leg with the free leg in eight different directions, was used to evaluate dynamic postural balance. The participants stood barefoot in the centre of a star-shaped pattern. The participant extends their foot as far as they can and touches the line with the tip of their toe. There are eight lines overall in which this process is repeated. The highest score obtained is recorded after the test is administered three times with each foot [12].

The BBS is a functional assessment tool that consists of 14 tasks designed to assess a person's capacity for maintaining balance when a support surface is reduced and their capacity to shift their body's centre of gravity. Each task receives a score between 0 and 4, with a score of 4 representing the easiest and fastest completion of the exercise. The perfect balance function is represented by a total score of 56, which is the highest possible score. While a number closer to 36 implies a higher risk of falling, one closer to 56 indicates a reduced risk. The BBS is regarded as the "gold standard" for assessing functional balance [13].

The FRT determines how far a person's centre of mass can move before hitting the limits of their base of support. The participants are told to take an upright position and extend their right arm as far as they can while keeping their fists locked and their palms facing down. The third metacarpal's placement is noted before and after the reach using a measurement rod attached to a wall, and the examiner notes the difference to assess how well they performed [14, 15].

An electrogoniometer was used to measure and record the degrees of plantar flexion (PF) in the ankle joints of the subjects. PF degrees were measured by performing active PF at the edge of the wall. Ankle degrees of dorsiflexion were evaluated using the WBLT. The patient was first examined while leaning against the wall. To align the knees midway with the wall, the second toe and heel of the foot needed to be measured were shifted. The maximum distance from the wall that the patient could touch without lifting the heel was measured. ROM measurements were averaged over three trials and were recorded for analysis [16, 17].

Treatment program

Both groups performed exercises for a duration of four weeks. Three days a week for a total of twelve sessions, the physical therapist followed the exercise schedule. The first group received neuromuscular exercises that included both mobility and stability, whereas the second group received stretching activities. The first group engaged in exercises including balance and reaching, heel rise, towel picking, 4-way resistance training, half kneeling with the knee to the wall, single leg ankle, doming exercise, eccentric heel drop, single leg balancing with the leg extended, rolling ice bottles beneath the feet, and short-foot exercises. The second intervention group was engaged in a comprehensive set of stretching exercises targeting a range of lower limb muscles, including the Achilles tendon, gastrocnemius, soleus, and plantar fascia. These exercises encompassed a variety of movements such as heel cord stretches, tippy toe walks, step stretches, and downward facing dog poses, each designed to specifically target and stretch different muscle groups involved in ankle mobility and foot function. Additionally, participants performed a specialised therapeutic exercise known as the tennis ball exercise. This exercise involved using a tennis ball to apply localised pressure to specific areas of the body, particularly the soles of the feet and lower legs, to release tension in the muscles and fascia, promote circulation, and enhance overall tissue flexibility and mobility.

Statistical analysis

In this study, the SPSS 26.0 computer program created by Statistical Package for Social Sciences in Chicago, Illinois, was used for statistical analysis. The normality of the data was evaluated using the Shapiro–Wilk test to determine whether the data were normally distributed. Mann–Whitney *U*-test was used for nonparametric data, and independent sample *t*-test was used for parametric data. Wilcoxon paired two-sample test for nonparametric data and paired samples *t*-test for parametric data were used to compare within-group values at baseline and four weeks later. If the *p*-value was less than 0.05, which was the cut-off value of statistical significance, a significant difference or correlation between variables was believed to exist.

Results

A total of 45 people were initially evaluated as part of the study. Two of them, however, were disqualified for orthopaedic, two for personal, and one for psychiatric reasons. One participant dropped out of the study, therefore, 39 people in total were included in the final analysis of the study.

There was no statistically significant difference between the groups when demographic information was compared (Table 1). The findings in groups 1 and 2 before and after treatment were compared (Table 2). There was a significant increase in SEBT, BBS and FRT parameters before and after treatment within both groups ($p < 0.05$). There was no

Table 1. Demographic information

Variable	Group 1	Group 2	*p*
Gender: female/male	16/4	10/9	0.070
Age (mean ± *SD*)	24.95 ± 6.63	23.68 ± 3.96	0.692
Height (mean ± *SD*)	166.2 ± 7.14	170.26 ± 8.33	0.112
Weight (mean ± *SD*)	68.85 ± 11.28	71.32 ± 11.79	0.509
BMI (mean ± *SD*)	25.16 ± 5.30	24.76 ± 4.88	0.807

BMI – Body Mass Index, * *p*-value < 0.001

Table 2. Intragroup and intergroup evaluation of assessment methods

Parameters	Group 1		*p*	Group 2		*p*	*p*
	before treatment (mean ± *SD*)	after treatment (mean ± *SD*)		before treatment (mean ± *SD*)	after treatment (mean ± *SD*)		
SEBT	61.05 ± 4.30	70.50 ± 4.48	< 0.001*	60.37 ± 5.83	69.89 ± 7.44	< 0.001*	0.953*
BBS	46.75 ± 1.89	51.25 ± 1.77	< 0.001*	46.89 ± 2.31	51.58 ± 2.48	< 0.001*	0.737*
FRT	37.50 ± 4.66	44.20 ± 5.06	< 0.001*	36.42 ± 5.01	43.84 ± 4.94	0.006*	0.644*
WBLT	5.38 ± 1.58	7.65 ± 1.40	< 0.001*	5.45 ± 1.67	7.32 ± 1.45	< 0.001*	0.163*
ROM PF	31.30 ± 4.76	36.55 ± 3.69	< 0.001*	34.95 ± 6.12	37.53 ± 4.21	< 0.001*	0.006*

SEBT – Star Excursion Balance Test, BBS – The Berg Balance Scale, FRT – The Functional Reach Test, WBLT – The Weight Bearing Lunge Test, ROM PF – Range of Motion Plantar Flexion, * $p < 0.05$

significant difference between the two groups ($p > 0.05$). Before and after treatment, there was a significant difference ($p < 0.05$) in WBLT and PF ROM between the two groups. Nonetheless, a significant increase in the PF ROM value was noted between the two groups favouring group 1 ($p < 0.05$).

Discussion

This study compared the effect of different exercise programs on balance in people with pes planus. The results of the 4-week study showed an increase in SEBT, BBS, FRT, and WBLT parameters in both groups after treatment. However, the increase in PF ROM findings in group 1 was statistically higher.

Different exercise techniques have been extensively researched for pes planus in the literature. Engkananuwat et al. [18] highlighted that exercise enhances foot functions. According to Dębiec-Bąk et al. [19], the treatment of foot defects should primarily focus on local corrections, despite the focus on the overall effects of interventions on body posture and gait. There is no specified protocol regarding the frequency, intensity, type, and duration of exercise in pes planus patients.

Current studies have shown that people with pes planus deformity experience loss of stability and balance as a result of the foot's biomechanics deteriorating [20, 21]. The intrinsic foot muscles support the medial longitudinal arch during stance propulsion and assist in maintaining static balance while walking and standing. Exercises performed on the ankle improve proprioception and muscle stabilisation [22].

Short-foot exercises which result in intrinsic muscle activation have been reported to have a neuromuscular function. Short-term exercises have been shown to improve foot biomechanics while increasing the strength of the inner foot muscles [6, 23]. According to a systematic review, short-foot exercises have been reported to be effective on balance for people with pes planus [8]. For this reason, in our study, we added short-foot exercises to the group who received stabilising exercises.

Stretching exercises, which are commonly used in patients with pes planus, are prescribed to increase the ROM of ankle DF. There are various methods used to stretch the gastrocnemius. These include manual passive stretching, self-stretching using a belt or towel while sitting for long periods of time, standing on an inclined board, heel drop on the edge of a step or stool, and standing wall stretching [24]. According to Brijwasi et al. [23], patients with pes planus who participated in a 6-week intensive exercise program showed improvements in their feet's aesthetic appearance and a decrease in pes planus symptoms. Active DF/PF, four quick foot exercises, and calf stretches, which are activities identical to those in our study, were all included in a comprehensive training program. However, as far as we know, there are no studies comparing stability exercises with mobility exercises and stretching exercises. For this reason, in our study, we compared stability and mobility exercises to stretching exercises. As pes planus has a significant impact on balance, it is important for healthcare professionals to explore effective exercise interventions. The investigation of customised exercises fills a gap in the literature, making a valuable contribution to practice.

Houck et al. [25], applied soleus, gastrocnemius and tibialis posterior stretching exercises to one group of patients with pes planus, while additional tibialis posterior and plantar flexor strengthening exercises were applied to the other group. Both therapies significantly decreased pain and improved functionality, but there were only slight differences between groups, according to treatment outcomes. Due to this, we used two distinct exercise groups instead of a combined exercise group in our study and looked at the impact on various balance measures. We contrasted their impact on one another in this manner.

It has been found that when foot posture is controlled during foot rehabilitation, it can provide an increase in balance [26]. Exercises for intrinsic and extrinsic muscle strengthening and stability have been reported to improve balance in pes planus patients [27]. Additionally, according to Yıldız et al. [28], short-foot exercises used in pes planus instances had a positive impact on balance metrics. In a different investigation, children characterised by flat feet demonstrated inferior outcomes in the star balance test in contrast to those with normal foot arches [29]. The SEBT results from Lynn et al. [30] after a 4-week brief foot training, which was comparable to the length of our investigation, showed no significant improvement in lateral displacement relative to post-treatment values.

It has been found that when foot posture is controlled in foot rehabilitation, it can provide an increase in balance. In their study, Moon and Jung [31] examined the efficacy of sensorimotor training and short-foot exercise activities. Balance both statically and dynamically improved in the group that included short-foot exercises. In our study, in accordance with the literature, we recorded significant improvements in the results of SEBT from the treatments we applied in both groups. However, treatments were not superior to each other between the two groups. The study's conclusions align with its initial research objectives, emphasising the impact of tailored exercise programs on balance parameters in pes planus. Findings underscore the importance of targeted therapeutic modalities for addressing postural instability in this population.

To the best of our knowledge, our study is the first to investigate the effect of exercises on balance parameters in pes planus using FRT and BBS. Jankowicz-Szymanska et al. [32] found an increase in FRT results after using insoles in people with pes planus. In a different study, patients with pes planus who used orthoses saw an improvement in their BBS score [33]. Functional reach and the BBS both showed improvement in our trial, where we used several exercise techniques independent of the use of orthotics. By improving foot function in people with pes planus, we believe that various applications improve balance measurements.

In our investigation, both groups' post-treatment WBLT and DF ROM scores significantly increased. Examining the PF range of motion treatment results, it was shown that the stability group's rise was statistically higher. It was noted that there aren't enough studies in the literature on the connection between foot workouts and WBLT performance. This study bridges a gap by exploring exercise interventions for balance in pes planus, enhancing evidence-based practices. Consequently, it benefits individuals with pes planus by improving balance and contributing to advancements in treatment research.

The study's strengths include its comprehensive design, incorporating both stretching and stability exercises to assess their impact on balance parameters in individuals with pes planus. Multiple outcome measures, such as SEBT, BBS, FRT, and WBLT, enhance the robustness of our findings.

Limitations

Study limitations include a small sample size, hindering generalizability. Future research with larger samples and longer follow-up periods is needed for deeper insights into exercise interventions' long-term effects on balance outcomes in pes planus. Additionally, our study only assessed the immediate effects of a 4-week exercise program. Long-term effectiveness and comparison of stability versus stretching exercises warrant further investigation.

Conclusions

There are many exercise approaches for individuals with pes planus who complain of foot pain, and both types of exercises we applied were found to be effective on mobility and balance. However, no superiority over each other was found. In this context, there is a need for combined exercise groups, including stretching and stability exercises, in future studies.

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Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Istanbul Medipol University Institutional Review Board and Ethics Committee (approval No.: E-10840098-772.02-5420). Registered on the clinical trials page with NCT05549063.

Informed consent

Informed consent has been obtained from all individuals included in this study.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflicts of interest

The authors state no conflicts of interest.

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Reference

[1] Raj MA, Tafti D, Kiel J. Pes Planus. In: StatPearls. StatPearls Publishing; 2023. Available from: http://www.ncbi.nlm.nih.gov/books/NBK430802/ (accessed 25.08.2023).
[2] Flores DV, Mejía Gómez C, Fernández Hernando M, Davis MA, Pathria MN. Adult acquired flatfoot deformity: anatomy, biomechanics, staging, and imaging findings. Radiografics. 2019;39(5):1437–60; doi: 10.1148/rg.2019190046.
[3] Şahin FN, Ceylan L, Küçük H, Ceylan T, Arıkan G, Yiğit S, Sarşık DÇ, Güler Ö. Examining the relationship between pes planus degree, balance and jump performances in athletes. Int J Environ Res Public Health. 2022;19(18):11602; doi: 10.3390/ijerph191811602.
[4] Utsahachant N, Sakulsriprasert P, Sinsurin K, Jensen MP, Sungkue S. Effects of short foot exercise combined with lower extremity training on dynamic foot function in individuals with flexible flatfoot: a randomized controlled trial. Gait Posture. 2023;104:109–15; doi: 10.1016/j.gaitpost.2023.06.013.
[5] Kobayashi T, Hirota K, Otsuki R, Onodera J, Kodesho T, Taniguchi K. Morphological and mechanical characteristics of the intrinsic and extrinsic foot muscles under loading in individuals with flat feet. Gait Posture. 2023;108:15–21; doi: 10.1016/j.gaitpost.2023.11.001.
[6] Hoang N-T-T, Chen S, Chou L-W. The impact of foot orthoses and exercises on pain and navicular drop for adult flatfoot: a network meta-analysis. Int J Environ Res Public Health. 2021;18(15):8063; doi: 10.3390/ijerph18158063.
[7] Lee E, Cho J, Lee S. Short-foot exercise promotes quantitative somatosensory function in ankle instability: a randomized controlled trial. Med Sci Monit. 2019;25:618–26; doi: 10.12659/msm.912785.
[8] Hara S, Kitano M, Kudo S. The effects of short foot exercises to treat flat foot deformity: a systematic review. J

Back Musculoskelet Rehabil. 2023;36(1):21–33; doi: 10.3233/BMR-210374.
[9] Yıldırım ŞT, Aydoğan AS, Demirci C, Oktaş B, Sertel M. Comparison of short-term effects of virtual reality and short foot exercises in pes planus. Foot. 2021;47:101778; doi: 10.1016/j.foot.2021.101778.
[10] Canca-Sanchez FJ, Morales-Asencio JM, Ortega-Avila AB, Gijon-Nogueron G, Cervera-Garvi P, Marchena-Rodriguez A, Canca-Sanchez JC. Predictive factors for foot pain in the adult population. BMC Musculoskelet Disord. 2024;25(1):52; doi: 10.1186/s12891-023-07144-9.
[11] García LC, Lorca-Gutiérrez R, Vicente-Mampel J, Part-Ferrer R, Fernández-Ehrling N, Ferrer-Torregrosa J. Relationship between anterior cruciate ligament injury and subtalar pronation in female basketball players: case-control study. J Clin Med. 2023;12(24):7539; doi: 10.3390/jcm12247539.
[12] Jamshidi AH, Mofateh R, Orakifar N, Seyedtabib M, Najarzadeh Z, Behdarvandan A. Immediate effects of local muscle vibration on static and dynamic balance control in individuals with chronic ankle instability. Phys Ther Sport. 2023;65:113–21; doi: 10.1016/j.ptsp.2023.11.008.
[13] Sahin F, Yilmaz F, Ozmaden A, Kotevolu N, Sahin T, Kuran B. Reliability and validity of the Turkish version of the Berg Balance Scale. J Geriatr Phys Ther. 2008;31(1): 32–7; doi: 10.1519/00139143-200831010-00006.
[14] Karataş L, Vurallı D, Günendi Z. The effect of medial longitudinal arch height and medial longitudinal arch support insoles on postural balance in perimenopausal women. Turk J Med Sci. 2019;49(3):755–60; doi: 10.3906/sag-1808-39.
[15] Savas-Kalender D, Kurt-Aydin M, Acarol FO, Tarsuslu T, Yis U. Dual task impact on functional mobility and interaction of functional level and balance in patients with Duchenne muscular dystrophy. Gait Posture. 2023;108: 282–8; doi: 10.1016/j.gaitpost.2023.12.010.
[16] Boob MA Jr, Phansopkar P, Somaiya KJ. Physiotherapeutic interventions for individuals suffering from plantar fasciitis: a systematic review. Cureus. 2023;15(7):e42740; doi: 10.7759/cureus.42740.
[17] Tan F, Guney-Deniz H, Harput G, Ulusoy B, Dönmez G, Nyland J, Doral MN. Altered ankle muscle activation at 2-year post Achilles tendon repair: an age, gender, and activity level-matched comparison with healthy subjects. J Sport Rehabil. 2023;32(3):305–14; doi: 10.1123/jsr.2022-0064.
[18] Engkananuwat P, Kanlayanaphotporn R. Gluteus medius muscle strengthening exercise effects on medial longitudinal arch height in individuals with flexible flatfoot: a randomized controlled trial. J Exerc Rehabil. 2023; 19(1):57–66; doi: 10.12965/jer.2244572.286.
[19] Dębiec-Bąk A, Skrzek A, Ptak A, Majerski K, Uiberlayová I, Stefańska M. Evaluation of the surface temperature distribution in the feet of patients with type 2 diabetes using the thermovision method. Physioth Q. 2023; 31(2):92–7; doi: 10.5114/pq.2024.125293.
[20] Ghorbani M, Yaali R, Sadeghi H, Luczak T. The effect of foot posture on static balance, ankle and knee proprioception in 18-to-25-year-old female student: a cross-sectional study. BMC Musculoskelet Disord. 2023;24(1): 547; doi: 10.1186/s12891-023-06678-2.
[21] Wilczyński J, Paprocki M. Correlations between foot deformities and balance reactions among young schoolchildren. Med Stud. 2020;36(4):265–72; doi: 10.5114/ms.2020.102320.
[22] Namsawang J, Eungpinichpong W, Vichiansiri R, Rattanathongkom S. Effects of the short foot exercise with neuromuscular electrical stimulation on navicular height in flexible flatfoot in Thailand: a randomized controlled trial. J Prev Med Public Health. 2019;52(4):250–7; doi: 10.3961/jpmph.19.072.
[23] Brijwasi T, Borkar P. A comprehensive exercise program improves foot alignment in people with flexible flat foot: a randomised trial. J Physiother. 2023;69(1):42–6; doi: 10.1016/j.jphys.2022.11.011.
[24] Gupta U, Sharma A, Rizvi MR, Alqahtani MM, Ahmad F, Kashoo FZ, Miraj M, Asad MR, Uddin S, Ahamed WM, Nanjan S, Hussain SA, Ahmad I. Instrument-assisted soft tissue mobilization technique versus static stretching in patients with pronated dominant foot: a comparison in effectiveness on flexibility, foot posture, foot function index, and dynamic balance. Healthcare. 2023; 11(6):785; doi: 10.3390/healthcare11060785.
[25] Houck J, Neville C, Tome J, Flemister A. Randomized controlled trial comparing orthosis augmented by either stretching or stretching and strengthening for stage II tibialis posterior tendon dysfunction. Foot Ankle Int. 2015; 36(9):1006–16; doi: 10.1177/1071100715579906.
[26] Turgut E, Yagci G, Tunay VB. Hip-focused neuromuscular exercise provides immediate benefits in foot pronation and dynamic balance: a sham-controlled crossover study. J Sport Rehabil. 2021;30(7):1088–93; doi: 10.1123/jsr.2020-0549.
[27] Panichawit C, Bovonsunthonchai S, Vachalathiti R, Limpasutirachata K. Effects of foot muscles training on plantar pressure distribution during gait, foot muscle strength, and foot function in persons with flexible flatfoot. J Med Assoc Thai. 2015;98 Suppl 5:12–7.
[28] Yildiz K, Medetalibeyoglu F, Kaymaz I, Ulusoy GR. Triad of foot deformities and its conservative treatment: with a 3D customized insole. Proc Inst Mech Eng H. 2021;235(7):780–91; doi: 10.1177/09544119211006528.
[29] Sagat P, Bartik P, Štefan L, Chatzilelekas V. Are flat feet a disadvantage in performing unilateral and bilateral explosive power and dynamic balance tests in boys?. A school-based study. BMC Musculoskelet Disord. 2023;24(1):622; doi: 10.1186/s12891-023-06752-9.
[30] Lynn SK, Padilla RA, Tsang KKW. Differences in static- and dynamic-balance task performance after 4 weeks of intrinsic-foot-muscle training: the short-foot exercise versus the towel-curl exercise. J Sport Rehabil. 2012;21(4): 327–33; doi: 10.1123/jsr.21.4.327.
[31] Moon D, Jung J. Effect of incorporating short-foot exercises in the balance rehabilitation of flat foot: a randomized controlled trial. Healthcare. 2021;9(10):1358; doi: 10.3390/healthcare9101358.
[32] Jankowicz-Szymanska A, Mikolajczyk E, Wardzala R. Arch of the foot and postural balance in young judokas and peers. J Pediatr Orthop B. 2015;24(5):456–60; doi: 10.1097/BPB.0000000000000202.
[33] Shukla SM, Behera TP, Suresh AMR, Jayavant S, Kashyap D. Effect of UCBL and medial longitudinal arch support in balance and functional performance in bilateral flexible flat feet in patients aged between 16 and 20 years. Int J Orthop Res. 2021;4(2),56–62; doi: 10.33140/IJOR.