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The relationship between foot proprioception and balance performance in young adults with pes planus

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Abstract

This study was conducted to investigate the relationship between foot proprioception and balance performance in young adults with pes planus. Thirty-four young adults with pes planus (mean age 20.15 ± 1.23 years) were included in the study. Pes planus evaluation was divided into 3 categories according to the Feiss line. Balance performance of the participants was evaluated with the Y Balance test and foot proprioception was evaluated with a digital goniometer at plantar flexion and dorsiflexion angles. The relationship between the variables was analyzed by spearman correlation analysis. A significant correlation was found between plantar flexion absolute error value and balance results in anterior, posterolateral, and posteromedial directions (r:-0.473, p<0.05; r:-0.428, p<0.05; r:-0.379, p<0.05, respectively). There was a significant correlation between dorsiflexion absolute error value and balance results in posterolateral direction (r:-0.548, p<0.05), but not in anterior and posteromedial direction (p>0.05). Significant negative correlations were identified between the severity of pes planus and Y-balance test scores in the anterior ($r = -0.553$, $p < 0.05$), posterolateral ($r = -0.475$, $p < 0.05$), and posteromedial ($r = -0.387$, $p < 0.05$) directions. Significant positive correlations were observed between the severity of pes planus and the absolute error values of ankle proprioception in plantar flexion ($r = 0.516$, $p < 0.05$) and dorsiflexion ($r = 0.423$, $p < 0.05$). This relationship should be taken into consideration in the evaluation and treatment programs of people with pes planus. The cross-sectional design of the study, the limited age range of the sample, and the fact that pes planus assessment was performed only in the static position limit the generalizability of the results and interpretations of causality.

Introduction

Foot structure plays a fundamental role in posture, balance, and mobility of the human body. The structural integrity of the medial longitudinal arch (internal longitudinal arch), which provides support in three dimensions in the foot, is critical, especially regarding proprioceptive feedback and postural balance (Birinci & Demirbas, 2017). The ability of the arch to adapt to cyclic loading without significant deformation suggests an intact proprioceptive mechanism that maintains its structural integrity during prolonged activities (Babu & Bordoni, 2020). Pes planus, commonly known as flatfoot, is a deformity characterized by collapse of the medial arch and can affect lower extremity biomechanics by causing mechanical changes in the foot (Van Boerum & Sangeorzan, 2003). This can have negative effects on both static and dynamic balance. The absence or reduction of the arch impairs the foot's ability to distribute forces during weight-bearing activities such as walking or running and can lead to altered gait patterns (Buldt et al., 2015).

Proprioception is the ability to perceive the position and movement of the body and is a vital sensory system for the healthy functioning of balance mechanisms (Wang et al., 2016). This sensory process involves the integration of both the peripheral and central nervous systems. Peripheral components include muscle spindles, Golgi tendon organs, joint receptors, and skin mechanoreceptors, while central components involve the processing of this information at the spinal cord, brainstem, cerebellum, and cerebral cortex levels (Grigg, 1994). The central nervous system

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integrates this multi-source sensory data to regulate motor responses and provide postural control. The foot is an important source of proprioceptive input due to its dense mechanoreceptor content (Van Deursen & Simoneau, 1999). However, pes planus deformity can reduce the effectiveness of this sensory feedback from the sole of the foot. The proprioceptive function of the MLA is linked to dynamic gait parameters such as dorsiflexion range of motion, which affects gait stability and efficiency (Persiane et al., 2021) Proprioceptive deficits can impair movement, emphasizing the importance of the MLA in proprioceptive feedback mechanisms (Hussain et al., 2024). This may lead to individuals having difficulty in maintaining postural stability.

Although several studies suggest that proprioception and balance are affected in individuals with pes planus (Rakhmatova et al., 2024), the direct relationship between proprioceptive sensation and balance performance has not been sufficiently explored. For example, a study by Ghorbani et al. showed that Flexible flatfoot can cause loss of balance and sense of joint position (Ghorbani et al., 2023). Another study examined the impact of flexible flatfoot on balance, functional movement and core muscle strength but did not assess proprioceptive function (Ghorbani et al., 2025). Moreover, little is known about how the severity of pes planus might influence these parameters. Therefore, the primary aim of this study was to investigate the relationship between proprioception and dynamic balance performance in young adults with pes planus. The secondary aim was to examine how the severity of pes planus correlates with proprioceptive accuracy and balance performance. The hypotheses of this study are as follows: It is hypothesized that there is a significant relationship between joint position sense (JPS) and dynamic balance performance in individuals with pes planus. Additionally, it is hypothesized that increased severity of pes planus will be associated with further reductions in proprioceptive accuracy and balance performance.

This study focused on young adults as they represent a population in which musculoskeletal and postural systems are fully developed, minimizing developmental variability seen in children and age-related decline observed in older adults. Moreover, young adults are often engaged in various physical activities where optimal proprioception and balance are critical, yet may not receive clinical attention unless symptoms are severe.

Methods

This cross-sectional study included young adult university students aged 18 to 25 years. The research was carried out from March 2025 to May 2025 at Erzurum Technical University, Faculty of Health Sciences. The research was executed in compliance with the Declaration of Helsinki. Approval for the study was secured from the ethics committee of Erzurum Technical University (2025/decision number: 05-14). All participants provided informed consent.

Participants

The study included university students aged 18 to 25 years with pes planus. Participants with any neurological, orthopedic, or cardiovascular conditions, foot surgery within the past six months, diabetes, multiple sclerosis, pathologies that could induce sensory issues, such as severe disc herniation, ligamentous laxity, or lower extremity pain, were excluded from the study. In order to minimize the inclusion of individuals with subclinical or undiagnosed sensory deficits (e.g., mild peripheral neuropathy), participants were screened through a brief clinical history and neurological examination, including vibration sense and light touch testing of the lower extremities, prior to testing.

The G*Power software (version 3.1.9.2, Axel Buchner, Universität Kiel) was utilized for sample size determination. The Coefficient of Determination was calculated to be 0.273529 (effect size: 0.523) in the relationship analysis by reviewing data from a comparable study, which investigated similar variables and analysis (balance and correlation analysis) conducted by Lee et al (Lee et al., 2014). Although this represents a moderate-to-large effect size, it was considered appropriate due to the similarity in population and outcome measures. Nevertheless, we acknowledge that this may slightly overestimate statistical power and should be interpreted with caution. The results indicate that a minimum of 30 participants is required when $\alpha=0.05$, $1-\beta$ (power)=0.90, and effect size=0.523. The study comprised 36 participants, excluding 2 individuals (one due to lower extremity pain and another who underwent surgery within the last 6 months). The study involved 34 young adult participants.

Assessments

Demographic characteristics such as age, gender, height and weight were recorded. The navicular position test was used to determine the severity of pes planus. Proprioception was evaluated with digital goniometer and balance performance was evaluated with Y Balance test. The dominant foot was considered in the measurements. All assessments were performed by a single physiotherapist.

Assessment of Pes Planus

Participants were graded for pes planus by a single physiotherapist while standing on a hard surface with equal weight on both feet. In a normal foot, the tubercle of the navicular bone is located on the Feiss line drawn through the center of the medial malleolus and the metatarsophalangeal joint of the big toe. Pes planus degrees are evaluated according to the separation of the navicular tubercle from this line and its approach to the ground. If the navicular tubercle is reduced by 1/3 of the distance between the Feiss line and the ground, pes planus is classified as grade 1, if it is reduced by 2/3, it is classified as grade 2, and if it completely touches the ground, it is classified as grade 3 (Spörndly-Nees et al., 2011).

Assessment of Proprioception

For proprioception assessment, a digital goniometer was used for the joint position sense (JPS) test. The target angle for ankle JPS was determined as 15° for dorsi flexion and 25° for plantar flexion (Karaduman et al., 2016). For the ankle JPS test, the participant was positioned on the back. In JPS tests, the joint was brought to the target angle with the child's eyes closed and asked to perceive the position by waiting 10 seconds. Then, the child was asked to return to the neutral position and repeat the target angle in the eyes closed position and the measurement was made with a digital goniometer. The difference between the target angle and the participants' result during the test was determined as the error score. Three measurements were made for all target angles and the arithmetic mean of the differences was calculated.

Assessment of Balance

For the Y Balance Test, the test procedures were designed on a flat floor; the angle between the anterior and posterior directions was 135° and the angle between the posteromedial-posterolateral direction was 90°. Three tape measures were fixed on the floor in the specified directions with the starting point as the center and the test was started by placing the feet of the individuals exactly in the center. Kattilakoski and colleagues recommended performing at least 7 trials of this test, including possible practice repetitions, and averaging over 3 repetitions to reduce the learning effect (Kattilakoski et al., 2023). Before starting the test procedures, the physiotherapist showed how to do it and the participants were tested 3 times. Afterwards, 3 attempts were made to reach towards the anterior, posteriomedial and posteriolateral directions, respectively, so that they could learn the test (Jagger et al., 2020). After the test was taught, the individuals were asked to reach 3 times in each direction according to the instructions and the average reaching distances of the individuals for each direction were recorded in cm. Considering the advantage of taller individuals, the results were normalized to leg length [(reach distance / limb length) × 100)] (Robinson & Gribble, 2008).

Statistical analysis

The distribution of the data was evaluated by Shapiro-Wilk test. The relationship between ankle position sense and Y Balance Test scores was analyzed by Pearson or Spearman correlation analysis depending on the data distribution. The magnitude scale established by Hopkins was employed to elucidate the correlation coefficients: <0.1, trivial; 0.1–0.29, small; 0.30–0.49, moderate; 0.50–0.69, high; 0.70–0.90, very high; >0.90, almost perfect (Hopkins, 2000). The significance level was accepted as $p<0.05$.

Results

Demographic data and balance, proprioception test results and pes planus severity of all individuals participating in the study are summarized in Table 1.

Table 1
Characteristics of the participants.

Variables		Mean ± SD	
Age (years)		20.15 ± 1.23	
Height (cm)		165.27 ± 7.01	
Weight (kg)		62.33 ± 12.15	
Body mass index (kg/m^2)		22.69 ± 3.40	
Y Balance test	*Anterior*	78.44 ± 8.10	
	Posteromedial	87.50 ± 11.40	
	Posterolateral	84.23 ± 12.11	
Proprioception			
AE of ankle dorsiflexion (degree)		3.96 ± 2.70	
AE of ankle plantarflexion (degree)		2.94 ± 2.06	
		n	%
Gender	*Female*	18	52.9
	Male	16	47.1
Pes planus severity	*1*	10	29.4
	2	13	38.2
	3	11	32.4
Dominant side	*Right*	32	94.9
	Left	2	5.1

AE: Absolute error.

Positive and significant correlations were detected between pes planus severity and ankle proprioception absolute error values (plantar flexion (r = 0.516; p < 0.05) and dorsiflexion (r = 0.423; p < 0.05)) These results suggest that as the severity of flatfoot increases, the proprioceptive accuracy of the ankle joint decreases. The slightly stronger correlation with plantar flexion errors may indicate that tasks involving posterior chain control are more affected by arch deformation. Again, some individual variability was noted, with a few participants showing high error rates despite moderate deformity levels (Figure 2).

Table 2
Relationship between Y Balance test and foot proprioception.

Variables	AE of ankle dorsiflexion (degree)		AE of ankle plantarflexion (degree)	
	r	p	r	p
Anterior	-0.312	0.072	-0.473*	0.005*
Posteromedial	-0.211	0.231	-0.428*	0.012*
Posterolateral	-0.548	0.001*	-0.379*	0.027*

*AE: Absolute error, * p < 0.05.*

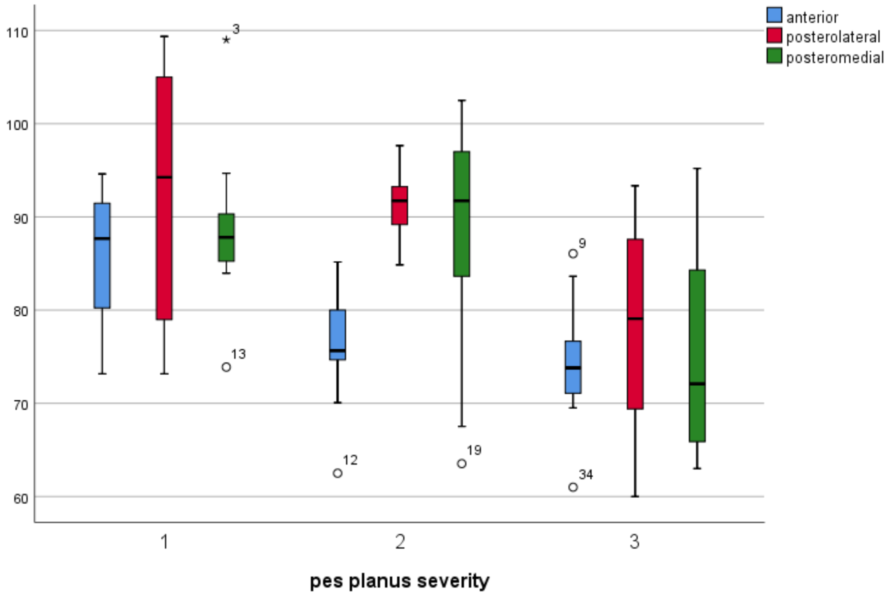

Figure 1. Boxplots of the relationship between pes planus severity and Y Balance test results.

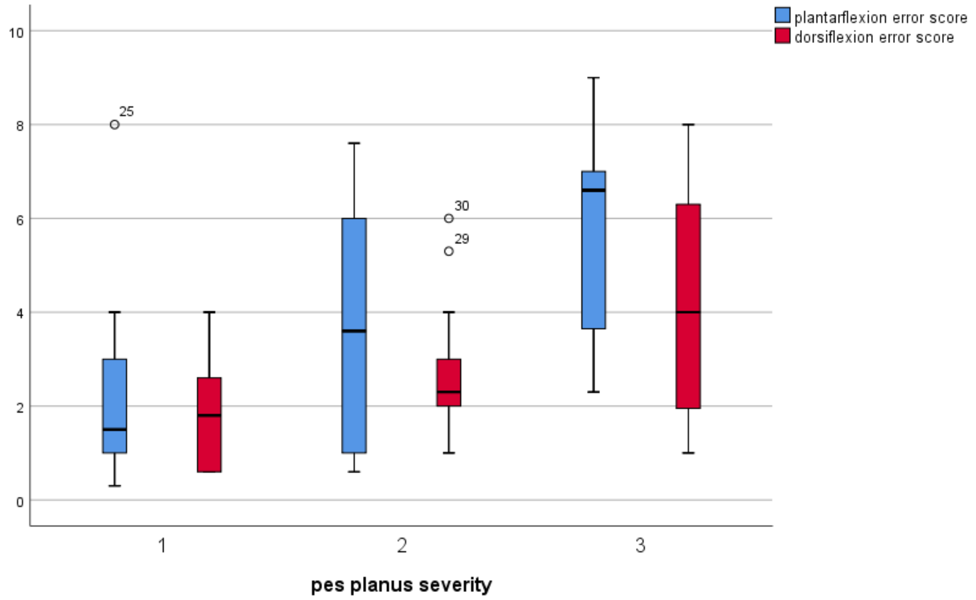

Figure 2. Boxplots of the relationship between pes planus severity and proprioception results.

Discussion

This study aimed to fill an important gap in the literature by investigating the relationship between foot proprioception and balance performance in young adults with pes planus. The findings revealed that greater severity of pes planus was moderately associated with lower balance performance and reduced accuracy in ankle joint position sense. In the Y-balance test, balance scores in the anterior, posteromedial and posterolateral directions were significantly negatively correlated with pes planus severity, supporting the direct effect of medial arch collapse on balance control. In addition, plantar and dorsiflexion absolute error values obtained in proprioception evaluations showed a significant and positive correlation with pes planus severity, suggesting that the deformity in the foot structure also negatively affects sensory feedback mechanisms.

In the literature, it has been reported that proprioceptive feedback is especially important in ankle strategy and that the individual creates an appropriate motor response based on this sensory information in imbalance situations (Proske & Gandevia, 2012). In a brain imaging study by Goble et al. (2011), it was reported that central processing of proprioceptive signals from the foot-ankle complex is necessary for posture and balance control. Harry-Leite et al. (2022) reported that proprioceptive exercises had positive effects on balance in athletes. Studies in which proprioceptive trainings were planned to improve balance in different populations also support the relationship between proprioception and balance (Amrinder et al., 2012; Drummond et al., 2018). The findings of our study also show that foot proprioception is associated with dynamic balance performance in individuals with pes planus. Both an increase in proprioception error and significant decreases in y-balance test scores were observed. These findings suggest a potential association between medial arch collapse and altered afferent input from plantar mechanoreceptors, which may influence the sensorimotor feedback loop. In addition, these decreases in balance performance suggest that individuals with pes planus may experience inadequacy in postural balance strategies due to weak proprioceptive mechanisms.

Studies supporting that pes planus deformity will negatively affect balance by changing foot and lower extremity biomechanics are included in the literature. Dikici & Demirdel (2023) reported that balance performance decreased as the severity of pes planus increased in people with pes planus. Primal et al. (2022) reported that pes planus caused postural stability disorders in student basketball athletes during static and dynamic activities. They also showed that balance is affected in individuals with pes planus and that there is a potential link between foot structure and balance performance, especially in athletes with longer exercise periods. Consistent with the literature, the severity of pes planus was associated with a decrease in balance performance in our study. The reduction of the medial longitudinal arch in pes planus and the weakening of muscles and ligaments in this region may affect balance and other performance measures (Kothari et al., 2015).

The relationship between pes planus severity and proprioception is a multifaceted issue involving both peripheral and central mechanisms (Viseux, 2020). Pes planus or flatfoot can lead to altered biomechanics and proprioceptive deficits that affect balance and coordination. These individuals may experience impaired ankle joint position sense, which is critical for maintaining balance. Studies show that proprioceptive accuracy is compromised in conditions such as plantar fasciitis, which shares biomechanical similarities with pes planus (Alshehri et al., 2025). The severity of pes planus can affect neuromuscular control, leading to instability and an increased risk of falls. This is particularly evident in children with pes planus, who may also have a history of delayed walking, suggesting a developmental link (Octavius et al., 2020). Proprioception relies on sensory neurons in muscles and joints. In pes planus, altered foot structure can disrupt normal sensory feedback, leading to reduced proprioceptive acuity (Suetterlin & Sayer, 2014).

In the study, significant decreases in both proprioception error and y-balance test scores were observed as the severity of pes planus increased. These findings suggest that the efficiency of mechanoreceptors in the sole of the foot decreases with the collapse of the medial arch and this negatively affects the feedback loop on the sensorimotor system. Furthermore, these decreases in balance performance suggest that individuals with pes planus may experience inadequacy in postural control strategies due to weak proprioceptive mechanisms. In conclusion, this study revealed that pes planus deformity is associated with foot proprioception and dynamic balance performance. Decreased proprioceptive feedback with the collapse of the medial arch caused balance to be affected, supporting the strong association of ankle position sense with balance. In addition, as the severity of pes planus increases, proprioceptive error rates increase and balance scores decrease, indicating that functional mobility may be limited in these individuals. In line with these findings, it is suggested that future evaluation and rehabilitation processes for individuals with pes planus may benefit from incorporating not only structural analyses but also multidimensional approaches targeting proprioceptive feedback and postural balance. However, these recommendations should be considered as preliminary suggestions, as they are not directly confirmed by experimental evidence from the current study.

This study has some limitations. First of all, since the study has a cross-sectional design, it is not possible to make inferences about the causality of the observed relationships. Information about the direction and time course of the relationship between pes planus severity and balance and proprioception cannot be obtained. Secondly, only individuals with pes planus were included in the study and a healthy control group was not included. Also, although the sample was nearly balanced in terms of sex and predominantly right-side dominant, no analyses were conducted based on sex or limb dominance. This situation prevents the evaluation of significant differences by comparing the findings obtained with individuals without pes planus and limits the interpretations. In addition, since the sample consisted only of university students aged 18-25 years, the generalizability of the results to different age groups or to the general population is limited. Pes planus assessment was performed using the Feiss line only in the static position, and dynamic arch behavior was not taken into consideration. For these reasons, it is recommended that future studies be conducted with larger sample groups, prospective designs and control groups, including both static and dynamic evaluations.

Conclusion

Ankle proprioception was generally associated with balance performance in individuals with pes planus. It was found that as the severity of pes planus increased, the balance performance and proprioceptive sensation decreased. However, due to the cross-sectional nature of this study, causal relationships cannot be established. Further prospective and intervention-based research is needed to clarify the direction and underlying mechanisms of this association. Additionally, the use of a single assessor for all JPS and balance evaluations may have introduced measurement bias. Physical activity levels and athletic background, which could significantly influence proprioception and balance, were not assessed and should be considered in future studies. In clinical practice, it is recommended that these individuals should be evaluated not only structurally but also in terms of sensory-motor control and holistic treatment approaches should be developed.

Authors' Contribution

Study Design: RY; Data Collection: RY, AY; Statistical Analysis: RY; Manuscript Preparation: RY, AY.

Ethical Approval

The study was approved by the Erzurum Technical University Scientific Research and Publication Ethics Committee (2025/decision number: 05-14) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

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Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

References

Alshehri, S. H. S., Alshahrani, M. S., Al Adal, S. Y., Alyazedi, F. M., Alnakhli, H. H., & Reddy, R. S. (2025). An examination of ankle joint position sense, postural control and associated neuromuscular deficits in patients with plantar fasciitis: a cross-sectional analysis with advanced biomechanical and psychosocial correlates. *J Orthop Surg Res*, *20*(1), 67. doi: 10.1186/s13018-025-05485-w

Amrinder, S., Deepinder, S., & Singh, S. J. (2012). Effect of proprioceptive exercises on balance and center of pressure in athletes with functional ankle instability. *Sports Medicine Journal/Medicina Sportivâ*, *8*(3), 1927-1933.

Babu, D., & Bordoni, B. (2020). *Anatomy, bony pelvis and lower limb, medial longitudinal arch of the foot*. StatPearls.

Birinci, T., & Demirbas, S. B. (2017). Relationship between the mobility of medial longitudinal arch and postural control. *Acta Orthop Traumatol Turc*, *51*(3), 233-237. doı: 10.1016/j.aott.2016.11.004

Buldt, A. K., Levinger, P., Murley, G. S., Menz, H. B., Nester, C. J., & Landorf, K. B. (2015). Foot posture is associated with kinematics of the foot during gait: A comparison of normal, planus and cavus feet. *Gait Posture*, *42*(1), 42-48. doi: 10.1016/j.gaitpost.2015.03.004

Dikici, T. F., & Demirdel, E. (2023). The relationship between pes planus severity and lower extremity functional performance in young adults. *Turk J Physiother Rehabil*, *34*(3), 304-312.

Drummond, A., Paz, C. C. d. S. C., & Menezes, R. L. d. (2018). Proprioceptive activities to postural balance of the elderly-systematic review. *Fisioterapia Em Movimento*, *31*, e003135. doi: 10.1590/1980-5918.031.AO35

Ghorbani, M., Yaali, R., Sadeghi, H., & Koumantakis, G. A. (2025). The impact of flatfeet on the correlation between functional movement scores, balance, agility, and core muscle strength in young females: a cross-sectional study. *Sci Rep, 15, 5077 (2025). doi: 10.1038/s41598-025-89364-8*.

Ghorbani, M., Yaali, R., Sadeghi, H., & Luczak, T. (2023). 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*, *24*(1), 547. doı: 10.1186/s12891-023-06678-2

Goble, D. J., Coxon, J. P., Van Impe, A., Geurts, M., Doumas, M., Wenderoth, N., & Swinnen, S. P. (2011). Brain activity during ankle proprioceptive stimulation predicts balance performance in young and older adults. *J Neurosci*, *31*(45), 16344-16352. doi: 10.1523/JNEUROSCI.4159-11.2011

Grigg, P. (1994). Peripheral neural mechanisms in proprioception. *J Sport Rehabil*, *3*(1), 2-17.

Harry-Leite, P., Paquete, M., Teixeira, J., Santos, M., Sousa, J., Fraiz-Brea, J. A., & Ribeiro, F. (2022). Acute impact of proprioceptive exercise on proprioception and balance in athletes. *Appl Sci*, *12*(2), 830. doi: 10.3390/app12020830

Hopkins, W. G. (2000). Measures of reliability in sports medicine and science. *Sports Med*, *30*, 1-15. doi: 10.2165/00007256-200030010-00001

Hussain, S. A., Gardezi, F., Ain, Q. U., Sajid, A., Afzal, R., Hassan, Z., & Khurshid, A. (2024). Effect of weight bearing on medial longitudinal arch of foot in healthy adults. *Journal of Health and Rehabilitation Research*, *4*(1), 442-446. doi: 10.61919/jhrr.v4i1.427

Jagger, K., Frazier, A., Aron, A., & Harper, B. (2020). Scoring performance variations between the Y-balance test, a modified Y-balance test, and the modified star excursion balance test. *Int J Sports Phys Ther*, *15*(1), 34-41.

Karaduman, A. A., Yılmaz, Ö. T., & Akel, B. S. (2016). *Fizyoterapi ve rehabilitasyon*. Hipokrat Publishing.

Kattilakoski, O., Kauranen, N., Leppänen, M., Kannus, P., Pasanen, K., Vasankari, T., & Parkkari, J. (2023). Intrarater reliability and analysis of learning effects in the Y balance test. *Method Protocol*, *6*(2), 41.

Kothari, A., Dixon, P., Stebbins, J., Zavatsky, A., & Theologis, T. (2015). The relationship between quality of life and foot function in children with flexible flatfeet. *Gait Posture*, *41*(3), 786-790. doi: 10.1016/j.gaitpost.2015.02.012

Lee, D.-K., Kim, G.-M., Ha, S.-M., & Oh, J.-S. (2014). Correlation of the Y-balance test with lower-limb strength of adult women. *J Phys Ther Sci*, *26*(5), 641-643. doi: 10.1589/jpts.26.641

Octavius, G. S., Sugiarto, T., Handy, F., & Hartanto, R. N. (2020). Flat foot at 5 to 6-year-old and history of delayed walking. *Paediatrica Indonesiana*, *60*(6), 321-327. doı: 10.14238/pi60.6.2020.321-7

Persiane, A. S., Negrão, D. M. G., Alves, R. D. P., Freitas, D. G. D., Cazarini, C., & Alves, V. L. D. S. (2021). Subtalar joint in neutral and relaxed positions for evaluation of medial longitudinal arch. *Acta Ortop Bras*, *29*(4), 177-180. doi: 10.1590/1413-785220212904240893

Primal, D., Kusumaningtyas, S., & Ibrahim, E. I. (2022). *Pes planus plantaris (flat foot) decreases postural stability of basketball student-athletes through ground reaction force vector (vGRF).* Proceedings of the 10th International Conference on Sport Sciences Research and Technology Support (icSPORTS 2022, pp. 143-151). Valletta, Malta.

Proske, U., & Gandevia, S. C. (2012). The proprioceptive senses: their roles in signaling body shape, body position and movement, and muscle force. *Physiol Rev,* 92(4), 1651-1697. doi: 10.1152/physrev.00048.2011.

Rakhmatova, R., Miçooğulları, M., & Tok, M. I. (2024). How does pes planus affect jumping performance and balance ability? *J Back Musculoskelet Rehabil*, doi: 10538127251324728.

Robinson, R. H., & Gribble, P. A. (2008). Support for a reduction in the number of trials needed for the star excursion balance test. *Arch Phys Med Rehabil*, *89*(2), 364-370. doı: 10.1016/j.apmr.2007.08.139

Spörndly-Nees, S., Dåsberg, B., Nielsen, R. O., Boesen, M. I., & Langberg, H. (2011). The navicular position test–A reliable measure of the navicular bone position during rest and loading. *Int J Sports Phys Ther*, *6*(3), 199.

Suetterlin, K. J., & Sayer, A. A. (2014). Proprioception: where are we now? A commentary on clinical assessment, changes across the life course, functional implications and future interventions. *Age Ageing*, *43*(3), 313-318. doi: 10.1093/ageing/aft174

Van Boerum, D. H., & Sangeorzan, B. J. (2003). Biomechanics and pathophysiology of flat foot. *Foot Ankle Clin*, *8*(3), 419-430. doi: 10.1016/s1083-7515(03)00084-6

Van Deursen, R. W. M., & Simoneau, G. (1999). Foot and ankle sensory neuropathy, proprioception, and postural stability. *J Orthop Sports Phys Ther*, *29*(12), 718-726. doi: 10.2519/jospt.1999.29.12.718

Viseux, F. J. (2020). The sensory role of the sole of the foot: Review and update on clinical perspectives. *Neurophysiol Clin*, *50*(1), 55-68. doi: 10.1016/j.neucli.2019.12.003

Wang, H., Ji, Z., Jiang, G., Liu, W., & Jiao, X. (2016). Correlation among proprioception, muscle strength, and balance. *J Phys Ther Sci*, *28*(12), 3468-3472. doi: 10.1589/jpts.28.3468