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DOES HIP-MUSCLE WEAKNESS IS ASSOCIATED WITH IMPAIRED FOOT POSTURES IN VOLLEYBALL PLAYERS?

ALI JE ŠIBKOST MIŠIC KOLKA POVEZANA S SLABŠO DRŽO STOPALA PRI ODBOJKARJIH?

ABSTRACT

This study aimed to explore the differences in the distributions of plantar pressure in dynamic states and assess the strength profiles in the hip muscle of professional volleyball players according to foot posture index. Dynamic plantar pressure distributions were evaluated via the Pedar®-X plantar pressure insole during walking. Load Cell sensors were used isometrically to measure hip adductor/abductor muscle strength. Independent-Samples t-Test was performed according to Levene's homogeneity test results. Pearson correlation coefficient was performed to understand the relationship between the variables. For these measurements, significance level was set as p<0.05. The right adductor and right abductor strength of the prone group had significantly lower than the neutral group (p <.05). Similarly, the left adductor strength of the prone group had significantly lower than the neutral group (p <.05). Also, plantar pressure distributions of volleyball players with prone feet were distributed evenly across metatarsal bones, but highly uniformly on the 1st, 2nd and 3rd metatarsal head and midfoot regions in dynamic walking. Results between the neutral and prone foot posture group found a moderate negative relationship (r = -.570; -,529) between both right and left adductor hip strength and foot posture. Finally, in right and left abductor hip strength to foot posture a low negative relationship was found (r = -.471; -375). Reduced strength of the hip abductor relative to the adductor is associated with increased pronation at the foot. Furthermore, the decrease in arch height increased the risk of lower extremity injuries related to excessive use, including patellofemoral pain syndrome and medial tibial stress syndrome, as well as may have a negative effect on jumping performance.

Keywords: volleyball, foot posture index, plantar pressure, sport, hip strength

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IZVLEČEK

Namen te študije je bil raziskati razlike v porazdelitvi plantarnega pritiska v dinamičnih stanjih in oceniti profile moči v mišicah kolka profesionalnih odbojkarjev glede na indeks drže stopala. Dinamične porazdelitve plantarnega pritiska so bile ocenjene s pomočjo vložka za plantarni pritisk Pedar®-X med hojo. Za merjenje moči mišic adduktorjev/abduktorjev kolka so bili izometrično uporabljeni senzorji celic obremenitve. Izveden je bil T-test za neodvisne vzorce glede na rezultate Levenovega testa homogenosti. Pearsonov korelacijski koeficient je bil uporabljen za razumevanje razmerja med spremenljivkami. Za te meritve je bila določena stopnja značilnosti p<0.05. Moč desnega adduktorja in abduktorja ter levega adduktorja je bila pri skupini s pronacijo stopala bistveno manjša kot pri nevtralni skupini (p <.05). Tudi porazdelitev plantarnega pritiska pri skupini s pronacijo stopala je bila enakomerno porazdeljena po metatarzalnih kosteh, pri dinamični hoji pa zelo enakomerno porazdeljena na glavico 1., 2. in 3. metatarzalne kosti ter srednji del stopala. Pri rezultatih med skupinama z nevtralno in pronirano držo stopala je bila ugotovljena srednja/zmerna negativna povezanost (r = -.570; -.529) med močjo desnega in levega adduktorja kolka ter držo stopala. Nazadnje je bila ugotovljena nizka/šibka negativna povezava med desnim in levim abduktorjem kolka in držo stopala (r = -.471; -.375). Zmanjšana moč abduktorja kolka glede na adduktorja je povezana s povečano pronacijo stopala. Poleg tega je zmanjšanje višine stopalnega loka povečalo tveganje za poškodbe spodnjih okončin, povezane s prekomerno uporabo, vključno s patelofemoralnim bolečinskim sindromom in medialnim tibialnim stresnim sindromom, prav tako pa lahko negativno vpliva na zmogljivost pri skokih.

Ključne besede: odbojka, indeks drže stopal, plantarni pritisk, šport, moč kolkov

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INTRODUCTION

Volleyball is a sport that has a dynamic and ballistic nature and requires advanced-level jumping and landing skills to avoid the risk of injury (Tillman et al., 2004). Even though it is not a contact sport, with 10.8% of adolescents injured, volleyball is ordered of the top three sports associated with injuries in adolescents (Wasser et al., 2021). Studies show that volleyball players have up to 10.7 injuries per 1000 hours (Bere et al., 2015; Kilic et al., 2017). Since volleyball has a complex structure that has motions such as quick change of direction, jumping and diving (Wasser et al., 2021) ankles, knees, and feet are primarily submitted to overloads (Giglia et al., 2011; Czarny et al., 2014; Numata et al., 2018; Piech et al., 2020). Therefore the most common injury sites were ankle (17%-18%), knee and (30%-33%) foot (3%-7%) among volleyball players (Aagaard and Jorgensen, 1996; Agel et al., 2007; Augustsson et al., 2011; Wasser et al., 2021). Safe performance of these specific movements during sports practice and competitions relies on the athletes' capacity to stabilize the hip and consequently, minimize movement impairments of more distal joints. The weakness of the hip external rotators leads to excessive femoral internal rotation during the single-leg squat, landing tasks and more distal movement impairments, such as dynamic knee valgus and abnormal foot pronation (Bird & Payne, 1999; Harradine, Bevan & Carter, 2006; Chuter & de Jonge, 2012; Mendonca et al., 2022). Abnormal foot pronation is typically defined by excessive calcaneal eversion, plantarflexion and adduction of the talus, the collapse of the medial longitudinal arch, and abduction of the forefoot on the hindfoot. Abnormal foot pronation has been associated with increased foot mobility, the collapse of the transverse arch, and compensatory knee and hip medial rotation (Cornwall MW, McPoil 2011, Chuter and de Jonge, 2012, Carroll et al., 2022; Mendonca et al., 2022).

The hip joint's strength and muscular balance may impact athletes' performance and decrease the tendency of athletes' injury, reducing the ratio of groin injuries and strains of the hip joint (Tyler et al., 2001; Kemp et al., 2013; Karatrantou et al., 2019). A highly pronated foot causes the tibia to maintain longer internal rotation than normal, which leads to valgus stress and increased internal rotation in the hips. As a result, iliopsoas muscle stretches and lumbar lordosis increase since the pelvis tilts forward (Tang et al., 2015). Also, weak hip stabilizers (hip extensors, abductors, and external rotators) cause an extreme inner rotation of the hip, which, in turn, leads to foot pronation (Rathnamala, Senthil, & Kulkarni, 2020). Investigating structural foot deformities has recently been suggested as an important method to prevent potential lower extremity injuries (Hreljac et al., 2000; Bowring & Chockalingam, 2010;

Simsek et al., 2021) and foot posture is one factor considered to examine (Sommer & Vallentyne, 1995; Burns, Keenan & Redmond, 2005; Terada, Wittwer & Gribble, 2014). Volleyball players have a high incidence of lower limb injuries, (Eerkes 2012; Trojian et al., 2013) mostly related to jumping, landing, and cutting movements (Hinshaw et al., 2019; Peebles et al., 2020). Perceptions of the relationship between divergent foot types and plantar pressure distribution could be useful in developing strategies to prevent lower extremity injuries. Plantar pressure patterns reflect the biomechanical variety of an individual's gait (Morag & Cavanagh, 1999; Giacomozzi, Leardini, & Caravaggi, 2014; Cardoso et al., 2021), and plantar pressure analysis has been used to measure magnitude and distribution of the force which is applied to the plantar surface pending walking (Landorf & Keenan, 2000; Wong et al., 2007; Shu et al., 2010; Simsek et al., 2021).

There are several studies in the literature investigating plantar pressure distribution. Fernandez-Seguin et al. (2014) compared the contact area between neutral and cavus feet during gait analysis and found that compared to neutral feet, pes cavus feet show a reduction in total contact surface and the load under the first toe. A significant increase is present in the load under the metatarsal areas, but the relative distribution of this load is similar in both groups. Ledoux and Hillstrom (2002) investigated vertical force values during gait between neutrally aligned and pes planus groups and found that pes planus feet had significantly more force at the subcallosal area with no difference seen under the other areas. Also, on volleyball, there are few studies, Farzami and Anbarian (2020) investigated the effects of fatigue on plantar pressure distribution in adolescent volleyball players and found a significant difference between the mean pressure and the pressure distribution of the healthy foot and the injured leg in individuals with a history of ankle injury also fatigue cause reduce the balance in adolescent volleyball players without a history of a unilateral ankle injury and reduce the balance in adolescent volleyball players with a history of a unilateral ankle injury. Zegang (2019) investigated the gait analysis of volleyball players and found that The gait features directly bear on the plantar pressure distribution of volleyball players. To effectively reduce the injury risk, the plantar pressure should be distributed more evenly by adjusting the gait features. There are no studies that investigated the relationship between hip strength and plantar pressure distribution according to different foot types.

The primary objective of this study was to investigate hip adductor and abductor torque for dominant and non-dominant legs of volleyball players with different foot arch structures. Our secondary objectives were to determine (1) differences in the distributions of plantar pressure of players of different foot arch structures and (2) the relationship between adductor and abductor hip strength and foot posture. Specifically, we hypothesize that athletes with a prone foot posture index would exhibit lower hip strength, higher plantar pressure distribution on the midfoot area, and lower plantar pressure on the hindfoot area. We, therefore, aimed to compare hip strength and plantar pressure distribution in young volleyball players with different foot postures. Determination of possible differences in these variables according to arch type may provide researchers and practitioners a better understanding of the effects of (i) abnormal plantar pressure, and (ii) hip strength on foot morphology.

METHODS

Participants

This study was conducted at Eskisehir Technical University, Faculty of Sports Sciences, between May 2021 and Agust 2021. A total of 90 volunteer volleyball players were included. The athletes were divided into two groups according to their Foot Posture Indexes (FPI) as follows: Group 1, neutral feet [(n=64, 166.6 ±12.1(cm), 61.3 ± 10.8(kg), 13.6 ± 1.2(year)]; and Group 2, pronated feet [(n=26, 161.8 ± 13,1(cm), 56.6 ± 9.2(kg), 14.1 ± 1.3(year)]. The participants were recruited from four similar-level volleyball clubs in Eskişehir. The participants were excluded if they had a history of lower extremity injuries in the past year, had an ankle and foot surgery, had a neurological or systemic disorder, not be able to understand and follow instructions, or if they were older than 18 years of age. Two of the participants were excluded since they had a history of lower extremity injuries, such as ACL and patellofemoral pain and one of them was excluded since the participant made not six steps but five during the procedure. It was reported that the athletes train 2 to 3 times a week and 2 to 4 hours per day. All subjects were given written information about the procedures of the study and informed consent was obtained by the declaration of Helsinki. The study was approved by the local ethics committee (E-87914409-050.03.04-18773).

Procedures

Assessment of foot posture index

Foot posture during full weight-bearing was assessed using the FPI-6 (Redmond, 2005), which was shown to have acceptable validity (Keenan et al., 2007) and good interrater reliability (Cornwall et al., 2008). The FPI-6 yields a composite score obtained by summing 6 submeasurements: talar head palpation, supra, and infra lateral malleolar curvature, calcaneal frontal plane position in the rearfoot, talonavicular joint prominence, medial longitudinal arch height, and congruence, and forefoot abduction/adduction (Redmond, Crosbie & Ouvrier, 2006). According to the total score and reference values suggested by Redmond (Redmond, 2005), feet were classified as pronated (+6 to +9), neutral (0 to +5) or supinated (−1 to −4). All assessments were made by a physiotherapist.

Measurement of plantar pressure distribution

Plantar distribution data were recorded during the procedure with Pedar®-X (Novel; Munich, Germany) insole which has 99 capacitive sensors. Feet were divided into three groups: forefoot, midfoot, and hindfoot based on a study by Cavanagh et al. (1997). Proper insoles were chosen according to athletes' shoe sizes and before the procedure made sure that the entire plantar surface was fully covered by the insole. Before the assessment, the participants were invited to use the insoles placed in the socks provided by the researchers and walk for familiarization (Cardoso et al, 2021). During the dynamic gait assessment, participants were instructed to walk in 10 meters long straight zone for at least 6 steps at a self-selected speed that would reproduce their daily gait (Sacco et al, 2014; McKay et al., 2017; Cardoso et al, 2021). An advantage of six steps was collected. Contact Area (cm^2), Maximal Force (N), Peak Pressure (kPa), Pressure Time Integral (kPa*s), and Force Time Integral (N*s) data were collected as plantar pressure variables. Data acquisition occurred at 100 Hz and plantar pressure data was processed with Database Pro, v.22.3.43 (Novel; Munich, Germany).

Measurement of hip adductor-abductor muscle strength

Hip adductor/abductor muscle strength isometrically measured via Load Cell (Pwer link sensor-S/N: PS000146B Made in GERMANY). The device was fixed to the wall with the assistance of a steel carabiner. Participants were asked to warm for 5 minutes before measurements. While the participants standing in an anatomical position, 37 cm from the wall and in the side stand as the procedure leg close the wall, the load cell was placed 5 cm proximal to the lateral malleolus of the leg to be measured with a strap, and the participant was asked to pull with maximal strength without turning their trunk and keep their knee tight with 180 degrees angle. For each leg and both adductor/abductor muscles, participants were asked to perform 5 seconds for 3 repeated measurements. There was a 60-second break between each repetition (Kollock et al., 2016). After converting the values in kg to Newtons, the torque value was calculated by multiplying the leg length (m).

Data Collection

In this research, the dependent variables were: Maximal Force (N), Contact Area (cm^2), Peak Pressure (kPa), Pressure Time Integral [PTI (kPa*s)], Force Time Integral FTI (N*s)]. **Maximal Force (N)** is defined as the total force for the left and right insole. **Contact Area (cm^2)** defines the total contact area for the left and right insole. **Peak Pressure (kPa)** defines the maximum pressure that occurred in one sensor element for the displayed frame for the left and right insole. **Pressure Time Integral (kPa)** defines the pressure-time integral value for the selected period for the left and right insole. **Force Time Integral (N*s)** defines the force-time integral value for the selected time for the left and right insole. For each of the aforementioned parameters, the average value of all acquired frames was selected as representative of the whole trial and used for comparisons among both arch groups. The independent variable of the study was the Foot Posture Index groups of athletes.

Statistical Analyses

Descriptive data included the mean and standard error of the mean of the variables used. Before the statistical analysis, the normality of data distributions was assessed with the Shapiro-Wilk test and Kolmogorov-Smirnov test depending on the number of participants for each group. Continuous data for quantitative variables were expressed in mean and standard deviation for normally distributed data and in median (25th-75th percentile) for non-normally distributed data. Independent-Samples t-Test was performed for normally distributed data and Mann Whitney U test was performed for non-normally distributed data according to normality test results. For the correlation analysis, the impact of hip strength on FPI was analyzed using Pearson's correlation coefficient. Confidence intervals were set at 95%. The correlation effect size was interpreted as follows:< 0.1, trivial; 0.11–0.3, low; 0.31–0.5, moderate; 0.51–0.7, large; 071, −0.9, very large;>0.9, almost perfect (Gignac and Szodorai, 2016). SPSS version 23.0 software was used to perform statistical analysis (IBM Inc., Chicago IL). For these measurements, a significance level was set as $p<0.05$.

RESULTS

The demographic characteristics of the participants are shown in **Table 1**. There were no significant differences among the groups in demographic characteristics ($p>0.05$) except for the foot posture index. ($p=0.001$). Comparisons of abductor-adductor strength values between the prone and neutral groups are presented in **Table 2**. The results representing the differences in plantar pressure values between different foot arch structures of the groups are presented in **Figure 1**. The correlation between the Foot Posture Index and Adductor-Abductor hip strength variables is shown in **Table 3**.

Table 1. Demographic characteristics of the participants.

	Neutral Group (n=64)		**Prone Group (n=26)**		
	Mean (SEM)	**Median (25th-75th percentile)**	**Mean (SEM)**	**Median (25th-75th percentile)**	**p**
Foot Posture Index		3 (2,00-4,00)		7 (6,00-7,75)	0,001
Age (year)	13,6 ± 1,2		14,1 ± 1,3		0,117
Weight (kg)	61.3 ± 10,8		56,6 ± 9,2		0,165
Height (cm)	166,6 ± 12,1		161,8 ± 13,1		0,349
Experience (year)	4,8 ± 1,8		4,4 ± 2,0		0,131
Training frequency (week)		3 (2,00-3,00)		3 (2,00-3,00)	0,661
Training duration (h)		3 (3,00-4,00)		3 (3,00-4,00)	0,681

Table 2. Comparisons of ABD-AD strength values between prone and neutral group.

Variables	**Neutral Group Mean (SEM)**	**Prone Group Mean (SEM)**	**F**	**t**	**p**
AD hip strength right leg (N)	91.31 ± 44.47	67.02 ± 31.26	0.89	2.03	0.04*
AD hip strength LEFT leg (N)	88.70 ± 43.03	66.26 ± 30.24	0.47	1.94	0.05*
ABD hip strength right leg (N)	84.80 ± 39.73	62.78 ± 31.64	0.53	2.03	0.04*
ABD hip strength left leg (N)	81.23 ± 43.56	65.59 ± 36.76	0.38	1.30	0.19
Right AD/ABD Ratio	0.95 ± 0.20	0.94 ± 0.25	2.23	0.24	0.80
Left ADD/ABD Ratio	0.92 ± 0.22	0.99 ± 0.30	0.30	-0.99	0.32

SEM: standard error of mean; **N**: Newton **AD**: adductor; **ABD**: abductor.

Results showed that the right adductor and abductor, left adductor strength of the neutral group had significantly higher than the prone group ($p < .05$). Although it was seen a difference in left abductor strength in favor of the neutral group, it was not statistically significant; however, there was no significant difference in the right or left AD/ABD ratio as shown in **Table 3.**

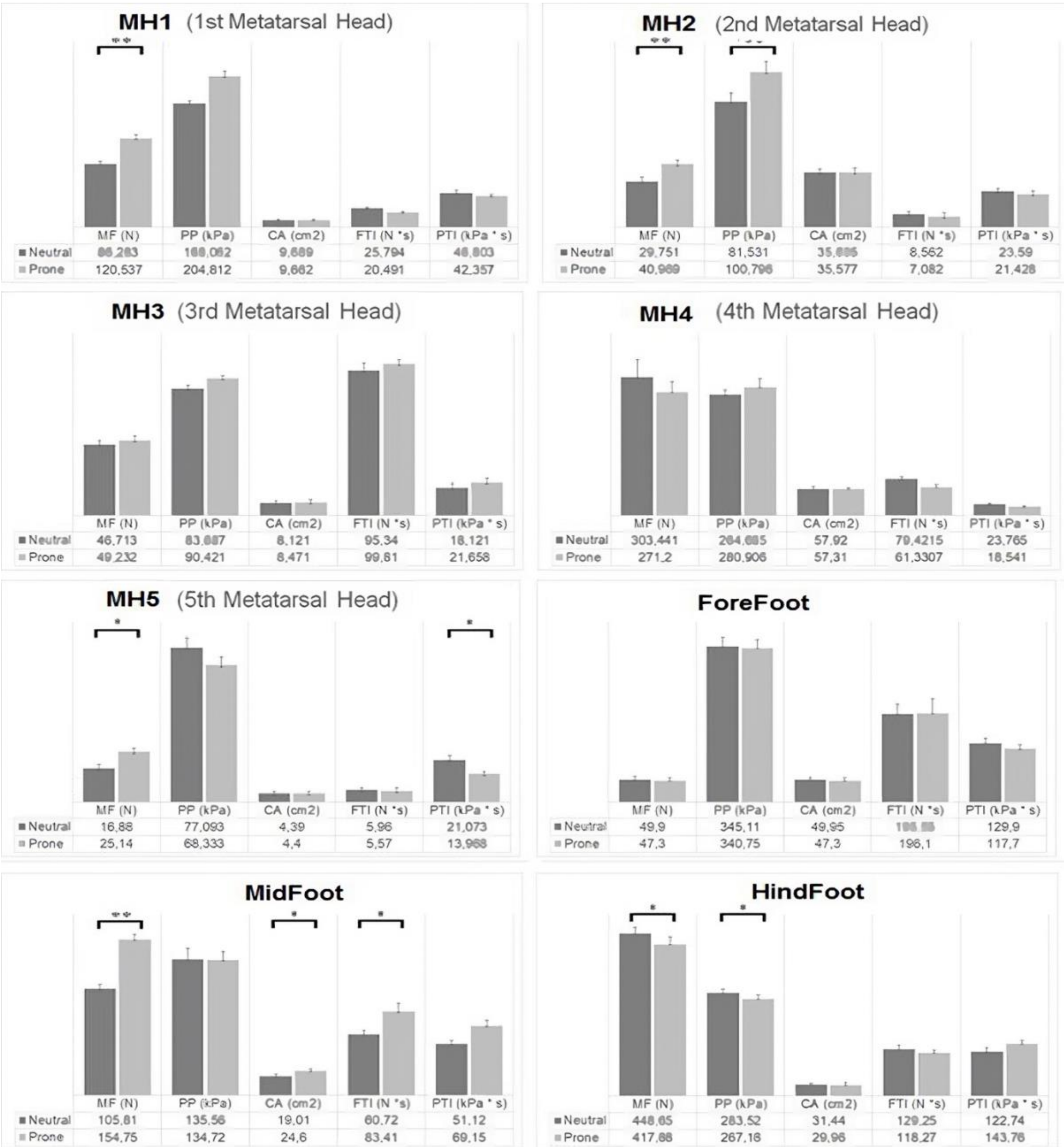
Table 3. Correlation between Foot Posture and AD-ABD hip strength.

		AD hip strength right leg (N)	**AD hip strength left leg (N)**	**ABD hip strength right leg (N)**	**ABD hip strength left leg (N)**	**Foot Posture**
AD hip strength right leg (N)	Pearson Correlation	1	,845**	,767**	,710**	-,570**
	Sig. (2-tailed)		,000	,000	,000	,000
	N	52	52	52	52	52
AD hip strength left leg (N)	Pearson Correlation	,845**	1	,870**	,731**	-,529**
	Sig. (2-tailed)	,000		,000	,000	,000
	N	52	52	52	52	52
ABD hip strength right leg (N)	Pearson Correlation	,767**	,870**	1	,746**	-,471**
	Sig. (2-tailed)	,000	,000		,000	,000
	N	52	52	52	52	52
ABD hip strength left leg (N)	Pearson Correlation	,710**	,731**	,746**	1	-,325*
	Sig. (2-tailed)	,000	,000	,000		,019
	N	52	52	52	52	52
Foot Posture	Pearson Correlation	-,570**	-,529**	-,471**	-,325*	1
	Sig. (2-tailed)	,000	,000	,000	,019	
	N	52	52	52	52	52

AD: Adductor ABD: Abductor; **Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed).

The results between the neutral and prone foot posture group, **Table 3**, found a moderate negative relationship (r = -.570; -,529) between both right and left AD hip strength and foot posture. Finally, when looking at right and left ABD hip strength to foot posture, **Table 3**, a low negative relationship was also found (r = -.471; -375). In sum, these relationships suggested that reduced strength of the hip abductors relative to adductors is associated with increased pronation at the foot.

Figure 1. Comparisons of pressure distribution at different sections of the foot in between prone and neutral group.



The dynamic pedobarographic evaluation revealed that the prone group had higher Maximal Force, Contact Area, and Force Time Integral values at midfoot comparing the neutral group whereas the neutral Group had higher values in Maximal Force, Peak Pressure values at the hindfoot mask ($p<.05$). In addition, the neutral group had also higher Contact Area values comparing prone group but it was not statistically significant ($p>.05$). Prone group showed higher Maximal Force values at 1st, 2nd and 3rd metatarsal head and higher Peak Pressure values at 2nd metatarsal head compared neutraş group whereas neutral group showed higher

Pressure Time Integral values on 5th metatarsal head comparing prone group ($p<.05$) (**Figure 1**).

DISCUSSION

This study aimed to explore the differences in the distributions of plantar pressure in dynamic states and assess the strength profiles in the hip muscle of elite volleyball players according to foot posture index. The findings of this study indicate that the Maximal Force, Contact Area, and Force Time Integral of prone group volleyball players were significantly higher in the midfoot area comparing neutral group volleyball players during walking. The current study shows similar results to several studies. Chuckpaiwong et al. (2008) found higher Force Time Integral and Maximal Force in subjects with a flat foot during the side-cut task and higher Contact Area in the medial midfoot during the cross-cut task. Simsek et al. (2021) found that pes planus have greater Force Time Integral, Maximal Force, Contact Area, and Pressure Time Integraş values than feet with pes cavus and pes rectus. The difference in Pressure Time Integral results may be explained by methodological differences. Burns et al. (2005) found a higher Pressure Time Integral for the medial midfoot in pes planus feet compared to normal feet. A possible cause for the increment in loading in the midfoot of the athletes with prone feet could be due to the foot failing to build a stiff arch hence locking the placement of the forefoot, midfoot, and rearfoot (Queen et al., 2009). The pes planus foot causes excessive stretch on the spring ligament and the tendon of the tibialis posterior to stabilize the foot while maintaining the upright stance and it may lead to greater plantar pressure values on the midfoot (Buldt et al., 2018).

In the current study 1st, 2nd, and 5th metatarsal-phalangeal joints (MTPJ) showed higher maximum force, and higher pick pressure was seen at the 2nd MTPJ in the prone group compared to the neutral group. Results show similarities with a recent study (Hillstrom et al., 2013) which found higher maximum force in the hallux and 2nd toe and lower maximum force in the combined 1st and 2nd MTPJs and the 5th MTP in pes planus feet compared to normal feet. Another variable that is increasingly used in evaluating plantar loading is the Pressure Time Integral. This variable describes the cumulative effect of pressure over time in a certain area of the foot, and thus provides a value for the total load exposure of a foot sole area during one step (Sauseng et al., 1999; Melai et al., 2011). Pressure Time Integral results of this current study indicate that the prone group has a lower Pressure Time Integral comparing the neutral group in the 5th MTPJ. Also, Pressure Time Integral was lowest at 5th and highest at 1st and 2nd MTPJs for prone feet. This finding suggests that greater stress to the 1st and 2nd MTPJ in pes planus feet may place this bone at risk of a stress-related injury such as a stress fracture (Simsek et al., 2021). In hindfoot, neutral group athletes showed greater Maximal Force and Peak Pressure comparing prone group athletes. According to several studies by Buldt et al. (2018), Simsek et al. (2021) pes cavus feet show higher Peak Pressure than pes rectus and pes planus feet. It may explain why prone feet have lower Peak Pressure values comparing normal feet. Similarly, the results of previous studies showed higher Contact Area results on cavus feet comparing pes planus and pes rectus feet. In our study Contact Area, results are lower in the prone group comparing the neutral group but it is not significant. The architecture of the foot plays a major role in directing the magnitude of load from body weight through different pedal structures. The poor gait mechanics that are present in individuals with a prone foot have been shown to increase Contact Area and increase load beneath the medial portion of the foot, which could result in abnormal loading of the adjacent ligaments and tendons and could alter normal joint mechanics (Sneyers et al., 1995; Ledoux et al., 2002). Previous research has suggested that athletes with an abnormal foot structure are at increased risk of injury. Traditionally, the pronated or pes planus foot type has been cited as a risk for injury, A study has shown that pes planus foot may eventually cause mechanical problems at the lower back, hip, and knee joints due to excessive calcaneal extroversion of about 2 to 3 degrees (Valmassy, 1996). Several studies indicate that for rehabilitation and injury prevention special insoles may be used by the prone group. Xu et al. (2019) have found that special 3d insoles are effective for the rehabilitation of flatfoot athletes. A study conducted by Aminian et al (2012) also shows that special insoles may lead to changes in the plantar distribution of flatfoot athletes. Hip muscle strength is another factor that affects foot function, posture, and lower extremity injuries. Hip weakness might have a role in lower extremity malalignment and the etiology of lower extremity overuse injuries such as foot and ankle problems (Nicholas, Strizak, Veras, 1976). More recently, the importance of adequate hip strength has been discussed in many lower extremity injuries (Nadler et al., 2000; Ireland et al., 2003; Leetun et al., 2004) such as anterior cruciate ligament rupture, patellofemoral pain syndrome, and stress fractures in lower-extremity (Leetun, Ireland, Willson, Ballantyne, & Davis, 2004). Indeed, stress fractures, knee pain, and anterior cruciate ligament rupture are the most common types of injury experienced by individuals with a pronated foot. Nicholas et al. (1976) reported a correlation between ankle and foot problems and impaired ipsilateral hip-abductor and hip adductor strength and found a weakness in hip abduction and adduction as compared to the unaffected side. The gluteal muscles (Maximus, medius, and minimus) stabilize the hip. The weakness of hip stabilizers (hip extensors, abductors, and external rotators) causes excess internal rotation of the hip inducing foot pronation (Rathnamala, Senthil, & Kulkarni, 2020). Gluteal muscles stabilize the hip by counteracting gravity's hip adduction torque and maintaining proper leg alignment controlling adduction and internal rotation of the thigh and externally rotating the alignment of the lower extremity, reducing foot pronation (Mulchandani, Warude & Pawar, 2017). Kinematically, dysfunction of hip abductors and external rotators leads to biomechanical positions that are proposed to be associated with foot pronation (Barwick, Smith & Chuter, 2012). Results of our study support those suggestions as it has been found that both right, and left adductor strength and right abductor strength are significantly higher for the neutral group comparing the prone group. However, left abductor strength is also higher for the neutral group comparing the prone group but it is not significant. A highly pronated foot causes the tibia to maintain longer internal rotation than normal, which leads to valgus stress and increased internal rotation in the hips. As a result, iliopsoas muscle stretches and lumbar lordosis increase since the pelvis tilts forward (Tang et al., 2015). Hollman et al. (2006) found that pronated foot structure correlates with a decrease in isometric muscle strength of the Abductor when compared to the hip adductor. Our results show a discrepancy with that suggestion. It was seen a difference in abductor adductor strength ratio on both the left and right hip for the prone group, but it is not significant. It may cause both abductor and adductor strength levels to be significantly lower for the prone group. It is necessary to strengthen hip muscles and improve hip joint stability so that the above-mentioned injuries can be avoided. Strong hip muscles are likely to have a significant effect on the knee and back foot mechanics (Snyder, Earl, Connor, Ebersole, & 2009). Rathnamala Senthil & Kularni (2020) conclude that gluteal and knee muscle strengthening along with intrinsic muscle strengthening exercises is most cost-effective and efficacious in reducing navicular drop, pain, disability, and activity limitation, thus improving foot posture and foot function.

CONCLUSION

We conclude that the prone group has different plantar pressure distribution and lower hip muscle strength comparing the neutral group. Several studies indicate that special insoles lead to changes in plantar pressure distribution and are effective for the rehabilitation of the prone group. It is crucial to strengthen hip muscles to improve foot posture and function. It may be useful for athletes with flatfoot to use special insoles and strengthen hip muscles with hip strengthening exercises.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

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