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Comparison of Functional Movement Screen Scores in Female Athletes with and Without Pronation Distortion Syndrome

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ABSTRACT

Aims: Pronation Distortion Syndrome (PDS) is a standard postural deviation that can lead to various complications. Prevention and reducing the risk of injury are more important than treatment, and a significant part of this issue can be achieved through pre-participation screening. This study aimed to compare the Functional Movement Screening (FMS) scores in female athletes with and without PDS.

Method and Materials: The participants in the present study included female athletes with and without PDS, divided into two groups: PDS (N = 20) and without PDS (N = 20). Pronation Distortion Syndrome was assessed with navicular drop index for flatfoot, flexible ruler for lumbar lordosis, and caliper for Genu valgum, respectively. The FMS kit was used to determine the FMS scores. The independent T-test was used to analyze inferential statistics, and the Mann-Whitney U test was used to analyze non-parametric data. The significance level was considered to be $p < 0.05$.

Findings: This study showed in the PDS group significant differences in deep squat ($P<0.001$), hurdle step ($P=0.007$), in-line lunge ($P=0.027$), active straight leg raise ($P=0.006$), trunk stability push-up ($P=0.011$), and rotary stability ($P=0.005$), indicating that the scores for these items were higher in group without PDS compared. Additionally, the findings suggested no difference in shoulder mobility ($P = 0.277$) between the two groups.

Conclusion: Pronation Distortion Syndrome seems to influence different musculoskeletal parts and functional status, resulting in lower FMS scores among female athletes with PDS. Routine screening and targeted corrective strategies should be implemented to enhance movement quality and decrease injury risk within this group.

Keywords: Pronation Distortion Syndrome, Functional Movement Screen, Female Athletes

Introduction

One of the fundamental needs of humans in daily activities is to have healthy upper and lower limbs [(1)]. Lower limb malalignment may lead to various compensatory patterns [(2)]. Excessive pronation of the ankle joint is the most common deformity observed in individuals prone to injuries [(3)]. During ankle pronation, external rotation of the heel causes the talus bone to slide medially and downward, which induces internal rotation of the tibia and, subsequently, knee valgus [(4, 5)]. This condition can disrupt the natural alignment of bones, the physical characteristics of lower limb joints, neuromuscular control, and the supportive function of surrounding soft tissues [(6)]. Moreover, excessive foot pronation influences sensory. input by modifying joint mobility, altering contact surface area, affecting ligament status, and contributing to ligamentous laxity[(7)]. Pronation Distortion Syndrome (PDS) is one of the most common deformities that can lead to impairments in both distal and proximal segments [(8)]. Individuals with this condition exhibit flat foot deformity, knee valgus, internal hip rotation, and exacerbated lumbar lordosis in severe cases [(9)]. It has been shown that PDS has a prevalence of 35.9% among athletes [(10)]. Moreover, PDS can predispose individuals to Achilles tendon injuries, plantar fasciitis, posterior tibial tendonitis, ankle sprains, patellar tendinopathy, patellofemoral pain syndrome, Anterior Cruciate Ligament (ACL) injuries, and Lower Back Pain (LBP) [(11)]. This deformity also

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involves functional tightening of the peroneal muscle, gastrocnemius muscle, hamstrings, soleus muscle, iliotibial band, hip adductors, and psoas muscle [12] Simultaneously, the posterior and anterior tibialis, gluteus medius, gluteus maximus, vastus medialis, and hip external rotators are inhibited [12]. Additionally, these individuals are at a higher risk of experiencing plantar pain, knee pain, foot injuries, stress fractures, poor athletic performance, and deficits in ankle proprioception and balance [13]. Movement impairments associated with PDS include restricted dorsiflexion in the talocrural joint, weakness in the foot and ankle supinators, intrinsic foot muscles, and external rotators of the hip [14]. With the growing importance of sports across all societal levels, attention to injury prevention has increased significantly [15].

Functional Movement Screen (FMS) is a tool designed to evaluate a series of movements, helping to identify compensatory patterns, functional limitations, and asymmetrical movement patterns [16]. The FMS test series places individuals in challenging positions where weaknesses and imbalances become apparent [16]. A study by Armstrong and Grieg (2018) demonstrated that the FMS is effective in identifying athletes at risk of injury, with an injury threshold score of 11.5 established for both male and female rugby players [17]. In addition, another study demonstrated that the FMS appears to be a reliable method for predicting the likelihood of nonstructural scoliosis [18]. Furthermore, a study investigating the association between the FMS outcome and the incidence of musculoskeletal injuries found that individuals identified as "high risk" according to the FMS assessment have a 51% greater likelihood of sustaining an injury than those categorized as low risk [19]. Also, a review study demonstrated that a reduced FMS score indicates compromised functional movement, and recognizing the movement dysfunctions related to lower back pain can aid in designing tailored treatment strategies and interventions [20].

Although FMS is widely used to evaluate movement patterns and identify potential risks for injury, limited research has explored its application in populations with specific postural deviations such as PDS. Moreover, there is a lack of studies comparing FMS scores between individuals with and without PDS to determine whether the FMS can effectively differentiate between these populations and identify functional limitations unique to those with PDS. Investigating this relationship could provide valuable insights into the diagnostic and preventive capabilities of the FMS in addressing the specific needs of this population. Therefore, this study aims to compare the FMS scores in female athletes with and without PDS.

Method and Material

This study included female athletes with and without PDS, who were selected using convenience sampling and divided into two groups: PDS (n = 20) and without PDS (n = 20). Using G*Power Ver 3.1 software, considering an effect size of 0.59, a significance level of 0.05, and a statistical power of 0.95, the sample size was calculated to be 20 in each group. The inclusion criteria for the study were as follows: being female, having an age range of 15-20 years, being a recreational athlete for at least three years, having painless increased lumbar lordosis, having a flexible flat foot with no symptoms, a navicular drop index exceeding 10 mm as measured by Brody's method [21], and knee valgus determined by the distance between the inner malleoli, where the gap between the malleoli is greater than 4 cm [9]. The exclusion criteria for the study included a history of ankle sprains, a history of surgery in the lower limb, a history of neurological or musculoskeletal disorders, and lower limb pain before or during the tests. At first, for ethical considerations based on the Declaration of Helsinki, all stages of the study were informed to the subjects, and then written informed consent was received. Secondly, individuals were informed that in the event of any issues during the tests, the examiner, a sports science expert pursuing a master's degree in kinesiology, would take all necessary actions. The subjects were instructed on how to perform each test. All steps were explained to the participants.

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Before starting the tests, the procedure was presented to them. Additionally, all measurements were performed three times, and the mean average of each variable was calculated from the study data. This study was approved by the Research Ethics Committee of Allameh Tabataba'i University, Tehran, Iran (Code: IR.ATU.REC.1401.088).

In this study, the measurement of navicular drop was initially performed by identifying the navicular tuberosity. Subsequently, the researcher assessed the height of the navicular bone with the subtalar joint in a neutral position, while the patient bore most of their weight on the contralateral leg. Ultimately, we instruct the patient to distribute their weight evenly on both feet and to pre-measure the height of the navicular. The disparity between the initial and subsequent measurements is the navicular drop. Participants exhibiting an navicular decline of more than 10 mm were classified in the research as having flatfoot [21]. The navicular drop was measured thrice for each individual, and the average of these observations was documented for analysis [22]. Furthermore, to measure genu valgum, the distance between the medial malleoli of the feet was assessed. In this assessment, the person stands barefoot and minimally clothed, allowing clear visibility of the knees and femurs without muscle contraction. The knees should be fully extended, with the patellae facing forward [23]. The distance between the medial malleoli is then measured using a caliper, which has been shown to have excellent validity and reliability [24]. If the distance between the two medial malleolus was more than 4 cm, the subjects were in the genus Valgum group [9].

Moreover, for measuring lumbar lordosis, a flexible ruler was used to calculate the lordosis angle, and the reliability and validity of the flexible ruler were reported to be very good [25]. To locate the T12 vertebra, first, by palpating the iliac crests on both sides, the spinous process of the L4 vertebra was identified. By counting the vertebrae upwards, the T12 vertebra was also located. The last vertebra was S2, where the spinous process was at the same level as the posterior superior iliac spine (PSIS). These spines were found in two lower back dimples [26]. Then, the specified points were marked with an easily erased marker. All measurements were taken in a relaxed standing position. After determining the marked points, the flexible ruler was placed on the spinous process to take the shape of the targeted area, with no space between the ruler and the spine. Then, the marked points on the spine were also transferred to the ruler. In the end, the ruler was carefully removed from the spine and placed on the paper. The curve was then drawn on the paper with a marker, and the targeted points were marked on the drawn curve. The distance between two points (L) and a line perpendicular to L (H) was measured with a ruler, and the resulting numbers were inserted into the formula $q = 4\text{Arc}\tan(2h/L)$ to calculate the lordosis angle [27]. Additionally, an angle exceeding 35 degrees was considered hyperlordosis [28].

The Functional Movement Screen (FMS) kit was utilized to assess FMS scores. The FMS consists of seven movement tests (Fig 1): Deep Squat (DS), Hurdle Step (HS), In-Line Lunge (ILL), Shoulder Mobility (SM), Active Straight Leg Raise (ASLR), Trunk Stability Push-Up (TSPU), and Rotary Stability (RS) [29, 30]. Each movement test is scored on a scale of zero to three, with higher scores indicating better performance. The scoring criteria are as follows: a score of 3 is awarded for a complete and correct movement; a score of 2 indicates compensation during the movement; a score of 1 is given when the movement cannot be completed; and a score of 0 is assigned if pain is experienced during the test [31, 32]. To calculate the total FMS score, the individual scores of all tests are summed. The total score can range from 0, indicating pain in all movement tests, to 21, representing perfect performance across all tests. Studies have reported moderate intra-rater and inter-rater reliability for FMS tests [33, 34]. Additionally, previous studies have demonstrated the FMS's sufficient capability to predict injury [35]. To ensure accurate scoring, the examiner must observe and evaluate the participant from all angles—anterior, posterior, and lateral—during the tests. In the present study, the mean and standard

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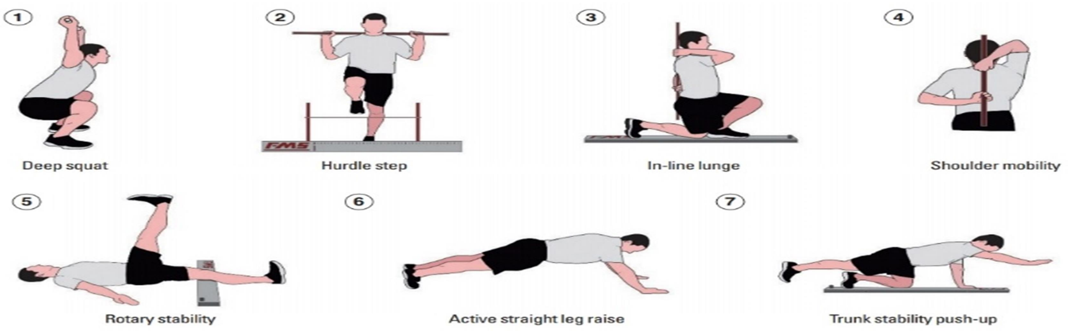

Fig 1) Illustration of FMS movements

deviation of height, weight, and age, as well as the Shapiro-Wilk test, were used. The independent T-test was applied to analyze inferential statistics, and the Mann-Whitney U test was used for non-parametric data.

The Shapiro-Wilk test results indicated that the data distribution in the variables was non-parametric. Therefore, the Mann-Whitney The U-test was used to examine group differences (Table 2).

Table 1) Demographic characteristics of participants of both groups

Data	Group	Mean ± SD	P-value
Age	PDS	17.70±2.12	0.963
	WPDS	18.05±1.95	
Height	PDS	1.69±0.05	0.985
	WPDS	1.73±0.05	
Weight	PDS	66.80±4.62	0.550
	WPDS	70.20±5.42	
BMI	PDS	23.11±0.64	0.991
	WPDS	23.21±0.72	

PDS Pronation Distortion Syndrome, WPDS without Pronation Distortion Syndrome

Table 2) The Mann–Whitney U test results for comparison of PDS and WPDS

Variable	Group	Mean Rank	Z	Mann-Whitney U	P-value
DS	PDS	14.08	-3.768	71.50	≤0.001*
	WPDS	26.93			
HS	PDS	15.85	-2.688	107.00	0.007*
	WPDS	25.15			
ILL	PDS	16.75	-2.209	125.00	0.027*
	WPDS	24.25			
SM	PDS	18.75	-1.088	165.00	0.277
	WPDS	22.25			
ASLR	PDS	15.70	-2.771	104.00	0.006*
	WPDS	25.30			
TSPU	PDS	16.15	-2.540	113.00	0.011*
	WPDS	24.85			
RS	PDS	15.60	-2.824	102.00	0.005*
	WPDS	25.40			

PDS Pronation Distortion Syndrome, WPDS without Pronation Distortion Syndrome, DS Deep Squat, HS Hurdle Step, ILL In-Line Lunge, SM Shoulder Mobility, ASLR Active Straight Leg Raise, TSPU Trunk Stability Push-Up, and RS Rotary Stability

Findings

Table 1 displays the demographic characteristics of participants in both groups.

The results in Table 2 showed significant differences in DS (P < 0.001), HS (P = 0.007), ILL (P = 0.027), ASLR (P = 0.006), TSPU (P = 0.011), and RS (P = 0.005), indicating that the scores for these items were higher in WPDS compared to PDS. Additionally, the findings suggested no difference in SM (P = 0.277) between the two groups.

Discussion

This study found that WPDS female athletes demonstrated higher FMS scores than those with PDS. From an injury prevention perspective, the observed differences in FMS scores underline the importance of early screening and targeted interventions for athletes with PDS. The FMS has been validated to show reduced movement and predict injury risk [36]. Regarding this matter, a study comparing the scores of FMS tests between individuals with chronic ankle instability and healthy controls showed significant differences between the two groups in the scores of the hurdle step, lunge, and rotary stability tests [37]. Another study investigating the FMS scores of physically active women with and without hypermobility revealed that the FMS scores were lower in women with hypermobility compared to their healthy counterparts [38]. Moreover, a study examining the FMS scores of adolescent male football players with and without knee deformities revealed significant differences between the groups with valgus deformity, varus deformity, and no deformity [39]. Furthermore, a study comparing the scores of the FMS in individuals with LBP versus healthy individuals found that a decreased FMS score is linked to dysfunctional movement patterns and a higher risk of injury in individuals with LBP [20]. It can be interpreted that the reduced scores can be attributed to the involvement of upper or lower limb movements in FMS tasks. Many individuals with LBP struggle to effectively engage specific muscles, mainly those responsible for trunk stability, and frequently exhibit restricted hip joint mobility [40]. This limitation is often reflected in lower scores on movements such as the deep squat, hurdle step, active straight leg raise, and rotary stability tests. Additionally, Izadi et al. (2023) found a moderate to potent negative relationship between the total FMS test score and certain upper body postural abnormalities in their investigation of the correlation between the FMS test and stature abnormalities in military personnel [41]. This suggests that structural and postural issues in the upper body may influence FMS test performance. Our results were consistent with the mentioned studies ($0,41). In contrast, two studies examining the differences in FMS scores between individuals with and without ACL reconstruction [42] and those with patellofemoral pain [43] found no significant differences in FMS scores between the two groups. The possible mechanism underlying this discrepancy could be attributed to the fact that the study population in the present study consisted of individuals with PDS. In contrast, the populations examined in the mentioned studies differed from ours. The ankle joint is one of the key joints in the human body, particularly vulnerable to injury due to its position and the physical stresses it endures in sports that involve landing movements. Such injuries can lead to various complications, including early degeneration of joint surfaces, multi-planar joint instability, and ultimately reduced ankle functionality in daily activities. According to the findings, PDS appears to be a significant factor influencing the performance of various body segments, ultimately resulting in impaired balance and lower FMS scores among female athletes with PDS. There are several limitations to the present study. First, while clinical assessments were used to identify PDS, the absence of advanced imaging or motion analysis technologies may have limited the accuracy and depth of the diagnosis. Second, potential confounding factors such as variations in training history, physical activity levels, and psychological aspects were not controlled, which could have influenced FMS scores. Lastly, this study focused exclusively on female adolescents, and the results may not directly apply to other age groups or male populations. Future

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research should consider employing longitudinal designs, collecting more extensive and diverse samples, and utilizing advanced diagnostic methods to better understand the relationship between PDS and functional movement performance.

Conclusion

Pronation Distortion Syndrome seems to influence different musculoskeletal parts and functional status, resulting in lower FMS scores among female athletes with PDS. Routine screening and targeted corrective strategies should be implemented to enhance movement quality and decrease injury risk within this group.

Authors' Contribution: All authors contributed to the conceptualization, methodology, project administration, resources, and formal analysis. All authors helped in the investigation. All authors contributed to data curation. All authors approved the final version of the manuscript.

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