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Foot posture and landing error scores in recreational basketball players: a novel approach to prevent lower-limb injuries

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Abstract

Background and Study Aim: Foot posture is an important determinant of a basketball player's performance. It influences their ability to generate power, maintain balance, and absorb shock. The aim of the current study was therefore to examine the association between foot posture and landing error score in recreational basketball players.

Material and Methods: A cross-sectional study design was adopted. Fifty recreational basketball players from selected basketball clubs were chosen for the study. Their Foot Posture Index (FPI) and Landing Error Score System (LESS) were assessed. Nonparametric statistics, such as chi-square tests and the Mann-Whitney U test, were employed to examine the relationship between selected demographic variables and FPI and LESS scores. Additionally, assessed the difference in foot posture between the dominant and non-dominant legs. p-value less than 0.05 was considered significant.

Results: Most participants exhibited normal foot posture, with no significant differences between the dominant and non-dominant legs, as assessed by FPI ($p < 0.05$). Additionally, an association was found between FPI and LESS scores, with 44% of participants showing a propensity for landing errors. The analysis revealed that a notable number of participants were categorized as 'poor' in LESS even with normal foot posture. This implies that landing errors are not only influenced by foot posture.

Conclusions: There is an association between foot posture and the occurrence of landing errors in basketball players. This study emphasizes the need to thoroughly examine basketball players' FPI. It also underscores the importance of developing strategies aimed at helping them maintain optimal foot posture. These strategies can assist in avoiding landing errors, reducing the risk of injury, and promoting good health and well-being.

Keywords: foot morphology, landing mechanics, basketball, injury prevention, health risks, wellbeing.

Introduction

Basketball is a contact sport with complex movements that include jumping, landing, and changing directions, which cause frequent musculoskeletal injuries in all body regions [1]. It has one of the highest injury rates among team sports, with 7 to 10 injuries per 1000 athletic exposures being documented. Basketball injuries to the trunk, head, and upper extremities are common; however, evidence indicates that the lower extremities are also prone to most injuries. (58–66%) [2, 3]. Specifically, ankles were injured most often (32.3%), leading to sprains (35.5%) in recreational basketball players [4]. The possible reason could be as the game uses a variety of techniques, such as repeated gestures, quick acceleration and deceleration, lateral movements, and repeated hops [5]. These movements sometimes require strong acceleration, force, explosiveness, and agility. In addition to these sport-specific functional movements, foot posture influences healthy individuals' dynamic balance

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[6]. Foot posture has been identified as a factor that may contribute to altered jump landing mechanics, which can increase the risk of lower limb injuries in athletes. Recent studies on the relationship between foot position and lower extremity injuries concluded that both pronated and supinated foot varieties are strongly associated with lower extremity injuries [7, 8]. According to a comprehensive review and meta-analysis of prospective studies on static foot posture, pronated foot posture was a risk factor for the emergence of both medial tibial stress syndrome and patellofemoral pain [9, 10]. Specifically, athletes have had more severe ankle sprains and knee injuries when jumping on one leg [11]. Besides, landing after a jump or stepping on another player's foot might also result in ankle injuries [12, 13].

Jumping is one of the most common activities performed by basketball players during a game and is used in many moves in basketball, from rebounding, defending, jump shooting, blocking, to interception and offensive play [14]. A previous study examined the physiological stress of basketball players during competitive games and reported an average of 46 jumps per player, performing 105 high-intensity running efforts (sprints) every 21 seconds and performing an average of 1000 movement pattern changes (one every 2.0 seconds) with 31% and 10% of movements consist of lateral shuffles and sprints [15]. Moreover, individuals with flatfoot have inadequate control over their foot movements in the ankle and foot complex, which can affect their ability to jump [16, 17]. When confronted with an activity that involves a rapid impact force, such as a vertical jump, those with flat-arched feet may have less ability to self-regulate, which will increase the risk of injuries [17]. An earlier study also reported that athletes with a pronated foot posture had a greater tendency to land with a knee valgus angle, which is associated with increased risk of anterior cruciate ligament (ACL) injuries [18, 19]. Thus, ACL tears, ankle sprains, and patellar tendinopathy are among the lower extremity problems faced by basketball players who exhibit poor landing mechanics, such as increased knee valgus, decreased hip and knee flexion, and greater foot pronation [20, 21]. Measuring landing mechanics in basketball players is crucial for injury prevention, performance improvement, movement efficiency, rehabilitation, and injury risk screening [22]. One of the systems most commonly used by physical therapists to measure landing mechanics is the Landing Error Scoring System (LESS), a low-cost clinical evaluation tool that uses two common video cameras to detect potentially dangerous movement patterns (or "errors") during a jump landing manoeuvre [23, 24]. The overall LESS score demonstrated good-to-excellent intrarater intraclass correlation coefficient [ICC], 0.82-0.99), interrater (ICC, 0.83-0.92), and intersession reliability (ICC, 0.81). The validity of the LESS total score against three-dimensional jump landing biomechanics was good when subjects were divided into 4 quartiles based on the LESS scores [25].

Despite basketball players use the correct jump landing maneuver, there are other important factors that contribute to landing errors i.e., foot morphology plays an important role in an athlete's performance, particularly in activities that involve landing, jumping, and cutting movements [26]. The structure and shape of an athlete's foot can affect its ability to generate power, maintain balance, and absorb shock. Additionally, research suggests that certain foot types may be more prone to landing errors, which can increase the risk of lower extremity injuries [10]. The multisegmented nature of foot posture in all three planes is evaluated by the Foot Posture Index (FPI), which does not require any specialized equipment to measure and has been shown to have good construct validity and reliability [27, 28].

Therefore, understanding the relationship between foot morphology and landing error scores can be helpful for coaches, trainers, and physiotherapists to identify athletes who may be at higher health risk of injury and take appropriate action to improve health and well-being of both professional and recreational basketball players. Even though, several studies investigated foot posture as a risk factor for lower limb injuries [10, 27, 29]; no research has investigated the relation between FPI and LESS in recreational basketball players.

Purpose of the Study. The purpose of this study was to examine the association between FPI and LESS in recreational basketball players.

Materials and Methods

Participants

All recreational basketball players belonging to INTI Basketball Club of INTI International University (Nilai, Malaysia), and UCSI Basketball Club of UCSI University (Kuala Lumpur, Malaysia), were included as the population for this study. Eligibility criteria were applied during the selection process, and all eligible subjects were invited to participate.

The required sample size was calculated assuming 90% power, a 0.5 effect size using a chi-square test, a significance level of 0.05, and a degree of freedom of (n-1) based on the number of categories in the outcome variables. Therefore, a minimum of 43 samples were needed for the study. Eventually, fifty samples (n=50) were recruited, considering a 10% drop rate. Subjects were selected based on the following inclusion criteria:

- only male subjects in the age range of 18 to 25;
- those who actively played basketball at least twice a week;

- non-competitive players.

Participants were excluded if they had current injuries and/or musculoskeletal pain that restricted their ability to complete the assessment, participated in sports other than basketball, or had previous hip, knee, or ankle surgery."

Research Design

A cross-sectional study design was adopted to examine the association between FPI and Landing Error in recreational basketball players.

Description of Measurement Procedures

Foot Posture Index

The Foot Posture Index (FPI-6) is an outcome measure commonly used to assess variations in foot posture and has excellent internal validity and lends itself to a range of clinical assessments [28]. The FPI-6 score can categorize foot postures as severely pronated, pronated, normal, supinated, and severely supinated. The six assessment components of the FPI, (A) palpation of the talar head, (B) supra- and inframalleolar curvature, (C) talonavicular prominence, (D) calcaneal frontal plane position, (E) abduction or adduction forefoot on the hindfoot, and (F) medial longitudinal arch congruence was evaluated. The scoring for each criterion followed a scale of 2, 1, 0, +1 or +2. Scores were added for each criterion. A score of 5 to 12 was designated as a severely supinated foot, 1 to 4 as a supinated foot, 0 to +5 as a normal foot, +6 to +9 as a pronated foot, and +10 to +12 as a highly pronated foot [30]. Data to measure foot type and its groupings are collected using the FPI scoring sheet proposed by [31].

Landing Error Scoring System

The Landing Error Scoring System (LESS) is a clinical assessment of jump landing mechanics and can be used to identify individuals at increased risk for lower extremity injuries [32]. The LESS has 17 scored items to evaluate landing from both sagittal and frontal views. The LESS score is a count of failures on a number of easily observable elements of the jump landing movement [33]. A higher LESS score indicates more errors and therefore poorer jump landing technique. Based on the previous research, participants were grouped into four categories based on their LESS scores: excellent (LESS score, 4), good (LESS score, 4-5), moderate (LESS score, 5-6), and poor (LESS score, >6) [24] and a scoring rubric has been used to record landing errors observed on the participants.

Testing Procedure

Demographics, height in centimeters (cm), weight in kilograms (kg), lower limb dominance, years of experience, and gaming frequency were recorded for each participant prior to the initial assessment. Visual demonstrations of the proper technique to conduct the assessment were provided.

FPI-06 Procedure

Each participant's foot position was assessed using the FPI-06. The subjects stood in a relaxed stance with double leg support and arms at their sides. They were instructed to stand barefoot with no shoes or socks and look straight ahead for about 2 minutes. In this position, the individual foot was divided into dominant and non-dominant and assessed by palpation and imaging of the foot from anterior, posterior, medial, and lateral views. All FPI values were evaluated by the same examiner to minimize measurement error as the FPI showed good interrater reliability (ICC = 0.890.96) [30].

LESS Procedure

The LESS testing protocol was adopted from previous studies [25]. The participant began the task standing on a 30-cm-high box placed at a distance of half the body height away from a landing area, marked by a line on the floor. Participants were instructed to jump forward so both limbs left the box at the same time, to land just past the line, and jump to maximum height immediately after landing. Verbal explanation and visual demonstration were provided to each participant before the testing. Participants were allowed to practice trials until they were familiar with the procedure. Each participant performed three jumps, and the average was taken for analysis using the LESS. The trial was recorded from frontal and sagittal view with two digital video cameras placed 10 ft (3 m) in front of and to the right of the participants at a height of 0.84 m above the ground on a commercially available tripod to take frontal pictures and sagittal images of all jump landing trails. Each LESS trial was analyzed using the scoring criteria [24]. Based on their LESS score, participants were individually divided into the following groups: excellent (LESS score, <4), good (LESS score, 4-5), moderate (LESS score, 5-6) and poor (LESS score, >6) jump landing mechanics. LESS grading data was analyzed using Kinovea software version 0.8.15, which is a valid, accurate, and reliable (both inter- and intra-rater) program to obtain data on angles and distance from coordinates [34]. The recorded videos were put into slow motion and all movements were converted into angles using the software's virtual goniometer.

Statistical Analysis

The collected data was then analyzed using Statistical Package for Social Sciences (SPSS) version 27.0. A descriptive analysis of the demographic data was performed to present all categorical variables by frequency and percentage. The foot posture and landing error observed in the samples were analysed using the mean and standard deviation for the FPI and LESS scores. Further analysis was made to examine the relationship between selected demographic variables and FPI and LESS scores using chi-square statistics. A Mann-Whitney U

test was used to examine the difference in foot posture observed between the dominant and non-dominant legs. In addition, the chi-square statistic was applied to examine the association between foot posture index and landing error in both the dominant and non-dominant legs of the subjects. All statistical analyses were performed at the 5% level of significance.

Results

Table 1 illustrates the demographics of the participants. Most of the participants are between 18 and 23 years old and 72% of them have a normal BMI. 74% of them have been playing basketball for more than two years and 52% of them play basketball 3 to 4 times a week. 70% of the participants made it a habit to regularly warm up before playing.

Table 2 shows the FPI of both the dominant and non-dominant legs of the participants. In the dominant leg, the mean (SD) was 1.98 (1.11), while the mean (SD) in the nondominant leg was 2.14 (1.12). However, analysis of the Mann-Whitney U test shows no significant differences between the dominant and non-dominant legs (P=0.455). Most participants have normal foot posture for both dominant and non-dominant legs, as shown in Table 2.

Table 3 reveals the landing error system score (LESS) among the basketball players. The mean (SD) of LESS was 5.80 (2.52). High number of

Table 1. Demographic characteristics of the participants

Demographic Variables	Categories	Frequency	Percentage	Mean± SD
Age	18-20	23	46.0	20.48 ± 1.89
	21-23	20	40.0	
	24-25	7	14.0	
BMI	Underweight	7	14.0	21.95 ± 2.87
	Normal	36	72.0	
	Overweight	7	14.0	
	Obese	0	0.0	
Years of experience	< 1 year	8	16.0	3.44 ± 1.07
	1 year-2 years	5	10.0	
	>2 years	37	74.0	
Playing Frequency per month	Every Day	9	18	2.28± 1.01
	2-3 times a week	26	52	
	Once weekly	10	20	
	Once in two weeks	2	4	
	Once in a month	3	6	
Rest Days per week	1 day	16	32	1.86±0.70
	2-4 days	25	50	
	More than 4 days	9	18	
Warm-ups	Yes	35	70	NA*
	No	15	30	
Cool-downs	Yes	25	50	NA*
	No	25	50	

*Not applicable, SD-Standard deviation, BMI- Body Mass Index

Table 2. FPI among recreational basketball players

FPI	Dominant leg (n=50)		Non-dominant leg (n=50)		p-value
	Frequency (%)	Mean ± SD	Frequency (%)	Mean ± SD	
Normal	22 (44)	1.98 ± 1.11	19 (38)	2.14 ± 1.12	0.455
Pronated	14 (28)		13 (26)		
Highly Pronated	7 (14)		10 (20)		
Supinated	7 (14)		8 (16)		

SD-Standard deviation, FPI - Foot Posture Index

Table 3. LESS in recreational basketball players

LESS	Frequency (%) (n=50)	Mean ± SD
Excellent	13 (26)	5.80 ± 2.52
Good	9 (18)	
Moderate	6 (12)	
Poor	22 (44)	

LESS- Landing error score system

Table 4. Association between the demographic variables and Foot Posture adopted by the participants.

Variables	Categories	FPI Non-Dominant Leg				FPI -Dominant Leg			
		Normal	Pronated	Highly Pronated	Supinated	Normal	Pronated	Highly Pronated	Supinated
Age	18-20	7	7	7	2	9	8	4	2
	21-23	8	5	3	4	8	5	3	4
	24-25	4	1	0	2	5	1	0	1
	P-value	p=0.614				p=0.406			
BMI	Underweight	2	2	2	1	2	3	1	1
	Normal	15	9	8	4	18	9	6	3
	Overweight	2	2	0	3	2	2	0	3
	Obese	0	0	0	0	0	0	0	0
	P-value	p=0.428				p=0.248			
Playing basketball (In Years)	< 1 year	7	0	0	1	8	0	0	0
	1 year-2 years	1	3	1	0	1	3	1	0
	>2 years	11	10	9	7	13	11	6	7
	P-value	p=0.132				p=0.092			
Playing Frequency per month	Every Day	2	2	4	1	2	3	3	1
	2-3 times a week	12	6	2	6	14	6	1	5
	Once weekly	4	4	2	0	5	3	2	0
	Once in two weeks	0	1	1	0	0	1	1	0
	Once in a month	1	0	1	1	1	1	0	1
	P-value	p=0.355				p=0.356			
Rest Days per week	1 day	4	4	5	3	4	5	4	3
	2-4 days	11	6	4	4	14	6	2	3
	More than 4 days	4	3	1	1	4	3	1	1
	P-value	p=0.802				p=0.558			
Warm-up	No	5	3	4	3	5	4	3	3
	Yes	14	10	6	5	17	10	4	4
	P-value	p=0.775				p=0.644			
Cool down	No	8	5	6	6	9	6	5	5
	Yes	11	8	4	2	13	8	2	2
	P-value	p=0.312				p=0.310			

*p>0.05

Table 5. Association between the demographic variables and Landing Error committed by the participants.

Variables	Categories	Landing Error Scoring System (LESS)				P-value *
		Excellent	Good	Moderate	Poor	
Age	18-20	5	3	3	12	p=0.52
	21-23	7	4	1	8	
	24-25	1	2	2	2	
BMI	Underweight	1	1	1	4	p=0.95
	Normal	10	6	4	16	
	Overweight	2	2	1	2	
	Obese	0	0	0	0	
Playing basketball	< 1 year	3	2	2	1	p=0.45
	1 year-2 years	0	1	1	3	
	>2 years	10	6	3	18	
Playing Frequency per month	Every Day	5	1	1	2	p=0.18
	2-3 times a week	5	4	4	13	
	Once weekly	2	2	0	6	
	Once in two weeks	0	0	1	1	
	Once in a month	1	2	0	0	
Rest days per week	1 day	3	4	4	5	p=0.15
	2-4 days	9	4	2	10	
	More than 4 days	1	1	0	7	
Warm-up	No	5	3	2	5	p=0.78
	Yes	8	6	4	17	
Cool-down	No	5	5	3	12	p=0.81
	Yes	8	4	3	10	

*p>0.05

participants falls under poor landing score (44%) as seen in Table 3.

Table 4 and 5 show the association between the demographic variables and Foot Posture adopted by the participants and the landing error they made. According to the findings, there is no association between demographic variables and foot posture and landing errors committed by recreational basketball players (p>0.05).

Table 6 demonstrates the association between the foot posture index and the landing error scoring system based on the rating criteria of each outcome measure. The findings show a significant association between the foot posture index and the LESS score (p< 0.05). Most participants (44%) have a poor LESS score, even with a normal Foot Posture Index score. Comparing FPI dominant and non-dominant leg associations with LESS, both legs show a significant association (p<0.05).

Discussion

Several studies have indicated that excessive pronation and supination is linked to a number of lower extremity problems, including stress fractures, plantar fasciitis, medial tibial stress syndrome, and other related disorders [10, 35, 36, 37]. Additionally, according to another study, pronated and supinated foot postures impair postural stability and proprioception, which can impact landing performance and overall quality of athletic performance [38]. Therefore, the authors conducted this study with the aim of investigating the association between FPI and LESS in amateur basketball players. According to the results of the current study, the majority of the participants had a normal foot posture in both their dominant (44%) and non-dominant (38%) foot, while 28% of them had a pronated foot posture in their dominant foot and 26% of them had a pronated foot in their non dominant foot. Consistent with our findings, a previous study also found that the majority of amateur basketball players were classified as normal or pronated according to the FPI (mean score = 2.31) [39]. Research findings indicate that individuals engaged in basketball activities who exhibit a pronated or supinated foot position have demonstrated a heightened susceptibility to various injuries, including sprained ankles, patellar tendinopathy, and overuse injuries [39, 40]. Due to the sport's nature, basketball players tend to move

Table 6. Association between Foot Posture and Landing Error committed by the participants.

FPI Score	FPI Categories	LESS score					
		Excellent n (%)	Good n (%)	Moderate n (%)	Poor n (%)	Total	P-value
FPI Non-Dominant Leg	Normal	9 (18.0)	3 (6.0)	1 (2.0)	6 (12.0)	19 (38.0)	0.020*
	Pronated	2 (4.0)	2 (4.0)	0	9 (18.0)	13 (26.0)	
	Highly pronated	1 (2.0)	1 (2.0)	2 (4.0)	6 (12.0)	10 (20.0)	
	Supinated	1 (2.0)	3 (6.0)	3 (6.0)	1 (2.0)	8 (16.0)	
	Total	13 (26.0)	9 (18.0)	6 (12.0)	22 (44.0)	50 (100)	
FPI Dominant Leg	Normal	9 (18.0)	4 (8.0)	2 (4.0)	7 (14.0)	22 (44.0)	0.049*
	Pronated	2 (4.0)	2 (4.0)	0	10 (20.0)	14 (28.0)	
	Highly pronated	1 (2.0)	0	2 (4.0)	4 (8.0)	7 (14.0)	
	Supinated	1 (2.0)	3 (6.0)	2 (4.0)	1 (2.0)	7 (14.0)	
	Total	13 (26.0)	9 (18.0)	6 (12.0)	22 (44.0)	50 (100)	

*$p<0.05$

towards the pronated foot, which requires more vertical jumps, resulting in more traction on take-off and landing and placing the medial plantar musculature in stress, causing the foot's bone structure to move towards pronation [41]. Therefore, with an emphasis on foot posture, effective exercise interventions and appropriate shoes to support the abnormal foot posture (pronation or supination) can be considered to improve performance and prevent the risk of injury among players.

Our study found that a considerable number of players had a poor LESS (44%) with a mean (SD) of 5.80 (2.52). Jump landings are an important part of the sport of basketball, and on average each player makes 70 jumps per game, each of which can cause an impact of up to nine times their body weight [11, 42]. This repeated impact with poor landing would inevitably lead to excessive load and stress on the lower extremities, leading to further injury and reduced performance in the players [42]. This is worrying as a previous study found that landing-related ankle injuries accounted for more than half (45%) of all cases [43]. Furthermore, in jump landing, landing on another person's foot causes 50% of acute knee injuries, while sub-optimal landing causes the remaining 50% [11]. An injury prevention approach with proper landing technique could potentially identify athletes who are more likely to sustain injuries and allow corrective movement techniques to be implemented by identifying altered landing strategies [11, 42].

Significant associations were found between LESS and FPI in both dominant and non-dominant legs. The analysis revealed that a notable number of participants were categorised as 'poor' in LESS even with normal foot posture, which implies that landing errors are not only influenced by foot posture. Similarly, an earlier study also found that foot posture had no impact on landing pattern [44]. In addition to foot posture, other factors such as age, gender, previous injuries, and exposure to neuromuscular training programs may also affect LESS scores [45]. However, our results show no association between the demographic variables, including age and foot posture and landing errors, of the participating recreational basketball players ($p>0.05$), and more studies are needed to investigate this.

Furthermore, based on the results, the authors have proposed some strategies to help sports coaches and physical therapists emphasize proper foot posture of athletes during jumps and landings, especially during basketball games, to avoid landing errors and reduce subsequent lower extremity injuries. Those strategies include:

(i) *Strengthen Foot and Ankle Muscles*: Strong foot and ankle muscles provide stability and support during movement for a healthy lifestyle. It is recommended to incorporate exercises that target the intrinsic muscles of the feet, such as toe curls, toe spreads, and calf raises on unstable surfaces like balance boards or foam pads [46, 47].

(ii) *Emphasize and reeducate Neutral Foot Posture*:

While pronation and supination are often discussed, it is important to note that a neutral foot posture, where the arch of the foot is neither too high or too low, is generally considered ideal for efficient force transmission and shock absorption [19]. Athletes with a neutral foot posture may be less prone to landing errors than those with excessive pronation or supination [48].

(iii) *Need to include Injury Risk Screening during pre-participation stage*: Landing mechanics monitoring can be used as part of pre-competition screening to identify athletes who may be at higher risk for lower extremity injuries [49]. By evaluating landing patterns, sports trainers and physiotherapists can implement targeted injury prevention programs such as strength and conditioning exercises or neuromuscular training for individuals with poor landing mechanics.

This study has few limitations and needs to be considered in future studies. First, foot-related variables such as measurement of the medial longitudinal arch and rotational deformities of the lower limbs were excluded. Future studies are expected to include the above variables, as well as knee-related factors such as Q-angle and tibia torsion to allow accurate analysis of landing error. The development of an effective strength and conditioning program or therapy to adequately prepare athletes for the physical demands of their sport would be highly advantageous for coaches and sports therapists. Given that the present study mostly examined recreational basketball players, it is recommended that future investigations concentrate on the analysis of foot posture and landing errors specifically in professional basketball players.

Conclusions

The study findings conclude that there is an association between foot posture and LESS among the recreational basketball players. The majority of basketball players had normal foot to pronated foot posture in both the dominant and non-dominant foot and a significant number of the participating basketball players are categorized under the "poor' category in LESS. Still, there is no association between the demographic variables, including age and foot posture, and landing errors. The study findings shed light on adopting appropriate foot posture to avoid landing errors so as to improve the quality of sports performance and reduce factors related to musculoskeletal injuries. The reported results would be useful to assist coaches and sports physiotherapists in developing posture correction exercise programs aimed at maintaining ideal foot posture and thereby minimizing landing errors in basketball sport, which would help players reduce the biomechanical health risk of lower extremity injuries, and achieve balanced athletic health and well-being.

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Conflict of interest

The authors declare no conflict of interest.

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