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Foot Posture Index and Plantar Pressure Distribution in Junior Badminton Players in Bangalore

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Abstract

Context: The foot is a strong and complex structure which bears weight and allows locomotion. It is divided into the hindfoot, the midfoot, and the forefoot. The plantar fascia is a dense band of connective tissue that is essential for normal foot function. It helps preserve the integrity of the foot's longitudinal arch, provides support during weight-bearing activities, assists in the distribution of mechanical loads, and contributes to efficient gait by enhancing foot stability and movement.
Objectives: The objective of this study was to assess the foot posture index and plantar pressure distribution among junior badminton players.
Materials and Methods: Forty junior badminton players between 9 to 12 years from Bangalore were recruited with purposive sampling in the study. They were evaluated with Harris mat and foot posture index for plantar pressure distribution.
Results: Plantar pressure distributions were seen with Grade 3 in 55% on rear foot and Grade 3 in 52% in fore foot. The left foot FPI-6 assessment indicated that 37[H1.1][NM1.2] (92.5%) of the 40 participants had a normal foot posture, while 3 (7.5%) exhibited pronation.
Conclusion: Most junior badminton players exhibited normal foot posture on FPI-6, while Harris Mat assessment demonstrated Grade 3 as the predominant plantar pressure distribution pattern in the forefoot and rearfoot. These findings highlight the importance of assessing both static foot posture and plantar pressure distribution to facilitate early identification of biomechanical variations in junior badminton players.

Key words: harris mat, foot posture index, plantar pressure

Introduction

Foot is a strong and complex structure which bears weight and allows locomotion.[1] It is divided into the hindfoot, the midfoot, and the forefoot. The plantar aponeurosis constitutes a critical anatomical structure that serves significant biomechanical functions during gait.[1] The plantar aponeurosis is a complex and important connective tissue. It has various functions in biomechanics for gait.[2] It facilitates transmission of force between foot and ground, helps in balancing weightbearing distribution on foot. It ends up to support transverse and longitudinal arch thus cushioning ground reaction force, and preventing the foot from injury.[2] Badminton had attracted huge amount of involvement when it was launched to the Barcelona Summer Games in 1992. There are about 200 million individuals practicing badminton around the globe. Long-term badminton playing causes a variety of physiological acclimatization and alterations to the motor system of the body. Physiological acclimatization is a type of feature for phenotypic characteristics of organisms which

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states acclimatizing to the selection which are required in accordance with the surroundings.[3] In accordance with the characteristics of sports, physiological acclimatization and alterations can be temporary or longstanding, which specify acclimatized alterations on all body types require complicated efforts. Previous researches exhibited that various foot shapes can show various foot purpose. Even if it presents the same physical characteristics, human feet have various structures and physio mechanical characteristics. Players with various mankind and athlete levels have varied plantar pressures and foot structures. When professional players finish their matches, the stress is gathered in their tendo calcaneus and patellar tendon.[4] Elevated plantar pressure can cause sports injury to lower limbs. Sports help in the development of physical and mental well-being of the body. The injuries in badminton players are most commonly sprains, strains and tendinopathies. In junior badminton players, who are still developing, abnormal foot posture can affect the way forces are absorbed in foot and transferred during fast-paced movements like lunges, sprints, and sudden direction changes.[10]

Foot Pressure Index evaluates the three body planes and provides information on the hindfoot, midfoot and forefoot.[5] The FPI-6 is a criterion-based scoring system for weight bearing foot alignment, the degree of weight bearing which can be observed to be rotated medially, laterally or mid position, also provides an indication of the overall foot posture. In Badminton, a tremendous amount of force on the foot applies during running and jumping. This leads to musculoskeletal adaptation and misalignment of the lower extremity. The pressure distribution is high on a certain area of foot which is likely to undergo injury.

The Harris mat serves as a straight forward instrument for acquiring a qualitative descriptive analysis of static weight-bearing characteristics of the foot.[7] It has gained wide utilization among clinicians and orthotists for the assessment of plantar variations. There exists a necessity to evaluate the dynamic balance of the feet, as walking is a fundamental activity.

Materials and Methods

Study Location: A total of 40 participants from a badminton academy in Bangalore, India between 9 to 16 years, participated in the study. The academy caters to junior badminton players who undergo regular supervised training and participate in competitive sports activities. The study setting was selected because it provided a suitable population of trained badminton players meeting the study criteria.

Study Design: The present study was a descriptive cross-sectional observational study. The study was conducted to assess plantar pressure distribution and foot posture among junior badminton players at a single point in time. Plantar pressure distribution was recorded using the Harris Mat, while foot posture was assessed using the Foot Posture Index-6 (FPI-6). No intervention was administered, and all assessments were carried out during a single evaluation session.

Study Population: The study population comprised junior badminton players aged 9–16 years of age. Junior badminton players were defined as individuals below 18 years of age who were regularly engaged in structured badminton training at the junior or school level.

Participants were included based on their active participation in badminton training or playing for more than one hour per session for a minimum period of two years. Only those who were willing to participate in the study and whose parents or legal guardians provided written informed consent were included. Participants were excluded from the study if they had sustained an upper or lower limb injury within the preceding six months, had any musculoskeletal, neurological, or congenital condition that could affect foot posture or gait, or had undergone recent lower limb surgery or sustained a fracture that might influence plantar pressure distribution.

Sampling Technique: A purposive sampling technique was employed to recruit participants for the study. Junior badminton players were selected based on the predefined eligibility criteria.

Sample Size determination: The sample size was estimated using the formula for estimating the mean of a continuous variable:

n=(Z^2 σ^2)/d^2

where n is the required sample size, Z is the standard normal deviate corresponding to the desired confidence level (1.96 for 95% confidence), σis the estimated standard deviation obtained from previous literature or a pilot study, and dis the desired precision. Based on a precision of 0.62, the calculated sample size was 40 participants, all of whom were recruited for the study.[21] The whole study was time bound for 3 months, hence feasibility was taken into consideration as well.

Ethical Issues: Institutional Ethics Committee approval IEC/ANRIPT/09/4/2024 was obtained prior to commencement of the study. Participant confidentiality and anonymity were maintained throughout the study, and no personal identifiers were used. The study involved minimal risk and all procedures were conducted in accordance with ethical guidelines. The parents of the participants signed a consent form and were told about the requirements and procedures prior.

Study Procedure: They were evaluated with Harris mat for plantar variation and FPI 6 for foot posture index. Along with these tools, stadiometer for assessing the height and a calibrated weighing scale for weight calculation were used. The foot imprinter Harris mat was utilized to display weight distribution on the sole of the foot. Upon the collection of demographic information, the Harris mat and the Foot posture index (FPI-6) were used as instruments for observational analysis.

For the Harris mat, a sheet of recording paper was placed within the container, with overlaying a layer of ink. Participants were then asked to step into the container onto the recording paper. This process allowed to capture the participant's impression of the weight-bearing geography of the feet onto the underside of paper. The participants were then asked to stand on one stance and both legs while analyzing the foot imprints. Depending upon the pressure exerted, there will be an imprint. The darker imprint will signify higher grades of plantar pressure.[7]

Foot posture index (FPI), as a clinical tool, can quantify the angle a foot can be pronated and supinated to. This is a relatively easy, fast, and reliable method. The six items on FPI were assessed based on: (1) talar head palpation, (2) curvature at the lateral malleoli, (3) inversion/ eversion of the calcaneus, (4) talonavicular bulging, (5) congruence of the medical longitudinal arch, and (6) abduction/ adduction of the forefoot on the rearfoot. Scoring of each item was done on a scale of −2, −1, 0, +1, and +2 (0 for neutral, −2 for clear signs of supination, and +2 for clear signs of pronation), and all scores were added. Larger the positive value, means foot is pronated more, while the final score ranged from −12 to +12. The scores were collected based on the 6 items and were then analyzed. It is accustomed to evaluate the degree in which a foot is pronated, neutral, or supinated.

For calculating the FPI scores, the participant was made stand in a comfortable stance posture with both legs supported on the ground. They were then directed to stand without moving, while their upper limbs at the side with their palms facing forwards. With this stance, the tool scores were calculated.

Study Instruments: Data collection was carried out over a period of three months after obtaining Institutional Ethics Committee approval. The plantar pressure distribution of each participant was assessed using the Harris Mat. Foot posture was evaluated using the Foot Posture Index-6 (FPI-6).

Data Analysis

All data were entered into a spreadsheet for statistical analysis.

The normality of the continuous variables was assessed using the Shapiro–Wilk test. Variables with a p-value greater than 0.05 were considered to be normally distributed, while variables with a p-value less than 0.05 were considered to deviate from a normal distribution. Data were analyzed using SPSS version 23.0 with descriptive statistics (mean, standard deviation, frequency, and percentage) calculated for continuous and categorical variables.

Result

The baseline demographic and anthropometric characteristics of the participants, including age, gender distribution, height, and weight, were recorded to provide a comprehensive profile of the study population. The age of participants ranged from 9 to 16 years, with a mean age of 11.0 years (SD = 1.9). Among the total sample of 40 participants, 23 (57.5%) were males and 17 (42.5%)

were females.

Table 1: Socio demographic and anthropometric measurements of participants

Gender	Frequency	Percent
Male	23	57.5%
Female	17	42.5%

The height of the players ranged from 136 cm to 160 cm, with a mean value of 145.78 cm (SD = 6.14). Similarly, body weight ranged from 28.0 kg to 43.0 kg, with a mean value of 35.40 kg (SD = 4.16).

Table 2: Anthropometric measurements of respondents

Anthropometry	N	Minimum	Maximum	Mean	Std. Deviation
Height(cm)	40	136.00	160.00	145.775	6.137
Weight (Kg)	40	28.00	43.00	35.400	4.162

Forefoot Plantar Pressure Distribution

The plantar pressure distribution at the forefoot, as assessed using the Harris Mat, demonstrated that Grade 3 was the most frequently observed pattern in both feet. In the right forefoot, 21 participants (52.5%) exhibited Grade 3 pressure distribution, followed by Grade 2 (25.0%), Grade 4 (17.5%), and Grade 1 (5.0%). Similarly, in the left forefoot, 17 participants (42.5%) were classified as Grade 3, followed by Grade 2 (25.0%), Grade 4 (22.5%), and Grade 1 (10.0%). Overall, Grade 3 plantar pressure distribution was the predominant pattern observed in both the right and left forefoot among the study participants.

Table 3: Harris mat -Fore foot

Plantar Pressure Distribution – Forefoot (Harris Mat)	Grade	Frequency	Percent
Fore foot Right (Harris mat)	G1	2	5.0
	G2	10	25.0
	G3	21	52.5
	G4	7	17.5
fore foot left (Harris mat)	G1	4	10.0
	G2	10	25.0
	G3	17	42.5
	G4	9	22.5

Midfoot Plantar Pressure Distribution

The plantar pressure distribution at the midfoot, as assessed using the Harris Mat, revealed that Grade 2 was the most common pattern observed in both feet. In the right midfoot, 20 participants (50.0%) demonstrated Grade 2 pressure distribution, followed by Grade 1 (35.0%), Grade 3 (12.5%), and Grade 4 (2.5%). Similarly, in the left midfoot, 17 participants (42.5%) exhibited Grade 2 pressure distribution, followed by Grade 1 (30.0%), Grade 3 (22.5%), and Grade 4 (5.0%). Overall, Grade 2 was the predominant plantar pressure distribution pattern in the midfoot region of both the right and left feet among the study participants.

Table 4: Harris mat -Mid foot

Plantar Pressure Distribution – Mid foot (Harris Mat)	Grades	Frequency	Percent
Mid foot Right (Harris mat)	G1	14	35.0
	G2	20	50.0
	G3	5	12.5
	G4	1	2.5
Mid foot Left (harris mat)	G1	12	30.0
	G2	17	42.5
	G3	9	22.5
	G4	2	5.0

Rearfoot Plantar Pressure Distribution

The plantar pressure distribution at the rearfoot, as assessed using the Harris Mat, showed that Grade 3 was the most frequently observed pattern in both feet. In the right rearfoot, 19 participants (47.5%) exhibited Grade 3 pressure distribution, followed by Grade 4 (37.5%) and Grade 2 (15.0%). Similarly, in the left rearfoot, 22 participants (55.0%) demonstrated Grade 3 pressure distribution, followed by Grade 4 (35.0%) and Grade 2 (10.0%). Notably, Grade 1 pressure distribution was not observed in either the right or left rearfoot. Overall, Grade 3 was the predominant plantar pressure distribution pattern at the rearfoot among the study participants.

Table 5: Harris mat-Rear foot

Plantar Pressure Distribution – Rear foot (Harris Mat)	Grades	Frequency	Percent
Rear foot Right (Harris mat)	G2	6	15.0
	G3	19	47.5
	G4	15	37.5
Rear foot Left (Harris mat)	G2	4	10.0
	G3	22	55.0
	G4	14	35.0

Foot Posture Assessment Using the Foot Posture Index (FPI-6)

Assessment of foot posture using the Foot Posture Index (FPI-6) revealed that the majority of participants demonstrated a normal foot posture in both feet. In the left foot, 37 participants (92.5%) had a normal foot posture, while 3 participants (7.5%) exhibited a pronated foot posture. Similarly, in the right foot, 37 participants (92.5%) were classified as having a normal foot posture, whereas 3 participants (7.5%) demonstrated a pronated foot posture. No participants were classified as having a supinated foot posture in either foot. Overall, the findings indicate that normal foot posture was predominant among the junior badminton players included in the study.

Table 6: Foot posture Index

Foot Posture Index (FPI-6)	Foot Posture Type	Frequency	Percent
FPI-6 [left foot]	Normal	37	92.5
	Pronated	3	7.5
FPI-6 [right foot]	Normal	37	92.5
	Pronated	3	7.5

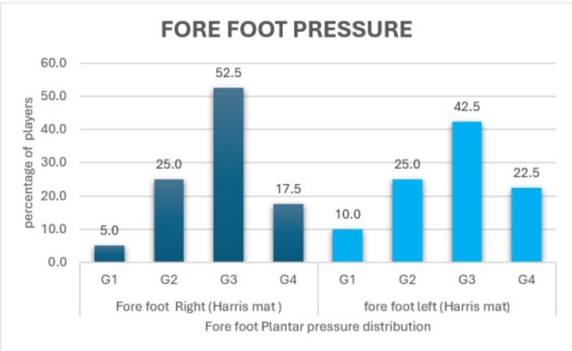

Figure 1: Fore Foot pressure -Harris mat

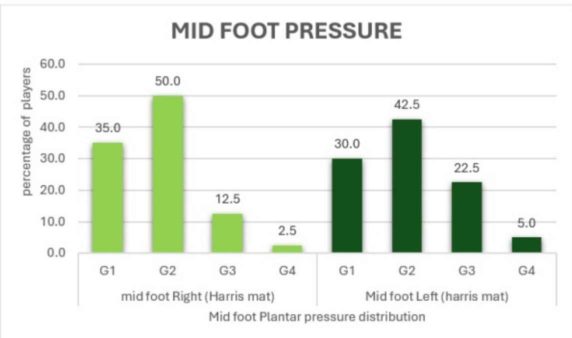

Figure 2: Mid foot pressure Harris mat

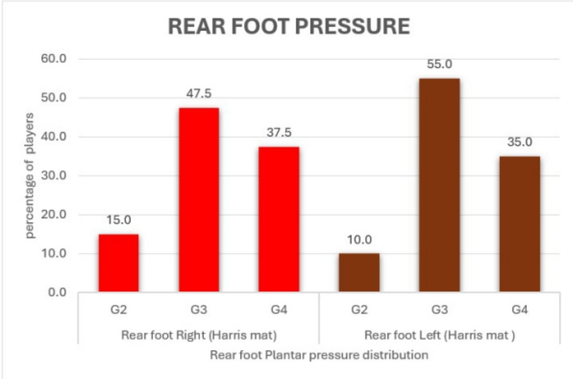

Figure 3: Rear foot pressure Harris mat

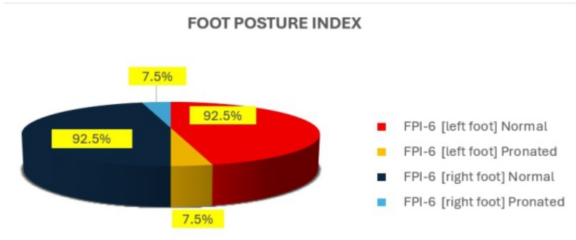

Figure 4: Foot Posture Index Analysis

Discussion

Objective 1: Assessment of Plantar Pressure Distribution Using the Harris Mat

When it comes to movement analysis, plantar pressure mapping offers a detailed look at how force is distributed across the plantar region of the foot during various phases of movement in badminton, as the sport requires quick, repetitive changes in direction and explosive footwork. [12]

In the present study, Harris Mat analysis revealed predominant forefoot and rearfoot plantar pressure distribution in the majority of junior badminton players. Thus, there is more heel pressure in these players. These findings are consistent with previous studies in badminton and other court-based sports, which have reported increased forefoot and rearfoot pressures. [26] Clinically, these results indicate that abnormal plantar pressure distribution can exist even in the presence of normal static foot posture, highlighting the importance of incorporating plantar pressure assessment alongside foot posture evaluation.

This finding suggests that despite predominantly normal static foot posture, the dynamic demands of badminton—such as repetitive lunges, jump-landings, and rapid directional changes—result in concentrated forefoot and rearfoot pressures. These sport-specific loading patterns may increase stress on the lower limb structures even in the absence of overt foot posture abnormalities, highlighting the importance of dynamic plantar pressure assessment in young athletes.

The junior age group is critical because the musculoskeletal system is still developing. Repetitive stress, combined with poor foot mechanics, can lead to long-term biomechanical adaptations, some of which may become permanent.[22] By assessing plantar pressure distribution early, coaches, trainers, and healthcare professionals can implement targeted interventions such as foot-specific strengthening and flexibility exercises, footwear recommendations or orthotic support, and movement technique modifications to optimize performance and reduce injury risk.

In plantar pressure distribution, the forefoot and rearfoot predominantly demonstrated Grade 3 pressure patterns. During badminton, players frequently land on the forefoot while performing lunges and jumps, facilitating shock absorption, whereas the heel plays an important role during stance and service, contributing to the increased rearfoot pressure observed in the present study.

Objective 2: To assess the foot posture using the Foot Posture Index (FPI-6)

In badminton, especially at the junior level, proper biomechanics play a crucial role in performance and injury prevention. Among the various biomechanical factors, foot posture and plantar pressure variations are often assessed because of their strong influence on how young athletes move on the court. Other important biomechanical factors influencing performance and injury risk in junior badminton players include lower limb alignment (hip–knee–ankle alignment and Q-angle), joint range of motion of the hip, knee, and ankle, muscle strength, endurance and flexibility, leg stiffness and shock absorption capacity, ground reaction forces, as well as neuromuscular control components such as balance, proprioception, motor coordination, and reaction time. Altered foot posture or abnormal plantar loading patterns can modify shock absorption, stability, and push-off efficiency, thereby increasing mechanical stress on proximal joints and predisposing young athletes to overuse injuries.

The Foot Posture Index (FPI-6) provides a comprehensive assessment of foot posture by evaluating the forefoot, midfoot, and hindfoot. In the present study, the majority of junior badminton players demonstrated a normal foot posture, with only 7.5% exhibiting a pronated foot posture and none demonstrating supinated feet. This indicates that most players possessed a normal static foot posture despite the repetitive physical demands of badminton.

Previous studies have suggested that overpronation, where the medial longitudinal arch is flatter than normal, may lead to insufficient force transfer and increased stress on the lower limbs.[11] Conversely, supinated feet may reduce shock absorption, thereby increasing the risk of stress-related injuries. Both extremes have the potential to impair athletic performance and contribute to chronic musculoskeletal problems if left unaddressed. However, in the present study, only 7.5% of the participants demonstrated a pronated foot posture, while no participants exhibited a supinated foot posture.

High-arched players (supinated) tend to exhibit increased pressure on the heel and lateral forefoot. These pressure patterns may influence comfort, performance, and susceptibility to injuries such as plantar fasciitis, Achilles tendinopathy, and shin splints.[21] Although no supinated feet were identified in the present study, routine assessment of foot posture using the FPI-6 remains valuable for the early identification of biomechanical deviations. Early screening allows coaches and healthcare professionals to implement preventive strategies and monitor athletes who may be at risk of developing lower limb injuries.

Implication

The verdicts gained through this research possess noticeable clinical changes, which come up with relevant understanding for healthcare practitioners, pediatrists, and designers to contemplate when addressing concerns related to musculoskeletal health and foot comfort in individuals who routinely play badminton. This study helps analyze Foot Posture Index and plantar pressure distribution in junior badminton participants and talks about the adaptive measure in foot. This will in return prevent long term lower limb impairments and complications.

Conclusion

The pressure gradient on heel and forefoot was relatively high as compared to midfoot. For FPI it was observed that 97% of the players showed normal foot while 3% showed pronated feet. The use of age-specific reference ranges provided in this paper will assist in classifying foot type for the motive of study and clinical decision-making. This research stipulates that young badminton players experience elevated plantar pressure in the rearfoot and forefoot.

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Disclosure

The author reports no conflicts of interest in this work.

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Author contribution

Nice Mathew: Conceptualization, methodology, formal analysis, writing—original draft. Tuba Shaikh -data collection and editing . Mallikarjunaiah HS – Methodology validation and review. All authors: Writing—review and editing, supervision, and final approval of the manuscript.

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