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ORIGINAL RESEARCH

Investigation of foot biomechanics in youth basketball players

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Abstract

This study aimed to evaluate foot biomechanics and plantar pressure in youth basketball players. The study included 70 male basketball players under the age of 18 years. Plantar pressure percentage distribution, hallux valgus angle (HVA), navicular drop test (NDT), subtalar pronation angle (SPA) and knee valgus angle (KVA) were measured. The data were subjected to homogeneity analysis using the Shapiro-Wilk test, and a Pearson correlation test was subsequently applied. Plantar pressure distribution was even. Moderate hallux valgus and subtalar pronation tendency were observed in both feet. NDT was positive, but the KVA was normal. Strong positive correlations were found between HVA, SPA, KVA, and NDT. There is a tendency for hallux valgus, subtalar pronation, and flatfoot in youth basketball players. These findings suggest that young athletes may be at risk for ankle and knee problems. Therefore, early preventive measures and regular foot biomechanical evaluations are recommended.

Introduction

Basketball is one of the most popular sports worldwide. This sport is played in teams, each consisting of five players. The aim of the game is to score points by passing the ball through the basket of the opposing team (Stojanovic et al., 2018). Basketball is a fun sport and a type of exercise that provides many benefits. Playing basketball increases muscle strength and endurance, improves coordination and balance, protects cardiovascular health, and reduces stress (Pang et al., 2020).

Basketball is a contact sport requiring high mobility. Therefore, static and dynamic balance, strength, flexibility, and motor skills of athletes are extremely important. Considering these factors, lower extremity biomechanics is of great importance. Injuries are frequently seen in basketball players, and ankle injuries are the most common following knee and shoulder injuries (Menon et al., 2024).

Since basketball is a contact sport, foot and ankle biomechanics are critical. Lateral ankle instability is a common problem, especially among elite basketball players. The rate of such injuries was recorded as 3.85 per 1000 players (McKay et al., 2001).

The foot's intricate structure comprises 26 bones, 33 ligaments, and numerous joints (Towers et al., 2003). The foot and ankle include 7 tarsal bones (the calcaneus, talus, navicular, cuboid, and three cuneiform bones), 5 metatarsal bones, and 14 phalanges. The foot is divided into three primary sections: the forefoot, midfoot, and hindfoot, which are critical for describing both deformities and functions. The forefoot contains the metatarsal and phalangeal bones; the midfoot comprises the navicular, cuboid, and cuneiform bones; and the hindfoot consists of the talus and calcaneus bones (Mueller, 2005).

The ankle joint, a functional hinge joint, includes the distal tibiofibular, tibiotalar, and fibulotalar joints. This joint, formed by the tibia, fibula, and talus bones, facilitates movements such as inversion, eversion, dorsiflexion, and plantar flexion (Richard et al., 2009; Ray, 2016). The subtalar joint, located between the talus's lower surface and the calcaneus's upper surface, enables dorsiflexion, eversion, and abduction during pronation, and plantar flexion, inversion and adduction during supination (Nordin & Frankel, 2001).

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Additionally, the midtarsal joint, or Chopart joint, connects the talocalcaneonavicular joint medially and the calcaneocuboid joint laterally (Ombregt, 2013).

Although a few studies have explored the biomechanics of the foot in youth basketball players, there is a notable absence of research specifically focused on plantar pressure analysis. This study aims to assess the foot biomechanics of children participating in a youth basketball club.

Methods

Participants Sample Group

Inclusion criteria to be under the age of 18, to participate in the study on a voluntary basis, to engage in regular basketball training at least three days per week for a minimum of three years, and to have participated in competitive basketball for a similar period. Exclusion criteria were; those who have undergone lower extremity surgery within the past year, or who present with neurological, psychiatric, pes planus, subtalar pronation of 7 degrees or more, or any orthopaedic problem, are excluded from participation.

Ethics Committee

The study was approved by a local ethical review board (Çankırı Karatekin University Health Sciences Ethics Committee, application number: cd09c8d1b4b64dce) in accordance with the ethical standards laid out in the Declaration of Helsinki. The study was conducted in accordance with the principles set forth in the Declaration of Helsinki. The parents or legal guardians of all participants provided written informed consent prior to the commencement of any evaluations, which were conducted in person.

Data Collection Tools

Sociodemographic form: It consists of information such as gender, height, weight, etc.

PPP (Pedobarography Plantar Pressure) measurement: The plantar pressure measurements will be conducted in a static manner, with the subject in a bipedal position. Subsequently, the percentage pressure distributions of the right foot (RF), left foot (LF), forefoot (FF) and hindfoot (HF) will be calculated (Figure 1). The plantar pressure data were subjected to static analysis using the AS Foot Scan (Analysis System, Istanbul, Turkey). The device has a sensor area of 400mm x 400mm, comprising a total of 2288 sensors (equating to 1.4 sensors/cm²) and a data acquisition rate of between 200 and 400Hz. The device exhibits a latency of less than 3%.

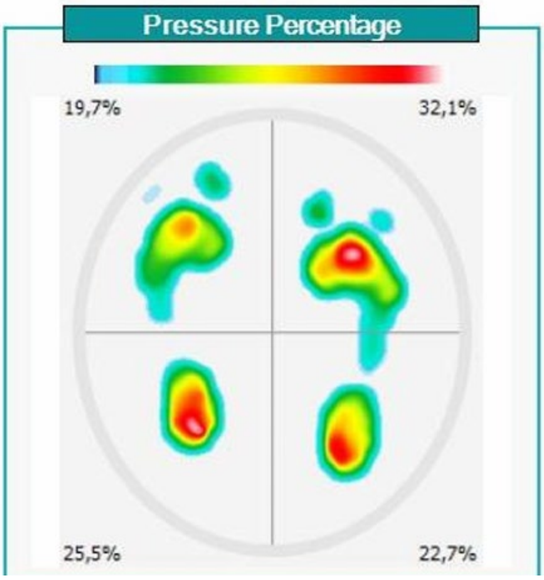

Figure 1. Static plantar pressure analysis on pedobarography device.

HVA Measurement: To measure the HVA using a goniometer, the pivot point of the device should be positioned on the medial prominence of the metatarsophalangeal joint. The goniometer's fixed arm should be aligned parallel to the medial side of the first metatarsal, while the movable arm should be placed along the medial aspect of the first proximal phalanx. The resulting acute angle is recorded to assess the severity of the deformity (Karabicak et al., 2015).

NDT Measurement: For this test, the patient stands in a bipedal stance with full weight distributed evenly on the lower extremities, ensuring the foot's subtalar joint is in a neutral position ('talar head compatible'). The most prominent point on the navicular tuberosity is marked, and the distance from this point to a supporting surface (such as the floor or a step) is measured. The patient is then asked to relax, and the movement of the navicular bone in the sagittal plane is measured with a ruler. A difference of less than 5 mm indicates pes cavus, while a difference greater than 10 mm suggests pes planus (Menz, 1998).

SPA Measurement: This test measures the angle between the midpoint of the calcaneus and the Achilles tendon. While the individual stands on a raised platform, the angle is determined using a goniometer (Jastifer & Gustafson, 2014).

KVA Measurement: In this measurement, the angle between the anatomical axis of the femur and that of the tibia is assessed, with the standard angle generally accepted as 171°. A goniometer is used to perform this measurement (Nikolopoulos et al., 2015).

Statistical Analyses

The data will be analyzed using IBM SPSS Statistics Version 26.0 (SPSS Inc., Chicago, IL, USA). Continuous variables will be expressed as the mean ± standard deviation, while qualitative variables will be presented as numbers and percentages (%). Descriptive statistics for quantitative variables and the distribution of qualitative variables will be evaluated through frequency analysis. The data were subjected to a homogeneity analysis using the Shapiro-Wilk test. The Pearson correlation test will be applied, with a significance level set at $p \leq 0.05$ for all statistical tests.

The study's sample size was determined using G*Power 3.1.9.7 software. The calculation considered an effect size of 0.80 (d = 0.80), a 5% margin of error ($\alpha = 0.05$), and a 95% power ($1-\beta = 0.95$), resulting in a required sample size of 70 participants based on these criteria (Kraszewski et al. 2024).

Results

The study included 70 male youth basketball players. The descriptive characteristics of the participants were age 16.04±1.17 years, height 175.94±6.04 cm, weight 77.71±8.98 kg and BMI 22.85±2.34. Detailed sociodemographic data form is given in Table 1.

Table 1
Sociodemographic data form analysis.

Variables	Mean	SD
Age (years)	16.04	1.17
Height (cm)	175.94	6.04
Weight (kg)	77.71	8.98
BMI	22.85	2.34

SD: Standard deviation; cm: Centimeter; kg: Kilogram; BMI: Body mass index.

In the results of static plantar pressure analysis in bipedal position in the pedobarography device, the percentage distributions were evenly distributed. It was given in more detail in Table 2.

According to the results of HVA, there is moderate hallux valgus onset in both feet. In addition, in the SPA test, there is a tendency for pronation in both feet. Knee valgus test results were normal. Details are given in Table 3.

The results of NDT were positive in both feet. The details are given in Table 4.

Table 2
Pedobarography device static plantar pressure analysis.

Variables	Mean	SD
RFF (%)	24.21	3.87
RHF (%)	24.14	4.60
LFF (%)	26.24	3.26
LHF (%)	25.40	3.88

RFF: Right Fore Foot; RHF: Right Hind Foot; LFF: Left Fore Foot; LHF: Left Hind Foot; %: Percentage; SD: Standard deviation.

Table 3
Lower extremity biomechanical measurements analysis.

Variables	Mean	SD
RF HVA (°)	18.61	3.15
LF HVA (°)	18.68	2.90
RF SPA (°)	6.35	1.42
LF SPA (°)	6.52	1.37
R KVA (°)	167.39	2.61
L KVA (°)	167.76	2.45

R: Right; L: Left; RF: Right foot; LF: Left foot; HVA: Hallux valgus angle; KVA: Knee valgus angle; SPA: Subtalar pronation angle; (°): Degrees; SD: Standard deviation.

Table 4
Navicular drop test (NDT) analysis.

Variables	Mean	SD
RF Weightless (mm)	4.37	.37
LF Weightless (mm)	4.40	.40
RF Weighted (mm)	3.26	.58
LF Weighted (mm)	3.30	.53

RF: Right foot; LF: Left foot; mm: Millimeter; SD: Standard deviation.

The results of the correlation analysis for the measured variables are presented in Table 5. Significant positive correlations were observed between several variables at the 0.01 and 0.05 levels of significance. The correlation between the weighted Navicular Drop Test (NDT) for the right foot (RF) and the weighted NDT for the left foot (LF) was found to be highly significant ($r = 0.93$, $p < 0.01$). Moderate correlations were observed between the weighted NDT for the LF and the weightless NDT for both the LF ($r = 0.71$, $p < 0.01$) and RF ($r = 0.66$, $p < 0.01$). Furthermore, a positive correlation was observed between the weighted NDT for the RF and the weightless NDT for both the RF ($r = 0.68$, $p < 0.01$) and LF ($r = 0.69$, $p < 0.01$). The right knee valgus angle (R KVA) demonstrated a moderate correlation with the weighted NDT for the RF (r = 0.33, p < 0.01) and a strong correlation with the weightless NDT for the RF (r = 0.51, p < 0.01). Moreover, the subtalar pronation angle (SPA) for the RF demonstrated a positive correlation with the hallux valgus angle (HVA) for the RF (r = 0.69, p < 0.01). Additionally, a strong positive correlation was observed between the HVA for the RF and LF (r = 0.84, p < 0.01). No significant correlations were observed between the knee valgus angle (KVA) and other variables for the left foot or between the SPA and the HVA for the left foot. These findings underscore the existence of robust interrelationships between measures of navicular drop under both weighted and weightless conditions, as well as between right-foot biomechanical angles. Moreover, a positive correlation was observed between the SPA for the RF and the HVA for the RF (r = 0.69; p < 0.01).

Additionally, a strong positive correlation was identified between the HVA for the RF and LF (r = 0.84; p < 0.01). However, no significant correlations were observed between the KVA and other variables for the LF or between the SPA and HVA for the LF. These findings underscore the existence of robust interrelationships between measures of navicular drop underweighted and weightless conditions, as well as between right-foot biomechanical angles.

Discussion

This study represents a pioneering contribution to the evaluation of foot biomechanics in young basketball players. The findings furnish valuable insight into the foot structure and function of young basketball players. In particular, a balanced distribution of plantar pressure may be indicative of healthy foot development in young athletes (Domaradzki, 2024). However, a moderate hallux valgus angle (HVA) and a tendency to subtalar pronation indicate an increased risk of developing ankle and foot problems in the future (Donatelli, 1987).

A review of the literature reveals a multitude of studies examining the impact of plantar pressure distribution on foot health and performance. In particular, overpronation has been associated with a number of problematic conditions, including plantar fasciitis, metatarsalgia and ankle instability (Chow et al., 2021). Furthermore, the subtalar pronation tendency identified in this study serves as a cautionary indicator that young basketball players may be at an elevated risk of ankle injury or chronic foot instability issues in the future (Hagen et al., 2018).

Conversely, a study conducted in 2019 demonstrated that an increased hallux valgus angle resulted in altered ankle motion and a reduction in forces on the sole of the foot, yet had no impact on first metatarsophalangeal joint motion (Bruce et al., 2019). This finding may be related to the moderate hallux valgus angle (HVA) level observed in the present study. The findings indicate that modifying the HVA in basketball players' footwear may limit the range of motion of the footwear itself but not the anatomical movement within the shoe. This emphasizes the intricate nature of the foot biomechanics exhibited by young basketball players and the potential for shoe modifications to yield unintended outcomes.

Table 5
Correlation analysis.

Variables	LF Weighted NDT (mm)	RF Weighted NDT (mm)	LF Weightless NDT (mm)	RF Weightless NDT (mm)	L KVA (°)	R KVA (°)	LF SPA (°)	RF SPA (°)	LF HVA (°)
RF Weighted NDT (mm)	.93**	1	.69**	.68**	.10	.30*	.10	.13	-.09
LF Weightless NDT (mm)	.71**	.69**	1	.90**	.03	.16	.08	.16	-.08
RF Weightless NDT (mm)	.66**	.68**	.90**	1	.04	.19	.11	.20	-.05
L KVA (°)	.17	.10	.03	.04	1	.51**	04	.05	.08
R KVA (°)	.33**	.30*	.16	.19	.51**	1	-.03	.01	-.04
LF SPA (°)	.15	.10	.08	.11	.04	-.03	1	.69**	-.05
RF SPA (°)	.13	.13	.16	.20	.05	.01	.69**	1	-.08
LF HVA (°)	-.11	-.09	-.08	-.05	.08	-.04	-.05	-.08	1
RF HVA (°)	-.04	.00	.01	.06	.09	-.03	-.10	-.11	.84**

*R: Right; L: Left; RF: Right foot; LF: Left foot; NDT: Navicular drop test; mm: minimetre; (°): degree; HVA: Hallux valgus angle; KVA: Knee valgus angle; SPA: Subtalar pronation angle. * There was a significant correlation at the 0.05 level; ** There was a significant correlation at the 0.05 level.*

A further noteworthy finding of this study was that both feet exhibited positive navicular drop (NDT) results. The NDT is a method used to assess the height and function of the arch of the foot. A positive NDT result is indicative of a flatfoot or low-arched foot, which may result in overloading of the ankle and knee joints (Nielsen et al., 2009). Accordingly, the positive NDT observed in the present study indicates that young basketball players may be susceptible to developing knee joint issues in the future. The existing literature indicates a correlation between flatfoot and an increased risk of knee problems, including anterior cruciate ligament injuries, patellofemoral pain syndrome and overuse injuries (Domaradzki et al., 2024). Furthermore, the combination of pes planus with subtalar pronation in athletes has been demonstrated to elevate the likelihood of ankle injury during competitive events (Levy et al., 2006).

In the aforementioned study, it was indicated that both feet of the young basketball players exhibited a positive NDT result. It is possible that there are specific basketball-related factors contributing to this phenomenon. One such factor is the repetitive nature of jumping movements inherent to the sport. The frequent performance of jumping movements in basketball places a considerable load on the ankle and the arch of the foot. Such loading may result in a reduction in the height of the arch of the foot, leading to a positive NDT (Beckett et al., 1992). Secondly, there are high-impact forces. Basketball is a sport that involves the application of high-impact forces, including those generated by running, jumping, and sudden changes in direction. Such forces can contribute to strain on the structures that support the arch of the foot, which may result in a positive NDT (Loudon et al., 2008). Another potential factor is the choice of footwear. The design and features of basketball shoes have the potential to influence foot biomechanics. Some footwear may lack sufficient support for the arch of the foot, thereby increasing the risk of a positive NDT (Sun et al., 2020).

The field of foot biomechanics is of significant relevance to a multitude of athletic pursuits beyond the domain of basketball. In particular, in high-impact sports such as running, volleyball and tennis, foot structure and function have a significant impact on performance and injury risk. A review of the literature reveals that studies conducted in these sports have demonstrated that foot biomechanics exhibit sport-specific differences (Almeida et al., 2015). For example, it has been demonstrated that the load on the ankle joint during jumping and landing in volleyball players differs from that experienced by basketball players (Hadzic et al., 2009). Consequently, when assessing the foot biomechanics of young basketball players, it is essential to consider the specific movement patterns and loading characteristics inherent to the sport of basketball.

Finally, the vertical jump height of young basketball players was assessed in the present study. The vertical jump is an important performance indicator in basketball, reflecting lower extremity strength and coordination (Ziv & Lidor, 2009). The findings of our study indicate that the vertical jump heights of young basketball players are inferior to those of similar age groups, as documented in the literature. This suggests that training programs designed to enhance lower extremity strength and coordination may be beneficial for young basketball players. Furthermore, no correlation was observed between vertical jump height and foot structure. This implies that vertical jump performance in young basketball players may be independent of foot structure.

Limitation

In the study of young basketball players, data could not be obtained from sensors examining foot kinematics during the competition due to the inability to affix the sensors to the players. Furthermore, the portatip version of the pedobarography device prevented us from acquiring data for the dynamic plantar pressure analysis.

Conclusion

In conclusion, this research represents a significant contribution to the study of foot biomechanics in youth basketball players. The findings emphasize that preventive measures should be taken in the early period to protect the foot health and performance of young basketball players. In particular, it should be considered that factors such as subtalar pronation tendency and positive NDT may pose a risk for ankle and knee joint problems in the future. Therefore, it is recommended that young basketball players should undergo regular foot biomechanical evaluations and be supported with appropriate shoe modifications, exercise programs, and orthopedic devices when necessary.

Authors' Contribution

Study Design: SS, GA; Data Collection: SS, GA, BÜ, ZM; Statistical Analysis: YY, HS; Manuscript Preparation: SS, GA, BÜ, YY; Funds Collection: SS, GA, BÜ, YY, HS.

Ethical Approval

The study was approved by the Çankırı Karatekin University of Health Sciences Ethical Committee (2024/15) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

Funding

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Conflict of Interest

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

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