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ORIGINAL RESEARCH

Differences in foot pressure distribution of males with and without basketball training in early adolescence

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Abstract

Background: In this study, the Rsscan V9 (RsScan International, Olen, Belçika) foot scanning system was used to determine the potential foot pressure distribution and foot contact times of individuals in early adolescence who did not receive sports training and those who received regular basketball training. **Methods**: The study involved 120 adolescent volunteers aged 11–14 years of which 60 did not receive sports training, and the other 60 received basketball training in Ankara for at least two years. The socio-demographic data of the study participants were documented. The foot pressure analyses were carried out in both fixed and moving postures. **Results**: When pressure values were compared between adolescents with and without basketball training, statistically significant differences were found between Q1 (left forefoot pressure) and Q2 (right forefoot pressure) values. Specifically the mean value ($p < 0.05$) of Q2 (right forefoot pressure) variable was higher in basketball participants compared to non-athletes. In non-athletes, Q1 (left forefoot pressure) ($p < 0.05$) was significantly higher than in participants who received basketball training. Similarly, with regard to the left forefoot pressure duration (left ms) variable, participants with basketball training showed significantly higher mean scores than non-athletes ($p < 0.001$). The findings revealed that there were differences in pressure imbalances and ground contact times between basketball players and non-players. **Conclusions**: If not controlled regularly, pressure imbalances can lead to serious discomfort in the feet, knees, hips and lower back, and serious injuries can be prevented if detected early. Minor injuries that develop due to repetitive movements and stress on joints from years of training can be treated early, and preventive applications can becarried out by recognising potential injuries. For this reason, it is recommended that basketball players have a regular foot pressure analysis carried out at the start of the season.

Keywords

Pedobarographic analysis; Basketball; Foot contact time; Sport

1. Introduction

Basketball is a dynamic sport in which players perform maximum and near-maximum jumps, accelerations, sudden stops and changes of direction during training and matches. Therefore, lower extremity injuries can occur frequently. The foot accounts for a large percentage of lower extremity injuries in most sports disciplines [1]. For the feet, which are in a developmental stage of early adolescence a period highly vulnerable to external factors (ground, repetitive impacts, footwear), injuries that occur cause athletes to interrupt training and matches. In basketball players, both acute problems such as foot muscle tendon injuries and soft tissue problems such as plantar fasciitis and problems caused by overuse and pressure imbalances are commonly observed [2].

Training at the age of 11–14 is very important for early adolescence, the time when physical education is intensified and participation in sports increases. This is when physical development is at its most rapid. In the early stages of puberty, amid rapid biological and physical changes, boys and girls experience different rates of growth [3, 4]. Since puberty starts earlier in women than in men, women grow taller than the opposite sex between the ages of 10 and 12. Growth stops between the ages of 16–18 in women and 18–20 in men. During this period, women mainly store fat [5]. In boys, the growth spurt occurs approximately two years after the specified age and the fastest increase of 10–16 centimetres per year occurs at the age of 14–15 years [6]. During this period, weight gain can be observed in boys, usually with an increase in muscle and bone mass. As the head grows, the facial bones of both boys and girls enlarge, the nose becomes larger and the chin becomes longer and thicker. Growth is accelerated not only in the head but also in the entire skeletal system. Feet and hands become longer, followed by arms and legs, and the breast bones, hips and shoulders become wider [5]. Functional changes in the foot occur from the first months of walking. These changes differentiate with increasing strength and postural control [7]. With the development that starts in childhood, a change in form is observed in addition to the hardening of the bones. The feet of females reach half of the adult foot length in the first year of life, and of boys at the end of one and a half years following birth. Ninety-eight per cent of women's feet grow completely between the ages of twelve and thirteen, while men reach this rate at the age of fifteen [8]. In addition to the genetic tendency, foot developement is influenced by external factors such as body weight with increasing age, level of participation in physical activity and preferred footwear. Moreover, weight-bearing activities (school backpack, *etc.*) are common in daily life, although the increase in weight may adversely affect the arch of the foot and lower extremities [9]. Thus, prolonged mechanical stress acting inhomogeneously on the preferred side and excessive peak pressure increase can cause injuries, especially during high-demand activities [10].

Early adolescence is the time when the first branching choices are made. To avoid negative effects on growth during this time, extreme care should be taken when exercising and not to perform intensive training unconsciously. During the period until the individual's development is complete, over-exercising can lead to injury by causing an imbalance in the flexibility and strength of the muscles, and cause postural damage in various dimensions if growth is not supported by sport and exercise [9, 11]. Therefore, accurate assessment of the adolescent's stage of development is an important factor in the ideal application of training methods and principles [12].

When considering the factors that influence the development of the foot, genetic and gender-specific differences also have an effect on the structural development of the foot, in addition to environmental and developmental factors. A small change in the foot structure alters the load distribution of the foot [13]. In addition to genetic predisposition, development is also influenced by external factors such as body weight with age, participation in physical activities and preferred footwear. However, the exact developmental process is not yet fully understood [14]. Although the intensity and duration of the stress to which the foot is exposed during sports training involving repetitive movements is thought to play a fundamental role in injury development, previous studies have shown that such a relationship is difficult to fully elucidate [15]. Therefore, the foot is part of a series of mechanisms responsible for absorbing impacts, maintaining balance and distributing forces in sports. Special attention should thus be paid to the distribution of plantar pressure [16]. In basketball, which is becoming increasingly popular in addition to general sports training, many movements such as sudden stops, turns, slides and jumps are performed with the feet. Studies have shown that basketball players perform high-intensity movements during most of the game and these movements place a large external and internal load on the lower extremities. Investigating the static and dynamic effects of basketball training on the feet of early adolescents may help to protect foot health and prolong the life span of athletes. It may also help to explain the role of basketball in foot health [17].

While there are studies in the field in which static and dynamic pressure values are measured for different age groups and sports branches, the lack of studies examining the effects of this training on the developing feet in early adolescence in basketball, as well as comparing the contact times with the ground, suggests that our study will contribute to the field. Therefore, the aim of this study was to determine the differences in body mass index, foot contact time, stride length, and plantar pressure in boys with and without basketball sports training in the developing feet during early adolescence.

2. Materials and methods

The study included 60 boys aged 11–14 years who received and continued basketball training in Ankara during early adolescence in the 2021–2022 season and 60 boys who did not receive sports training. The inclusion criteria were boys who received regular basketball training at least 3 days a week and played basketball regularly for at least 2 years and boys who did not receive sports training. Participants who did not have any lower extremity injury in the last 12 months and who had a right leg at the beginning of the swing or movement were also included in the study. The limitations of the study include not being able to evaluate different positions in basketball playing groups, fixing shoe preferences and performing only static evaluation. All participants were informed about the aims and application of the study and voluntary informed consent was obtained from all participants and their legal guardians. The Gazi University Ethics Committee approved the study with a decision dated 30 April 2024 under the code 2024-729.

2.1 Data collection

Each child was examined by the same physiotherapist according to the same protocol. In both groups, all measurements were performed in the same time period between 16:00–17:00 hours at the last hour of school lessons and before training in order not to affect the pressure distributions. During the measurements, the participants were barefoot and wore thin clothes (shorts and t-shirt). The body mass index (BMI) of the study participants was measured using a bioimpedance analyser (Tanita BF350, Tanita, Tokyo, Japan) with an accuracy of 0.1 kg and BMI was calculated by the formula weight (kg)/height^2 (m) [18]. Pedobarrographic analyses were performed using the Footscan® 3D printing system (RSscan International, Brussels, Belgium). Before each measurement, the plantar pressure for each child's weight was calibrated on a pressure-sensitive mat at a sampling rate of 500 Hz [19]. Data were collected with the subjects standing upright, feet shoulder-width apart and barefoot for static measurements. Dynamic pressure measurements to record contact time were performed barefoot and at a walking speed chosen by the child. Pedabarographic analyses were performed three times for each participant. A plantar pressure plate was used to measure the participants' foot contact pressure [20]. The risk analysis system is used to prevent problems with the sole. Furthermore, this system provides a detailed analysis of when and where the force is applied in static and dynamic measurements and shows the pressure distribution of the foot in percentage. If an imbalance occurs at any of these critical stages, the D3D™ section of the software identifies where the inequality is and the type of correction recommended [21, 22]. This system divides the right and left foot into four regions (static front, static back, static left, static right) and determines the percentage regional pressure distribution on the sole.

Using a static electronic pedobarography device (RSscan V9 (RSscan International, Olen, Belgium)), the pressure distributions of the four sites on the dominant and non-dominant side of the foot were first mapped during data collection. The front of the left foot is labeled Q1, the front of the right foot is labeled Q2, the back of the left foot is labeled Q3, and the back of the right foot is labeled Q4 (see Fig. 1). Distribution of percentages in the static pressure analysis: The total percentage (Q1 + Q2) of the pressure values falling on the front of the two feet is referred to as the static forefoot. The total percentage (Q3 + Q4) of the pressure values falling on the rear part of the two feet is referred to as the static hindfoot or rearfoot. The term "fixed left" refers to the left foot and stands for the sum of the pressure values (Q1 + Q3) that fall on this foot. The term "fixed right" refers to the total proportion of the pressure values that fall on the right foot (Q2 + Q4) [17].

A pedobarography device (RSscan V9) is used to determine foot contact times by recording the time from the first to the last contact of the foot during data acquisition while walking. Fig. 2 shows the contact times of the right and left foot as well as the contact time differences of both feet in ms [23].

2.2 Data analysis

In this study, SigmaPlot 11.0 (Systat Software Inc., San Jose, CA, USA) program was used in the analysis of the data. Firstly, normality tests of the data were carried out with this program. The *t*-test was used for the data showing normal distribution in the comparison of the two groups playing basketball and not playing basketball, and the Mann Whitney U-test was used for the comparison of the two independent groups for the data not showing normal distribution.

3. Results

According to the findings in Table 1 obtained from the research, there is no statistically significant difference in the average age of the two independent groups who play basketball and do not play sports (Table 1).

The analysis results showed that the average BMI value of the individuals who do sports is 21.357 ± 3.897 and that of individuals who do not do sports is 20.108 ± 4.997 ($p = 0.025$). This result shows that those who do sports have significantly higher values in terms of BMI (Table 2). In terms of fat percentage, the average value was found to be 18.26 ± 7.917 in individuals who do sports, and 16.908 ± 9.496 in individuals who do not do sports. However, this difference is not statistically significant ($p = 0.236$). In terms of lean mass, it was found to be 47.262 ± 8.754 in individuals who exercise, and 38.743 ± 11.304 in individuals who do not exercise, and this difference is statistically significant ($p < 0.001$). Finally, the average foot number of individuals who play sports was found to be 42.000 ± 2.322, while the average foot number of individuals who do not play sports was found to be 38.583 ± 2.812. This difference is also statistically significant ($p < 0.001$).

When BMI values were examined, the athletes' values were found to be high, but it was found that the difference was due to an increase in lean mass (Table 2).

Static L. (Left Foot Static Measurement): The average value of individuals who do sports was found to be 50.69 ± 4.625, those who do not play sports were found to be 53.708 ± 6.355 ($p = 0.003$), this difference is statistically significant ($p < 0.01$). Static R. (Right Foot Static Measurement): 49.477 ± 4.622 in those who do sports and 46.242 ± 6.499 in those

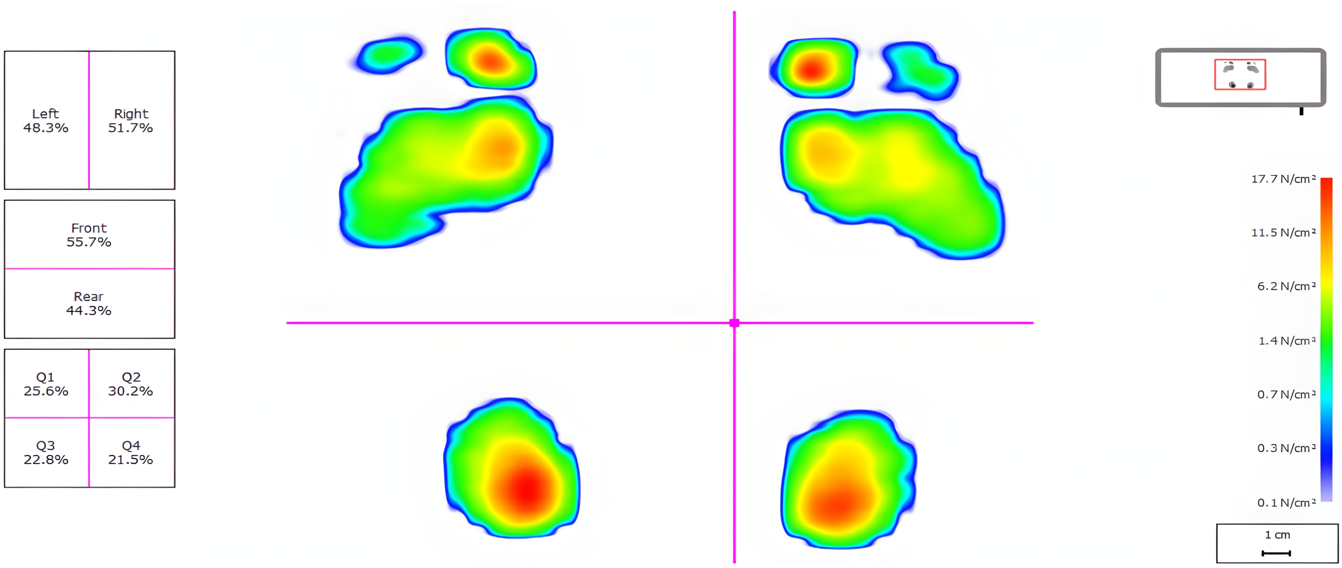

FIGURE 1. RSscan V9 regional pressure distribution map.

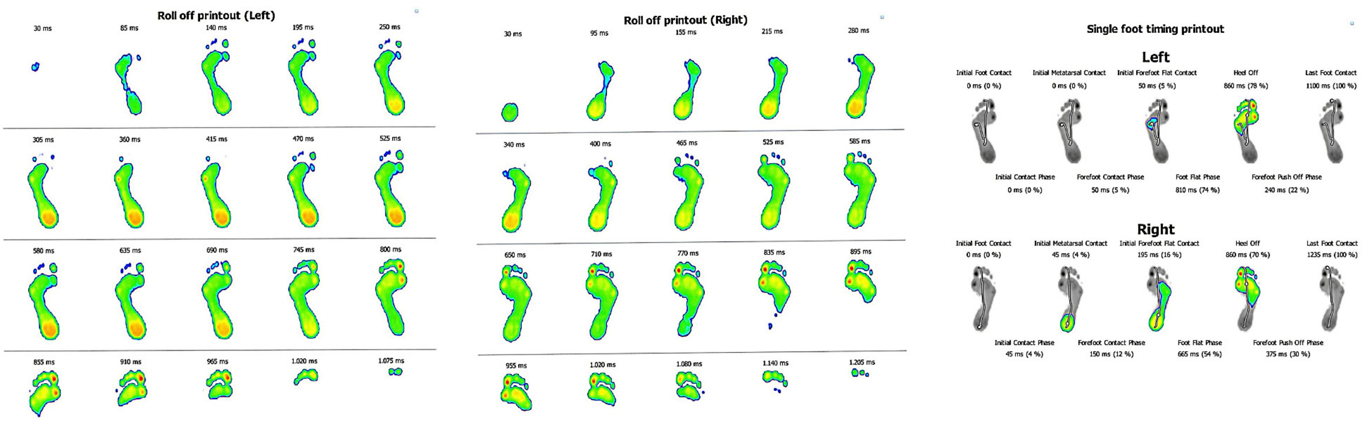

FIGURE 2. Roll of printout left and right.

TABLE 1. Mean age of participants.

	Basketball training group (n = 60)		Group without basketball training (n = 60)		
	χ	s.d.	χ	s.d.	*p*
Age	12.500	1.127	12.500	1.127	0.998

s.d.: standard deviation.

TABLE 2. Anthropometric measurements of participants.

Variables	Basketball training group (n = 60)		Group without basketball training (n = 60)		
Anthropometric Measurements	χ	s.d.	χ	s.d.	*p*
Body Mass Index (BMI)	21.357	3.897	20.108	4.997	0.025*
Fat Percentage	18.260	7.917	16.908	9.496	0.236
Lean Mass	47.262	8.754	38.743	11.304	<0.001**
Foot size	42.000	2.322	38.583	2.812	<0.001**

$^*p < 0.05$; $^{**}p < 0.01$. s.d.: standard deviation.

who do not sports, the difference is statistically significant ($p = 0.002$). S. In front (Q1 + Q2) forefoot static measurements, those who played basketball were 48.053 ± 8.979, those who did not play sports were 47.227 ± 6.757, which was not significant ($p = 0.320$). S. In the Rear (Q3 + Q4) hindfoot measurement, those who play basketball were 51.763 ± 9.005, those who do not play sports were 52.757 ± 6.744, which is not significant ($p = 0.234$). The Q1 value was 23.6 ± 5.489 in those who played basketball and 25.693 ± 4.944 in those who did not play sports, and there was a statistically significant difference ($p = 0.030$). In the Q2 value, those who do sports are 24.63 ± 5.471, those who do not do sports are 21.46 ± 5.746, the difference is significant ($p = 0.002$). There was no significant difference between the two groups in terms of Q3 and Q4 values ($p > 0.05$). Dec. Left foot ms (Left foot ground contact time): 911.833 ± 145.794 in basketball playing individuals and 820.5 ± 112.561 in non-sports individuals, the difference is significant ($p < 0.001$).

When the pressure values are examined, it is seen that the static left (left foot) and Q1 (left foot anterior region) pressure values of the non-sports group increase (Table 3). In the pressure values of the basketball playing group, it is observed that foot pressure increases in the Static right (left foot) and Q2 (right front foot) region (Table 3). It was determined that the values of the left foot ms (left foot ground contact time) basketball playing group were longer lasting (Table 3).

4. Discussion

The age of 11–14 years, a period of early adolescence when rapid physical development takes place, is also important for foot development. All kinds of physical activities and repetitive stresses practised during this period can affect foot development against external factors. This study investigated the percentage of static foot pressure distribution and foot contact time in individuals with and without regular basketball training in early adolescence (11–14 years).

Studies conducted with adolescents and adults have reported that increasing BMI values influence static and dynamic plantar pressure values [24, 25]. When the BMI values of both groups were examined, it was found that the ratio of lean mass in the exercising group was significantly higher compared to the other group. While November muscle gain, which is the main benefit of exercise, is clearly seen in this age group, it is thought that it affects the distribution of pressure of the sole of the foot. Studies conducted with adults in this field

TABLE 3. Comparison of the relevant measurement parameters of two groups who play basketball and do not play.

Variables	Basketball training group (n = 60)		Group without basketball training (n = 60)		*p*
	χ	s.d.	χ	s.d.	
Static Left foot	50.690	4.625	53.708	6.355	0.003**
Static Right foot	49.477	4.622	46.242	6.499	0.002**
Static Front	48.053	8.979	47.227	6.757	0.320
Static Rear	51.763	9.005	52.757	6.744	0.234
Q1	23.600	5.489	25.693	4.944	0.030*
Q2	24.630	5.471	21.460	5.746	0.002**
Q3	26.910	6.120	28.080	5.690	0.281
Q4	24.720	5.700	24.590	5.790	0.897
Left ms (Milliseconds)	911.833	145.794	820.500	112.561	<0.001**
Right ms	855.830	123.420	858.750	130.850	0.807

**p < 0.05; **p < 0.01. s.d.: standard deviation.*

have reported a slight change in the foot structure depending on the participant's posture and the health status of the foot, and the distribution of pressure on the human foot changes significantly depending on the type of sport performed [13, 16]. Inequalities in BMI are mostly related to differences in fat-free mass [26]. People with the same BMI values but different distributions of fat mass and lean mass have different foot structures. It is assumed that BMI has no influence on the load on the feet when there is an increase in lean muscle mass and a decrease in fat mass in people who train for basketball, as their strong musculature ensures a balanced distribution of pressure. At the same time, the study stating that children with a stronger muscular structure can better manage the load on their feet supports our findings [27].

In our pressure analysis, the decrease in pressure on the static posterior region (Q3 + Q4) (Table 3) is probably due to the fact that the load on the anterior part of the body increases as the muscles strengthen, momentum is directed forward and the body tries to maintain balance (Q1) (Table 3), which is observed in those who do not exercise, and the increase in pressure in the area indicates the anterior region of the left foot, which is seen as the balance leg due to the participants having the right foot as the starting leg for tossing or movement. At the same time, (static left) refers to the total pressure of the front and back regions of the left foot, which is the sum of the (Q1 + Q3) region. In contrast to those who do sports, the increase in the total pressure of the left foot and the anterior region of the left foot is thought to be due to the balance legs being left. Most individuals make more mechanical demands on their preferred foot as a result of voluntary motor movements they make during their daily lives or during sports training. Therefore, prolonged mechanical loading of the preferred side in an inhomogeneous manner and an excessive increase in peak pressure can lead to injury, especially during high-demand activities [10, 21].

The results of the study show that one of the parameters of increased pressure in the Q2 region (right forefoot) (Table 3) in adolescents who play basketball is strength development, which depends on the conditional development of the athletes. One of the most important factors in strength development is the quadriceps muscle, which is characterized as a large muscle group and is divided into four parts. Together with this muscle, the development of the gastrocnemius muscle and the muscles of the core area in general ensures a more upright posture. As the body is always in a position ready for forward movement in this way, the significantly high ratio in the Q2 region may be a result of it being the primary foot in the direction of movement, often referred to as the swing leg. Compared to running, sprinting and tourniquet in basketball were reported to have higher plantar loading in the forefoot and 45° cutting provided increased plantar loading in most parts of the foot [28]. Another study reported that prolonged basketball play increases forefoot pressure and affects foot strength during normal gait [29]. In basic basketball training, many movement exercises are performed while standing in the trunk flexion position. In a similar study, foot pressure was shown to increase with increasing trunk flexion and foot pressure increased in sport climbers [30]. In our study, the increase in pressure values in the right anterior foot region of the basketball playing group is supported by the research findings mentioned above. In another study, similar to our findings, foot pressure was observed in adolescents aged 10–11 years, boys who played soccer and boys who did not play soccer. It was found that the pressure on the right forefoot was higher in the group of soccer players [31]. In another study, when comparing individuals who did and did not play sports in early adolescence, it was found that the group which played sports had higher pressure in the Q2 region [32]. Increased regional foot pressure and repetitive impacts can cause deformations such as stress fractures, fasciitis, Achilles tendonitis and other contractions in the foot muscle joints of the developing feet. Studies on strengthening the back muscles, especially in branches where trunk flexion is greater, such as basketball, can be recommended by trained trainers, especially with attention to foot pressures or pressure drops [33, 34].

One of our research findings, ground contact time (left ms) (Table 3), showed an increase in left foot ground contact time in the basketball player group compared to the non-athletes.

It is hypothesised that this increase is due to the left foot being used as a support foot during the preparation phase of the position and as a starting foot during the movement. Ground reaction force is of great importance in sport, as many movements (*e.g.*, jumping, throwing, punching movements) rely on a kinetic chain to achieve high performance results (*e.g.*, jumping height, throwing distance, punching speed). As the most important link in the kinetic chain, the feet are the only part of the body in contact with the ground. This situation increases the importance of pressure analysis in sport [35]. We think that the fact that the pressure distribution is balanced, despite the increased pressure duration in the left foot in basketball players, is due to the fact that the pressure values are more balanced, thanks to the strengthened leg and hip muscles. Studies in this area suggest that stronger hip and hind leg muscles reduce pressure [36, 37]. In our research, the existence of the characteristics of the pressure valueswas supported by the increase in the contact time of these plants with the ground.

It is accepted that the pressure difference in the Q2 region (Table 3) of basketball players has different characteristics from the feet of adults in terms of structure and function, and their plantar pressure valuesare different from adults. Therefore, the importance of these studies for normal values for different age groups and age-specific appropriate comparisons for early adolescents in the rapid developmental phase increases [38]. Early diagnosis and treatment, particularly focusing on offloading, lifestyle modification and footwear, with the help of a multidisciplinary team, can prevent the development of chronic musculoskeletal pain and speed recovery and return to activity. Understanding the plantar pressure characteristics of different movements may be useful in optimizing footwear designs, the use of orthotics or training strategies to minimize regional plantar loading in amateur basketball play. Establishing age-standardized norms will provide more reliable data to evaluate both foot deformities and clinical outcomes following intervention.

The limitations of our research are that different positions could not be evaluated in the basketball playing group, shoe preferences were fixed and only static evaluation was performed. The proliferation of such regimes in the field, the evaluation of static and continuous regimes together, and the monitoring of position-specific pressure distributions are recommended. Nevertheless, our results suggest that basketball training increases pressure, particularly in the right forefoot, which may be useful in optimizing training strategies to minimize regional plantar loading during basketball play and prevent conditions such as fasciitis, Achilles tendonitis and other foot muscle joint inflammation after training.

5. Conclusions

Our results suggest that basketball training increases pressure, particularly in the right forefoot, which may be useful in optimizing training strategies to minimize regional plantar loading during basketball play and prevent conditions such as fasciitis, Achilles tendonitis and other foot muscle joint inflammation after training.

AVAILABILITY OF DATA AND MATERIALS

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

NK and AÖP—designed the research study. TC and ME—performed the research. BY—provided help and advice on statistical analysis. AB and KAK—analyzed the data. HYÇ, CB, MK, HT and LC—wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Gazi University Ethics Committee Commission dated 30 April 2024 and numbered 2024-729. Informed consent was obtained from all participants and their legal guardians prior to their inclusion in the study. The participants were provided with detailed information about the study's purpose, procedures, potential risks and benefits. It was emphasized that participation was entirely voluntary, and they could withdraw at any time without penalty or loss of benefits. Confidentiality and anonymity of personal data were assured throughout the study in compliance with ethical standards outlined in the Declaration of Helsinki.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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