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Relationship between quadriceps angle (Q) and plantar pressure distribution in football players

Relação entre o ângulo quadriciptal (ÂQ) e a distribuição da pressão plantar em jogadores de futebol

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Abstract

Objectives: To determine whether there is an association between the Q-angle (Q) and the distribution of plantar pressure in football players, and to compare the characteristics of these athletes with non-practitioners of this sport. **Methods:** 121 male participants were selected: 50 football practitioners (FP) and 71 non-practitioners (NP). We concurrently evaluated the Q-angle and the plantar pressure through the software of postural assessment (SPA) and the *F-Mat System*, respectively. To verify the correlation between the Q-angle and peak pressure values in four segments of the foot (medial and lateral forefoot, medium-foot and hind-foot), the *Pearson* coefficient (r) for parametric analysis was used. The independent *t*-test was used to compare these variables between the groups. Data normality was verified by the *skewness* values, adopting a significance level of 5%. **Results:** A negative and weak correlation was found (r=-0.32) between the Q-angle and the plantar pressure in the right medium-foot. The groups differed with regards to the right Q-angle (11.36° in FP *versus* 13.80° in NP) and the left Q-angle (11.03° in FP *versus* 13.96° in NP). Plantar pressure was also different between the groups, with FP showing higher mean values for the right side and for the left side of the forefoot (0.77 kg/cm^2 in FP *versus* 0.63 kg/cm^2 in NP, and 0.65 kg/cm^2 in FP *versus* 0.54 kg/cm^2 in NP, respectively). However, mean peak pressure values for the left medium-foot were higher among NP (0.37 kg/cm^2 in FP *versus* 0.46 kg/cm^2 in NP). **Conclusions:** There was no evidence of an association between the Q-angle and the distribution of plantar pressure in FP. The athletes showed reduced Q-angle values and higher mean peak pressure values for the right and left aspects of the forefoot, suggesting a varus malalignment and a supine distribution of plantar bases.

Key words: football; Q-angle; plantar pressure; baropodometry; photogrammetry.

Resumo

Objetivos: Verificar possível associação entre ângulo quadriciptal (ÂQ) e distribuição de pressão plantar em jogadores de futebol, comparando-os com indivíduos não praticantes da modalidade. **Métodos:** Cento e vinte e um participantes do sexo masculino foram selecionados: 50 jogadores de futebol (JF) e 71 sujeitos para o grupo controle (GC). Avaliaram-se concomitantemente o ÂQ, por meio do Softwar*e para Avaliação Postural* (SAPO), e a pressão plantar, pela plataforma *F-Scan/F-Mat System*. Para verificar correlação entre o ÂQ e os valores de picos de pressão em quatro segmentos do pé (antepé medial e lateral, médio-pé e retropé), utilizou-se o Coeficiente de *Pearson* (r) para análises paramétricas. O teste *t* independente foi empregado para comparar isoladamente essas mesmas variáveis entre os grupos. A normalidade dos dados foi verificada pelos valores de *skewness*, adotando nível de significância de 5%. **Resultados:** Encontrou-se correlação negativa e fraca (r=-0,32) somente entre ÂQ e médio-pé direito. Os grupos diferiram quanto ao ÂQ bilateralmente, sendo que o grupo JF teve média de 11,36°, e GC, de 13,80° à direita e de 11,03° contra 13,96° à esquerda, respectivamente. Em relação à pressão plantar, o JF teve maior média de força nas faces laterais do antepé direito (0,77 contra 0,63 kg/cm^2) e esquerdo (0,65 e 0,54 kg/cm^2), enquanto o GC apresentou maior pico de pressão no médio-pé esquerdo (JF: 0,37 e GC: 0,46 kg/cm^2). **Conclusões:** Não houve relação entre os valores de ÂQ na distribuição da pressão plantar nos jogadores de futebol. Os atletas apresentaram, porém, ÂQ diminuído e maiores picos de pressão nas faces laterais de ambos os pés, o que sugere alinhamento em varo dos joelhos e distribuição supinada das bases plantares.

Palavras-chave: futebol; ângulo Q; pressão plantar; baropodometria; fotogrametria.

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Introduction

Football is one of the most popular sports in the world and it is characterized by short duration and high intensity motor actions, which are alternated with periods of longer duration and lower intensity motor actions[1]. Despite the health benefits associated with football, its regular practice increases the likelihood of mechanical instabilities due to excessive training load and competitions, which can result in changes in both muscular and articular systems[2].

The concept of overtraining is applied to high level athletes and reflects an imbalance between stress and recovery, causing greater vulnerability to physical injuries[3]. According to Fuller et al.[4], these injuries should be classified according to their site, laterality, type, mechanism of injury and recurrence. Within this context, a traumatic injury refers to an identifiable specific event; however, overtraining injuries caused by repetitive microtraumas are not linked to a single apparent factor.

Even though sedentarism is a key determinant to changes in posture, repetition of the sport gesture and the biotype of the football athlete contribute to the development of sport-specific biomechanical changes[5]. The knee joint is often affected, with patellofemoral dysfunction being the most common problem[6]. One factor that favors the onset of pain and/or instability is the patellar malalignment in relation to the femur. This malalignment is measured by the quadriciptal angle (Q-angle)[7], which is the acute angle formed by imaginary lines drawn from the anterior superior iliac spine to the center of the patella, and from the tibial tuberosity to the center of the patella[8].

There is no consensus on what an ideal Q-angle value would be, but it is known that men show smaller Q-angle values than women due to their higher mean height and smaller pelvic width[8-10]. According to Hamill and Knutzen[10], Q-angles higher than 15 degrees are considered a *genu valgum*, whereas values lower than 10 degrees indicate a *genu varum*.Schweitzer and Miqüelluti[11] analyzed the postural pattern of young football players and found changes such as flexed knees and *genu varum*, which are due to the repetitive use of flexor and abductor muscles during kicking. One study with individuals 12 to 17 years old found that competitive football favors *genu varum* in male athletes when compared to non-athletes. It is assumed that repetitive microtraumas over the intern condyles due to training favor varism[12].

Bipedal postural control relies on sensory and motor information that is controlled by the central nervous system. Corrections in the vertical body axis in the upright posture induce slight and constant oscillations that have an important role in distributing plantar pressure[13]. The position of osseous parts of the lower limbs is controlled by the tonus of the muscles to which they are attached. However, joints also move around their own mechanical axes, causing tonic reactions and modifying pelvic and lower limb alignment. Thus, variations occurring at the feet may influence superior segments when load is received, and vice versa[14].

Structural changes in the knee joint and their influence on plantar pressure distribution can contribute to an increased incidence of overtraining injuries. Thus, the identification of overload areas that are capable to induce microtrauma or mechanical dysfunctions is relevant for athletes, as it provides information that is important for the maintenance of their physical integrity and is also useful for preventive research. One of the techniques used to assess the pressure exerted at the foot during standing is baropodometry, which quantifies the antero-posterior and lateral oscillations while the subject stands on a force platform[14].

The aims of this study were to verify the existence of an association between the Q-angle and the distribution of plantar pressure in football players, and to compare the characteristics of these athletes with non practitioners of this sport. The specific aims were to compare Q-angle values between football practitioners and non practitioners, and to compare plantar pressure values for different foot segments between the groups.

Methods

Design

A cross sectional study was undertaken.

Sample

A convenience sample of 121 male subjects 18 to 30 years old was selected: 50 football practitioners (FP) and 71 non practitioners (NP), totalizing 242 lower limbs. Subjects were not considered for inclusion if they presented with any of the following: subjects who were goal keepers (due to the specific requirements of this position) or amateur athletes; had suffered a recent traumatic/orthopedic injury to the lower limb that would make the assessment difficult to perform; had congenital malformation of the lower limbs; had sensory alteration in the feet; had body mass index (BMI) equal or superior to 31,6 kg/m^2 or inferior to 18.8 kg/m^2 (these limits were based on the findings of Pontes, Souza and Lima[15]).

The FP group was formed by professional players and university academics from Distrito Federal, Brazil. Professional players were recruited from Brazlândia Esporte Clube and Esporte Clube Dom Pedro II. University academics were recruited from Universidade Católica de Brasília (UCB), Faculdade Santa Terezinha (FAST) and União Pioneira de Integração Social (UPIS). The NP group was formed by academics and employees from UCB. Participants in the FP group practiced football-related activities on a regular basis; i.e., they had a minimum of three years of practice and enjoyed financial benefits (salary or scholarship) related to sport. Participants in the NP group were sedentary or practiced another non-professional sport modality.

After a brief explanation of the study, all participants signed an informed consent form, which was written according to the 196/96 resolution of the Conselho Nacional de Saúde, Brazil. The study was approved by the Research Ethics Committee of UCB (CEP/UCB nº 177/2007).

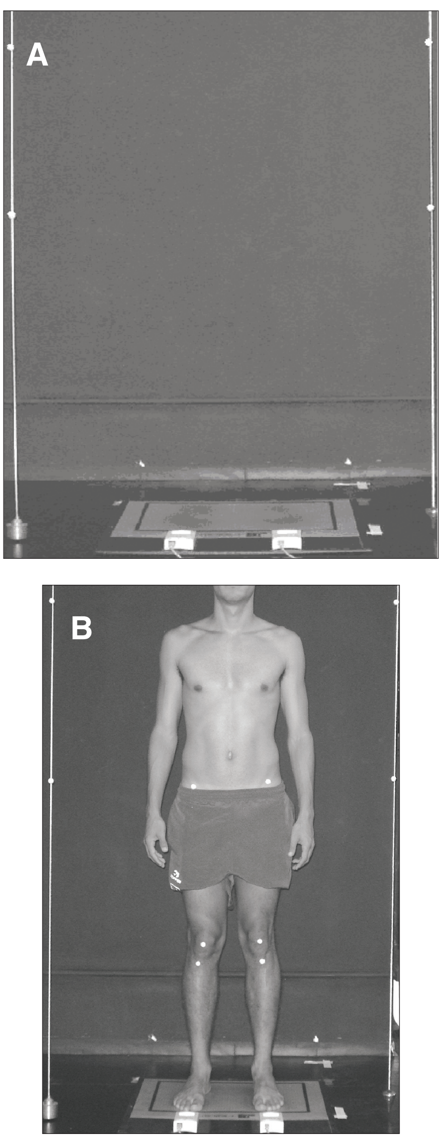


Figure 1. Environment for assessment and capture of previous view image, concomitant with plantar pressure.

Environmental assessment

This study was carried out in the Laboratory of Biomechanics of UCB between December 2007 and March 2008. In order to prepare the environment for photogrammetry, two plumb lines (parallel to each other and 100 cm apart) were fixed on the ceiling. Each line was marked with two styrofoam balls with 4.5 cm diameter and 50 cm apart. Superior marks were placed 150 cm from the floor (thus, inferior marks were 100 cm away from the floor). A pressure sensing floor mat (*F-Scan/F-Mat* System*, model 3100, version 4.21, Tekscan Inc, South Boston) was positioned between the two plumb lines, and the system was connected to a computer (Figure 1-A). The evaluation room was equipped with a table, two computers, a properly calibrated weighing scale (*Filizola*®, max 150 kg), a wall-mounted stadiometer (*Seca*®, precision 0.1 cm) and a digital camera (Sony® DSC-W35, 7,2 megapixels) mounted on a tripod (Manfrotto®, model 3047). The tripod was placed 300 cm away from the plumb lines and the camera lens was positioned at half of the participant's height[16].

Procedure and data collection

Participants were instructed to wear only shorts to facilitate the placing of anatomical markers for Q-angle measurement and to avoid any interference with the measurement of total body mass (TBM). First, participants' TBM and height (H) were measured. BMI was calculated by the *software of postural assessment* (SPA, version 0.68, updated in July 2007) through the formula BMI (kg/m^2) = TBM (kg) / H^2 (m). To screen for any sensory alteration in the feet (one of the exclusion criteria), sensation was evaluated by an estesiometer (0.2 g Semmes-Weinstein monofilament).

Then, for the assessment of Q-angle values, participants were asked to lay supine with the quadriceps muscle in a relaxed position and markers were placed on the center of the anterior aspect of the patella, tibial tuberosity and the anterior superior iliac spine[17]. Palpation skills were used for the correct placement of these markers, which followed the standards established by France and Nester[17], Hoppenfeld[18] and Kendall, McCreary and Provance[19]. Styrofoam balls similar to those previously described were used to identify the anatomical structures relevant for the measurement of the right and left Q-angles. The Q-angle value was determined by digital photogrammetry, with the software validated by Braz, Goes and Carvalho[16].

The participant was then instructed to stand between the two plumb lines, with both feet positioned on the pressure sensing floor mat. This positioning allowed simultaneous image caption of participant's anterior view and the static plantar pressure distribution (Figure 1-B). If necessary, the examiner corrected any rotation of the hip. The second toe, considered the feet midline and the axis of the tibiotarsal joint[20,21], was positioned in the same direction of the ipsilateral calcaneus without losing its contact with the platform. The second toe was also positioned perpendicular to the frontal plane not to influence Q-angle measurement[22]. As soon as the plantar pressure assessment began, an anterior view photograph was taken for the Q-angle analysis by SPA[16]. After the image caption, the participant was instructed to remain still on the platform for 10 seconds for the plantar pressure analysis[23]. The variables considered in the static pressure analysis were total peak pressure (kg/cm^2), right and left peak pressures (kg/cm^2) and force distribution in medial and lateral areas of the forefoot, medium-foot and hind-foot in each lower limb. Thus, four areas of interest were selected for the analysis of bilateral plantar pressure (Figure 2): medial region of the forefoot divided by the second toe line (D1 and E1); lateral region of the forefoot (D2 e E2); medium-foot (D3 e E3); calcaneus (D4 e E4).

Statistical and data analysis

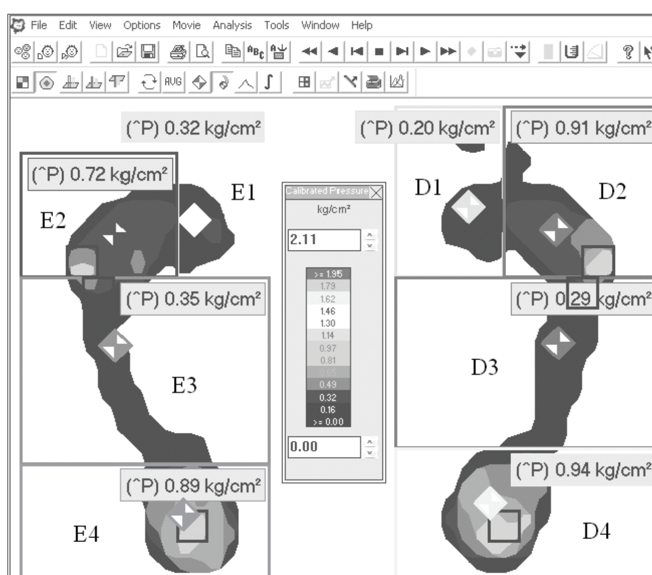
Statistical tests were selected as follows: (a) *Student-t* test for independent samples was used to compare the groups with respect to age, BMI, bilateral Q-angle value and bilateral plantar pressure in the four areas of interest; b) *Pearson* correlation coefficient was used to assess the correlation between the Q-angle value and peak pressure values in all areas of interest (this was done independently for each group and for each lower limb). Exploratory analyses and tests for normality of data were performed, showing that all variables were normally distributed with the exception of peak pressure values in the medial region of the left forefoot among NP. In this case, non-parametric tests were performed. All statistical procedures were performed using the *Statistical Package for Social Science* software for Windows (SPSS, version 10.0). A level of significance of 0.05 was considered for all analyses.

Results

No significant differences were found between groups with regards to age (p=0.31) and BMI (p=0.47), indicating some homogeneity within the sample. The *t*-test for independent samples demonstrated that bilateral Q-angle values were significantly smaller among FP than NP (p=0.001). Groups showed similar total peak pressures and peak pressures in each foot (Table 1).

When plantar pressure values were analyzed by foot segment, groups showed statistically significant differences in two segments (Table 2): FP presented higher peak pressures in the lateral region of the right (p=0.01) and left forefoot (p=0.05); NP presented higher peak pressures in the medium-foot area of the left foot (p=0.001). A strong trend was observed (p=0.06) for greater peak pressures in the medial region of the right forefoot among NP. No significant differences between the groups were found for plantar pressure values in the other segments. The *Mann-Whitney* non-parametric test was performed to compare peak pressure values in the medial region of the left forefoot and results showed no significant differences between the groups (z=-1.34; p=0.18) (Table 2).

Results of correlation analyses for the FP group showed a negative and weak correlation between the right Q-angle value and the peak pressure in the medium-foot area of the right foot (r=-0.32; p=0.02); i.e., in the right lower limb, a reduced Q-angle is associated with a higher peak pressure in the medium-foot area (Table 3). For the remaining foot areas, no evidence of correlation was found between their peak pressure and the Q-angle value in this group. However, a positive and weak trend (r=0.24; p=0.09) was found between Q-angle and peak pressure values in the left hind-foot. Results of all correlation analyses for the NP group were non-significant (Table 3).



D1=right forefoot, medial; D2=right forefoot, lateral; D3=mid-right foot; D4=right hind-foot; E1=left forefoot, medial; E2=left forefoot, lateral; E3=mid-left foot; E4=left hind-foot.

Figure 2. Separation of the feet in four areas in the FSCAN program version 4.21.

Table 1. Characterization of the sample by age, BMI, right and left Q-angles, right and left peak pressures, and maximum peak pressure.

Variables	FP (n=50)	NP (n=71)	t	p
Age (years)	23.7±3.2	24.3±2.5	-1.02	0.31
BMI (kg/m^2)	23.8±2.2	24.2±3.3	-0.73	0.47
Right Q-angle (degrees)	11.4±1,8º	13.8±1.4º	-7.98	0.001*
Left Q-angle (degrees)	11.0±1,6º	13.9±1.3º	-10.41	0.001*
Right Peak (kg/cm^2)	1.33±0.31	1.36±0.33	-0.56	0.57
Left Peak (kg/cm^2)	1.26± 0.37	1.26±0.31	-0.07	0.94
Maximum peak (kg/cm^2)	1.43±0.34	1.44±0.32	-0.28	0.77

*p≤0.05.

Table 2. Distribution of plantar pressures (kg/cm^2) for different foot segments in study groups.

Areas	FP (n=50)	NP (n=71)	t	p
D1: Right forefoot, medial	0.45±0.22	0.52±0.16	-1.91	0.06
D2: Right forefoot, lateral	0.77±0.32	0.63±0.22	2.66	0.01*
D3: Mid-right foot	0.51±0.24	0.54±0.18	-1.00	0.32
D4: Right hind-foot	1.23±0.41	1.32±0.39	-1.25	0.21
E2: Left forefoot, lateral	0.65±0.32	0.54±0.26	1.97	0.05*
E3: Mid-left foot	0.37±0.16	0.46±0.13	-3.39	0.001*
E4: Left hind-foot	1.16±0.40	1.22±0.35	-0.88	0.38

*p≤0.05. The E1 area, corresponding to the medial region of the left forefoot, was analyzed separately using the *Mann-Whitney* test, which showed no difference between the groups (z=-1.34; p=0.18).

Discussion

This study demonstrated a negative and weak association between Q-angle values and peak pressures in the medium-foot area of FP (right lower limb), which reflects a smaller angular value at the knee for a higher pressure at the osseous region of anterior tarsus and part of the metatarsus. No correlation was found between peak pressures in segmental areas of both feet and Q-angles among NP.

Tillman et al.[23] pointed out that an excessively large Q-angle can increase calcaneal eversion, thus positioning the subtalar joint in pronation. These changes would partially be responsible for the drop of foot's longitudinal arches. Tillman et al.[23] compared the Q-angle value and the positioning of the subtalar joint between genders and found a significant discrepancy only with regards to the Q-angle value (13.1±3.0º in men *versus* 17.5±3.8º in women). Olerud and Berg[24] assessed changes in Q–angle values following the positioning of lower limbs and found that values decreased as the feet moved from pronation to supination. This may suggest that a more pronated foot posture leads to higher medium-foot pressures, an indication that is consistent with our results for the FP group, even though the observed correlation was negative and weak.

When comparing the FP and the NP groups only in relation to the Q-angle, results of the present study are in agreement with the literature. Hahn and Foldspang[25] used goniometry to evaluate Q-angle values in 339 athletes, of whom 173 were FP participating in sports activities for a mean of 10 years. They found mean values of 10.0±0.5º for the right Q-angle and of 6.0±0.5º for the left Q-angle, and concluded that this variable was negatively associated to football. In the present study, photogrammetry was used to evaluate Q-angle values in 50 FP with mean sports participation of 12 years. Mean values found in this study were 11.4±1.8º for the right Q-angle and 11.0±1.6º for the left Q-angle.

As mentioned by Hamill and Knutzen[10], structural changes in the knee (*genu valgus* or *genu varum*) have an influence on Q-angle measurement. The greater the intercondylar distance, the smaller would be the angle formed by the anterior superior iliac spine, the center of the patella and the tibial tuberosity. Yaniv et al.[27] assessed the intercondylar distance in tennis players and FP and observed a higher prevalence of *genu varum* among FP (i.e., mean distances were 1.31 cm in tennis players and 2.99 cm in FP). According to the authors, this finding would indicate a genetic predisposition with a consequent natural selection process to the modality.If the Q-angle of these athletes had been investigated, it would be possible to observe smaller values among FP, as observed in the present study.

Woodland and Francis[28] stated that the Q–angle value can suffer changes due to muscle imbalance, tibial torsion, femoral anteversion and a high or low patella. In football, Abreu, Barbosa and Coelho[12] atributted the *genu varus* malalignment and the consequent decrease in the Q-angle to microtraumas over the femoral condyles of the athletes, which can be justified by constant changes in direction with greater load distributed over the lateral border of the foot. Chaudhari, Hearn and Andriacchi[29] associated the reduction in *genu valgum* to the practice of high-level football. Junge et al.[30] verified changes to the intercondilar space related to age, suggesting that the long-term practice of sports is associated with greater varism.

Hebert et al.[31] highlighted the popularity of the baropodometric exam, but warned that the standardization of data presentation is not yet in use. The authors therefore suggested that the following is assessed: plantar area; peak pressures (kg/cm^2); identification and quantification of overload areas; sensory perception. Wong et al.[32] evaluated peak plantar pressures in 15 FP while they were performing specific gestures for the sport. The authors divided the foot into 10 regions, including the medial and lateral regions of the forefoot, the medium-foot (medial, central and lateral parts), and the calcaneus (medial and lateral parts). Cavanagh and Rodgers[33] also divided the foot into segments to measure peak plantar pressures in 107 subjects with a mean age of 30.1±9.9 years old. Considering both limbs, mean pressure values were 1.40 kg/cm^2 in the calcaneus, 0.48 kg/cm^2 in the mid-foot, 0.71 kg/cm^2 in the lateral

Table 3. Correlation between the Q-angle and the distribution of plantar pressures for different foot segments in study groups.

Groups	Right Q-angle		Groups	Left Q-angle	
FP Right lower limb	r	p	FP Left lower limb	r	p
Foot area D1	-0.17	0.22	Foot area E1	-0.08	0.59
Foot area D2	0.02	0.88	Foot area E2	-0.17	0.23
Foot area D3	-0.32	0.02*	Foot area E3	-0.14	0.34
Foot area D4	0.21	0.15	Foot area E4	0.24	0.09
NP Right lower limb	r	p	NP Left lower limb	r	p
Foot area D1	0.00	1.00	Foot area E1†	-	-
Foot area D2	0.09	0.46	Foot area E2	0.04	0.72
Foot area D3	0.11	0.37	Foot area E3	-0.08	0.50
Foot area D4	-0.06	0.61	Foot area E4	-0.13	0.28

*$p \leq 0.05$. †For the distribution of plantar pressure in area E1 of NP (left lower limb), the *Spearman* correlation test was performed, which showed no association between variables ($r=-0.006$; $p=0.96$).

aspect of the forefoot, and 0.57 kg/cm^2 in the medial aspect of the forefoot. In the current study as well as in previous studies[32,33], the foot was divided into the four areas considered to be the most relevant for analysis. Results for NP were similar to those reported by Cavanagh and Rodgers[33], except for the lateral aspect of the forefoot, which presented a mean value of 0.58 kg/cm^2. FP presented mean values that were quite inferior to the mentioned study for the calcaneus (1.19 kg/cm^2) and the medial aspect of the forefoot (0.37 kg/cm^2).

When analyzing the plantar pressure variables in isolation, the FP group presented higher pressures in the lateral aspect of the right and left forefoot when compared to the NP group. In the region of the left medium-foot, the mean pressure value was significantly higher among NP. Gross and Foxworth[34] indicated that a larger Q-angle leads to a greater amount of pronation at the subtalar joint and consequently to greater levels of pressure in the medium-foot area. Therefore, smaller Q-angles would be associated with greater pressures in the lateral aspects of the foot. In the present study, even though participants in the FP group presented smaller Q-angle values and a greater area of contact in the middle-foot (which would suggest a greater flattening of the medial longitudinal arch), they also presented higher peak pressure values in the lateral aspect of the forefoot, confirming the assumptions made by Gross and Foxworth[34].

In the present study, there was an attempt to use only valid measurement instruments for the assessments. The authors acknowledge that the goniometer is not ideal to assess the Q-angle since the distance between the points disrupts the positioning of both fixed and mobile arms of the instrument[28,35]. Braz, Goes and Carvalho[16] validated the SPA for the assessment of body angles. Luo, Berglund and An[36] consider the pressure sensing floor mat as a reliable method and recommend it for the measurement of the static distribution of plantar pressure. One possible limitation of this study was the change in subjects' position during data collection. However, the investigators sought to minimize this problem.

Biomechanical investigations in FP contribute to the prolongation of their sport career, avoiding its interruption due to chronic-degenerative causes. Future studies should investigate biomechanical changes in beginner athletes to allow for early intervention, and evaluate the best intervention options; i.e., orthoses, posture correction or sport gesture appropriateness.

Conclusion

No association was detected between Q-angle values and the distribution of plantar pressure in NP. A weak and negative correlation was found only between the Q-angle value and peak pressure in the right medium-foot among FP. However, the athletes showed reduced Q-angle values and higher pressure peaks in the lateral aspects of both feet, suggesting the presence of a *genu varus* malalignment in the knee and a supine distribution of plantar bases.

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