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Original Article

Determining the relationship between the quadriceps and tibiofemoral angles among adolescents

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الملخص

أهداف البحث: فحص وجود أو عدم وجود علاقة بين زاوية العضلة الرباعية وزاوية الساق والفخذ، والمقارنة بين الطرفين السفليين فيما يتعلق بالطرف المهيمن، وفحص وجود اختلاف من عدمه في حالة ممارسة الرياضة.

طرق البحث: شارك في البحث ١٥٠ من اليافعين من عمر ١٢-١٨، وتم تقسيمهم إلى مجموعتين. مجموعة أ (المجموعة الرياضية)، بما في ذلك أربع مجموعات فرعية من مختلف الرياضات، ومجموعة ب (المجموعة غير الرياضية)، وتم قياس الزوايا عن طريق التصوير المحوسب.

النتائج: وجدت علاقة قوية بين زاوية العضلة الرباعية وزاوية الساق والفخذ، ووجد اختلاف بين الطرفين السفليين فيما يتعلق بقيم نفس الزوايا، ووجد اختلاف في القيم لنفس الزوايا بين الممارسين للرياضة وغير الممارسين للرياضة. ولكن لا يوجد اختلاف بين الرياضات المختلفة.

الاستنتاجات: لابد من قياس الزاويتين عند التقييم، والفحص للطرف السفلي مع مراعاة قياس كل طرف على حدا، وأيضا لابد من الأخذ في الاعتبار ممارسة الشخص للرياضة من عدمه عند التقييم.

الكلمات المفتاحية: التصوير المحوسب؛ الرياضين؛ اليافعين؛ زاوية الساق والفخذ؛ زاوية العضلة الرباعية

Abstract

Objectives: This study aims to determine the relationship between the quadriceps angle (Q-angle) and tibiofemoral angle (TF-angle) among adolescents. We also compared the angles between both the lower limbs with respect to dominancy, measured the difference between athletic and non-athletic angles, and explored the variations of these features in different sports.

Methods: We recruited 150 adolescents aged between 12 and 18 years and classified them into two groups; group A (athletic group), including four subgroups of players of different sports, and group B (non-athletic group). We measured the Q-angle and TF-angle via computerized photogrammetry.

Results: This study showed a strong and statistically significant relationship between Q-angle and TF-angle ($p < 0.05$). Similarly, we found a statistically significant difference in the Q-angle and TF-angle between both the lower limbs concerning dominance. Lastly, we identified a significant difference between the athletic and non-athletic groups. However, there was no difference among players of different sports ($p > 0.05$).

Conclusion: Our study showed a strong relationship between the Q-angle and the TF-angle. The Q-angle and the TF-angle should be measured bilaterally and the nature of sports should also be considered.

Keywords: Adolescents; Athletes; Photogrammetry; Quadriceps angle; Tibiofemoral angle

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Introduction

Posture is the kinematic relationship between the positions of the body segments at a certain moment. A state of dynamical balance between the muscles, joints and skeletal structures should be present in an ideal postural alignment, which would result in the generation of a minimal amount of effort and overload, leading to an optimal efficiency of the locomotive system.[1,2] Both, the postural assessment and the objective joint range of motion measurement are essential for diagnosis, planning and follow-up of the evolution and results of physical therapy treatment.[1]

Physical activity and sports practice have great benefits. However, concerns about injuries and overuse injuries are increasing especially among adolescents, who have higher rates of patellofemoral pain syndrome and knee injuries.[3]

Excessive increase in knee valgus could result in patellofemoral joint disorders such as chondromalacia and lateral dislocation of the patella[4] which would alter biomechanics and impair muscle levers, and thus, their functions.[5]

Both the Quadriceps angle (Q-angle) and the Tibiofemoral angle (TF-angle) are considered predictors of proper lower limb alignment from the frontal plane and proper knee joint functioning.[6]

The Q-angle is known as the angle formed between the patellar tendon and the muscles of the Quadriceps. It was first described by **Brattstrom.**[7] It is formed by two lines; the first line is extended from the centre of the patella to the anterior superior iliac spine ASIS, while the other line is extended from the centre of the patella to the tibial tuberosity.[6]

The TF-angle is defined as the angle formed between both anatomical axes of femur and tibia,[8] which could also be expressed indirectly by the intercondylar distance and intermalleolar distance.[9]

Although the Q-angle and the TF-angle are important tools in assessing knee joints, there are insufficient data regarding their relationship with each other, the variability of each angle in the same person concerning dominancy, and the effect of sports practice on them, especially the TF-angle. Thus, the objectives of this study are to investigate the relationship between the Q-angle and the TF-angle, the bilateral variability between both the lower limbs concerning dominance and sports practice.

We formulate the following hypotheses: a) there is no relationship between the Q-angle and TF-angle; b) there is no variability in angles between both the lower limbs concerning dominance; and c) there is no difference in the values of the Q-angle and the TF-angle caused by sport practice.

Materials and Methods

Study design

This study is the result of an observational cross-sectional design research conducted from September 2018 to January 2020.

Participants

A total of 150 healthy adolescents were recruited from schools and universities in Cairo/Giza Governorate and enrolled from egypt into this study. They were divided into two groups: group A (athletic group), including four subgroups of players of different sports (football, basketball, volleyball, and handball), and group B (non-athletic group). The inclusion criteria for both groups were: 1) adolescents aged 12−18 years old of both genders; 2) physically normal; 3) with an average body mass index (BMI), weight and height[10]; and 4) able to follow the instructions. Participants were excluded if they had a previous history of: 1) any neurological or musculoskeletal disorders affecting the lower limbs; 2) fractures or surgeries on the lower limbs; or 3) chronic cardiovascular or pulmonary disorders. The participant enrolment flowchart is provided in Figure 1.

The sample size for this study was estimated using the equation by **Hulley** et al. **(2013),**[11] which resulted in a total of 83 participants enrolled in this study. The equation is as follows:

The standard normal deviate for $\alpha = Z_\alpha = 1.9600$.
The standard normal deviate for $\beta = Z_\beta = 0.8416$

$$C = 0.5 * \ln[(1+r)/(1-r)] = 0.3128$$

$$\text{Total sample size} = N = [(Z_\alpha + Z_\beta)/C]^2 + 3 = 83$$

*r: the expected correlation coefficient.
*n: the total sample size.

Instrumentation

- A weight and height scale (RGZ-120 Health Scale, SMIC, Shanghai, China) was used to measure height in cm and weight in kg.
- Eight white markers were placed over selected anatomical landmarks during the measurement procedure to ease the analysis of the angles.
- A digital camera (Nikon COOLPIX S4300, resolution of 16MP″4608X3456″) was used to record the measuring procedure for later processing of angles. It was placed on a tripod.
- CorelDraw software, a 2D software, was used in the postural analysis.[12]

Procedure

All participants were informed of the procedures and the aim of the study and that they were free not to participate. A consent form was signed by their parents. All the data for this study were obtained by the same examiner.

Determining the dominant leg

Each subject was gently pushed while standing to disturb their balance, and it was noted which leg they used to break their fall; this was considered their dominant leg.[13]

Measuring of Q-angle and TF-angle

This study used a valid, reliable computerized photogrammetry method,[12,14−16] which is defined as a method that uses photographs as a tool to obtain body angle definitions in quantified data, with or without the use of external markers.[16] Each participant wore shorts during the procedure to allow the proper identification of landmarks. We palpated the bony landmarks of each angle carefully.

For the Q-angle, a white mark was placed over the ASIS, the centre of patella and the tibial tuberosity.

For the TF-angle, a white mark was placed over the ASIS, the centre of patella and the point in the middle between the lateral malleolus and the medial malleolus. After the marks were placed, each subject stood with their feet together, arms beside the body, and looking straight ahead with a black background behind them (Figure 2).

A camera was placed over a tripod at a height of 90 cm and was placed at a distance of 3 m from the subject.[14]

We took an image of the participant and processed it via CorelDraw X7 as follows:

- Each image was transformed into a black and white scale for better contrast;
- Unnecessary edges were cropped;
- The angular dimension tool was used to measure both angles. This was done by placing the node at the centre of the patella and extending both lines of the angle towards the ASIS and tibial tuberosity for the Q-angle, and extending them towards the ASIS and the midway point between the lateral malleoli and medial malleolus for the TF-angle (Figure 3).
- The calculation for the final value of the angle is as follows:

(Q-angle or TF-angle) = 180 - angle measured by CorelDraw.

Statistics

All statistical measures were performed using the statistical package for social studies (SPSS) version 24 for windows. Data were screened for normality, homogeneity of variance and presence of extreme scores. The Shapiro−Wilk test showed that the Q-angle and TF-angle were not normally distributed, so the spearmen correlation coefficient test was used to test the relationship between the Q-angle and TF-angle. The Man-Whitney U test was used to compare group A and group B. The Kruskal−Wallis test was used for further analysis regarding different sports branches in group A. The level of significance for all statistical tests was set at *P*-value < 0.05.

Results

The results revealed no significant differences ($p > 0.05$) between the subjects of the two study groups in terms of mean age, weight and height (see Table 1). Regarding the relationship between the Q-angle and TF-angle, a significant correlation existed between both the angles ($r = 0.73$ and $P < 0.05$). There was a significant difference between both legs in terms of the Q-angle in both the dominant and non-dominant legs of all subjects. Also, the TF-angle showed a significant difference between the dominant and non-
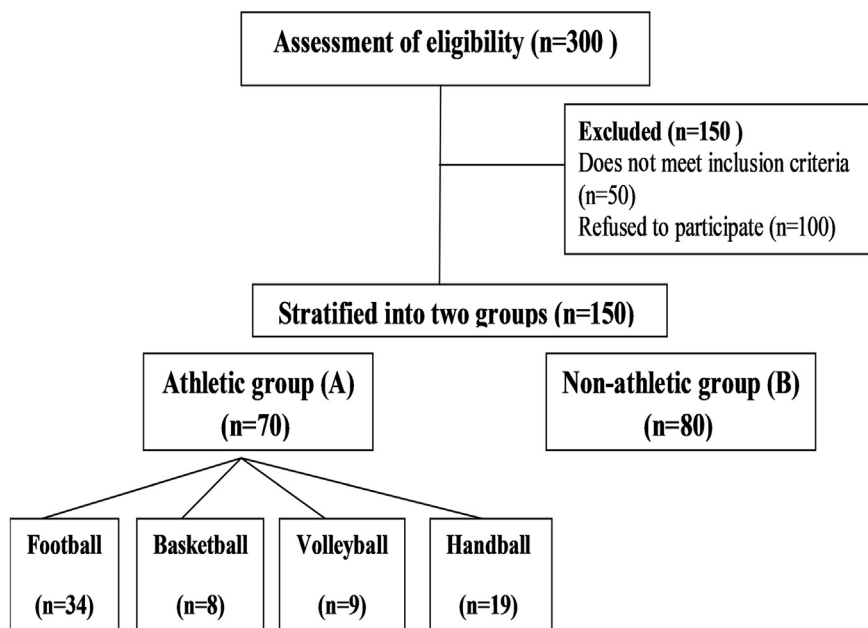

Figure 1: The participant enrolment flowchart.

Figure 2: The imaging process.

Table 1: The characteristics of participants' study groups.

| | Group A (n = 70) | Group B (n = 80) | t | p- |
	Mean ± SD	Mean ± SD	-value	value
Age (Years)	14.14 ± 2.038	13.61 ± 1.797	1.694	0.092
Weight (Kg)	52.81 ± 9.604	50.7 ± 10.067	1.311	0.192
Height (Cm)	159.06 ± 9.783	153.79 ± 9.397	1.591	0.114

SD: standard deviation; P-value: probability value.

Table 2: Comparison of the angles of both the dominant leg and non-dominant leg in each group.

	Dominant mean rank	Non-dominant mean rank	Mann W U	Z	P-value
Q-angle Group A	60.49	80.51	1749	−2.922	0.003
Q-angle Group B	69.84	91.16	2347.5	−2.909	0.004
TF-angle Group A	50.4	81.96	1648	−3.343	0.001
TF-angle Group B	71.16	89.84	2452.5	−2.551	0.011

MR: mean rank; Q-angle: Quadriceps angle; TF-angle: Tibiofemoral angle

dominant legs of all subjects(see Table 2). There was a significant difference in the Q-angle in both the dominant and non-dominant legs of both the groups. There was a significant difference in the TF-angle as well in the dominant and non-dominant legs of both the groups (see Table 3). However, in group A, there was no significant difference among the different sport categories regarding either angle (see Table 4).
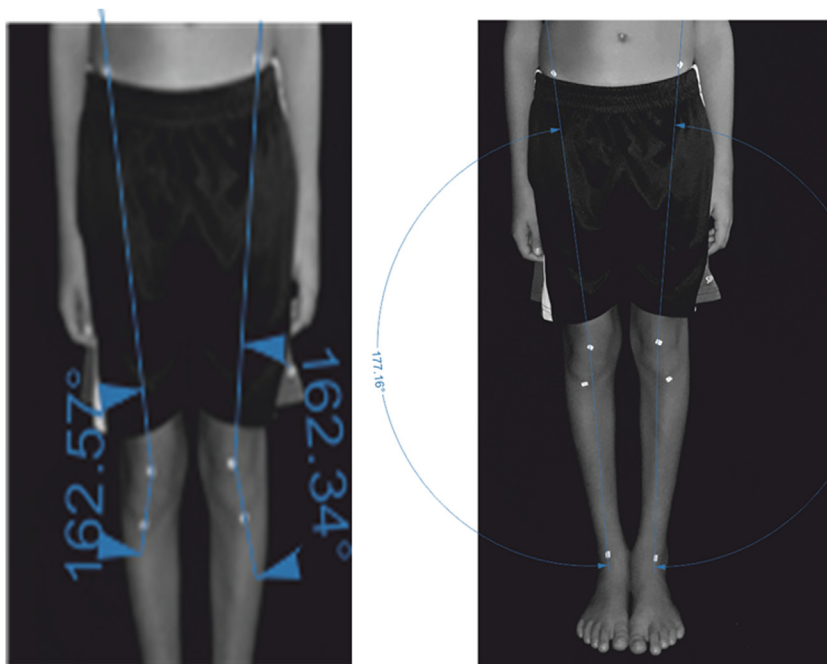

Figure 3: Processing of Q-angle and TF-angle by CorelDraw X7.

Table 3: Comparison of both the lower limb angles between group A and group B.

	Group A MR	Group B MR	Mann W U	Z	P-value
Q-angle dominant	40.89	105.79	337	−9.128	0.000
Q-angle non-dominant	40.45	106.17	364.5	−9.243	0.000
TF-angle dominant	47.76	99.78	858	−7.316	0.000
TF-angle non-dominant	44.3	102.8	616	−8.228	0.000

MR: mean rank; Q-angle: Quadriceps angle; TF-angle: Tibiofemoral angle.

Table 4: Comparison of Q-angle and TF-angle of players different sports in group A, concerning dominance.

	Mean rank				Chi	P-value
	Football	Basketball	Volleyball	Handball		
Q-angle dominant	35.76	25.88	45.11	34.53	3.846	0.279
Q-angle non-dominant	35.84	28.06	44.78	33.63	3.109	0.375
TF-angle dominant	35.63	42.56	38.56	30.84	2.163	0.539
TF-angle non-dominant	37.47	38.5	38.00	29.53	2.266	0.519

Chi: Chi-square.

Discussion

The objectives of this study are to investigate the relationship between the Q-angle and TF-angle in adolescents and examine the differences between both the lower limbs by taking into consideration leg dominance and sports practice.

The Q-angle is a very important tool in assessing the knee joint function and describing the biomechanical alignment and function of the lower limbs.[6] Abnormal values may lead to subsequent articular problems, and in certain cases may lead to subluxation of the patella or an increase in the risk of development of anterior cruciate ligament ACL injuries by influencing the quadriceps reflex time.[6] A Q-angle value of $20°-22°$ or more is considered one of the predisposing factors for patellar dislocation and anterior knee pain.[17]

Malone and Pfeifle[18] state that the normal range for Q-angle should fall between $13°$ and $18°$, with boys at the lower end of the range and girls at the upper end.

However, there is no consensus over the exact values of the TF-angle. While some studies state that the normal values are between $5°$ and $7°$,[19,20] others point out that a TF-angle of $10°$ is considered normal.[21] An increased TF-angle would place the patella more medially relative to the ASIS, and thus result in knee valgus placing greater stress on the lateral compartment of the knee.[8,20]

Considering the relationship between both the angles, our findings show that there is a strong positive relationship between the Q-angle and the TF-angle. These results were consistent with the findings of Daneshmandi et al.[22] who stated that a greater TF-angle leads to a greater Q-angle. Also, Nguyen et al.[8] and Mohanty and Koley[23] found a positive relation between the TF-angle and Q-angle, with r = 0.303 for the right lower limb, r = 0.352 for left lower limb, and p-value = 0.001 and r = 0.25. According to

Mohanty and Koley,[23] although the relation is positive, it is considered to be weak.

With regard to the bilateral variability of Q-angle, Raveendranath et al.[24] state that the Q-angles in male subjects have significant differences. Fatahi et al.[25] also investigated the Q-angle for the body side in volleyball athletes, their results showing no significant difference between both sides of values.

A study by Jaiyesimi and Jegede[26] found the Q-angle to have a significant difference between the right and left values, with the right side having higher values than the left. The study also found greater value asymmetry in females than in males. However, when it comes to dominance, there was no significant difference found between both the Q-angles.

Contrary to our results, most of the studies found that bilateral variability was not statistically significant.[18]

Our results are in concurrence with the findings of Sra et al.[27] and Livingston et al.[28] Even they found the Q-angle values were not bilaterally similar and that the difference was statistically significant. Further, in their investigation of bilateral variability between the left and right lower limbs' Q-angle, Chhabra et al.[29] found a significant difference between both the lower limbs.

The Q-angle shows an inverse relationship with quadricep strength. Thus, the smaller the angle, the greater is the quadricep's power, which suggests that individuals with above normal Q-angle have lower quadriceps strength and are more prone to the diseases of joint patellofemoral.[30]

Most researchers found that engaging in a regular sports practice with high lower limb activities would cause the Q-angle to be lower than normal.[31] This was consistent with our results, as group A, who played sports, had lower values than group B. This could be explained by the means of quadriceps muscle strength, in which the higher the muscle strength, the lower the Q-angle.[31]

Comparing the Q-angle of football players and wrestlers, Sen et al.[32] found significant difference between both values, with football players showing lower values among female football players and male wrestlers showing lower values than male football players.

Yilmaz et al.[33] found significant difference in the Q-angle of female athletes engaged in different sports (badminton, rugby, volleyball, basketball and futsal). However, our study showed the opposite, with no significant difference in the Q-angle of athletes playing different sports.

El Fouhil et al.[34] and Ekwedigwe et al.,[35] who were concerned with the bilateral variability of the TF-angle, found no significant difference between both the sides. However, our findings were the opposite of theirs.

The results of this study show a strong direct relationship between the Q-angle and TF-angle, and demonstrate that an increase or decrease in one of them would lead to the same in the other. The study also found that both the lower limbs do not have the same values concerning the Q-angle and TF-angle. Lastly, the study found the subjects engaged in sports have different values of the Q-angle and TF-angle from those not engaged in sports. However, the type of sports played might not make a difference.

Study limitation

Many subjects, especially the girls refused to participate in the study owing to the involvement of photography and issues pertaining to privacy, which made it difficult to collect samples.

Conclusions

The Q-angle and TF-angle are closely related, and thereby, the two angles should be measured concurrently in assessment. Bilateral evaluation of both the lower limbs should be taken into consideration while dealing with the Q-angle and TF-angle. Furthermore, the aspects of dominance and sports practice should be taken into consideration.

Recommendations

There is a need for further studies that investigate the difference in the Q-angle and TF-angle of people by considering the factors of gender and age.

Source of funding

This research did not receive any specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Conflict of interest

The authors have no conflict of interest to declare.

Ethical approval

The study was approved by the Ethical Research Committee of the Faculty of Physical Therapy, Cairo University, Egypt P.T.REC/012/002007 - 15th July, 2018.

Consent

The study's procedure was explained clearly to the subjects. Their parents signed a consent form before the subjects participated in the study.

Authors' contributions

MHG, AMT and NEM were involved in the formulation of ideas, the selection procedure and the study design. MHG provided research material, the clinical application of the procedure gathered and the organized data. MHG and NEM wrote the initial and final drafts of the paper. AMT and MHG carried out the analysis and interpretation of the data. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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