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Original Article

Correlation between the Q angle and the isokinetic knee strength and muscle activity

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ABSTRACT

Objectives: The aim of this study was to investigate the correlation between the Q angle and the isokinetic knee strength and muscle activity.

Patients and methods: Between March 2016 and April 2016, a total of 50 healthy and right-leg dominant men (mean age 22.3±2.3 years; range, 18 to 27 years) with a Q angle between 5° and 20° and active in sports were included. An isokinetic strength test of the knee joint extensor and flexor muscles at angular velocities of 60, 120, 180, 240, and 300°·s^{-1} was tested who had a Q angle of 5 to 20° and were active in sports. Surface electromyography (sEMG) was used to determine these muscles' activity levels.

Results: Negative correlations were between the Q angle and the average peak torque (APT) in extension $_{(E)}$ and flexion $_{(F)}$, the average power ($AP_{E,F}$) at all angles, the joint angle at the PT ($JAPT_E$) at 240, 180, 120 and 60°·s^{-1}; $JAPT_F$ at 300, 240 and 180°·s^{-1}; and the time to PT (TPT_F) at 180°·s^{-1}. There was a positive correlation between the Q angle and TPT_E (at 60°·s^{-1}). No significant relationship between the Q angle and the level of EMG activity at any angular velocity of the muscles, as well as the VM:VL EMG activity ratio was found.

Conclusion: A higher Q angle is associated with decreased isokinetic knee strength, power output, and torque angles. It is thought that possible high Q angle-related knee joint disorders and sports injuries can be avoided by including proper quadriceps strength exercises in exercise prescriptions to be prepared.

Keywords: Electromyography; isokinetics; muscle strength; patellofemoral joint; quadriceps angle; torque.

The Q angle is formed by the lines between the combined pull of the quadriceps and the patellar tendon[1] and is linked with the alignment of the lower extremity.[2] The biomechanics behind the pulling force from the quadriceps to the patellar tendon's knee joint is rather complex. Essentially, the role of the quadriceps in the knee joint motion is rather large both during physical activity and on absorptive capacity, when the joint is exposed to compressive and shear force.[2] According to studies, larger than normal Q angle values are the reason that the neuromuscular response and the reflex of the quadriceps increase and the explosive power and vertical jump power decrease.[3,4] It has been shown that an abnormally increased Q angle value, coupled with changes in neuromuscular control or a decrease in sporting activity, causes the knee joint activity plane to exceed its range, placing excessive stress on the joint.[5,6] Therefore, it can be suggested that the observed changes in the Q angle result in disabling individuals through the quadriceps abnormal exertion of force on the knee joint, and it is suggested that this potential for disability be acknowledged as a risk factor.[7]

Many studies have highlighted a negative correlation between the Q angle and quadriceps strength.[8-10] This negative relationship has been reported to depend on the developmental differences in force production ability in terms of increased muscle tone in the quadriceps and a drop in the Q angle.[11,12] Furthermore, this indicates that, relative to the vastus lateralis, the vastus medialis has observable starting time delays in muscle activity, and the proportional differences in balance between them is dependent upon the Q angle;

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the resulting misalignment of the lower extremity is due to excessive lateral patellar tracking.[2,13]

The Q angle, which has an important impact on evaluating both the knee joint and the knee joint's mechanical state in athletes, has been the subject of research studies. The Q angle, which is an indicator of normal alignment in the lower extremity as well as biomechanical function, simultaneously provides important data on the athlete's lower extremity functional capacity.[7,14]

In the present study, we aimed to investigate the correlation between the Q angle and the isokinetic knee strength and muscle activity.

PATIENTS AND METHODS

Between March 2016 and April 2016, a total of 50 healthy and right-leg dominant men (mean age 22.3±2.3 years; range, 18 to 27 years; height: 182.3±6.4 cm; weight: 78.0±9.3 kg) with a Q angle between 5° and 20° (mean Q angle: 13.0±6.4 degree; median Q angle: 10.5 degree) and active in sports were included on a voluntary basis. A written informed consent was obtained from each participant. The study protocol was approved by the Ondokuz Mayıs University Clinical Research Ethics Committee (No. OMÜ-KAEK 2015/154). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Procedures

Q angle measurements

No universally accepted normal or abnormal values of the Q angle exist due to lack of adequate reliability coefficient of the different methods and measures for this angle.[15] However, previous studies reported that the correlation between magnetic resonance imaging (MRI)-based measurements and goniometer-based measurements were similar.[1] In our study, Q angle measurements were taken manually with a standard goniometer. In the standing position, the participants faced forward and aligned the longitudinal axis of the foot, with the quadriceps in a relaxed state, and with equal load on each foot. It was ensured that the second digit and mid-heel were aligned perpendicular to the coronal plane. The goniometer's pivot point was placed in the center of the patella; the stationary arm was aligned with the tibia tubercle, and the moving arm was aligned with anterior inferior iliac spine. The goniometer value obtained was recorded as the "Q angle".

Electromyographic (EMG) measurements

During the isokinetic strength test, the vastus medialis (VM), vastus lateralis (VL), rectus femoris (RF), and biceps femoris (BF) muscle activity levels were measured. To prevent any potential artifacts from occurring, the areas where the electrodes were places were cleaned with rubbing alcohol. The electrodes were placed on the right lower extremity's responsive muscle fibers, which is parallel to the muscular belly.

Once the electrodes were placed on and strapped to the skin, the athletes, while seated, were provided with isokinetic dynamometers. The muscle activity responses were recorded using a 16-channel portable sEMG device (Biomonitor ME6000, Mega Electronics Ltd., Kuopio, Finland). The mean root mean square (RMS) values were calculated and analyzed using a 1000-Hz sample data-regulating EMG device, together with specifically-created computer software (MegaWin 3.0) for the collected data. In this study, the RMS value was used, as it is a parameter that better reflects the level of muscle activity at rest and during contraction, and, therefore, one of the most widely used in scientific studies.[16]

Isokinetic measurements

The isokinetic strength tests were performed using a Humac Norm dynamometer and the data were collected with Humac2009 v10 software (CSMI, Stoughton, Massachusetts, USA). Before beginning the isokinetic test, a five-min warm up exercise on a cycle ergometer was done to keep the athletes' heart rates between 100 and 120 beats per min. To allow participants to be able to sit comfortably, the dynamometer seat's back support was adjusted at a hip-joint angle of 85° (0°=full extension). At the extremity being measured, knee adaptors were placed at approximately 2 to 3 cm proximal to the dorsal surface of the foot. During measurement, to stabilize and isolate the entire body, the chest, pelvis and femoral arches were kept stationary with straps. To avoid contralateral extremity movement, the ankles were secured by stabilizing them underneath the chair.

To familiarize the participants with the isokinetic dynamometer isokinetic contractions were done with angular velocities of 240 and 300°·s^{-1}. For adaptation, each participant performed 15 maximal concentric extension and flexion with 45-s rest between velocities, which included a two-min resting period before the test. After the adaptation period, each participant completed five maximal repetitions at 60, 120, 180, 240, and 300°·s^{-1}. One-min rest periods were allowed

Table 1. Correlation coefficients between Q angle and isokinetic knee strength measurements, electromyographic measurements at five different velocities

	300°·s⁻¹		240°·s⁻¹		180°·s⁻¹		120°·s⁻¹		60°·s⁻¹	
	r	p	r	p	r	p	r	p	r	p
APT_E (Nm)	-0.350	0.013	-0.464	0.001	-0.550	<0.001	-0.565	<0.001	-0.309	0.029
APT_F (Nm)	-0.363	0.010	-0.383	0.006	-0.420	0.002	-0.470	0.001	-0.342	0.015
AP_E (watt)	-0.322	0.023	-0.249	0.002	-0.520	<0.001	-0.525	<0.001	-0.325	0.021
AP_F (watt)	-0.317	0.025	-0.379	0.007	-0.447	0.001	-0.470	0.001	-0.394	0.005
$JAPT_E$ (o)	-0.236	0.098	-0.416	0.003	-0.415	0.003	-0.551	<0.001	-0.571	<0.001
$JAPT_F$ (o)	-0.377	0.007	-0.317	0.025	-0.407	0.003	-0.214	0.135	-0.108	0.456
TPT_E (s)	0.048	0.738	-0.001	0.995	-0.193	0.179	0.141	0.328	0.295	0.037
TPT_F (s)	-0.240	0.093	-0.245	0.086	-0.353	0.012	-0.183	0.204	0.103	0.477
VM (μV)	0.050	0.730	0.068	0.640	0.027	0.854	0.065	0.656	0.121	0.404
VL (μV)	-0.083	0.568	-0.049	0.733	-0.082	0.576	-0.028	0.847	-0.081	0.578
RF (μV)	-0.191	0.184	-0.164	0.254	-0.103	0.477	-0.037	0.800	-0.013	0.926
BF (μV)	-0.102	0.482	-0.090	0.535	-0.083	0.565	-0.011	0.942	0.153	0.290
VM:VL (%)	0.219	0.126	0.133	0.359	0.177	0.218	0.132	0.361	0.054	0.710

APT: Average Peak Torque; AP: Average Power; JAPT: Joint Angle at Peak Torque; TPT: Time to Peak Torque; VM: Vastus medialis; VL: Vastus lateralis; RF: Rectus femoris; BF: Biceps femoris; $_E$: Extensor; $_F$: Flexor.

between repetitions. All participants were given encouragement for their efforts throughout the test.

Outcomes of the isokinetic strength test included average peak torque (the average of all peak torques for each repetition performed), average power (total work divided by the time taken to perform the work), joint angle at peak torque (the joint angle at which peak torque occurs), and time to peak torque (a measure of time from the start of the muscular contraction to point of the highest torque development) for knee flexion and extension. All outcome measurements were calculated by the Humac2009 v10 software (HUMAC2009, CSMi, Stoughton, MA, USA).

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 20.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean and standard deviation. The normality of the data was tested using the Shapiro-Wilk test, and the results showed a normal distribution. The statistical relationship between variables was confirmed using the Pearson's correlation analysis. A p value of <0.05 was considered statistically significant.

RESULTS

Negative correlations were between the Q angle and average peak torque (APT) in extension$_{(E)}$ and flexion$_{(F)}$, the corresponding average power (AP), the joint angle at the PT ($JAPT_E$) at 240, 180, 120 and 60°·s^{-1}; $JAPT_F$ at 300, 240 and 180°·s^{-1} ; and the time to PT (TPT_F) at 180°·s^{-1} (Table 1). There was a positive correlation between the Q angle and TPT_E (at 60°·s^{-1}) (Table 1). No correlation was indicated between the Q angle and the level of EMG activity as well as the vastus medialis:vastus lateralis (VM:VL) EMG activity ratio (Table 1).

DISCUSSION

Binder et al.[17] compared peak torque, work, and power values and researched the effects of the Q angle; and they observed that as the Q angle decreased, while APT and AP values increased. The results of the isokinetic tests carried out at 60, 180, and 300°·s^{-1} showed that only a velocity of 300°·s^{-1} did individuals with a low Q angle produce higher APT values, which, nevertheless, indicated a negative relationship between overall APT values and the Q angle. As for the relationship between the AP parameter and the Q angle, significant statistics were recorded at 60°·s^{-1}, also yielding a negative relationship between the AP values and the Q angle. Another study investigating the Q angle value differences showed similar outcomes and the authors concluded that there was a negative, but weak correlation between the APT and Q angle.[8] Messier et al.,[18] in a study investigating the etiological factors behind patellofemoral pain syndrome (PFPS) observed in runners, found that individuals with high Q angle values had both a low APT and low overall work parameters. Another study by Boucher et al.[19] compared the direct relationship between high Q angle values and PFPS with 90, 30, and 15°·s^{-1} of knee extension torque and observed that, for PFPS-diagnosed individuals with high Q angle values, as the flexion-extension narrowed, a drop in peak torque was indicated.[19] In analyzing the data obtained from this study and the aforementioned studies, statistically more significant findings are drawn. The results of the isokinetic contractions carried out at all angular velocities indicate a negative correlation between the Q angle at 120, 180, and 240°·s^{-1} and APTE parameters, and a weak negative correlation at 60 and 300°·s^{-1}. When the knee extensor mechanism, together with the Q angle, increased due to the vector from the applied pulling force of the patellar tendon, a sharp spike in the force vector occurred in lateral anterior aspect of the patella.[20,21] This is referred to as the Q angle effect.[22] This effect describes a force by the quadriceps's vastus medialis oblique (VMO) section to apply more force to narrow the Q angle. A high Q angle leads to more lateral tracking of the patella, and, to correct such a situation, the VMO also has to apply more force.[23] The differences in JAPT and AP parameters of the participants could be due to weak muscle strength of displacing laterally movement of the patella or should not being able to provide dynamic stabilization of the proper movement by placing patella in intercondylar sulcus of femur with quadriceps. Thus, as with the patellar maltracking, this might also be why there is a drop in power production capacity during the range of motion (ROM) of the knee joint. Many studies have shown that the quadriceps muscle strengthened by dynamic strength exercises tends to straighten the Q angle.[12,24-26]

In the literature, differences pertaining to the JAPT indicate a potential tie to the participants' type of sports as well as demographic, anthropometric, and physiological qualities; however, as we have seen both in our study and other studies, a limited number of studies on the direct relationship between the Q angle and both the important role of the knee joint's biomechanics and the lower extremity's alignment, strength, and power output are available. Lyon et al.[27] examined how the Q angle, during isokinetic knee extensions performed at 30, 60, and 180°·s^{-1}, elicited changes in the JAPT. The study was conducted on on-duty female personnel of the United States Army, in which participants were categorized into those having Q angles of 11° and below (low), between 12° and 18° (medium), and 19° and above (the highest). Considering the differences in Q angles, when comparing the JAPT parameters, no significant differences were found. Contrary to Lyon et al.'s findings, in this study, there was a negative correlation between the values of the knee's extensor muscle groups JAPT parameters at 60, 120, 180, and 240°·s^{-1} and the Q angle. Regarding the correlations of the knee joint flexor muscle groups, they were negative at 240 and 300°·s^{-1}; at 180°·s^{-1}, they were negative but weak. No statistically significant relationship between the $JAPT_F$ at 60 and 120°·s^{-1} and the $JAPT_E$ at 300°·s^{-1} was found. Regarding the relationship between the difference in JAPT and Q angle, JAPT parameters and differences in age, sex, and type of sport, as well as JAPT flexor and extensor differences, many researches have been performed from the perspective of muscle fiber length. The common consensus from the vast majority of those involved in this research is that there is a reverse relationship between muscle fiber length and JAPT parameters, and a significant correlation between age and the JAPT; from the perspective of sex, women, who have a weaker strength production potential than men, have higher JAPT values, and the protocols that trainers use and those parallel in different type of sports seem to affect JAPT parameters.[28,29] When taking male performance and sex-based factors into consideration, the findings from this study and other studies are qualitatively supported.

Using the TPT from the results released from the isokinetic strength test and its correlation with the Q angle, only the TPT_E at 60°·s^{-1} produced positive and the TPT_F at 180°·s^{-1} produced negative but weak results. A study was found in the literature reviews comparing the Q angle with TPT parameters. Concurrently, in studies among children and adults accounting for differences in sex, it is worth mentioning that sex factors do not affect TPT parameter; however, age may. Although there are no major distribution differences between men and women's muscle fiber types, there is a possible effect in terms of the rapid rate of changes in power output.[30,31] It has been reported that the effect of age factor on the TPT may be due to the effects of dynamically faster contraction of the sarcomeres and increased muscle strength with exercise in the adults.[30] The lack of a statistical relationship in our study between the TPT parameters and the Q angle could be because the participants were all adult men who were trained; they all had predominantly similar muscle fiber types and were active in their type of sports.

Upon analysis, a significant correlation between EMG data collected from the study and the Q angle was not found. Thus, independent of the Q angle differences, in the isokinetic tests performed on the participants at different angular velocities, the outcome may be because maximum effort was exerted. In our findings, as participants were encouraged to put in maximum effort, variation in muscle contraction, independent of angular velocity differences and sex-based factors, points to the observed similar muscle action resulting from all motor units being utilized, which is consistent with the findings of many other studies.[32,33] When considering differences in the angular velocity as well as comparing the Q angle and EMG values, a significant correlation between the VM, VL, RF, BF and the Q angle was unable to be established. None of the participants had knee injury, and thus the VM:VL EMG activity ratio was set at approximately 1:1. Our confirmed results are supported by the similar results encountered in the research of Sogabe et al.[34] on individuals with neither knee pain nor with knee injury.

In conclusion, according to our study findings, a correlation was observed between the Q angle and the knee joint strength and its related parameters; on the contrary, there was no correlation with muscle activity levels. It has been established that an increased Q angle causes the knee joint torque and power values to decrease, showing the angle to have a negative correlation with the resulting peak torque; thus, it has an important effect on the development of the peak torque. Based on the results, it is thought that potential high Q angle-related knee joint disorders and sports injuries can be avoided by including proper quadriceps strength exercise prescriptions to be prepared. The results suggest a need for further examination of the knee extensor and flexor mechanism in a variety of activities. Additionally, as the investigations were only performed on healthy athletes, it is not clear whether a sedentary or patient population would show the same amount of isokinetic strength and muscle activity during these exercises.

Declaration of conflicting interests

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