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ORIGINAL ARTICLE

QUADRICEPS FEMORIS ANGLE OF ELITE AND NON-ELITE ATHLETES IN OLYMPIC STYLE WEIGHTLIFTING

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ABSTRACT

OBJECTIVE: To find out the quadriceps femoris angle (Q-angle) values of elite and non-elite athletes in Olympic style weightlifting.

METHODS: This study included 22 male elite athletes that won medals in international Olympic style weightlifting championships and 22 male non-elite athletes who won medals in national Olympic style weightlifting championships. A goniometer was used to determine the angle of the quadriceps femoris muscle while the athletes were in supine position and the muscle was inactivated. Anthropometric measurements of right-left thigh and lower leg length, right-left thigh and calf girth, and pelvic width of athletes were obtained. One repetition maximum of snatch, clean and jerk and leg strength of the athletes was recorded. To study demographic characteristics and some anthropometric values of lower extremity of the athletes, t-Test was conducted for independent groups. To compare anthropometric measurements of right-left lower extremity and right-left Q-angle values, paired sample t-Test was used. Right-left Q-angle values and relations among other variables were studied by Pearson correlation analysis. SPSS was used for all analyses.

RESULTS: Mean age was 19.73±2.97 years and 18.73±1.55 years for of elite and non-elite athletes respectively. No significant difference was observed in demographic characteristics and in some anthropometric values of lower extremity of elite and non-elite athletes ($p>0.05$). However, right-left Q-angle values of non-elite athletes (10.14±1.55° and 10.14±1.52°, respectively) were higher than the right-left Q-angle values of elite athletes (8.32±1.39° and 8.32±1.32°, respectively) [$p<0.003$].

CONCLUSIONS: Olympic style weightlifting, which is maintained in elite level, affects the quadriceps femoris angle.

KEY WORDS: Athletes (MeSH); Elite Athletes (MeSH); Goniometry (Non-MeSH); Olympic style weightlifting (Non-MeSH); Q-angle (Non-MeSH); Quadriceps Muscle (MeSH); Weight Lifting (MeSH); Anthropometry (MeSH); Body Weights and Measures (MeSH).

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INTRODUCTION

The quadriceps angle (Q-angle) is defined as the acute angle formed between lines from the anterior superior iliac spine to the center of the patella, and from the center of the patella to the center of the tibial tubercle.[1-3] Q-angle is frequently used to define relations between athletic injuries and physical factors, besides, it is a primary indicator of tendency to injuries.[4] When the Q-angle exceeds 15-20°, it is thought to increase knee extensor mechanism dysfunction and patellofemoral pain as it also increases the tendency for lateral patella mal-position.[5] Unusual increases in the value of Q-angle are can cause changes in neuromuscular control, extreme stress on joints owing to change in the knee-joint movement plane and low athletic performance.[6,7] In some studies, it is reported that Q-angle is correlated with knee joint and muscular power, and an increase in Q-angle lowers the power of quadriceps muscular.[5,8,9] Moreover, it is also reported that Q-angle is affected by many factors such as gender, dominant foot use, the type of sports and training years and that sports comprising a great number of quadriceps trainings might be associated with lower Q-angle values.[10] In studies including individuals into different types of sports, it is reported that Q-angle is correlated with parameters like femur length, thigh girth, calf circumference, pelvic width and training years.[11,12] Some studies refer that right-left Q-angle develop asymmetrically[4,10,12-14] whereas some other studies report no asymmetry.[15] The observed Q-angle asymmetry is reported to be related to knee injuries in different athletic activities.[16]

This study aims to find out Q-angle values of elite weightlifting (EWL) athletes and non-elite weightlifting (non-EWL) athletes in Olympic style weightlifting and to compare Q-angle value findings with some physical parameters such as high length, thigh girth, lower leg length, calf girth, pelvic width along with other parameters like leg force, training years, the number of weekly trainings, athletic performance.

METHODS

Participants

The study included 44 volunteer male athletes, 22 elite medal-winner athletes whom participated in international Olympic style weightlifting championships (EWL) (n=22, 60% participated in European Weightlifting Championship, 15% participated in World Weightlifting Championship, 25% participated in International Weightlifting Tournaments and 22 non-elite athletes participated in national Olympic style weightlifting championships (non-EWL) (n=22, ranking in the first three athletes in Turkish Weightlifting Championships). Our study group included elite weightlifting athletes, however, due to pandemic conditions we were unable to reach all elite weightlifters in the country, therefore, we could not carry out G-power analysis and we chose 22 EWL and 22 non-EWL. As these groups of 22 athletes were enough to conduct t-Test, we decided on a total number of 44 athletes. EWL group was selected from a number of athletes having regular and active exercise (at least 6 days a week) for the last 5 years in Turkish Olympic Preparation Centers (participated in 2019 and 2020) and non-EWL group was selected from athletes having regular exercise (at least 3 days a week, participated in weightlifting championships in 2019 and 2020) for the last 2 years in different cities of Turkey. Before measurements, each participant was asked whether he had an injury or an operation on lower extremity and physical treatment of the groups was conducted by an expert physician (O.T). All athletes in the study were asked to sign informed consent form.

For both groups, athletes with orthopedic problems, surgery in lower extremity, pain on lower extremity and those under 18 were excluded from the study. Since muscular force might be higher in dominant extremity, which might affect Q-angle, athletes with dominant left lower extremity were also excluded (those using left leg dominantly during jerk shot were also excluded). Athletes with dominant right lower extremity were included in the study. To determine dominant foot, the participants were asked which foot they use regularly in daily life or in athletic activities and their answers were recorded. The study complies with the Declaration of Helsinki and the ethical approval of the study was obtained from the University of Necmettin Erbakan, Health Sciences Scientific Research Ethics Committee (Numbered 14-81, 2021).

EXPERIMENTAL PROTOCOL

Q-angle and lower extremity measurements

The right and left knee Q-angles of the athletes were measured when the knee and hip were in full extension in supine position without shoes. Before measurements, the borders of the patella, the tibial tuberosity and the anterior superior iliac spine were located by careful palpation. The goniometer (Base line plastic goniometer, Netherlands) was placed on the center of the patella; the longer arm was directed to the anterior superior iliac spine and the shorter arm to the tibial tuberosity. The athletes were instructed to keep the quadriceps muscles as relaxed as possible. Right and left Q-angle measurements were recorded in degrees.[17-19] When the athletes were in supine position, thigh and lower leg length- girth of both sides, pelvic width were measured by a measurement tape (with 1mm interval). Thigh length (TL): The distance between trochanter major and patella (from the center) was measured. Thigh girth (TG): The athletes were asked to stand and open their legs as far as the length of their shoulders. The measurement was made from the largest part closest to the groin (at m. quadriceps extension). Lower leg length (LL): The distance between tibial condyle and medial malleolus was measured. Calf girth (CG): The athletes were asked to open your legs slightly and the measurement was made from the greatest circumference of the calf. Pelvic width (PW): The pelvic width was measured as the distance between the anterior superior iliac spines in supine.[19-21] At the time of the Q-angle and anthropometric measurements, all subjects completed a questionnaire on baseline characteristics including age, the number of weekly trainings, the total time of trainings, total years of training. Anthropometric measurements were taken on day/days when the athletes did not train. All measurements were taken by the same investigator (M.K.A).

The determination of athletic performance and leg force of athletes in Olympic style weightlifting

One-repetition maximal (1RM) snatch and clean-and-jerk records for the last two years (2019-2020) gained by the athletes in World weightlifting championships, European weightlifting championships, International tournaments and weightlifting championships in Turkey were taken from the official websites of World Weightlifting federation (https://www.iwf.net/new_bw/results_by_events/), European Weightlifting federation (http://result.ewfed.com/) and Turkish Weightlifting Federation (https://halter.gov.tr/sonuclar/). Before leg force measurements, they were asked to warm up for 5 minutes. The dynamometer (Takkei-Japan) was set to start position for test when their knees in flexion. Later, when their elbows were in extension, backs were straight and bodies were in flexion, they were asked to grasp the dynamometer by hands and lift it up vertically with maximum force by feet. The lift up procedure was repeated for three times and the best score was recorded.[22]

STATISTICAL ANALYSIS

Before basic analyses, descriptive statistics related to demographic characteristics were examined. To study demographic characteristics and some anthropometric values of lower extremity of EWL and non-EWL, a series of t-Test was conducted for independent groups. To find out normality premise, Skewness-Kurtosis, histograms and Q-Q plots were also studied. As the findings proved to comply with normality premise of the variables, t-Test analysis was used for independent groups. To compare anthropometric measurements of right-left lower extremity and right-left Q-angle values, paired sample t-Test was used. Besides, as the study included many comparisons, Bonferroni correction was preferred[25]. Moreover, right-left Q-angle values and relations among other variables in the study were studied by Pearson correlation analysis. Statistical significance level in t-Test of independent groups was $p<0.003$ and $p<0.01$ for paired sample t-Test. SPSS [23] software was used for all analyses (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.).

TABLE I: COMPARISON OF DEMOGRAPHIC, PHYSICAL CHARACTERISTICS AND Q-ANGLES OF ATHLETES

Variables	Groups	n	Mean	SD	*T*	*P*	95% Confidence Range	
							Lower Value	Upper Value
Age (years)	EWL	22	19.73	2.97	.09	.93	-1.98	2.16
	Non-EWL	22	18.73	1.55				
Height (m)	EWL	22	1.71	.04	-2.13	.04	-.06	.00
	Non-EWL	22	1.73	.05				
Weight (kg)	EWL	22	81.05	17.03	-.08	.94	-11.68	10.81
	Non-EWL	22	81.48	19.82				
BMI (kg/m^2)	EWL	22	27.73	5.14	.41	.68	-2.74	4.16
	Non-EWL	22	27.02	6.15				
Right TL (cm)	EWL	22	39.93	2.27	-2.69	.01	-3.18	-.45
	Non-EWL	22	41.75	2.21				
Left TL (cm)	EWL	22	39.93	2.27	-2.69	.01	-3.18	-.45
	Non-EWL	22	41.75	2.21				
Right TG (cm)	EWL	22	61.48	7.20	.19	.85	-4.27	5.18
	Non-EWL	22	61.02	8.28				
Left TG (cm)	EWL	22	61.07	7.13	.26	.80	-4.00	5.18
	Non-EWL	22	60.48	7.94				
Right LL (cm)	EWL	22	41.98	2.26	-.99	.33	-2.00	.68
	Non-EWL	22	42.64	2.15				
Left LL (cm)	EWL	22	41.98	2.26	-.99	.33	-2.00	.68
	Non-EWL	22	42.64	2.15				
Right CG (cm)	EWL	22	38.86	4.36	-.19	.85	-3.12	2.58
	Non-EWL	22	39.14	4.99				
Left CG (cm)	EWL	22	38.71	4.39	-.16	.87	-3.08	2.62
	Non-EWL	22	38.93	4.96				
PW (cm)	EWL	22	30.16	3.14	1.21	.23	-.80	3.21
	Non-EWL	22	28.96	3.44				
Right Q-angle (^{0})	EWL	22	8.32	1.39	-4.09	.000	-2.72	-.92
	Non-EWL	22	10.14	1.55				
Left Q-angle (^{0})	EWL	22	8.32	1.32	-4.23	.000	-2.69	-.95
	Non-EWL	22	10.14	1.52				

EWL: Elite athletes in Olympic style weightlifting, TL: Thigh length, TG: Thigh girth, LL: Lower leg length, CG: Calf girth, PW: Pelvic width, $p < 0.003$

RESULTS

Demographic characteristics and anthropometric values of EWL and non-EWL are shown in Table I. From a series of t-Tests for independent groups, a significant difference was observed only in right-left Q-angle values of the groups ($t(42)= 4.09$, $p<0.001$ and $t(42)= 4.23$, $p< 0.001$, respectively). From the findings, it was observed that both right and left Q-angle values of EWL were lower than right and left Q-angle values of non-EWL. Moreover, to compare anthropometric measurements of right-left lower extremity of EWL and non-EWL and right-left Q-angle values, paired sample t-Test was conducted. From the findings, both in EWL and non-EWL, right TG was determined to be higher than left TG ($t(21)= 3, 50$, $p<0.01$, $t(21) = 3,32$, $p<0.01$, respectively). No significant difference was observed among Q-angle values and other measurements in the study ($p>0.05$).

To evaluate EWL and non-EWL groups for 1RM snatch, 1RM clean and jerk, leg strength, training experience and the number of weekly trainings, a series of

TABLE II: WEIGHTLIFTING PERFORMANCE, LEG STRENGTH, TRAINING YEARS AND THE NUMBER OF WEEKLY TRAININGS OF THE ATHLETE GROUPS IN THE STUDY

Variables	Groups	n	Mean	SD	t	*p*	95%Confidence Range	
							Lower Value	Upper Value
1RM snatch (kg)	EWL	22	130.09	19.146	5.709	.000	20.66	43.25
	Non-EWL	22	98.14	17.966				
1RM clean and jerk (kg)	EWL	22	157.00	25.213	5.208	.000	22.69	51.40
	Non-EWL	22	119.95	21.851				
Leg strength (kg)	EWL	22	183.477	39.5873	.865	.392	-12.98	32.43
	Non-EWL	22	173.750	34.8960				
Training experience (years)	EWL	22	7.00	2.309	6.428	.000	2.37	4.54
	Non-EWL	22	3.55	1.011				
The number of weekly trainings (day)	EWL	22	6.27	.550	13.342	.000	2.08	2.83
	Non-EWL	22	3.82	.664				

EWL: Elite athletes in Olympic style weightlifting, 1RM: One-repetition maximal

TABLE III: THE CORRELATIONS BETWEEN Q-ANGLE VALUES AND DEMOGRAPHIC CHARACTERISTICS, SOME ANTHROPOMETRIC VALUES AND OTHER VARIABLES OF EWL AND NON-EWL GROUPS

Variables	EWL		Non-EWL	
	Right Q-angle (^{0})	Left Q-angle (^{0})	Right Q-angle (^{0})	Left Q-angle (^{0})
Right Q	1	.976***	1	.980***
Left Q	.976***	1	.980***	1
Age (years)	-.127	-.122	-.142	-.125
Height (m)	.037	-.034	-.244	-.249
Weight (kg)	.001	-.092	-.121	-.178
BMI (kg/m^2)	-.020	-.103	-.071	-.129
Right TL (cm)	.000	-.016	-.110	-.175
Left TL (cm)	-.119	-.190	.395	.403
Right TG (cm)	.233	.197	.469*	.464*
Left TG (cm)	.233	.197	.469*	.464*
Right LL (cm)	-.118	-.209	-.184	-.225
Left LL (cm)	-.105	-.197	-.158	-.205
Right CG (cm)	-.315	-.300	.044	.074
Left CG (cm)	-.315	-.300	.044	.074
PW (cm)	-.098	-.211	-.055	-.081
1RM snatch (kg)	-.066	-.180	-.067	-.103
1RM clean and jerk (kg)	-.230	-.208	-.026	-.026
Leg strength (kg)	-.310	-.345	-.231	-.311
Training experience (years)	-.282	-.318	-.217	-.305
The number of weekly trainings (day)	-.316	-.328	-.373	-.416

*p < 0.05, ***p< 0.001, EWL: Elite athletes in Olympic style weightlifting, TL: Thigh length, TG: Thigh girth, LL: Lower leg length, CG: Calf girth, PW: Pelvic width, 1RM: One-repetition maximal

independent samples t-Test was conducted. It was found that the values of EWL in 1RM snatch, 1RM clean and jerk, training experience and the number of weekly trainings were higher than those of non-EWL, $t(42) = 5.71$, $p<0.001$; $t(42) = 5.21$, $p<0.001$; $t(42) = 6.43$, $p<0.001$; $t(42) = 13.42$, $p<0.001$, respectively (Table II). Also, though leg strength values of EWL were numerally higher than those of non-EWL, no statistically significant difference was observed ($p>0.05$).

Table III shows demographic characteristics, anthropometric measurements of lower extremity, 1RM snatch, 1RM clean and jerk, leg strength, training experience, the number of weekly trainings and right-left Q-angle values of EWL and non-EWL groups.

Right and left TG values of non-EWL were positively and moderately correlated with right and left Q-angle values ($p<0.05$). In both groups, right-left Q-angle values were observed to be correlated ($p<0.001$). In both groups, it was found that Q-angle values were not correlated with other parameters ($p>0.05$).

DISCUSSION

In literature, no definite value is referred to determine normal value of Q-angle. In general, it is reported that reference value range for males is 8-14° (an average of 10 degrees) and 11-20° (an average of 15 degrees) for females.[24,25] Q-angle value over 15°, is accepted to be abnormal for males and over 20°, it's abnormal for females.[2,24] Hahn and Foldspang, report that Q-angle in athletes fluctuates on average of 6° to 13° depending on the gender, body side and type of sport.[10] We observed in our study that right and left Q-angle values of EWL (right-left Q-angle 8.32 ± 1.39^0, $8.32\pm1.32°$, respectively) and non-EWL (right-left Q-angle $10.14\pm1.55°$, $10.14\pm1.52°$, respectively) is within normal values with the studies in literature. Right and left Q-angle values of EWL in our study was found to be lower than those of athletes in other studies in literature.[11,12,14,15,26,27] These differences in Q-angle values might be said due to differences in age, height, body weight anthropometric characteristics of lower extremity and measurement procedures. Nevertheless, we consider that the observed Q-angle differences in elite level athletes might result from the exercises of Olympic style weightlifting, which is maintained in elite level, such as snatch, clean and jerk, special trainings of this sport, which dynamically use the quadriceps femoris muscle.

There have been many studies on the correlations of anthropometric measurements of lower extremity, dominant foot use, demographic characteristics, athletic activity and Q-angle.[5,10,15,16] Kishali NF et al. mentioned that a negative correlation exists between right-left Q-angle and femur length in soccer players, a correlation exists between right Q-angle and thigh-calf circumference and a correlation between right-left Q-angle and body weight in taekwondo athletes.[11] It's emphasized that when Q-angle values of amateur and professional athletes are compared, Q-angle values of amateur and professional athletes are lower than those of sedentary individuals and Q-angle values of amateur athletes are higher than those of professional athletes. The researchers also declare that a weak correlation exists between Q-angle and femur length (negatively) and training status and no correlation exists between Q-angle and pelvis width.[12] It's reported that Q-angle values of male athletes doing different sports are not correlated with parameters such as age, height, weight, fitness age, leg force, flexibility and leg force.[26] In another study including athletes participating in local Olympic style weightlifting championships, it is also mentioned that Q-angle values of sedentary individuals are higher than those of weightlifting athletes. Furthermore, right Q-angle values of the participants are negatively and moderately correlated with right-left femur circumference and are positively and moderately correlated with right femur length.[15]

When pelvic width, demographic characteristics and some anthropometric values of lower extremity of homogenously combined EWL and non-EWL groups are compared, no difference was observed. However, right-left Q-angle values of EWL were lower than those of non-EWL. Also, weightlifting performance, training experience and the number of weekly trainings of EWL were significantly higher than those of non-EWL. In EWL groups, we observed no correlation between right and left Q-angle values and age, height, body weight, BMI, length and circumference measurements of lower extremity, pelvis width, 1RM snatch, 1RM clean-and-jerk, leg strength, training experience and the number of weekly trainings. For non-EWL, we observed that only right TG and left TG were positively and moderately correlated with right-left Q-angle.

It's mentioned in studies that a high Q-angle or greater difference between right and left Q-angle are correlated with knee injuries in athletic activities.[16] It's reported that right passive Q-angle of athletes doing gymnastics, jumping, throwing, tracking, karate, winter sports, taekwondo is much lower than their left Q-angle.[27] Hahn and Foldspang stated that right Q-angle of soccer, swimming and jogging athlete groups is higher than their left Q-angle and asymmetrical Q-angle difference might occur due to dominant foot use.[10] In a study to determine Q-angle of weightlifting athletes, the researchers declared that the reason for the fact that their left Q-angle values are higher than right Q-angle values is due to dominant foot use.[14] When Kishali NF et al. evaluated Q-angle values of soccer and taekwondo athletes, they reported that Q-angle of dominant foot is higher than the angle of non-dominant foot.[11] In Q-angle determination studies including athletes doing different types of sports, soccer players and sedentary individuals, it's reported that no differences exist in right and left Q-angle values of the participants.[15] In our study, right and left TG are found to be asymmetrical in both EWL and non-EWL groups. The observed TG size difference in both groups is on the right side and we consider that this might closely be related with dominant foot use. Although we observed asymmetry in right and left TG of the groups, no difference between right and left Q-angle was observed.

Byl T et al. Stated in their study that the greatness of Q-angle is correlated with the power of the quadriceps muscle, and though there exists a weak correlation between Q-angle and the peak torque of the quadriceps muscle, the greatness of Q-angle lowers when the peak torque of the quadriceps muscle increases. The researchers reported that decrease in Q-angle is closely correlated with the fact that when the quadriceps muscle is contracted, it superiorly and laterally pulls patella.[5] In a study into the correlation between right-left Q-angle and concentric and eccentric muscular force of the quadriceps muscle, it was mentioned that left passive Q-angle of athletes in throwing, jumping and gymnastics is negatively and moderately correlated with eccentric force of knee extensors.[27]

A higher Q angle is correlated with decreased isokinetic knee strength, power output, and torque angles. It is thought that high Q angle-related knee joint disorders and sports injuries can be avoided by including proper quadriceps strength exercises.[9] Bayraktae B et al. Studied Q-angle values of athletes and sedentary individuals and they reported that due to strength increase resulting from changes in muscular tonus in the quadriceps femoris, a decrease in Q-angle occurs.[15] In the comparison of leg strength of EWL and non-EWL groups in our study, the leg strength values of EWL was numerally higher than those of non-EWL, however, no statistically significant difference was observed and not correlation was observed between leg strength and right-left Q-angle in both groups.

The limitations of this study are that it included only national and international male weightlifting athletes and didn't include any female athletes due to corona virus pandemics.

CONCLUSION

Consequently, our study shows that Q-angle values of elite weightlifting athletes are lower than non-elite weightlifting athletes in Olympic style weightlifting. Moreover, we found out that an asymmetry exists in right-left TG of both groups and a symmetry exists in right-left Q-angles. From the view of the fact that different trainings of the athletes during the year and asymmetrical developments in lower extremity due to athletic loads might cause athletic injuries, we consider that following asymmetric developments in lower extremity of both EWL and non-EWL athletes at different time intervals during the season and taking needed steps might be beneficial.

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AUTHOR'S CONTRIBUTION

Following authors have made substantial contributions to the manuscript as under:

KE: Conception & study design, acquisition, analysis and interpretation of data, drafting the manuscript, critical review, approval of the final version to be published

MKA & BI: Conception & study design, acquisition of data, drafting the manuscript, approval of the final version to be published

OT: Study design, drafting the manuscript, approval of the final version to be published

RÖ & SBÜ: Acquisition of data, drafting the manuscript, approval of the final version to be published

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICT OF INTEREST

Authors declared no conflict of interest

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