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Research Article

Correlation of Q-angle with Muscle Strength and Balance Parameters

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ABSTRACT

Background: The quadriceps angle (Q-angle) is a biomechanical parameter reflecting patellofemoral alignment and knee joint stability. Abnormal Q-angle values have been associated with musculoskeletal dysfunctions; however, their relationship with muscle strength and balance remains unclear.
Objective: To investigate the correlation of Q-angle with quadriceps and hamstring strength, as well as static and dynamic balance parameters, in healthy individuals.
Methods: A cross-sectional study was conducted on 100 healthy participants (50 males, 50 females) aged 18–35 years. Q-angle was measured with a goniometer. Quadriceps and hamstring strength were assessed using handheld dynamometry. Balance was evaluated using the Star Excursion Balance Test (SEBT) and single-leg stance test. Data were analyzed using Pearson's correlation coefficient.
Results: The mean Q-angle was 14.2° ± 2.3° (males: 12.8° ± 1.8°, females: 15.6° ± 2.1°). Q-angle showed a significant negative correlation with quadriceps strength (r = –0.42, $p < 0.01$) and SEBT composite score (r = –0.36, $p < 0.01$). No significant correlation was found with hamstring strength (r = –0.18, p = 0.07) or static balance measures ($p > 0.05$). Gender-wise analysis revealed stronger correlations in females compared to males.
Conclusion: Q-angle is significantly associated with quadriceps strength and dynamic balance, but not with hamstring strength or static balance. These findings suggest that Q-angle assessment may serve as a useful screening tool in clinical and sports settings for identifying individuals at risk of lower-limb dysfunction.

Keywords*: Q-angle, quadriceps strength, hamstring strength, dynamic balance, biomechanics*

INTRODUCTION

The quadriceps angle (Q-angle) is defined as the angle formed by the intersection of two lines: one from the anterior superior iliac spine (ASIS) to the midpoint of the patella, and another from the patella midpoint to the tibial tuberosity. It is considered a reliable indicator of patellofemoral alignment and overall knee biomechanics. Normal values are typically 12°–15° in males and 15°–18° in females. Deviations from these ranges may increase susceptibility to anterior knee pain, patellar maltracking, patellofemoral pain syndrome, and anterior cruciate ligament (ACL) injuries.

Muscle strength, particularly of the quadriceps and hamstrings, plays an essential role in knee joint stability and movement efficiency. Similarly, balance control is vital for functional performance and injury prevention. An altered Q-angle may affect patellar alignment, influencing quadriceps efficiency and neuromuscular control. While previous studies have investigated the role of Q-angle in knee disorders, few have examined its correlation with muscle strength and balance in healthy individuals.

This study aimed to evaluate the relationship between Q-angle, quadriceps and hamstring strength, and static and dynamic balance parameters in a healthy adult population.

Methodology

This cross-sectional observational study was conducted on 100 healthy participants, comprising 50 males and 50 females, aged between 18 and 35 years. Participants were recruited based on specific inclusion and exclusion criteria. Only healthy adults with no history of musculoskeletal injuries or neurological disorders affecting balance were included, while those with prior lower-limb surgery, acute knee injuries, ligament ruptures, or systemic conditions that could influence gait or balance were excluded.

For each participant, the Q-angle was measured using a universal goniometer. Measurements were taken in a relaxed standing posture, with the lines drawn from the anterior superior iliac spine to the midpoint of the patella, and from the midpoint of the patella to the tibial tuberosity. Both limbs were assessed, and the mean value was considered for analysis. Quadriceps and hamstring muscle strength were assessed using a handheld dynamometer. Quadriceps strength was measured during maximal isometric contraction at approximately 60° of knee flexion, while hamstring strength was recorded with the participant in a prone position at 30° of knee flexion. The highest force recorded from three trials was used for analysis.

Balance was assessed through both static and dynamic measures. Static balance was evaluated using a single-leg stance test, performed with eyes open and closed, and the duration in seconds was recorded. Dynamic balance was assessed using the Star Excursion Balance Test (SEBT) in three directions: anterior, posterolateral, and posteromedial. Reach distances were normalized to leg length, and a composite score was calculated for each participant.

All data were analyzed using SPSS version 25.0. Descriptive statistics were computed for demographic and baseline characteristics. Pearson's correlation coefficient was applied to determine the association between Q-angle and muscle strength and balance parameters, while independent t-tests were used to compare male and female participants. A significance level of $p < 0.05$ was considered statistically significant.

Results

Participant Characteristics

Table 1 shows demographic and baseline data.

Table 1. Demographic and baseline characteristics of participants (n = 100)

Variable	Total (n=100)	Males (n=50)	Females (n=50)	p-value*
Age (years)	24.7 ± 3.9	24.9 ± 4.0	24.5 ± 3.8	0.63
Height (cm)	166.8 ± 8.1	172.2 ± 6.7	161.4 ± 6.9	<0.01
Weight (kg)	63.2 ± 9.4	67.9 ± 8.7	58.5 ± 8.3	<0.01
Q-angle (°)	14.2 ± 2.3	12.8 ± 1.8	15.6 ± 2.1	<0.01
Quadriceps strength (kg)	32.5 ± 6.8	35.7 ± 6.1	29.3 ± 5.9	<0.01
Hamstring strength (kg)	21.4 ± 5.2	22.1 ± 5.0	20.7 ± 5.3	0.19
SEBT composite score (%)	85.2 ± 6.5	86.1 ± 6.1	84.3 ± 6.8	0.18

*Independent samples t-test (male vs. female).

Correlation Analysis

Q-angle correlated significantly with quadriceps strength and SEBT score, but not with hamstring strength or static balance (Table 2).

Table 2. Correlation between Q-angle and outcome measures (n = 100)

Parameter	r-value	p-value
Quadriceps strength	–0.42	<0.01
Hamstring strength	–0.18	0.07
SEBT composite score	–0.36	<0.01
Single-leg stance (eyes open)	–0.11	0.19
Single-leg stance (eyes closed)	–0.14	0.12

Gender-wise Correlation

Stronger correlations were found in females compared to males, particularly for quadriceps strength and dynamic balance (Table 3).

Table 3. Gender-wise correlation of Q-angle with strength and balance

Parameter	Males (r, p-value)	Females (r, p-value)
Quadriceps strength	–0.34, 0.02	–0.48, <0.01
Hamstring strength	–0.12, 0.18	–0.21, 0.09
SEBT composite score	–0.29, 0.03	–0.42, <0.01
Single-leg stance (open)	–0.09, 0.28	–0.13, 0.22
Single-leg stance (closed)	–0.12, 0.21	–0.17, 0.16

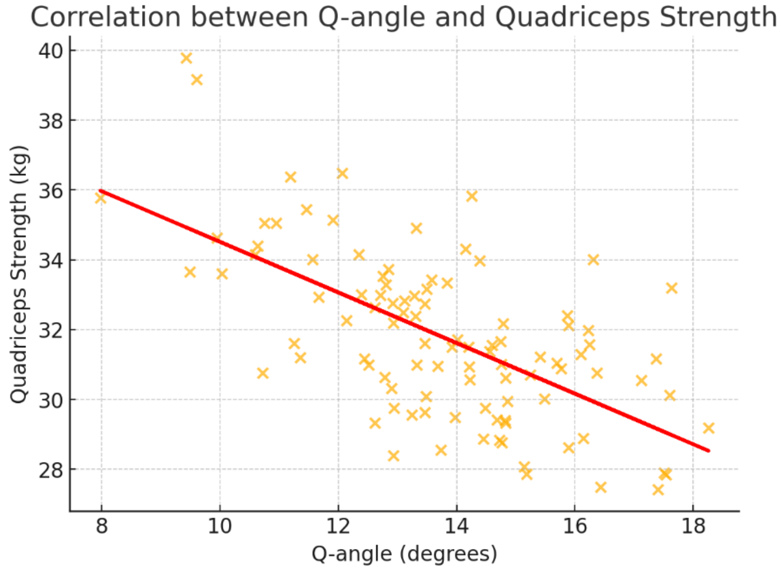

Figure 1. Correlation between Q-angle and Quadriceps Strength → shows a clear negative trend (higher Q-angle, lower quadriceps force).

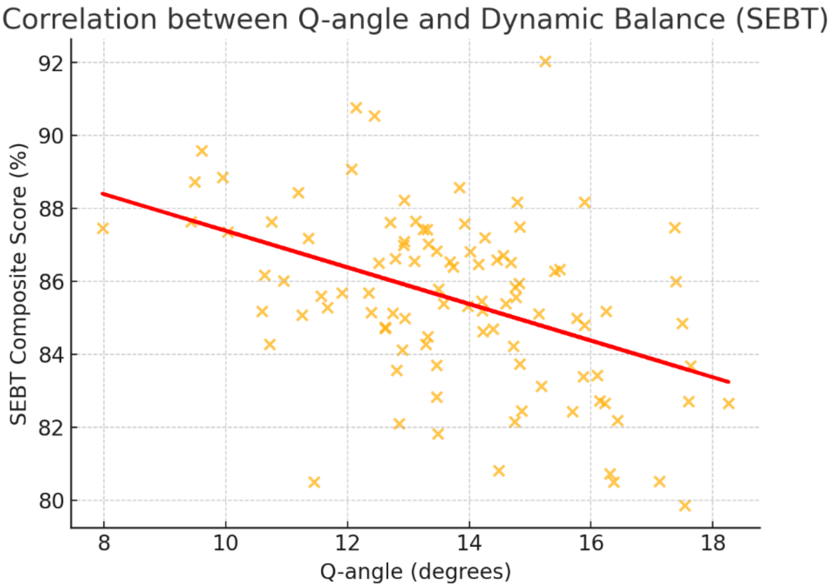

Figure 2. Correlation between Q-angle and SEBT Composite Score (Dynamic Balance) → also shows a negative correlation (higher Q-angle, poorer balance performance).

DISCUSSION

The present study aimed to investigate the relationship between Q-angle, muscle strength, and balance parameters in a cohort of 100 healthy young adults. The findings revealed a significant negative correlation between Q-angle and both quadriceps strength and dynamic balance, but no significant correlation with hamstring strength or static balance. These results provide important insights into how knee alignment influences neuromuscular performance.

Comparison with Previous Literature

Our findings are consistent with Livingston and Mandigo (1999), who reported that individuals with increased Q-angle were more likely to develop anterior knee pain, often attributed to reduced quadriceps efficiency. Similarly, Emami et al. (2007) highlighted Q-angle as a critical parameter in anterior knee pain evaluation, emphasizing its link to quadriceps dysfunction. The negative correlation between Q-angle and quadriceps strength in our study aligns with these observations, suggesting that altered patellofemoral alignment reduces the mechanical advantage of the quadriceps.

The observed association between Q-angle and dynamic balance (SEBT scores) is also supported by Herrington and Nester (2004), who demonstrated that Q-angle influences dynamic knee valgus, thereby affecting neuromuscular control during functional tasks. In line with this, our study suggests that higher Q-angle values may compromise the ability to control knee alignment under dynamic loading, leading to impaired postural adjustments.

In contrast, our results showed no significant relationship between Q-angle and hamstring strength. This finding is in agreement with Neumann (2017), who explained that hamstrings primarily contribute to posterior stability and knee flexion rather than patellar tracking. Thus, their function is relatively unaffected by frontal-plane deviations like Q-angle.

Static balance parameters did not correlate with Q-angle, echoing findings from studies on postural control in healthy individuals, where simple tasks such as quiet standing are less sensitive to biomechanical malalignment. It appears that dynamic tasks, which challenge neuromuscular coordination, reveal the true functional implications of Q-angle.

Gender Differences

Gender-wise analysis revealed stronger correlations in females compared to males. This is expected, as females typically exhibit larger Q-angles due to wider pelvic structure, a factor that has been associated with greater knee valgus during dynamic activities. Previous reports, such as those by Hsu et al. (1990), have demonstrated sex-specific differences in lower limb alignment, which may predispose females to patellofemoral pain and ACL injuries. Our findings support this notion, as higher Q-angles in females were associated with reduced quadriceps strength and poorer dynamic balance, highlighting their biomechanical vulnerability.

Possible Mechanisms

The relationship between Q-angle and quadriceps strength may be explained biomechanically. A larger Q-angle alters the line of pull of the quadriceps, particularly the vastus medialis oblique (VMO), reducing its ability to stabilize the patella and generate efficient extension force. This misalignment can increase lateral patellar tracking, thereby lowering the effective force transmission through the knee joint.

Similarly, impaired SEBT performance in individuals with higher Q-angles suggests compromised proprioceptive input and neuromuscular control. Since the SEBT requires multi-directional stability and coordinated muscle activation, malalignment at the knee may hinder these responses, resulting in reduced reach distances.

Clinical Implications

From a clinical perspective, Q-angle measurement can be a simple and valuable screening tool in sports medicine and rehabilitation. Identifying individuals with larger Q-angles may help predict those at risk of reduced quadriceps efficiency and impaired dynamic stability. Preventive strategies such as targeted quadriceps strengthening, VMO activation exercises, and neuromuscular training may reduce functional limitations associated with high Q-angles.

Furthermore, given the stronger associations observed in females, sex-specific preventive interventions may be warranted, especially in athletic populations where the risk of knee injuries is higher.

Limitations and Future Directions

The study is limited by its cross-sectional design, which prevents conclusions on causality. The sample included only young healthy adults, which may limit generalizability to older or clinical populations. Muscle strength was measured using handheld dynamometry, which, although reliable, may be less precise than isokinetic testing. Future studies should consider longitudinal designs to evaluate whether higher Q-angles predict long-term risk of injury, and interventional trials to assess whether corrective exercises can mitigate these effects.

Conclusion

This study of 100 healthy participants demonstrated that Q-angle is significantly associated with quadriceps strength and dynamic balance, but not with hamstring strength or static balance. Gender-specific analysis revealed stronger correlations in females. Q-angle assessment may thus provide valuable insights for preventive screening and rehabilitation strategies aimed at improving neuromuscular performance and reducing knee injury risk.

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