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# The Impact of the Quadricep Angle on Female Athletes

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# The Impact of the Quadricep Angle on Female Athletes

**by**

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Table of Contents

**Abstract**

Despite being initially discovered in the 1950s, the quadricep angle (Q-angle) is still a widely unknown and unresearched anatomical feature of the human body. This paper will explore existing knowledge of the Q-angle and observe its implications on female athletic performance and athletic risks. Through research it was found that the Q-angle plays a large role in the differences in strength observed in male and female athletes. Additionally, it was found that the Q-angle is responsible for the increased probability of knee-related injuries observed in female athletes. By educating themselves on the findings of this paper, athletes, coaches, and athletic trainers can better understand and prepare for the advantages and disadvantages of the Q-angle.

## Introduction

The human body is similar to a machine. Every part of the system works together in order to achieve the function of the machine. This can be seen in the human body through the coordination of body systems. The digestive system cannot function properly without the endocrine system releasing hormones that aid in digestion, and that impact the body's ability to use the digested nutrients. The endocrine system and the digestive system are not the only two body systems that work together. The muscular system and the skeleton system rely heavily on each other. Without the skeletal system, the muscles would not have attachment points. Tendons connect muscles to bones and these connections are what allows the body to move with the help of electrical impulses. The entirety of the human body is a carefully assembled machine in which every system impacts the others. A very specific example of this coordination can be found in the quadricep angle.

The quadricep angle, also known as the Q-angle, was first defined in 1964 [1]. The Q-angle is the angle formed by the line created by the anterior superior iliac spine (ASIS) and the midpoint of the patella intersecting with the line formed by the patella midpoint and the tibial tubercle. Physicians can measure this angle by placing the center of a goniometer–an angle measuring tool–on top of the individual's knee. Then the physician will angle one arm of the goniometer towards the ASIS of the hip and the other arm of the goniometer joining the line created by the tibial tuberosity [2]. This measurement can be gathered with the patient in either a sitting or standing position. Another way to define this angle is by determining the angle between the anatomical and mechanical axes of the femur. This angle varies from person to person and from sex to sex with an average angle of 14° for males and 17° for females [3]. Lower Q-angles are associated with taller subjects [4]. This is because taller individuals have longer femurs which help to decrease the Q-angle. Because males are generally taller than females, males tend to have lower Q-angles. Although females have a wider pelvis than males, the ASIS in males and females are the same with neither sex having a more lateralized ASIS than the other. Despite this anatomical feature, the idea of females having a wider pelvis being a cause for the higher Q-angle is still widely accepted and used in a large percentage of articles referring to the Q-angle.

While this angle is created by an individual's skeletal anatomy, it can have a heavy impact on the muscular system and its components. The Q-angle has a direct impact on the strength of the knee, the amount of force that can be applied by the muscles, and can even increase risk of injury. These effects of the Q-angle make it an area of interest for coaches, athletes, and athletic trainers.

## Chapter 1: The Anatomy of the Q-Angle

The Q-angle has a direct impact on the knee and the ankle. While the Q-angle refers to the angle formed between bones–the ASIS of the ilium and the midline of the patella–it influences the angle of attachment for the quadricep muscle and the patellar tendon [5]. The alignment of the hips in relation to the lower extremity impacts how weight is distributed on the joints and can place unnecessary strain on certain ligaments and parts of the bones. This alignment impacts the alignment of inferior areas, such as the foot and ankle. The Q-angle influences muscles and tendons that play crucial roles in the biomechanics of the leg. For example, an abnormally large Q-angle alters the movements of the patellofemoral joint and increases the lateral traction placed on the patella by the quadricep group. Another example of the Q-angle's impact on the lower limb is the significant relationship between an increased Q-angle and over-pronation of the ankle [6]. Despite being a measurement of the hip to the knee, the Q-angle has an impact on the entire lower extremity ranging from strength to health.

To better understand how the Q-angle affects the knee, one must first understand the anatomy and simple concepts of the biomechanics of the knee. The knee is composed of bones including the femur, the patella, and the tibia. Additionally, it contains both articular and meniscus cartilage. However, the anatomy of the knee that the Q-angle impacts the most is the ligaments of the knee. The knee contains two types of ligaments: the cruciate ligaments and the collateral ligaments. The collateral ligaments are responsible for stability in the lateral direction. The knee has two collateral ligaments: the medial collateral ligament (MCL) which provides valgus stability and the lateral collateral ligament (LCL) which supports the lateral side of the knee joint. The cruciate ligaments provide stability in the frontal and posterior direction. The two cruciate ligaments of the knee are the anterior cruciate ligament (ACL) and the posterior cruciate ligament (PCL). All of these components–bones, cartilage, and ligaments–work together to improve the overall stability of the joint, hold the knee together, and work with the quadricep and hamstring muscles to create skeletal movement.

The Q-angle affects the anatomy of the knee by altering the biomechanics and altering the distribution of weight on the knee joint. Females typically have a larger Q-angle than males. The problem with this is that a larger Q-angle causes the knees to bend inward and displaces more weight and force on the lateral side of the knee [7]. By displacing more force on the lateral side of the knee, the Q-angle places more stress on the MCL and the ACL. Over time, this stress can weaken these ligaments and reduce the strength and stability of the knee. This additional stress could potentially lead to partial or total ligament tears. The Q-angle also affects the tracking of the patella [1]. Because the Q-angle impacts the angle at which the quadricep muscles connect to the patella, the Q-angle impacts the direction that the patella is being pulled in. The higher average Q-angle that females have means that the patella is pulled laterally. This lateral pull increases as flexion increases and can lead to the dislocation of the patella. The increased lateral stress placed on the knee joint and its pieces by the Q-angle leads to a higher risk of injury and an overall weaker knee.

In addition to altering the overall strength and stability of the knee, the Q-angle can also impact the ankle joint. The ankle joint is the point where the tibia, fibula, and talus bone meet [8]. The lateral border of the joint is formed by the articular facet of the lateral malleolus while the articular facet of the medial malleolus forms the medial border. The superior portion of the ankle joint is formed by the inferior articular surface of the tibia and the superior margin of the talus. The entire joint is surrounded by the articular capsule. In addition to the bones and the capsule, the ankle joint has multiple ligaments that aid in stabilizing the ankle. The deltoid ligament stabilizes the medial side of the ankle and is composed of four ligaments that connect the tibia to the navicular, calcaneus, and the talus: the anterior and posterior tibiotalar ligaments, the tibionavicular ligament, and the tibiocalcaneal ligament. In addition to the deltoid ligament, the anterior and posterior talofibular ligament as well as the calcaneofibular ligament support the ankle joint laterally. The anterior and posterior talofibular ligaments connect the talus and the fibula to each other while the calcaneofibular ligament connects the fibula and calcaneus. These ligaments work together to strengthen the joint.

The Q-angle can change the alignment of the tibia in respect to the femur [9]. An increase or a decrease in the Q-angle influences tibial rotation: external rotation is associated with an increased Q-angle [3]. This relationship works both ways though: the Q-angle can increase tibial rotation while tibial rotation can impact the Q-angle. In most cases, the Q-angle leads to overpronation of the ankle. Overpronation has the most damaging effects on the subtalar joint–the location of articulation between the facets of the talus and the calcaneus. During overpronation, the ligament that attaches the lateral malleolus and the talus remains taught while the ligament that attaches the medial malleolus and the talus remains loose [10]. This places strain on the laterally attached ligament. In addition to placing strain on this lateral ligament, several pathologies are also associated with overpronation of the ankle. Some pathologies associated with ankle overpronation include Achilles pathology, tibialis posterior dysfunction, patellofemoral pain, as well as an increase in the likelihood of knee injuries [10].

The Q-angle impacts the entire lower extremity in multiple ways. The Q-angle can lead to excess strain placed on specific ligaments of both the knee and the ankle. It can change the rotation of the foot which is associated with several different lower limb pathologies. The Q-angle can increase an individual's likelihood of patellar subluxation or dislocation. Despite being a measurement of the angle between the ASIS of the hip and the midline of the patella, the Q-angle impacts the entire anatomy of the knee, the ankle, and even impacts the orientation of bones such as the tibia.

## Chapter 2: The Impact of the Q-angle on Performance

Top-tier athletes are built for competition. They either have a genetic predisposition for speed or strength. They were gifted with the perfect athletic build, height, or muscular density for their sport and have dedicated their lives to building upon what their DNA has given them and honing their skills [11]. Just like Michael Phelps's wingspan and torso give him an advantage in swimming by increasing his power output, an athlete's Q-angle can either improve or oppose athletic performance. This is because the Q-angle impacts the distribution of power output seen in an athlete.

The different systems of the human body coordinate in order to function. As previously stated, the skeletal system and the muscular system work together to generate skeletal movement. Because of this, bone structure can cause effects on muscular strength and power output. This is why the Q-angle creates biological advantage in sports. The impact of the Q-angle on athletic performance is due to its effect on the direction in which force is exerted: this also accounts for differences in muscle gain in the quadricep [12]. When the same amount of exerted force is applied at an angle (the Q-angle) the force accounts for both a downward force (extensor force) and a lateral force. As the angle is increased, more force is applied laterally and less force is applied downward [12]. Therefore, a greater Q-angle leads to less force for the extension of the leg. This also means that less strength is produced by the quadriceps when compared to individuals with a smaller Q-angle [13]. As previously mentioned, males and females have different average Q-angles–14°and 17° respectively. This means that male athletes can exert more extensor force than female athletes. Additionally, a greater Q-angle leads to overall decreased knee strength, power output, and torque angles [14]. Thus, the Q-angle prohibits female athletes from achieving the same power output as males as well as increasing the risk of injury.

This difference can be shown through physics and trigonometry. Because male athletes have a smaller Q-angle–14°–more of the exerted force is placed in the extension of the leg [12]. This allows the work done by the quadricep muscles to better translate into movement. Female athletes have a higher Q-angle–17°–which means that more of the work done by the quadriceps is displaced in the lateral direction [12]. This does not pose much of a difference at low levels or in single instances, but this difference can accumulate to impose a genetic difference between male and female athletes. As seen in **Table 1**, the female athlete must exert a larger amount of force in order to obtain the same amount of extensor force as their male counterparts. This difference continues to grow as weight increases. In power sports–such as weight lifting and powerlifting–this difference could account for a portion of the performance difference seen between the male and female athletes. In sports such as running, this difference in power output can accumulate with each stride and could account for differences observed in male and female competitor’s times.

| Displacement of Forces Due to the Q-angle | | | |
|---|---|---|---|
| Weight in kg | Type of Force | Male Force Output | Female Force Output |
| 60 | Exerted | 61.86 | 62.76 |
| | Extensor | 60 | 60 |
| | Lateral | 14.52 | 17.52 |
| 80 | Exerted | 82.47 | 83.68 |
| | Extensor | 80 | 80 |
| | Lateral | 19.36 | 23.36 |
| 100 | Exerted | 103.09 | 104.60 |
| | Extensor | 100 | 100 |
| | Lateral | 24.20 | 29.20 |
| 120 | Exerted | 123.71 | 125.52 |
| | Extensor | 120 | 120 |
| | Lateral | 29.04 | 35.04 |
| 140 | Exerted | 144.32 | 146.44 |
| | Extensor | 140 | 140 |
| | Lateral | 33.88 | 40.88 |

**Table 1**: This table displays how the male and female average Q-angles–14° and 17° respectively–influence the direction of force as well as the distribution of force. These forces were calculated using the male and female average Q-angles. Additionally, when calculating these values, an acceleration of one was used.

While the Q-angle plays a significant role in the biomechanics of all activities, some sports are affected by the Q-angle more than others. In addition to being more important to some sports than others, the Q-angle also affects one sex more than others. The Q-angle is present in every sport, however it plays its most notable role in athletic performance in post-puberty female athletes [15]. Until puberty, male and female adolescents have similar average Q-angles [16]. Children between ages 7 and 12 have no significant differences in Q-angle with young males having an average Q-angle of 15.7° and young females having an average Q-angle of 15.6° [16]. These values mean that young males and young females have similar levels of power output and force distribution which allow for similar levels of performance. This can be seen in the similar sprinting speeds of young athletes [17]. These values begin to differ once females reach puberty. When a female goes through puberty she goes through a series of events and changes. One of these changes is the widening of the hips. As previously mentioned, the Q-angle is the measurement of the angle created by the midline of the patella and the ASIS of the hip. As the hips widen, the Q-angle increases. Because a higher Q-angle correlates with a smaller extensor force, puberty negatively impacts female athletes [12]. This means that most female athletes notice a decline in their athletic capabilities very early on in life. This phenomenon is very well-known in the world of running [15]. While male athletes generally get faster throughout adolescence, female runners see improvements before puberty before experiencing a plateau at some point between 9th and 11th grade–around the ages of 14-17 years old [15]. In addition to the Q-angle slowing down young female runners, the widening of the hips also places more stress laterally on the knee and increases the risk of an ACL injury.

## Chapter 3: The Effect of the Q-Angle on Injury Risks

The Q-angle plays a crucial role in the biomechanics of the knee joint, and its effect on injury risks, particularly in female athletes, is a topic of interest in sports medicine and biomechanics. Some key points regarding the effect of the Q-angle on injury risks are patellofemoral pain syndrome, ACL injuries, patellar dislocation, and ankle injuries.

**Patellofemoral Pain Syndrome (PFPS)**:

PFPS, commonly known as runner's knee or jumper's knee is characterized by pain around or behind the patella (kneecap), especially during activities that involve bending the knee, such as running, jumping, or squatting [18, 19]. While the exact cause of PFPS is multifactorial and still not fully understood, the association between a wider Q-angle and increased risk of PFPS has been a topic of research interest [20-22]. However, it's important to note that the relationship between Q-angle and PFPS is not entirely straightforward, and findings from studies investigating this association have been scanty. The study by Hvid  and Andersen [23], which observed a significant difference in mean Q-angle values between males and females with patellofemoral diseases, provides further insight into the potential role of Q-angle in PFPS among female athletes.

**Anterior Cruciate Ligament (ACL) Injuries**:

An ACL tear is the most severe knee ligament injury in sports [24]. ACL tears are more prevalent among female athletes compared to male athletes [25]. While the relationship between the Q-angle and ACL injuries is not as straightforward as with PFPS or patellar instability, some studies suggest that a larger Q-angle may contribute to increased risk of ACL injuries, particularly in female athletes [24, 26]. The increase in the Q-angles among females are related to several anatomical factors including increased pelvic width, shorter femur length, or more laterally placed tibial tuberosity [27]. Understanding these anatomical differences and their relationship to Q-angle can help sport medicine, clinicians and researchers better assess and manage ACL conditions.

**Patellar Dislocation:**

The increase in Q angle is linked with patellar dislocation. A study of in vitro knee simulation to find the relationship between the Q angle and patella kinematics showed that the increase in Q-angle led to significant lateral shifting (20 to 60 degrees), medial tilting (20 to 80 degrees), and medial rotation (20 to 50 degrees) of the knee flexion. This study suggests that the increase in the Q angle is a risk factor for lateral patellar discoloration [20]. An increase in Q angle is also one of the factors causing Patellofemoral pain syndrome (PFPS) [28]. Patellofemoral pain syndrome (PFPS) is a pathological condition characterized by pain around or behind the patella. The increased Q angle causes lateralization of the patella, which can cause mistracking and excessive stress on the patellofemoral joints during sports. The maltracking of the patella is caused by the delayed muscle activity of the VMO relative to vastus laterals (VL) [29]. A study found that female athletes are more prone to PFPS than male athletes [30].

**Ankle Injuries**

The increase in Q-angle is linked with ankle injuries. A study of young men who had completed 12 weeks of army infantry training found that those with valgus knee and a Q value greater than 15 were at increased risk of suffering injuries in the lower leg [31]. Another study of

45 subjects showed a positive relationship between Q angle and ankle sprain in recreational basketball players [32]. However, the study by Pefanis and colleagues found that age and BMI significantly contribute to ankle sprains, while Q angle was not a decisive factor [33]. Rauh et al., 2007 studied the role of Q angle in lower extremities injury in 393 high school cross-country runners. The study found that runners with Q angle greater than 20 degrees were 1.7 times at greater risk of injury than runners with Q angle less than 15 degrees [34]. In another study of 300 patients with ankle sprain, it was found that age, BMI, and Q angle significantly correlated with a history of ankle sprain. The Q angle was wider by 2 degrees in patients with a history of ankle sprain [35].

## Chapter 4: Combatting the Risks and Setbacks of the Q Angle

The quadriceps angle, also known as the Q angle, refers to the angle between the quadriceps muscle tendon and the patellar tendon [2]. The Q angle is used to evaluate the biomechanical alignment of the knee joint and influence the distribution of forces across the knee during physical activity [36, 37]. The abnormal and excessive Q angle causes an imbalance between the vastus medialis and vastus lateralis muscles, leading to an increased risk of knee problems, including patellofemoral pain syndrome, anterior knee pain, osteoarthritis, and degenerative knee disorders [38, 39]. Athletes with abnormal Q angle can stabilize the knee joint by strengthening and stretching the muscles around the knee [40, 41]. The quadriceps muscles, comprising the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius, are crucial for knee stability and function [42, 43]. Thus, quadriceps muscle strength is required for a variety of athletic activities, including running, jumping, cutting movements, and landing movements [44, 45]. Although exercises that can strengthen quadriceps muscles include squats, lunges, leg press, and leg extension [46], growing evidence shows that weight-bearing exercises such as knee extension weight-bearing exercise, hip flexion weight-bearing exercise, hip abduction weight-bearing exercise are effective for athletes with abnormal Q-angle [47].

Specifically, the vastus medialis oblique (VMO) muscle is the most medial portion of the quadriceps muscles [48]. The fibers of the VMO run obliquely and are inserted directly into the upper border of the patella bone. Consequently, the primary function of the VMO muscle is medial stabilization of the patella during knee extension [49]. Weakness or imbalance in the VMO muscle results in patellar maltracking, where the patella deviates laterally during movements including squatting, jumping, or running [50, 51]. This patella tracking disorder can increase the risk of patellofemoral pain syndrome and other knee injuries [51]. Therefore, strengthening the VMO muscle is effective in stabilizing the knee joint and preventing injury in female athletes with abnormal Q angle. The exercises that strengthen the VMO include terminal knee extensions, short arc quad exercises, quad sets, and wall squats with a ball [52, 53].

Patellofemoral pain syndrome induced by a large Q angle can result from core muscle instability because the dynamic imbalance of the torso and lower extremity can contribute to the development the patellofemoral pain [54]. The dynamic stability refers to the ability of the body to sustain its position or intended path despite external or internal disruptions [55, 56]. The core of the body includes the spine, abdominal region, pelvis, hips, and proximal lower extremities [54, 57]. Exercises that can strengthen the core muscles include cross curl-ups, side bridge, and quadrupedal stance [54].

Recently, strengthening the hip muscles has been suggested as an effective treatment for athletes with abnormal Q angle [58]. Excessive hip movements in frontal and transverse planes can place stress on the patellofemoral joint [59, 60]. Weakness or imbalance in hip muscles, including the gluteus medius, gluteus maximus, and hip abductors, can lead to excessive hip adduction and internal rotation, which contribute to an increased Q angle and altered lower limb alignment [61, 62] . Further, hip muscles are important for dynamic knee valgus, which is characterized by the inward collapse of the knee towards the middle of the body during functional movements [63, 64]. The dynamic knee valgus is associated with an increased Q angle and is a risk factor for various lower limb injuries, including patellofemoral pain syndrome [65]. Strengthening the hip abductors and external rotators can help control dynamic knee valgus by stabilizing the pelvis and controlling hip adduction and internal rotation, reducing the Q angle [66]. Therefore, strong hip muscles play a significant role in stabilizing the pelvis and controlling hip movement [67, 68]. Exercises that can strengthen hip muscles include side-lying leg lifts and clamshells for hip adduction exercise, band walks and seated hip external rotation for hip external rotation exercise, bridge exercise and standing hip extension for hip extension exercise, standing hip flexion and supine hip flexion for hip flexion exercise, standing hip adduction and side-lying hip adduction for hip adduction exercise [69-71].

Warming up before exercise is essential for athletes with abnormal Q angles to reduce the risk of pain and injury [72]. Warm-up increases blood flow to the quadriceps muscles, raising muscle temperature [73]. This increased blood flow prepares the muscles, tendons, and ligaments for the demands of exercise, reducing the risk of strains and other injuries. Warming up stretches quadriceps muscles and tendons, improving range of motion [74]. The improved range of motion allows the muscles to lengthen and contract more efficiently during exercise, reducing the risk of muscle strains and tears, especially in athletes with abnormal Q angles [75].

The female anatomy exhibits distinct biomechanical characteristics compared to male anatomy, specifically concerning hip structure and movement patterns [76]. The anatomical difference includes a wider pelvis, larger Q angle, and looser ligaments [77]. For this reason, female athletes often face increased risk of injury during sports activities [76]. It becomes imperative for female athletes to practice proper techniques to prevent the risk of injury. Landing mechanics are considered to prevent the risk of knee and hip injuries. A soft-landing technique with knees slightly bent and weight distributed across the entire foot, not just the heels can reduce stress on the patella [78]. Jumping techniques engaging the glutes and core muscles can reduce stress on the quadriceps. Cutting and changing direction mechanics that improve footwork, hip rotation, and controlled deceleration can prevent imbalanced forces that stress the knee joint [79]. Exercises such as glute bridges, side-lying leg lifts, and clamshells that focus on hip strength and mobility improve pelvic alignment and reduce excessive inward collapse of the knees [80, 81].

## Conclusion

The Q-angle–the angle formed between the ASIS of the hip and the midline of the patella–has a significant impact on female athletes. The Q-angle plays a role in performance as well as injury risk. Studies show that athletes with higher Q-angles face multiple setbacks when compared to athletes with lower Q-angles. A high Q-angle impacts athletic performance by distributing force more laterally than downward. This means that individuals with a higher Q-angle need to exert more force in order to equal the extensor force of an individual with a smaller Q-angle. In addition to its impact on performance, a high Q-angle also increases the risk of injury by changing the biomechanics of the knee. By knowing more about the Q-angle, athletes and coaches alike can be better prepared for competition and the setbacks and advantages of an individual's Q-angle.

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