A Biomechanical Comparison of Back and Front Squats in Healthy Trained Individuals

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Abstract

Gullett, JC, Tillman, MD, Gutierrez, GM, and Chow, JW. A biomechanical comparison of back and front squats in healthy trained individuals. *J Strength Cond Res* 23(1): 284–292, 2008—The strength and stability of the knee plays an integral role in athletics and activities of daily living. A better understanding of knee joint biomechanics while performing variations of the squat would be useful in rehabilitation and exercise prescription. We quantified and compared tibiofemoral joint kinetics as well as muscle activity while executing front and back squats. Because of the inherent change in the position of the center of mass of the bar between the front and back squat lifts, we hypothesized that the back squat would result in increased loads on the knee joint and that the front squat would result in increased knee extensor and decreased back extensor muscle activity. A crossover study design was used. To assess the net force and torque placed on the knee and muscle activation levels, a combination of video and force data, as well as surface electromyographic data, were collected from 15 healthy trained individuals. The back squat resulted in significantly higher compressive forces and knee extensor moments than the front squat. Shear forces at the knee were small in magnitude, posteriorly directed, and did not vary between the squat variations. Although bar position did not influence muscle activity, muscle activation during the ascending phase was significantly greater than during the descending phase. The front squat was as effective as the back squat in terms of overall muscle recruitment, with significantly less compressive forces and extensor moments. The results suggest that front squats may be advantageous compared with back squats for individuals with knee problems such as meniscus tears, and for long-term joint health.

Key Words tibiofemoral joint, EMG activity, compressive force, knee extensor moment

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Introduction

The squat is a widely used exercise that activates the largest, most powerful muscles in the body and may be the greatest test of lower-body strength (12,14,23). The major muscles involved are the quadriceps, hamstrings, gastrocnemius, and the gluteus maximus (5,9,11). The squat also relies on muscle activity at both the hip and ankle joints and recruits the abdominals and spinal erectors as well (9). The purpose of the squat is to train the muscles around the knees and hip joints, as well as to develop strength in the lower back, for execution of basic skills required in many sporting events and activities of daily living. Because a strong and stable knee is extremely important to an athlete's or patient's success, an understanding of knee biomechanics while performing the squat is helpful to therapists, trainers, and athletes alike (11). Because most activities of daily living require the coordinated contraction of several muscle groups at once, and squatting (a multijoint movement) is one of the few strength training exercises that is able to effectively recruit multiple muscle groups in a single movement, squats are considered one of the most functional and efficient weight-bearing exercises whether an individual's goals are sport specific or are for an increased quality of life (22,25).

Two forms of the squat are the back squat and the front squat. Athletes and persons concerned with fitness regularly perform the back squat; the front squat is performed much less often. Although both squats effectively work the lower back, hip, and leg muscles, there are slight variations in technique and muscular involvement. In addition, the maximum amount of weight an individual can lift varies between the two techniques, with increased capacity possible for the back squat. As shown in Figure 1, the back squat involves positioning the barbell across the shoulders on the trapezius, slightly above the posterior aspect of the deltoids, and allowing the hips and knees to slowly flex until the thighs are parallel to the floor (5,9). The individual then extends the hips and knees until reaching the beginning (starting) position, with emphasis on keeping the back flat, the heels on the floor, and the knees aligned over the feet (5,9). The front squat (Figure 2) involves the lifter positioning the barbell across the anterior deltoids and clavicles and fully flexing the elbows to position the upper arms parallel to the floor (5,9). The descending and ascending motions are much the same as in the back squat.

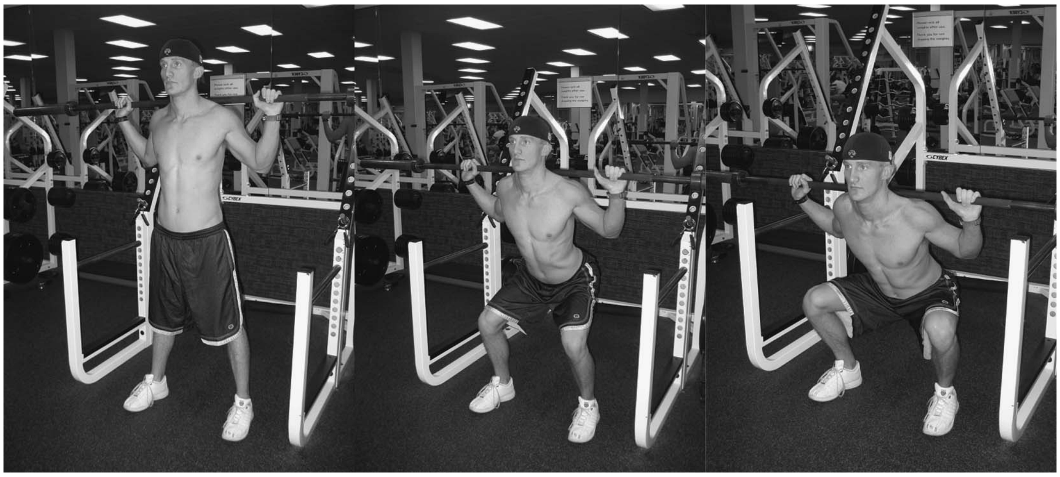

Figure 1. Bar positioning during the back squat.

Strength and conditioning professionals have recognized the similarities between the front and back squat, but they feel that these variations can be used to protect and isolate different muscle groups. It is believed that the front squat requires lower muscular force in the low back (16). In addition, front squats may also isolate the quadriceps more than back squats or induce greater recruitment from the distal quadriceps (16,18). These common beliefs are not supported by empirical evidence.

Several other variations of the squat exercise exist and have been studied (13,26). However, few have investigated knee joint kinetics while performing the front and back squat. Russell and Phillips conducted a preliminary investigation to determine the relative differences in knee extensor requirements and low-back injury risk (27). These authors have concluded that front and back squats elicited similar knee extensor demands. However, only eight subjects were tested, and no statistical analysis was performed. More recently, Stuart et al. compared front squats, back squats, and lunges (29). They determined that the exercises tested do not produce excessive tibiofemoral shear or compressive force in anterior cruciate ligament (ACL)-intact subjects. However, the sample size was limited ($N = 6$). Furthermore, it remains unclear which variation is more appropriate for maximizing

Figure 2. Bar positioning during the front squat.

muscle activation and minimizing joint forces and torques of the lower extremity.

Methods

Experimental Approach to the Problem

A repeated-measures, within-subjects design was used to determine which squat variation places the least force and torque on the knee and to examine the effects of front and back squats on primary as well as secondary and stabilizing muscle groups. More specifically, we compared the net compressive and shear forces applied to the tibiofemoral joint during both types of lifts as evaluated using an inverse dynamics approach, and we compared lower-extremity muscle activity as well. Because of the inherent change in the position of the center of mass of the bar between the front and back squat lifts, we hypothesized that the back squat would result in increased loads on the knee joint compared with the front squat and that the front squat would result in increased knee extensor and decreased back extensor muscle activity.

Subjects

Fifteen healthy individuals who were experienced at performing front and back squats (nine men, six women), averaging 22.1 ± 3.6 years of age, participated in this study. More specifically, each participant met our stringent requirement of at least 1 year of experience in both lifts used a minimum of one time per week each in their regular weight training programs. The average height and mass of the subjects were 171.2 ± 6.4 cm and 69.7 ± 6.2 kg, respectively. All subjects were free from orthopedic injuries that would have limited their ability to perform the squatting techniques described below. Before participation, informed consent was obtained from each subject. An institutional review board approved all procedures before testing.

Procedures

To assess the electromyographic (EMG) activity of selected muscles, six pairs of Ag/AgCl surface EMG electrodes (Blue Sensor type M-00-S, Medicotest, Inc., Rollings Meadows, Ill) were attached to the right side of the body overlying the muscles of interest (Table 1). Electrodes were placed over the belly of each muscle parallel to the muscle's line of action with a center-to-center distance of 2 cm. The skin surfaces used for electrode placement were cleansed with alcohol and shaved when necessary. Using a MESPEC 4000 telemetry system (Mega Electronics Ltd., Finland), the EMG signals were preamplified with a gain of 500 and band pass filtered at 8–1500 Hz (CMRR > 130 dB) near the electrodes and telemetrically transmitted to a central receiver (gain = 1, Butterworth filter, 8–500 Hz band pass). The amplified EMG signals were sampled at 900 Hz (12-bit A/D conversion) using a Peak Motus 2000 system (Peak Performance Technologies, Englewood, Colo).

Three genlocked video cameras collecting at 60 Hz (TK-C1380, JVC Americas Corp., Wayne, NJ) and a Bertec force plate (Type 4060–10, Bertec Corporation, Columbus, Ohio) collecting at 900 Hz were used to collect data. The video cameras and force plate were time synchronized using a Peak Motus video analysis system. Video recordings were subsequently analyzed using the Peak Motus. A calibration frame (16 control points, 1.3 × 1.1 × 0.9 m) was used for 3-D space reconstruction. Object space calibration errors in the X, Y, and Z directions are required to be below 0.5% of the calibration frame dimensions (ranging from 2 to 3 mm) for all data collections.

The subjects were required to attend two sessions lasting about 1 hour each during a period of approximately 1 week. The first session was a pretesting session. The subjects were asked to warm up on a stationary bike for 3–5 minutes at the beginning of the first session. Their one-repetition maximum (1RM) was determined by having the participants lift approximately four to five short sets of both front squats and back squats (order chosen randomly) at increasing loads until reaching their maximum load. They were allowed to rest for 5 minutes between sets, or until they felt sufficiently

Table 1. A description of the positioning of each electrode in relation to the muscle being tested (6).

Muscle	Electrode placement
Rectus femoris	Approximately midway between the anterior inferior iliac spine and the patella on the anterior side of the thigh
Vastus lateralis	Approximately two thirds of the thigh length from the greater trochanter on the lateral side of the thigh
Vastus medialis	Approximately three fourths of the thigh length from the anterior inferior iliac spine on the medial side of the thigh
Biceps femoris	Midway between the ischial tuberosity and the lateral condyle of the femur on the posterior side of the thigh
Semitendinosus	Midway between the ischial tuberosity and the medial condyle of the femur on the posterior side of the thigh
Erector spinae	Three centimeters lateral to the L3 spinous process

rested, and then they were asked to repeat the above steps for determining 1RM, this time performing the other squat variation.

Subsequently, the subjects were asked to report for a second session for data collection. Participants were fitted with black, tight-fitting shorts and were asked to remove their shoes and socks. At this point, a series of anthropometric measures were made including body mass, height, shank length, thigh length, pelvic width, circumferences of the upper thigh and calf, length of the foot, and the breadths of the knee, ankle, and metatarsal heads using an anthropometer (Seritex Inc., New York, NY). To eliminate interrater variability, the same investigator made all anthropometric measurements.

After the EMG, electrodes were placed over the rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM), biceps femoris (BF), semitendinosus (ST), and erector spinae (ES), and electrode placement was confirmed with manual muscle tests. The subjects were asked to perform maximum voluntary isometric contractions (MVICs) for each muscle group being recorded (quadriceps, hamstrings, and lower back) (6). Specifically, MVICs were performed for knee extension, knee flexion, and trunk extension. For knee extension, each subject sat on the end of a treatment table with the knee flexed to 90°. On being signaled by the investigator, the subject then maximally contracted the knee extensors against manual resistance for 5 seconds. The same positioning was used for knee flexion. The subject then performed an MVIC against manual resistance using the knee flexors. Finally, the subject lay prone on the table with hands behind the head and extended the back against manual resistance with the lower extremity stabilized.

Spherical reflective markers were then placed over the greater trochanter, midthigh, lateral knee, midshank, second metatarsal head, lateral malleolus, and calcaneus of the participant's right leg. After the marker placement, each participant performed three to five practice squats without weight plates on the Olympic bar for each squat type, to ensure good technique, relative comfort, and free range of motion. Visual and verbal feedback was offered before, during, and after each practice squat with regard to both the approximate duration and depth of the required squatting maneuver. Each subject was then instructed to perform one of two variations of the squat exercise (the front squat or the traditional back squat), chosen randomly, with the right foot on the force plate and the left foot on a wooden platform adjacent to and consistent with the height of the force plate (using a stance approximately shoulder width apart).

Once the participant felt comfortable, prepared, and the collection instrumentation was cued, he or she was asked to begin the descent, staying consistent to the form taught and used in the earlier practice sessions. Technique was monitored closely throughout to ensure the validity of our results. The sampling of video recording was initiated simultaneously with the beginning of the first squat repetition of each set being performed; it continued for 10 seconds. For each trial, the subject squatted a load of 70% of his or her predetermined 1RM. Two trials consisting of three repetitions each were performed for each squat variation. Average data obtained from the second repetition of the two trials were used in subsequent analyses. Adequate rest periods were provided between trials. Subjects lifted nearly 90% of their body mass during the back squat (61.8 ± 18.6 kg) and almost 70% of their body mass during the front squat (48.5 ± 14.1 kg).

Data Reduction

After the testing session, each reflective marker was digitized, and the 3-D positional data were scaled and smoothed, using a fourth-order Butterworth filter with an optimal cut-off frequency (3–5 Hz) determined by the Jackson Knee Point Method and Peak Performance software (19). The location and magnitude of the lower-extremity segmental masses and their moments of inertia were estimated using mathematical models, averaged segmental masses, and the individual participant's anthropometric data (31). Net joint reaction forces and joint moments of force relative to a tibia-embedded local reference frame [anterior (+)/posterior (−), compressive (+)/tensile (−)] were calculated for the lower extremity using an inverse dynamic analysis that combined the anthropometric, kinematic, and ground-reaction force data. To minimize the variation attributable to individual differences in body weight, the estimated joint resultants (maximum forces and moments) were normalized to the subject's body mass. More specifically, the following kinetic dependent variables relative to the knee were measured: net compressive/tensile (axial) force, net anterior/posterior (shear) force, and net extensor moment.

For the MVIC trials, a 2-second sliding average was performed to smooth the data after the raw signals were full wave rectified. The maximum EMG value for each muscle was then determined. To calculate the average normalized EMG values, the raw EMG signals were full wave rectified and divided by the appropriate maximum EMG value for that muscle. All EMG data were partitioned into ascending and descending phases. The time from the initiation of the flexion of the hips and knees until the greater trochanter reached its lowest point defined the descending phase of each repetition of the squat. The ascending phase followed the descending phase and consisted of knee and hip extension from the parallel thigh position until the subject was standing erect at the end of the repetition.

Statistical Analyses

The same relative weight (70% 1RM) was used for each squat technique; therefore, knee kinetics and muscle activity were compared directly between the front and back squat (14). To identify any potential differences between the front and back squat for the kinetic variables, separate paired t-tests were performed. A Bonferroni adjustment was used to reduce the likelihood of making a Type I error when multiple tests were performed. The original level of significance was set at the traditional level of 0.05. Thus, the adjusted level of significance was 0.017 (0.05/3). Electromyographic data for each of the six muscles tested were analyzed using separate 2 × 2 (bar position × phase) repeated-measures analyses of variance with $\alpha = 0.05$. The dependent variables were as follows: average maximum proximal/distal force, average maximum anterior/posterior force, average maximum extensor moment, and average normalized EMG for each phase.

Results

Kinetic Data

Statistically significant differences were evident between the two squat variations for the net compressive/tensile force at the knee ($t_{14} = -3.720$, $p = 0.002$). More specifically, the back squat resulted in higher average maximum compressive forces on the knee (11.0 ± 2.3 N·kg^{-1}) than the front squat (9.3 ± 1.5 N·kg^{-1}). Average maximum anterior/posterior (shear) forces were calculated throughout the motion and were posteriorly (negatively) directed in all cases. Shear forces at the knee did not vary between the back and front squat ($t_{14} = 0.425$, $p = 0.667$). Shear force averaged -5.0 ± 1.5 N·kg^{-1} during the back squat and -4.9 ± 1.3 N·kg^{-1} for the front squat. Representative data appear in Figure 3.

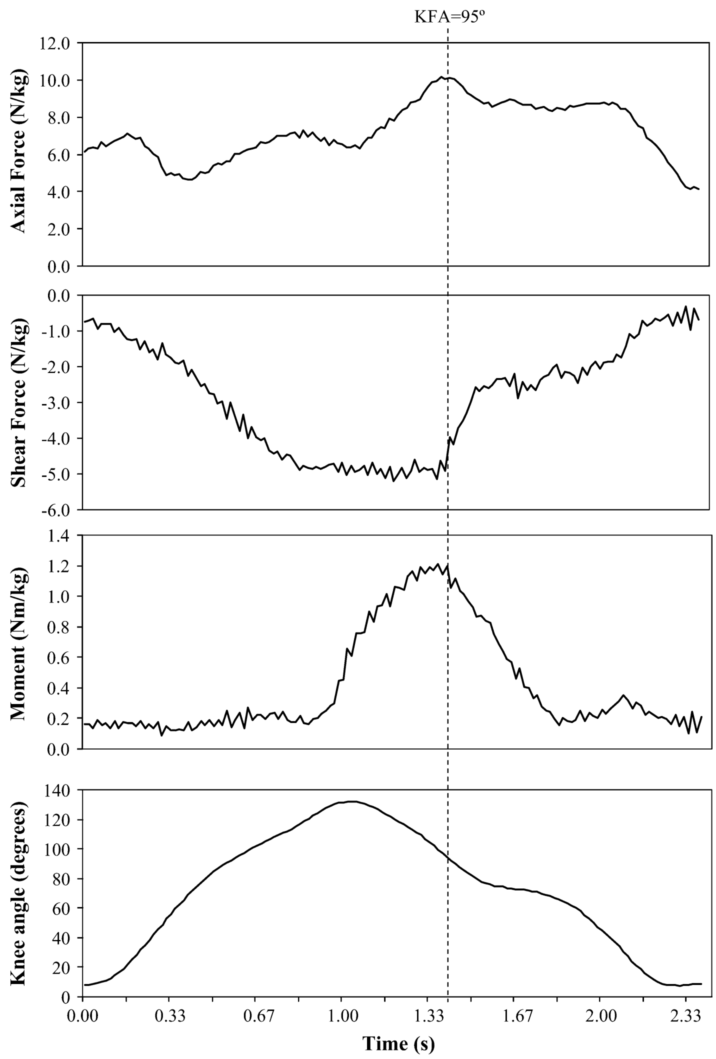

Figure 3. Kinetic and kinematic data from a single subject performing the back squat. Positive axial forces represent compression of the knee joint, negative shear forces represent posterior shear, and positive moments equate to knee extension. Maximum forces and moments occurred at 95° of knee flexion (KFA) during the ascent phase.

Average maximum net knee joint moments were measured in ascending and descending phases and were positive (extensor) in all instances (Figure 3). Extension moments at the knee varied significantly between the two types of squats ($t_{14} = -3.957$, $p = 0.001$). Mean maximum knee moments were as follows: back squat $= 1.0 \pm 0.4$ N·m·kg^{-1}, front squat $= 0.7 \pm 0.2$ N·m·kg^{-1}.

EMG Data

Muscle activity was relatively low during the descent phase and reached maximal levels during the ascent phase (Figure 4). However, bar position did not influence muscle activity (Figure 5). The analyses of variance revealed that average muscle activity was significantly different between the ascending and descending phases for the biceps femoris ($F_{1,56} = 15.772$, $p < 0.001$), rectus femoris ($F_{1,56} = 19.846$, $p < 0.001$), semitendinosus ($F_{1,56} = 4.832$, $p = 0.032$), vastus lateralis ($F_{1,56} = 27.978$, $p < 0.001$), vastus medialis ($F_{1,56} = 19.484$, $p < 0.001$), and erector spinae ($F_{1,56} = 15.033$, $p < 0.001$; see Figure 6).

Discussion

The primary objectives of this investigation were to quantify and compare net compressive and shear forces of the tibiofemoral joint and extensor moments as well as muscle activation while executing front and back squats. However, the limitations of our kinetic analyses should be stated before discussing the results. The results of any project using inverse

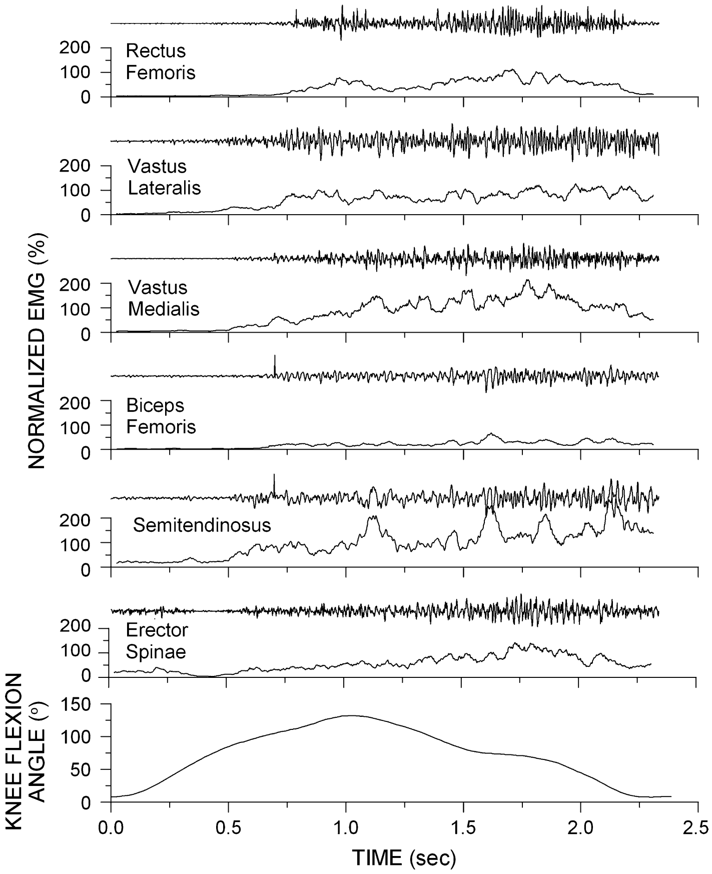

Figure 4. Raw rectified and normalized electromyographic data obtained from a back squat trial. Muscle activation was lower during the descent phase and increased to maximal values during the ascent.

dynamics should be interpreted with caution because the resultant forces calculated represent the net effect of muscle, passive tissue, and joint contact forces. It is impossible to discern the exact contribution that each individual structure contributes to the net force. Future studies could predict forces in individual joint structures using musculoskeletal modeling and optimization techniques.

Interestingly, the two squat variations were similar in some ways and quite different in others. For example, net shear (anterior/posterior) forces at the knee did not vary with bar position, whereas net compressive forces and extensor moments increased for the back squat. The knee extensor moments measured here are similar to those of Salem et al., who evaluated bilateral lower-extremity kinematics and kinetics during submaximal back squats (using a load equal to 35% of their body weight) in rehabilitating patients after unilateral ACL reconstruction (28). Despite the low weight lifted, the similar knee extensor moment values may be explained by technique differences used by the ACL-reconstructed individuals compared with the healthy subjects in the present study. Stuart et al. also compared tibiofemoral joint forces and muscle activity during the power squat, front squat, and lunge (29). They report similar knee extensor moments of 1.0 N·m·kg^{-1} for the back/power squat (compared with 1.0 N·m·kg^{-1} in the current study) and 0.8 N·m·kg^{-1} (compared with 0.7 N·m·kg^{-1} in the current study) for the front squat. Although Stuart and colleagues have reported lower posterior shear forces than the present study, they were unable to detect significant differences between the front and back squat, whereas we were able to do so. Presumably, the increased knee extensor moment required during the back squat is attributable to the additional load lifted during the back squat. More specifically, our subjects lifted 61.8 kg during the back squat and 48.5 kg for the front squat. The lower anterior/posterior (shear) forces measured by Stuart et al. can be attributed to the use of a lower mass during testing (22.7 kg compared with 61.8 kg used here).

In our study, the back squat resulted in higher net compressive (proximal/distal) forces on the knee than the front squat. Escamilla et al. (15) studied the effects of technique variations on knee biomechanics during the back squat and leg press and have reported higher compressive force values than the current values (approximately 32.1 vs. 10.8 N·m·kg^{-1}). However, their subjects were lifting more than twice the mass (133.4 vs. 61.8 kg). In addition, Escamilla et al. estimated individual muscle forces (quadriceps, hamstrings, and gastrocnemius), which produce additional compressive and shear forces (15). Joint contact forces calculated in this manner are typically greater than net compressive forces as reported in the current study. Stuart et al. did not make a distinction between the tibiofemoral joint compression forces that occurred in the two squat variations (29).

Compressive loading on the knee joint is an important variable when good joint health is a concern. Osteoarthritis results from deterioration or loss of the cartilage that acts as a protective cushion between bones, particularly in

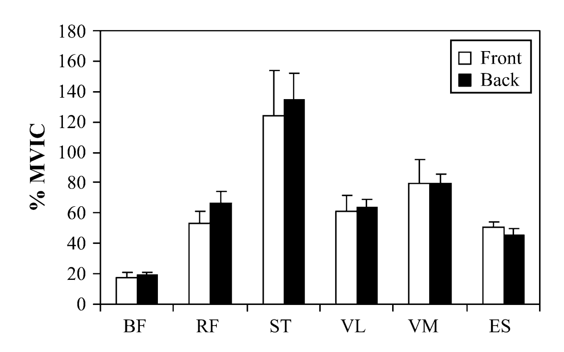

Figure 5. Average muscle activity during the front and back squat as a percentage of maximal voluntary isometric contraction (%MVIC).

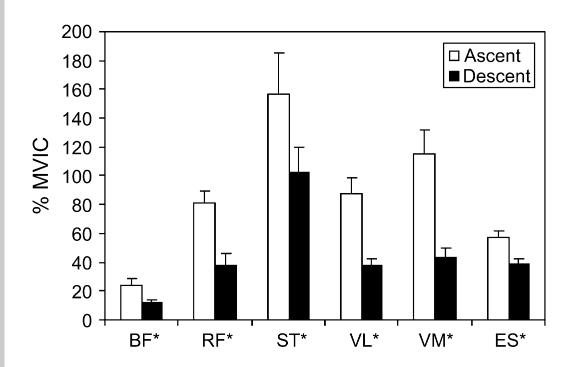

Figure 6. Average muscle activity during the ascending and descending phases of the squat as a percentage of maximal voluntary isometric contraction (%MVIC). *Significant difference between phases ($p < 0.05$).

weight-bearing joints such as the knees and hips (1,8,21). Obesity can contribute to osteoarthritis through continual increased pressure on the knee joint. Similarly, chronic excessive loading on the knee joint, through heavy weight-bearing exercise, could likely have the same result. Thus, by decreasing the compressive force encountered while performing squats, the risk of osteoarthritis and the pain associated with this degenerative disease may be reduced.

Net anterior/posterior forces on the knee were negative, or posteriorly directed. The posteriorly directed A/P forces indicate that the resultant forces serve to resist the anterior displacement of the tibia relative to the femur. In other words, a posteriorly directed shear force on the knee as determined by free body analysis may reveal that the ACL is loaded. This phenomenon has been described in detail by Chow (7). Specifically, the "anterior" shear used by clinicians is the resultant force that draws the tibia forward relative to the femur (e.g., anterior drawer test). On the other hand, a posteriorly directed resultant force at the knee as calculated using inverse dynamics resists the anterior motion of the tibia relative to the femur (potentially loading the ACL). However, a more likely scenario regarding the interaction between the tibia and femur might be that the posterior shear force is being shared by friction and the joint capsule force in addition to ligamentous (ACL) and muscle (hamstring) forces. An average maximum posterior shear force of 440 N was observed in the present study. This value is well below the tensile strength of a normal ACL (1725 N) and a semitendinosis ACL graft (2330 N). Although the calculated shear force is, in all probability, distributed across several structures, the total net posterior shear force is only 25% of the ultimate strength of an ACL and, most likely, would not result in ligamentous damage (17). Because several structures are capable of resisting posterior shear, the ACL may only be responsible for resisting a fraction of the 440 N.

Although excessive tibiofemoral shear forces can be harmful to the cruciate ligaments, several other studies have demonstrated the favorable use of squats during knee rehabilitation, such as after cruciate ligament reconstructive surgery (11,22,24,29). For example, Stuart et al. state that because no anterior shear forces were observed, performing the squat might be appropriate for ACL patients (29). Similarly, Toutoungi et al. (who observed cruciate ligament forces during the body weight squat) have proposed that the squat seems to be a safe exercise to perform during ACL rehabilitation (30).

In addition to Escamilla et al., others have reported potential nonsignificant ACL tensile forces (i.e., posterior shear forces) during the squat (11,15,29,32). This may be partially attributed to moderate hamstring activity, which helps to unload the ACL by producing a posteriorly directed force to the leg throughout the knee movement (4,10,11,20,24). As confirmed in the present study (Figure 3), peak shear forces occur when the knee is flexed 85–105° (32). In this position, the hamstrings are capable of creating a posterior shear force on the tibia. In fact, the EMG level for the ST averaged approximately 130% MVIC for both bar positions and phases (Figures 3 and 4). This information suggests that squats can safely and effectively be used to strengthen the leg muscles that surround and support the knee for ACL patients, and for the general population as well.

Other squat situations may endanger the cruciate ligaments. According to Ariel (who investigated forces acting about the knee joint during deep knee barbell squats), bouncing at the bottom of the squat increased shear force by approximately 33% (3). Additionally, the subject lifting the most weight had the lowest shear force, whereas the subject who had the greatest forward knee motion had the highest shear force (11). Interestingly, Andrews et al. (2) (who calculated knee shear forces using subjects experienced in both the barbell and machine squat) concluded that shear forces were 30–40% higher during the machine squat. Consequently, potential harm to the cruciate ligaments may be increased while performing the machine squat as compared with the barbell squat.

Bar position did not influence muscle activity in the current study. Similarly, Stuart et al. found that muscle activity was equivalent during both lifts (29). However, all six muscles tested were more active during the ascending phase of the squat than during the descending phase. These findings are in accordance with those of several other studies (13,15,23,29). For example, in our study, lower EMG values were found during eccentric (descent) contractions for the rectus femoris compared with concentric (ascent) contractions (Figures 4 and 6). The similarity in EMG activity between bar positions is an intriguing result.

Although more mass was lifted during the traditional back squat, bar position did not influence muscle activity. Because the muscles tested were equally active during the front squat while lifting less mass, it is presumable that the same workout can be achieved with less compressive forces on the knee. It seems the extra load lifted during the back squat (the average 1RM for the back squat was 88.3 kg [ranging from 52.3 to 125 kg], compared with 69.2 kg [ranging from 45.5 to 102.3 kg] for the front squat) is what accounts for the increased compressive forces and extensor moments observed during these lifts. This information suggests that front squats could be advantageous for people with knee problems such as ligament and meniscus tears, and for general long-term joint health. Front squats could also be useful for individuals with shoulder problems that limit their range of motion, making it hard to grip the bar during the regular back squat.

Practical Applications

The present study represents an effort to differentiate between the potential advantages and disadvantages of the two most commonly used forms of the squat exercise. Although bar position did not influence muscle activity, muscle activity was significantly different between the ascending and descending phases. The front squat was shown to be just as effective as the back squat in terms of overall muscle recruitment, with significantly less compressive forces on the knee. Although this suggests that front squats may be more beneficial for certain individuals, we believe that coaches, therapists, and fitness professionals who consistently use the front squat in their training protocols are the exception, and that it is not as widely used as commonly thought. Subsequently, we strongly urge its recognition in the fitness community as an excellent alternative to the more commonly used back squat. It must be noted, however, that for individuals untrained in the front squat, this exercise should be eased into his or her regular training program (gradually increasing both load and frequency of use) to maximize the loading stress on the pertinent muscle groups involved while decreasing unnecessary stress to the relevant joints via the development of proper technique in the lift.

Just as it can be difficult for some individuals to perform the front squat because of flexibility deficiencies, flexibility limitations also exist for some when attempting to perform the back squat. Additionally, there are several variations of the front squat that allow for said lift if flexibility is a concern. For instance, some facilities carry special bars that allow for proper alignment of the elbows (parallel to the floor) without the need for significant flexibility in the wrists or shoulders, as well as without compromising the mechanics of the lift. More commonly, however, wrist straps may be used as an equally serving compromise, which will allow for such a deficit. With this information, one could avoid unnecessary exercise prescription by matching an individual's needs to the safest and most comfortable lift for him or her to perform.

Acknowledgments

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