Sports Performance Series:

The parallel squat

Pat O'Shea, Ed.D.
Center for Theoretical and Applied Sports Physiology
College of Health and Physical Education
Oregon State University

The squat holds a unique and unparalleled position of eminence in athletic strength training and conditioning. It is unique in the sense that, as the so-called “king” of all weight-lifting exercises, it stands supreme in its ability to maximize athletic potential.

For the young athlete, the intrinsic value of long-term squatting is that it stimulates optimal physical growth and development. Some of the significant physiological benefits derived from squatting are:

1. Increased bone density together with a corresponding increase in ligament and tendon strength leading to greater joint stability.
2. Development of large muscle groups in the body’s “power zone,” composed of the lower back, hips, buttocks and thighs.
3. Greater neuromuscular efficiency, making for excellent transfer of power to other biomechanically similar movements requiring a powerful thrust from the hips and thighs—jumping for height or distance, all forms of running, throwing and lifting and pushing with the lower body.

Generally, in speaking of strength we are referring to body joint strength and the torques they generate. Joints grow thicker and stronger in direct response to the stress and strain placed upon them. No other lifting movement, with the exception of the two Olympic lifts (snatch, clean and jerk) places as much stress and strain on the musculoskeletal system as does the squat.

Between the two lifting styles however, there is one crucial difference. Squatting permits the lifter to maintain a mechanically strong lifting base throughout the full-range of movement. The knees are not subjected to the danger of maximum hyperflexion as in snatching and cleaning. When executed correctly, the squat generates far less stress and strain on the knee joints and back than either of the two Olympic lifts. In the parallel squat, the athlete has a full-body strength lift which, from a mechanical standpoint, maximizes dynamic strength while minimizing joint stress.

Mechanics of the parallel squat

In the performance of the parallel squat, there are two distinct styles: the “high-bar” squat in which the bar sits high across the shoulders right at the base of the neck, and the “low bar” or “power” squat in which the bar rests about two inches below the top of the shoulders.

The primary difference between the two styles is a matter of mechanical leverage and the stress imposed on the working muscles, with both factors changing in relationship to the shoulder height position of the bar and the width of the stance. In the power squat with the bar positioned low, heavier loads can be lifted, due to the greater leverage offered by a reduced lever arm.

Basically, the techniques of both squat styles share many common mechanical features of execution. In making a biomechanical analysis of the parallel squat, it would be broken down into three segments—ready position, descent, and ascent. The correct execution of each segment sequence is crucial in producing a strong, fluid, mechanically effective squat movement.

Ready position

The bar is positioned across the shoulders with the load distributed over the mass of the back.

Hands are positioned as close in on the bar as possible.

Head is up; the chest is out.

Shoulders are back; the back is flat with an arch at the base. The spinal erectors are in a strong isometric contraction.

Feet are flat on the floor and spaced wider than shoulder width, with the toes turned out at approximately 30 degrees.

Immediately prior to the squat descent, isometrically contract all the muscles of the upper thigh and torso. This facilitates the “stretch reflex” mechanisms which assist in producing a strong eccentric contraction in the flexors dominate muscles involved in the descent. Whenever a muscle is pre-stretched just prior to lifting (in this case squatting) the response of the muscle is a stronger contraction.

Descent

After inhaling deeply, commence to squat down in a slow and controlled manner, utilizing a strong eccentric contraction of the hip and quadricep extensors, to a position where the top of the thighs are slightly lower than parallel (where the break in the legs at the thigh is lower than the top of the leg at the knee). Never “free fall” into rock bottom hyper-knee flexion position and attempt to bounce out. The knee joint is not designed to withstand this type of stress.

On the descent, a strong eccentric contraction is critical for two reasons: To minimize the bar’s vertical velocity (which should be approximately 45 degrees per second), and to allow time for the hip and quadricep muscles to store “kinetic” energy generated by eccentric contraction. Stored kinetic energy plays a major role in the transition from the descent to the ascent (Chart 1).

During the descent, avoid excessive forward lean of the torso by keeping the hip under the bar as much as possible. The greater the forward lean, the greater is the hip extension torque and reduced thigh extension torque.

In the high bar squat, the bar follows a perpendicular path downward and upward and is centered through the arch of the feet. In the power squat, the bar follows an arched descent as the hips move down and out at the bottom position. With the bar positioned low on the shoulders there is a tendency toward forward trunk lean which is minimized by concentrating on
keeping the hips under the bar as long as possible and utilizing the quadriceps to initiate the ballistic drive out of the bottom position. Biomechanically speaking, it is far safer to lift with your legs rather than your back.

Ascent

The transition from the descent to the ascent commences with a powerful drive to accelerate out of the bottom position utilizing strong quadriceps extension. This is facilitated by the stored kinetic energy generated by eccentric contraction of the hips and thighs during the descent. Simultaneously, with the quadriceps action thrust the head back to benefit from a strong contraction of the trapezius. (This aids in counteracting upper torso lean.) Once upward acceleration has started, immediately begin to forcefully thrust the hips forward under the bar.

Throughout the ascent, maintain a tight torso. Don't relax until knee lock is achieved in the standing position. Upon passing the sticking point (about 30 degrees above parallel) begin to slowly expel air through the mouth, thereby avoiding the Valsalva effect and the sharp increase in blood pressure and heart tension it creates.

The application of the stored kinetic energy concept is a vital key to instantaneous power output as required in the execution of the squat. During the descent, strong eccentric contraction mechanically stretches the hip and quadriceps extensors, resulting in kinetic energy being generated and stored in the muscles. On the ascent this energy helps provide the muscular force necessary to accelerate out of the bottom position. (Force—Velocity relationship at work. Chart 2.)

Squat variations

In addition to the back squat, there are a number of variations which can be effectively isolated and work the muscles of the power zone. These exercises also need to be a part of the total leg and torso strength training program because variation is one of the keys to continued progress and optimal athletic performance.

Front squat: Invaluable for providing maximum stress on the quadriceps. Produces increased thigh torque and decreased hip torque.

Hack squat: Stresses the hips and quadriceps but not the back.

Leg extension: Isolates the quadriceps, especially the vastus medialis.

Isoinertial squat (accommodating resistance): Stresses the neuromuscular system. Permits the athlete to exert maximal force throughout the entire ascent of the squat.

Partial squats are not a good substitution to performing the regular full squat. From

Figure 1: Starting position of the high bar squat.

<table>
<thead>
<tr>
<th>Flexors dominate</th>
<th>Extensors dominate(^a)</th>
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<tbody>
<tr>
<td>(Squatting down)</td>
<td>(Going up)</td>
</tr>
<tr>
<td>1. Trunk</td>
<td>Abdominals</td>
</tr>
<tr>
<td></td>
<td>Hip flexors</td>
</tr>
<tr>
<td></td>
<td>Gluteus maximus</td>
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<tr>
<td></td>
<td>Spinal erectors</td>
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<tr>
<td></td>
<td>Hamstrings</td>
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<tr>
<td></td>
<td>Abdominals</td>
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<tr>
<td></td>
<td>Quadriceps</td>
</tr>
<tr>
<td></td>
<td>Hamstrings</td>
</tr>
<tr>
<td></td>
<td>Gastrocnemius</td>
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</tbody>
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\(^a\)Ascent from the bottom squat position is mainly thigh power up to the sticking point (approximately halfway up). At this point, trunk and shank torques reach their highest value.

Chart 1: Major muscle groups used in squatting.

<table>
<thead>
<tr>
<th>Squat flexion</th>
<th>Eccentric contraction of hips and quadriceps</th>
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<tbody>
<tr>
<td></td>
<td>stretch reflex facilitation</td>
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<tr>
<td></td>
<td>Kinetic energy stored (hips and quadriceps)</td>
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<tr>
<td>Squat extension</td>
<td>Stored kinetic energy utilized</td>
</tr>
<tr>
<td></td>
<td>High quadriceps force</td>
</tr>
<tr>
<td></td>
<td>Greater hip and torso rotational force</td>
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<td></td>
<td>Maximum extension acceleration</td>
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Chart 2: Stored kinetic energy as applied to the squat.
a biomechanical standpoint there are a number of reasons for this. First, to develop maximum hip or knee joint strength, the joint has to be worked through as full a range of movement as possible. Second, you don’t realize an optimal neuromuscular training effect. Third, partial squats lead to over-development of the quadriceps at the expense of the hamstrings. This produces an imbalance in the hamstring-quadriceps strength ratio which can contribute to both knee and hamstring injuries.

Assistance exercises which can play an important role in isolating and strengthening the muscles of the power zone are:

1. Stiff-leg deadlifts for the glutes, hamstrings and spinal erectors.
2. Good-morning lift (with knees slightly unlocked) for the hips and spinal erectors.
3. Leg curls to develop a balance ratio (3 to 2) between the quadriceps and hamstrings.
4. Back hyperextension for the glutes, hamstrings, and spinal erectors.
5. Diagonal-rotational trunk movements:
   a. incline sit-up curl
   b. lateral trunk flexion
   c. seated barbell twist
   d. hyper-roll-up (horizontal)
   e. medicine ball—all variations
6. Plyometric training

**Squatting and knee injuries**

Due to the fact that the knee is probably the most complicated joint in the human body, is it safe to expose it to the stresses and strains of squatting?

The answer to this question is twofold. If there are no congenital problems or acquired knee injuries, the use of the squat can be considered safe. In fact, sufficient evidence exists indicating that a knee joint strengthened through squatting is far less susceptible to injury from the stresses imposed upon it during athletic competition (e.g., football, basketball and ice hockey).

The degree of safety however, is all relative to the squat technique employed. The only time risk-factors come into play is when accepted biomechanically correct procedures are ignored. A functional anatomical look at the complex flexion and extension of the knee when squatting demonstrates why.

When executing the full squat, flexion is accompanied by internal rotation of the tibia upon the femur and extension accompanied by external rotation. The ligaments alternate slacken or become taut—the menisci move backward in flexion and forward in extension.

The combination of the squat load with rotary stress during flexion and extension can be a cause of meniscus injury. With maximum flexion (deep squat) the posterior portions of the menisci are compressed between the posterior aspects of the tibial and femoral condyles. Internal rotation of the femur upon the tibia in this hyperflexed position forces the posterior segment of the medial meniscus toward the center of the joint space. This places strain upon the inner concave margin of the meniscus causing it to tear.

The factors causing this type of injury to the meniscus are hyperflexion of the knee in a deep squat position combined with forceful internal rotation that occurs when the tibia is fixed to the ground. In this position the leg cannot avoid or minimize the torsion stress placed upon it. Ascending from the deep squat position with the knees hyperflexed, the femur must strain to internally rotate upon the tibia. This places further stress on the meniscus.

Ligamentous injuries can occur to the knee when a force (strain) is exerted that exceeds normal range of motion or causes an abnormal motion of the joint. Abnormal motion includes executing a deep squat and bounding out of the bottom which causes excessive rotation and hyperflexion of the knee. Use of this type of squatting technique may result in a knee sprain with a minor tearing of a few fibers without loss of integrity of the ligaments. Ligament injuries of a more serious nature may include: 1) tearing of the deep medial ligament, 2) tearing of the tibial collateral ligament, 3) tearing of the anterior cruciate ligament, and 4) rupture of the patellar ligament.

Again, it must be emphasized that by executing the full squat correctly, the knee joint is not exposed to excessive forces that will in any way damage it.

**Ergogenic aids**

**Lifting belts**: Their primary purpose is to provide added support to the layers of (Continued, page 78)