KNEE JOINT KINETICS AND LOWER EXTREMITY MUSCLE ACTIVATION DURING FRONT AND BACK SQUATS

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INTRODUCTION

Most activities of daily living require the coordinated contraction of several muscle groups simultaneously. Squats require this type of synchronization and 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 (Lutz et al., 1993). 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 (Escamilla, 2001).

Two forms of the squat lift are the back squat and the front squat. Strength and conditioning professionals have recognized the similarities between the lifts, but 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 and may also isolate the quadriceps more than back squats. These beliefs are not supported by empirical evidence. The two primary purposes of this study were 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 muscle groups. More specifically, we compared the compressive forces, shear forces, and moments applied to the tibiofemoral joint, and lower extremity muscle activity as well.

METHODS

Nine healthy males and six healthy females (22.1 ± 3.6 yr, 171.2 ± 6.4 cm, 69.7 ± 6.2 kg) who were experienced at performing both front and back squats participated in this study. All subjects were free from orthopedic injuries that would have limited their ability to perform. To assess the electromyographic (EMG) activity of selected muscles [Rectus Femoris (RF), Vastus Lateralis (VL), Vastus Medialis (VM), Biceps Femoris (BF), Semitendinosis (ST), and lumbar Erector Spinae (ES)], six pairs of surface electrodes were attached to the right side of the body. The amplified EMG signals were sampled at 900 Hz using a Peak Motus® 2000 system. Three genlocked video cameras collecting at 60 Hz and a force plate collecting at 900 Hz were used to collect data for knee kinetics calculations. Subjects performed one of two variations of the squat exercise, chosen randomly, with their right foot on the force plate. For each trial, the subjects squatted a load of 70% of their pre-determined 1 repetition maximum lift. Subjects lifted nearly 90% of their body weight during the back squat and almost 70% of their body weight during the front squat. Two trials consisting of three repetitions each were performed for each squat variation being tested. The second repetition of each trial was used for subsequent analyses. Joint reaction forces and moments were calculated for the knee using an inverse dynamic analysis that combined the
anthropometric, kinematic, and ground reaction force data. In order to calculate the average normalized EMG values, the raw EMG signals were full-wave rectified and divided by the corresponding maximum EMG value for that muscle. All EMG data were partitioned into ascending and descending phases.

In order to identify any potential differences between the front and back squat for the kinetic variables, separate paired t-tests with Bonferroni corrections were performed. EMG data for each of the six muscles tested were analyzed using a 2 x 2 (bar position x phase) repeated measures MANOVA with $\alpha = 0.05$.

RESULTS AND DISCUSSION

The back squat resulted in higher compressive forces on the knee (10.8 ± 2.1 N/kg) than the front squat (9.2 ± 1.5 N/kg) ($t_{14} = 3.661, P = 0.003$). Shear forces at the knee did not vary between the back and front squat ($t_{14} = -1.243, P = 0.234$). Extension moments at the knee did not vary between the two types of squats ($t_{14} = 1.284, P = 0.220$). Bar position did not influence muscle activity. Univariate tests indicated that all six muscles were more active ($P \leq 0.003$) during the ascent phase of the exercise (Figure 1). By decreasing the compressive force encountered while performing squats, the risk of osteoarthritis and pain may be reduced. Since the muscles monitored were equally active during the front squat while lifting a lighter load, it is presumable that the same workout can be achieved with less compressive forces on the knee. 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.

SUMMARY

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. This suggests that front squats may be more beneficial for certain individuals.

REFERENCES


Figure 1. 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).*