# EIECTROMYOGRAPHIC COMPARISON OF THE BACK SQUAT AND OVERHEAD SQUAT

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The present study sought to compare the electrical activity of core and lower-body muscles during performance of the back squat and overhead squat. Fourteen male rugby union athletes performed repetitions of both squatting movements with 60, 75 and 90% of their respective 3RM loads. Additional comparisons were made with isolation exercises designed to target the core musculature and a further condition to equate the absolute load lifted. The overhead squat resulted in slight increases in activity of the rectus abdominus and external oblique, with larger decreases in activity of the erector spinae and lower-body muscles. The results show that the differences in muscle activity are largely a function of the absolute load lifted and that anterior core muscles are recruited to a greater extent during isolation exercises compared with squatting movements.

**KEY WORDS:** strength & conditioning, weight-training, muscle activity.

**INTRODUCTION:** The back squat is recognised as one of the most effective resistance exercises to develop the musculature of the lower-body (Gullett et al. 2009). Due to the popularity of the exercise a number of variations have been created with the belief that each presents an effective but somewhat distinct biomechanical and physiological stimulus (Hasegawa 2004). Popular variations include the front squat, sumo squat, split squat and overhead squat. Of all the variants commonly performed, the original back squat enables displacement of the heaviest loads which thereby explains the strong stimulus presented by the exercise. In contrast, the lightest loads are displaced during performance of the overhead squat. However, this variation is commonly prescribed for athletes based on the assumption that the exercise elicits greater activation of the core musculature in comparison to the other squatting movements (Gullet et al. 2009; Hasegawa 2004). As the core musculature stabilizes the important lumbopelvic region and is considered integral to adopting appropriate postures and facilitating transmission of forces through the body (Willardson 2007), the overhead squat has become a widely prescribed exercise. The assumed increased activation of the core musculature during the overhead squat is thought to be caused by the unique positioning of the external resistance (Brown 2006). When performing the overhead squat the shoulders are used to position the barbell above the head with the elbows fully extended. Due to the instability of this configuration, it is believed that the core musculature is strongly recruited to maintain balance and correct postural perturbations (Brown 2006). However, despite widespread acceptance of the effectiveness of the overhead squat to recruit and provide an appropriate training stimulus for the core musculature, there have been no experimental studies conducted to test these hypotheses. Therefore, the primary aim of this investigation was to compare electrical activity of muscles commonly selected to represent the core musculature during performance of the back squat and overhead squat. A selection of popular isolation exercises used to recruit the core musculature was included to provide additional comparisons. In addition, EMG readings from the major muscles of the lower body were measured to investigate the total effect of altering the position of the load from the posterior shoulders to overhead.

**METHODS:** Fourteen elite male rugby union athletes (age: 26 ±5 yr; stature: 182.5 ±12.5 cm; mass: 90.5 ±17.5 kg; 3RM back squat: 147.5 ±27.5 kg; 3RM front squat: 77.5 ±17.5 kg) provided informed consent to participate in this study, which was granted institutional ethical approval. Data were collected for each subject over two sessions separated by one week.

The first session comprised 3RM testing in the back squat and overhead squat in a randomised order. During the second session EMG activity was recorded as subjects performed the back squat and overhead squat with 60, 75 and 90% of their respective 3RM loads. In addition, to investigate the effect of the magnitude of the load on muscle activity across the exercises the subjects performed a fourth back squat condition with the same absolute load lifted during their heaviest overhead squat trial. Subjects were instructed to perform the eccentric phase of all squats to a depth where the top of the thighs became parallel with the floor, and to perform the concentric phase at maximum velocity. Once the squat repetitions were completed each subject then performed four core exercises comprising the front plank (FP), side plank (SP), swiss ball jack-knife (SJK) and straight-leg situp (SLU). All conditions comprised two separate repetitions to assess intra-trial reliability. For the isometric FP and SP, two repetitions comprising a 15 second hold were completed.

Surface EMG signals were recorded from eight muscles: 1) anterior deltoid (AD) on the anterior aspect of the arm 4cm below the clavicle; 2) rectus abdominus (RA) 2cm lateral to the umbilicus; 3) external oblique (EO) lateral to the RA and above the anterior superior iliac spine; 4) erector spinae (ES) 2cm lateral to the L3 vertebra; 5) gluteus maximus (GM) half the distance between the trochanter and sacral vertebrae; 6) vastus lateralis (VL) 2-5cm above the patella and lateral to the midline; 7) biceps femoris (BF) lateral aspect of the thigh between the tochanter and back of the knee; and 8) gastrocnemius (GA) 2cm lateral of the midline of the knee on the belly of the muscle. Electrodes were placed on the muscle belly, parallel to the orientation of the muscle fibres and on the right side of the subjects' body. The skin was shaved, abraded and cleansed with acetone before placing a disposable bipolar surface electrode over the muscle 2 cm apart. The myoelectric signal was transmitted through the use of a telemetry transmitter using a wireless EMG system (Zero-wire EMG, Aurion, Italy). The amplified myoelectric signal was detected by the receiver-amplifier and then sampled at 2000 Hz. The signal was full wave rectified and filtered (6-pole Butterworth, band pass filter 10-500 Hz). The integrated value was calculated and then averaged over the entire repetition, the concentric phase and the eccentric phase. Values were normalised relative to the average integrated EMG recorded during maximum voluntary isometric contractions (MVIC's) recorded for each muscle and then expressed as a percentage. Eccentric and concentric phases were demarcated by manual transmission of an electronic pulse. A general linear model with repeated measures and Bonferroni *post hoc* tests were used to determine significant differences. All statistical analyses were conducted using SPSS Version 17.0, with statistical significance accepted at a level of $p<0.05$

**RESULTS:** Intra-trial reliability for average integrated EMG activity across the full repetition, eccentric phase and concentric phase were all high (ICC= 0.96, 0.92 and 0.91 respectively). Across the full repetition significant main effects of squatting exercise were obtained for all muscles. The results showed that when the athletes switched from the back squat to the overhead squat there was a significant increase in activity of the AD, RA and EO; and a significant decrease in activity of the ES, GM, VL, BF and GA. The same pattern of results was obtained when repetitions were analysed across the eccentric and concentric phases (Table 1).

Comparisons between the activity of the core musculature during both squatting movements and popular isolation exercises were made using data collected during the 90% 3RM trials (Figure 1). Significantly greater muscular activity was recorded for the RA and EO in the front plank, side plank and straight-leg situp compared with both squatting exercises. In contrast, significantly greater muscular activity was recorded for the ES in both squatting movements in comparison to each of the isolation exercises.

To assess whether differences in EMG activity between the squats were the result of load position or the absolute magnitude of the external load, a final comparison was made with the loads equated between the exercises (Figure 2). The results revealed that when the same absolute load was used, RA and EO activity remained elevated in the overhead squat and differences in EMG activity previously noted in the lower body muscles and the ES became nonsignificant.

**Table 1: Normalized (%MVIC) electromyographic comparisons (mean±SD) of back squats and overhead squats performed with 60, 75 and 90% 3RM barbell loads. *Significantly greater than corresponding condition**

| | | Back Squat | | Overhead Squat | |
|---|---|---|---|---|---|
| Load | Muscle | Eccentric | Concentric | Eccentric | Concentric |
| | AD | 13.3 ±6.7% | 19.7 ±9.3% | 44.8 ±22.1%* | 48.8 ±20.4%* |
| | RA | 3.9 ±2.3% | 9.9 ±4.6% | 5.9 ±3.1%* | 11.2 ±4.9% |
| | EO | 9.1 ±3.5% | 21.8 ±7.5% | 15.2 ±6.1%* | 23.7 ±11.9% |
| 60% | ES | 61.4 ±15.5* | 75.9 ±26.6%* | 54.7 ±13.9% | 56.4 ±17.3% |
| 3RM | GM | 19.2 ±10.0%* | 66.9 ±34.1%* | 14.4 ±9.3% | 49.0 ±26.1% |
| | VL | 50.6 ±20.1%* | 87.5 ±25.4% | 43.9 ±18.2% | 80.4 ±24.5% |
| | BF | 29.0 ±17.2% | 56.0 ±24.4%* | 26.4 ±15.0% | 45.9 ±25.0% |
| | GA | 25.8 ±15.4% | 44.9 ±22.9% | 24.1 ±11.2% | 48.7 ±29.8% |
| | AD | 13.6 ±9.5% | 17.5 ±9.8% | 56.2 ±26.5%* | 52.1 ±19.3%* |
| | RA | 4.3 ±2.4% | 10.1 ±4.1% | 6.4 ±3.5%* | 9.9 ±4.6% |
| | EO | 11.1 ±4.2% | 24.4 ±10.2%* | 15.1 ±6.2%* | 21.8 ±7.5% |
| 75% | ES | 72.1 ±22.2%* | 83.8 ±21.4%* | 53.1 ±18.8% | 75.9 ±26.6% |
| 3RM | GM | 24.0 ±12.1%* | 85.7 ±45.2%* | 13.4 ±6.9% | 66.9 ±34.1% |
| | VL | 58.9 ±24.1%* | 91.7 ±26.6% | 48.5 ±20.4% | 87.5 ±25.4% |
| | BF | 33.0 ±20.0% | 66.5 ±29.1%* | 28.1 ±16.7% | 56.0 ±24.4% |
| | GA | 31.4 ±21.3% | 56.5 ±35.9%* | 24.7 ±10.3% | 44.9 ±22.9% |
| | AD | 13.6 ±9.5% | 25.1 ±14.7% | 74.9 ±30.4%* | 59.7 ±18.7%* |
| | RA | 4.3 ±2.4% | 10.7 ±4.1% | 6.8 ±3.5%* | 11.4 ±4.6% |
| | EO | 11.1 ±4.2% | 22.5 ±11.0% | 18.7 ±6.9%* | 27.2 ±9.2% |
| 90% | ES | 72.1 ±22.2% | 94.7 ±20.8%* | 66.7 ±13.5% | 68.7 ±22.5% |
| 3RM | GM | 24.0 ±12.1%* | 92.7 ±50.0%* | 18.5 ±9.5% | 53.5 ±32.1% |
| | VL | 58.9 ±24.9%* | 99.2 ±30.6%* | 58.5 ±22.4% | 82.3 ±24.1% |
| | BF | 33.0 ±22.1% | 71.1 ±27.6%* | 34.9 ±21.6% | 44.9 ±26.8% |
| | GA | 34.4 ±17.3%* | 62.5 ±38.4% | 27.4 ±9.9% | 45.2 ±23.7% |

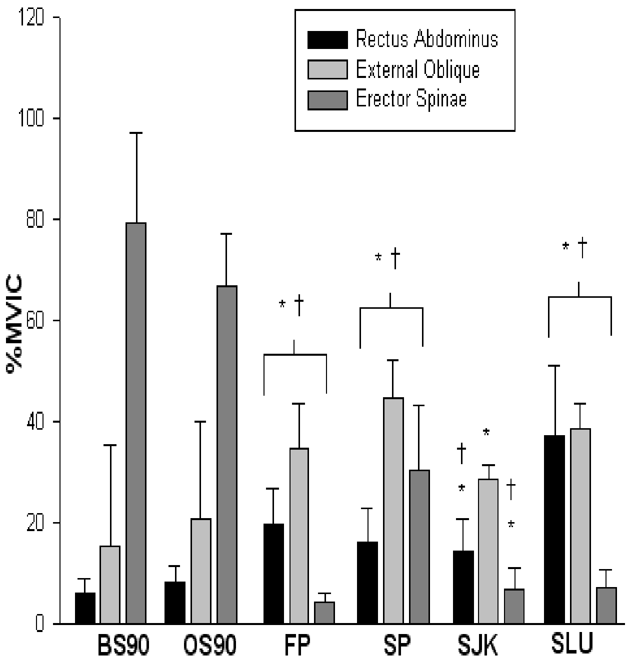


**Figure 1: Squat and isolation exercise comparison**
***significantly different from back squat**
**†significantly different from overhead squat**

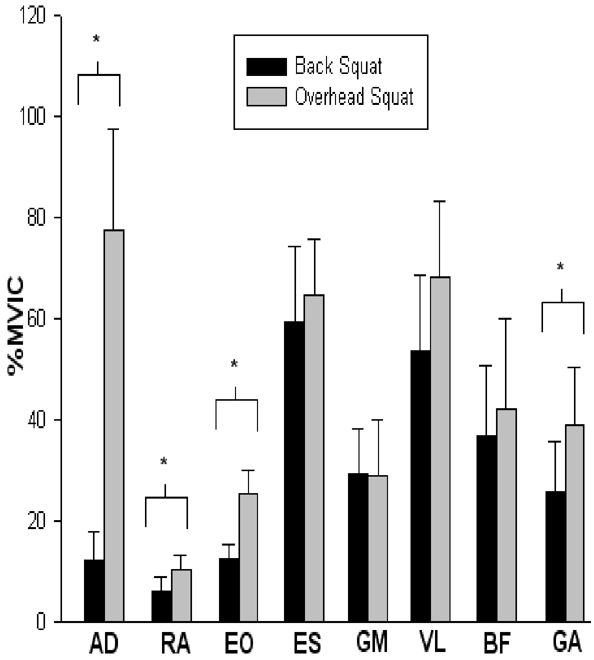


**Figure 2: Equated load comparison**
***significant difference between squats**
**Error bars represent +SD**

**DISCUSSION:** The results of the present study show that electrical activity of a range of skeletal muscles can be altered by choosing to perform either the back squat or overhead squat. In support of anecdotal claims, the results demonstrate that significantly greater muscle activation occurs in the anterior core muscles (RA and EO) during performance of the overhead squat in comparison with the back squat. However, the increases in RA and EO activity when performing the overhead squat were shown to be low in magnitude and, importantly, substantially less than that which could be developed during exercises commonly used to isolate the core musculature. In contrast, muscular activity in the ES was shown to be significantly greater when performing the back squat. The ES is an important core muscle which acts in concert with the anterior muscles to create multi-segment stiffness across the lumbopelvic region (Willardson 2007). The greater ES activity measured during the back squat is explained by differences in the external resistance and positioning of the trunk. When squatting with the bar overhead the torso position must be held relatively upright in order to maintain the barbell position directly above the shoulders to minimise the resistive torque. Conversely, when performing the back squat the torso can be inclined to more effectively distribute the muscular effort between the knee and hip extensors (Wretenberg 1996). As a result, the heavier external resistance and more inclined torso during the back squat create a larger resistance moment which requires greater muscular effort to counterbalance. Across both squat exercises muscular activity increased consistently with heavier resistances. The results of this study also demonstrate that resistance was the primary factor differentiating muscular activity of the ES and lower-body muscles between the two squatting exercises. When using relative resistances, the heavier absolute loads lifted during the back squat resulted in significantly greater activity in the ES and lower-body muscles. However, when the magnitude of the external resistance was equated the differences in muscle activity decreased and in the case of the GA became significantly greater during the overhead squat. The increased muscular activity in the GA and tendency towards greater values in the VL during the overhead squat after equating resistances were most likely the result of differences in exercise kinematics. In particular, increased anterior displacement of the knee during overhead squats to compensate for the more upright torso position may explain the greater muscular activity recorded. A more detailed biomechanical investigation would be required to test this explanation.

**CONCLUSIONS:** The results of this study question the use of the overhead squat as an alternative exercise to increase recruitment of the core musculature. Performance of the overhead squat does result in slight increases in the activity of anterior core muscles in comparison to the back squat; however, these small increases are unlikely to have practical significances. In addition, performance of the overhead squat results in a substantial decrease in ES and lower-body muscle activity in comparison to the back squat. The large RA and EO recordings from the popular core exercises suggest that these movements should be combined with the more functional multi-joint exercises as part of a comprehensive training regime. Whilst the overhead squat does not appear to provide any benefit over the back squat in terms of recruitment of the core musculature, the exercise may be effective in other areas, including enhanced stability of the shoulder girdle and improved mobility of the lower-body joints. Further research is required to investigate the potential impact of the overhead squat in these areas.

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