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Electromyographic and Kinetic Analysis of Traditional, Chain, and Elastic Band Squats

WILLIAM P. EBBEN[1] AND **RANDALL L. JENSEN**[2]

[1]Department of Physical Therapy/Exercise Science Degree Program, Marquette University, Milwaukee, Wisconsin 53201; [2]Department of Health, Physical Education, and Recreation, Northern Michigan University, Marquette, Michigan 49855.

ABSTRACT

This study examined mean integrated electromyography (I-EMG) for the quadriceps and hamstring muscle groups, as well as mean and peak vertical ground reaction forces (GRFs), for 3 conditions of the back squat. Conditions included (a) squat with barbell and weight plates, (b) squat with barbell and weight plates plus chains hung on each end of the barbell to replace approximately 10% of the squat load, and (c) squat with barbell and weight plates plus elastic bands offering resistance equivalent to approximately 10% of the squat load. Weight plates equal to the load added by either the chains or elastic bands were removed for the latter 2 squat conditions. Vertical GRFs were obtained during a single testing session for all 3 squat conditions. The tests were performed on a 2-cm thick aluminum platform (0.76 × 1.0 m) bolted directly to a force plate (OR6-5-2000, AMTI, Watertown, MA). Surface electrode I-EMG data from the quadriceps and hamstrings were recorded at 500 Hz. The exercise order was randomly determined for 11 NCAA Division I athletes who had experience using these types of squats. A repeated measures analysis of covariance revealed no differences in I-EMG and GRF during the eccentric or concentric phase for any of the 3 squat conditions. Analyses showed that mean GRF and I-EMG was significantly different between eccentric and concentric phases for all groups. The results question the usefulness of performing squats combining barbell and weight plates with chain and elastic resistance.

Key Words: compensatory resistance, strength, back squat

Reference Data: Ebben, W.P., and R.L. Jensen. Electromyographic and kinetic analysis of traditional, chain, and elastic band squats. *J. Strength Cond. Res. 16(4):547–550. 2002.*

Introduction

The back squat is frequently performed according to the methods specified by the National Strength and Conditioning Association position paper (3). But other variations of the squat have been recommended. Variations include the addition of elastic bands and chains attached to the end of the barbell in addition to, or as a replacement for a portion of, the weight plates.

Descriptions of training methods combining free weights and elastic or chain resistance are limited. Simoneau et al. (9) described biomechanic considerations of elastic resistance for rehabilitation. Treiber et al. (10) evaluated the effects of using Theraband and dumbbell training with tennis players, specifically looking at shoulder rotation torque and serve performance. Behm (1) and Borek (2) described the use of elastic resistance as a strength training method.

Recently, Simmons (7, 8) has recommended the combination of chains or elastic resistance for training strength/power athletes. For example, chains or elastic bands are attached to the end of the barbell so that as the lifter ascends during the squat, an increasing load is assumed as the chain is lifted off the floor or the elastic band lengthens. The increased loading during the ascent theoretically offers a greater concentric training load thought to be manageable because of the mechanical advantage that occurs as the lifter ascends during the squat. In sum, the load increases as the mechanical advantage increases.

Behm (1) hypothesized that free weights and elastic resistance together overcome the shortcomings of each other. More specifically, Behm claimed that resistance training with elastic tubing does not provide muscle overload early in the range of motion (ROM) of an exercise. Alternatively, using only free weights provides less than optimal resistance throughout the ROM of many exercises due to momentum and mechanical advantage.

But no research has evaluated the purported advantages of these training methods. It was hypothesized that squats performed with the addition of chain or elastic resistance will result in differences in motor unit activation and reaction forces compared with squats performed without the addition of chains or elastic bands, even under circumstances in which the load is equated. The purpose of this study was to assess motor unit activation, rate of force development, and peak force development of these variations of the squat.

Methods

Experimental Approach to the Problem

This study compared mean integrated electromyography (I-EMG) values for the quadriceps and hamstring muscle groups, mean vertical ground reaction forces (GRFs), and maximum GRF for each of the 3 squat conditions. Data were collected during the third repetition of the subjects' 5RM (5 repetition maximum) performance of each squat condition.

All data were collected during a single testing session with the order of testing randomized. Five minutes of rest was allowed between exercises for recovery of the phosphagen system. Warm-up, static stretching, and exercise-specific warm-up activity, including 1 set of 5 repetitions at 50% of the subjects' estimated 1RM and 1 set of 3 repetitions at 80% of the subjects' estimated 1RM, were performed before the test exercises. Following the warm-up, the subjects were allowed at least 5 minutes of rest, during which time their skin was prepped for surface electrode placement. Skin preparation for surface electrodes included shaving hair, removing dead skin from the surface with a roughing pad, and cleansing the surface with alcohol. Three surface electrodes were used for each muscle. For the quadriceps, 1 electrode was placed on a longitudinal axis halfway between the greater trochanter and the medial epicondyle of the femur; the second electrode was placed 1 cm distal to and in the same longitudinal axis as the first electrode and the ground electrode was placed on the lateral condyle of the tibia. For the hamstring, the first electrode was placed in the center of the thigh midway between the gluteal fold and the back of the knee; the second electrode was placed 1 cm distal to and in the same longitudinal axis as the first electrode and the ground electrode was placed on the lateral condyle of the femur. Following placement of the surface electrodes and connection of the electrodes to the computer, the subject was tested during each of the 3 squat conditions.

Electromyographic data were recorded at 500 Hz by surface electrodes. According to Isear et al. (4), it is unnecessary to separately evaluate EMG muscle activity of the medial and lateral hamstrings. The surface electrodes were connected to an amplifier and streamed continuously through an analog to digital converter (Biopac Systems, Inc. Goleta, CA) to an IBM-compatible notebook computer and diskette. All GRFs were limited to the surface area of a 2-cm thick aluminum platform (0.75 × 1.0 m) bolted directly to a force plate (OR6-7-2000, AMTI, Watertown, MA). Vertical GRFs were determined at 500 Hz through the force plate, which was connected to an amplifier (SCA-3, AMTI) and streamed continuously through an analog to digital converter (Biopac) to an IBM-compatible notebook computer and diskette. All data were filtered with a 10-Hz high pass filter according to the methods described by Winter (11) and saved with the use of computer software (AcqKnowledge 3.2, Biopac). Saved EMG data were full wave rectified and integrated for the duration of the contraction. Zeroing the force plate for the weight of the subject and subtracting the weight of the bar minimized GRF variability between subjects. Comparisons were then made of the mean I-EMG and the mean and peak vertical GRFs for all 3 squat conditions during the eccentric and concentric phases.

Subjects

Eleven NCAA Division I athletes, including 4 female volleyball and 2 female basketball players (age = 19.1 ± 1.7 years; height = 179.8 ± 2.9 cm; weight = 76.5 ± 4.1 kg) as well as 5 male wrestlers (age = 19.4 ± 1.5 years; height = 176.2 ± 5.7 cm; weight = 74.9 ± 5.6 kg), volunteered to serve as subjects for the study. All subjects performed all 3 conditions of the squat in their regular weight-training program. Subjects completed a Physical Activity Readiness Questionnaire and signed an informed consent form before participating in the study. Approval for the use of human subjects was obtained from the institution before initiation of the study. Subjects had performed no strength training in the 48 hours before data collection.

Statistical Analyses

Mean vertical GRF, maximum vertical GRF, and mean I-EMG data for the quadriceps and hamstrings were analyzed using a 2-factor analysis of covariance (ANCOVA) (contraction phase × squat condition) with repeated measures using gender as the covariate. The repeated measures were eccentric vs. concentric contraction phase and squat conditions of traditional, chain, and elastic bands.

Results

Values of the mean I-EMG for hamstring and quadriceps muscle activity and the mean and peak vertical GRFs are displayed in Tables 1–4, respectively.

A 2 × 3 (contraction phase × squat condition) Repeated measures ANCOVA of the mean I-EMG quadriceps activity revealed no significant main effects ($p > 0.10$) for contraction phase, squat condition, or the interaction. Likewise there were no significant main effects ($p > 0.10$) for squat condition, or the interaction for mean I-EMG hamstring activity during the squat. However, the EMG activity of the hamstrings during contraction was significantly higher ($p < 0.05$) during the concentric phase (mean = 0.6006 ± 0.2488 V) than during the eccentric phase (mean = 0.4395 ± 0.1769 V).

Table 1. Mean quadriceps integrated electromyography (V) response (mean ± *SD*) for the 3 squat conditions across 2 contraction phases ($n = 11$).

Squat type	Contraction phase	
	Eccentric	Concentric
Traditional	0.9074 ± 0.1904	0.9631 ± 0.3129
Chain	0.9284 ± 0.3084	0.9891 ± 0.2197
Elastic bands	0.8886 ± 0.2255	0.9397 ± 0.1992

Table 2. Mean hamstrings integrated electromyography (V) response (mean ± *SD*) for the 3 squat conditions across 2 contraction phases ($n = 11$).

Squat type	Contraction phase	
	Eccentric	Concentric*
Traditional	0.5339 ± 0.1984	0.6205 ± 0.2512
Chain	0.4768 ± 0.1802	0.5995 ± 0.2656
Elastic bands	0.4699 ± 0.1601	0.5818 ± 0.2523

* Denotes significant difference between the concentric and eccentric phases.

Table 3. Mean vertical ground reaction force (N) (mean ± *SD*) for the 3 squat conditions across 2 contraction phases ($n = 11$).

Squat type	Contraction phase	
	Eccentric	Concentric
Traditional	1188 ± 303.9	1260 ± 301.4
Chain	1129 ± 333.6	1238 ± 320.4
Elastic bands	1186 ± 317.9	1229 ± 308.6

Table 4. Peak vertical ground reaction force (N) (mean ± *SD*) for the 3 squat conditions across 2 contraction phases ($n = 11$).

Squat type	Contraction phase	
	Eccentric	Concentric*
Traditional	1401 ± 360.8	1603 ± 360.8
Chain	1347 ± 366.5	1528 ± 344.4
Elastic bands	1408 ± 356.8	1603 ± 311.4

* Denotes significant difference between the concentric and eccentric phases.

The repeated measures ANCOVA for mean vertical GRF revealed no significant effects contraction phase, squat condition or their interaction ($p > 0.10$). Peak vertical GRF had no differences for squat condition or the interaction ($p > 0.10$). But the concentric phase of the movement for the peak GRF (1577.8 ± 313.0 N) was significantly greater ($p < 0.05$) than the eccentric phase (1385.7 ± 351.0 N).

Discussion

Elastic resistance has been evaluated as the mode of resistance for rehabilitation (9) and developing strength (1, 2). Recently, Simmons (7, 8) described the combination of elastic and free weight resistance and chain and free weight resistance for exercises such as the squat.

The squat is considered an important training stimulus for developing the hip and leg muscles (3). Anecdotal observations and power lifting practices suggest that alternative methods of performing the squat, such as using added chain or elastic resistance, may offer advantages over the traditional squat (7, 8).

The results of the present study question the potential advantage of performing squats with a load of approximately 10% squat RM added in the form of chain or elastic resistance. Other combinations of weight plates and chain or elastic resistance may offer an advantageous training stimulus.

This study demonstrated that motor unit activity was greater during the concentric portion compared with the eccentric portion of all modes of the test exercises. These results are consistent with the findings of Kellis and Baltzopoulos (5) and Selseth et al. (6), who examined eccentric and concentric EMG associated with isokinetic exercise and step-ups, respectively.

Practical Applications

Research results suggest that variations of the squat that incorporate chains or elastic resistance offer no advantage or disadvantage compared with the traditional squat according to the variables assessed in this study. Additionally, there was no statistically significant difference between the squat conditions for the variables assessed. Nonetheless, research participants reported that the 2 methods ''felt'' different. Cost of equipment, the additional work associated with handling and setting up these methods (e.g., determining length of chains and elastic bands), and calculating the percentage of chain or elastic resistance compared with weight plates are also limitations of these methods.

Protocols other than the one used in this study may result in different outcomes. For example, for purposes of this study, it was necessary to equate testing loads for each of the squat conditions. Future research may examine the differences in absolute loads that can be managed because of the potential mechanical advantage associated with adding chains or elastic resistance. An athlete may be able to train with a greater maximum load using chain or elastic resistance in addition to weight plates because the athlete experiences greater resistance from these methods, perhaps in proportion to an increased mechanical advantage, during the ascent phase of exercises such as the squat.

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Address correspondence to William P. Ebben, webben70@hotmail.com.