KINETIC AND KINEMATIC DIFFERENCES BETWEEN SQUATS PERFORMED WITH AND WITHOUT ELASTIC BANDS

MICHAEL A. ISRAETEL, JEFFREY M. MCBRIDE, JAMES L. NUZZO, JARED W. SKINNER, AND ANDREA M. DAYNE

Neuromuscular Laboratory, Department of Health, Leisure and Exercise Science, Appalachian State University, Boone, North Carolina

ABSTRACT

Israetel, MA, McBridem, JM, Nuzzo, JL, Skinner, JW, and Dayne, AM. Kinetic and kinematic differences between squats performed with and without elastic bands. *J Strength Cond Res* 24(1): 190–194, 2010—The purpose of this investigation was to compare kinetic and kinematic variables between squats performed with and without elastic bands equalized for total work. Ten recreationally weight trained males completed 1 set of 5 squats without (Wht) and with (Band) elastic bands as resistance. Squats were completed while standing on a force platform with bar displacement measured using 2 potentiometers. Electromyography (EMG) was obtained from the vastus lateralis. Average force-time, velocity-time, power-time, and EMG-time graphs were generated and statistically analyzed for mean differences in values between the 2 conditions during the eccentric and concentric phases. The Band condition resulted in significantly higher forces in comparison to the Wht condition during the first 25% of the eccentric phase and the last 10% of the concentric phase ($p \leq 0.05$). However, the Wht condition resulted in significantly higher forces during the last 5% of the eccentric phase and the first 5% of the concentric phase in comparison to the Band condition. The Band condition resulted in significantly higher power and velocity values during the first portion of the eccentric phase and the latter portion of the concentric phase. Vastus lateralis muscle activity during the Band condition was significantly greater during the first portion of the eccentric phase and latter portion of the concentric phase as well. This investigation indicates that squats equalized for total work with and without elastic bands significantly alter the force-time, power-time, velocity-time, and EMG-time curves associated with the movements. Specifically, elastic bands seem to increase force, power, and muscle activity during the early portions of the eccentric phase and latter portions of the concentric phase.

KEY WORDS force, power, velocity, EMG

INTRODUCTION

Variable resistance can be achieved during exercise using elastic bands or cams attached to a weight stack in a machine (7,12,13). Very few attempts have been made to quantify the unique stimulus provided by variable resistance exercises using elastic bands (12,13). The relationship between torque production and joint angle of the knee has been extensively defined during exercise (1,2,5,6,11,14). A combination of varying knee and hip extensor moments during different depths of squatting determine overall force output and thus determine the amount of weight that can be lifted (1,8). External force output seems to be higher at greater knee angle toward the top portion of the squat movement (8). Therefore, the relationship, in terms of strength, in the squat movement is that more resistance can be lifted in the top portion of the squat (i.e., larger knee angles) in comparison to the bottom portion of the movement (i.e., smaller knee angles).

Given the above information, it could be concluded that variable resistance in the squat exercise should be manipulated to allow for greater resistance at the top portion of the movement and less at the bottom portion of the movement. Indeed, elastic bands have been shown to provide this type of variable resistance (12). One previous investigation has attempted to quantify the forces associated with elastic bands in the free-weight squat but presented limited evidence as to the differences in comparison to a standard free-weight squat (13). This study indicated higher forces associated with the use of elastic bands. However, this investigation did not report force throughout the entire range of motion during the eccentric and concentric phases. In addition, this previous investigation did not match the total work performed during each condition, and thus the result of higher forces reported during the elastic band condition was an obvious result (13).

Address correspondence to Dr. Jeffrey M. McBride, mcbridejm@appstate.edu.

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Therefore, the current investigation has attempted to compare the force-time, velocity-time, power-time, and electromyography (EMG)-time values for the whole concentric and eccentric phases of the squat matching each condition (with elastic bands and without elastic bands) for total work.

METHODS

Experimental Approach to the Problem

No current investigations have adequately defined the biomechanical implications of using free-weight squats with and without elastic bands. In particular, information concerning force-time, velocity-time, power-time, and EMG-time variables does not exist concerning this topic. This design of the current investigation was established to provide a foundation for future discussion on the implications of using variable resistance by reporting, for the first time, the biomechanical implications of using elastic bands during a free-weight squat. Therefore, the current investigation matched 2 conditions of free-weight squatting with and without elastic bands for total work. This allows for a legitimate comparison between the force-time, velocity-time, power-time, and EMG-time variables between these 2 conditions.

Subjects

Ten recreationally weight trained men participated in this investigation (age = 19.8 ± 1.4 years, height = 177.5 ± 8.8 cm, weight = 92.3 ± 20.4 kg). For inclusion into the study, subjects were required to have at least 2 years of previous strength training. Before testing, subjects were informed of the study procedures and were required to sign an informed consent. Approval from the Appalachian State University Institutional Review Board was obtained before the start of the investigation.

Study Design

Subjects participated in 1 testing session, which included measurements of height and weight. Subjects then performed a warm-up set of 5 repetitions with a 20-kg barbell and an elastic band (approximate resistance = 491 N [50 kg] at top of squat movement) attached to each side of the barbell. Subjects then performed an additional set of 5 repetitions using a 20-kg barbell and an elastic band (approximate resistance = 981 N [100 kg] at top of squat movement) (12) attached to each side of the barbell while standing on a force plate. The barbell was also attached to 2 potentiometers to monitor barbell displacement during the movement. All squat repetitions were performed to a knee angle of 70° with a voluntary maximum repetition speed. Subjects then performed 1 set of squats for 5 repetitions with no elastic bands using a barbell mass equivalent to the average force exerted during the elastic band condition. Total work (force × displacement) was calculated for the 2 conditions (with and without elastic bands) to ensure that each condition was equivocal. Electromyography was measured from the vastus lateralis (VL) during both conditions as well.

Measurement of Kinetic and Kinematic Variables

The methods used for collecting and analyzing the squat performances have been validated and described previously (3). All squats were performed on a force plate. Attached to the bar were 2 linear position transducers (LPTs, PT5A-150; Celesco Transducer Products, Chatsworth, CA), which were mounted on top of the rack, anterior and posterior to the subject. Combining trigonometry using known displacements and the displacement measurements from the LPTs, vertical displacement and velocity were measured. Signals from the 2 LPTs and the force plate underwent rectangular smoothing with a moving average half-width of 12. The analog signals were collected at 1,000 Hz using a BNC-2010 interface box with an analog-to-digital card (NI PCI-6014; National Instruments, Austin, TX). Custom-designed LabVIEW (Version 8.2; National Instruments) programs were used to collect and analyze the data. Data from the displacement-time curves of the squats allowed for appropriate separation of eccentric and concentric phase variables. The point at which the bar displacement started to become negative was considered the start of the eccentric phase. The end of the eccentric phase and start of the concentric phase were determined as the point at which the most negative bar displacement occurred. Vertical force-time curves were obtained from the force plate, vertical velocity-time curves were obtained from displacement measures from the potentiometers, and power-time curves were obtained by taking vertical force multiplied by the vertical velocity.

Electromyography

Electromyography was collected and analyzed from the VL during the eccentric and concentric phases of the squats. The skin was shaved, abraded, and cleansed with alcohol before placing a disposable bipolar surface electrode (Noraxon USA Inc., Scottsdale, AZ; 2-cm interelectrode distance, 1-cm^2 circular conductive area) over the belly of the muscle and parallel to the direction of the muscle fibers. The myoelectric signal was collected through the use of a telemetry transmitter (8-channel 12-bit analog-to-digital converter; Noraxon USA Inc.). The amplified myoelectric signal was detected by a receiver-amplifier (Telemyo 900, gain = 2,000, differential input impedance = 10 MΩ, bandwidth frequency 10-500 Hz, common mode rejection ratio = 85 dB, Noraxon USA) and then sampled by an A/D card (NI PCI-6014; National Instruments) at 1,000 Hz. The signal was full-wave rectified and filtered integrated electromyography (IEMG) (6-pole Butterworth; notch filter, 60 Hz; band-pass filter, 10-200 Hz).

Average Curve Analysis

Average curve analysis has been used previously to express performance during resistance exercise (4). Using a custom-designed LabVIEW program, this analysis technique permits the expression of all individual variable-time curves into 1 representative average variable-time curve. Typically, variable-time curves from different subjects cannot be added together and averaged because the time it takes each subject

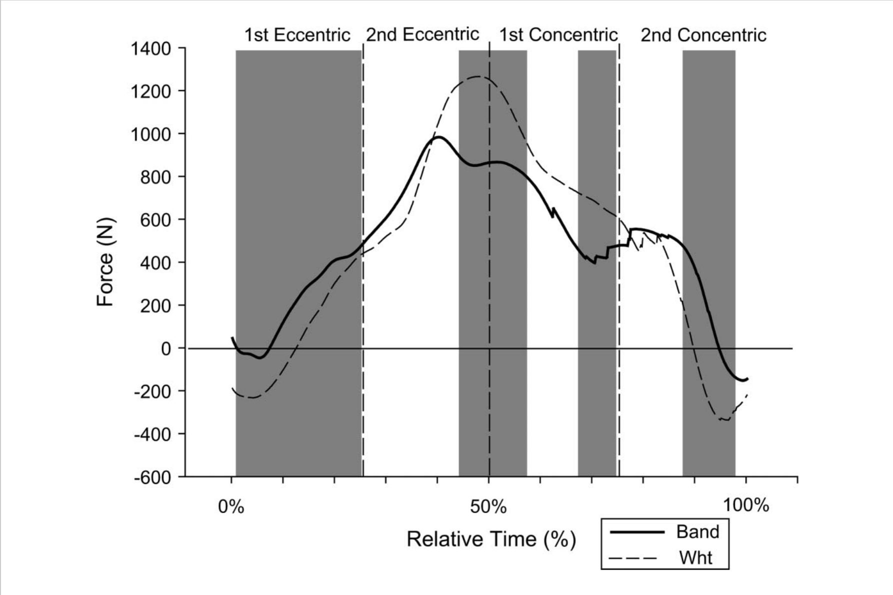

Figure 1. Force-time curve for all subjects (averaged) comparing work-equivalent squats with bands (Band) and without bands (Wht). Shaded areas indicate statistical significance at $p \leq 0.05$.

to complete the exercise in absolute time is different. However, through a resampling procedure that interpolates 500 samples of data from each of the original variable-time curves, all subjects' resampled variable-time curves can be expressed on the same relative time scale (0-100% normalized time). Subsequently, because all individual variable-time curves are on the same relative time scale, they can be added together and averaged to produce a single average curve for that group of subjects. In the current investigation, average curves were developed for the 2 squat conditions (with and without elastic bands) for force, velocity, power, and average IEMG from the VL. The average resampling frequencies were approximately 575 ± 17 Hz. For statistical analysis, an average of 575 mean samples were compared between the 2 squat conditions for the force-time, velocity-time, power-time, and EMG-time curves during the eccentric and concentric phases.

Statistical Analyses

Descriptive data were summarized as mean ± *SD*. Differences between kinetic and kinematic variables and EMG between the different conditions were determined using a multivariate general linear model. The criterion alpha level for all statistics was set at $p \leq 0.05$. All statistical analyses were completed using a statistical software package (SPSS Version 15.0; SPSS Inc., Chicago, IL).

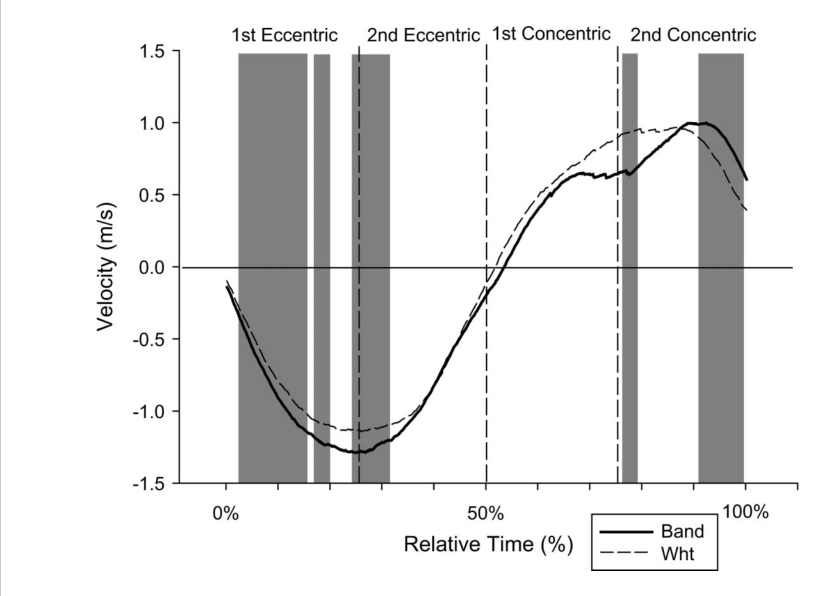

Figure 2. Velocity-time curve for all subjects (averaged) comparing work-equivalent squats with bands (Band) and without bands (Wht). Shaded areas indicate statistical significance at $p \leq 0.05$.

Results

Average force-time curves for the 2 squat conditions (with [Band] and without elastic bands [Wht]) are presented in Figure 1. *SD*s for means in both curves are not presented for visual clarification. Significantly higher force values were observed for the Band condition during approximately the first 25% of the eccentric phase (gray area indicates statistical significance at $p \leq 0.05$) and during approximately the last 10% of the concentric phase. Force values for the Wht condition were significantly higher during approximately the

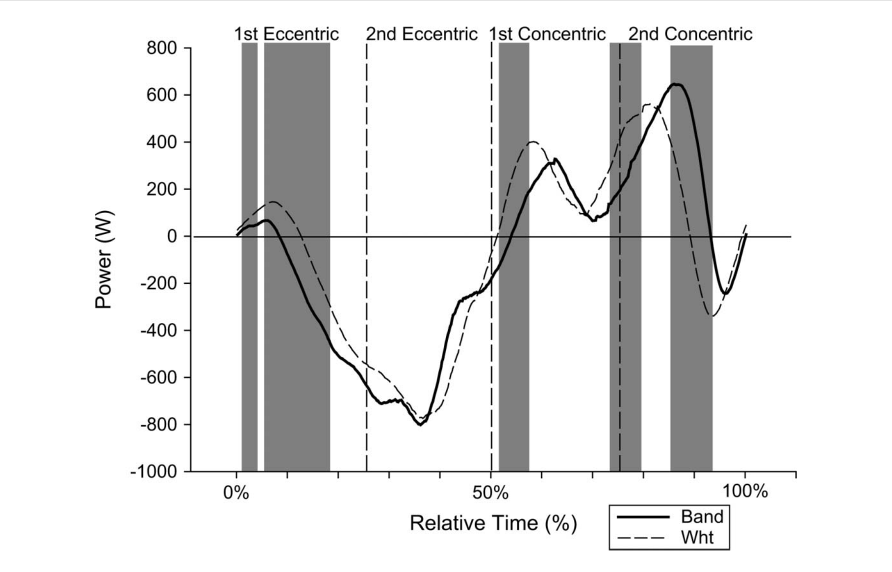

Figure 3. Power-time curve for all subjects (averaged) comparing work-equivalent squats with bands (Band) and without bands (Wht). Shaded areas indicate statistical significance at $p \leq 0.05$.

last 5% of the eccentric phase and the first 5% of the concentric phase. Force was also significantly higher during the Wht condition at relative time values of 68–72% of completion of the movement.

Average velocity-time curves for the 2 squat conditions are presented in Figure 2. Significantly higher velocity values were observed for the Band condition during approximately the first 30% of the eccentric phase and during approximately the last 10% of the concentric phase. Velocity during the Wht condition was significantly higher at relative time values of 75–80% of completion of the movement.

Average power-time curves for the 2 squat conditions are presented in Figure 3. Significantly higher power values were observed for the Band condition during the approximately the first 20% of the eccentric phase and at relative time values of approximately between 85–95% of completion of the movement. The Wht condition resulted in higher power values at relative time values of 50–60% and 75–80% of completion of the movement.

Average IEMG-time curves (VL IEMG) for the 2 squat conditions are presented in Figure 4. Vastus lateralis muscle activity was significantly higher for the Band condition during approximately the first 20% of the eccentric phase and the last 5% of the concentric phase. The Band condition also resulted in significantly higher muscle activity values at relative time values of 85–95% of completion of the movement.

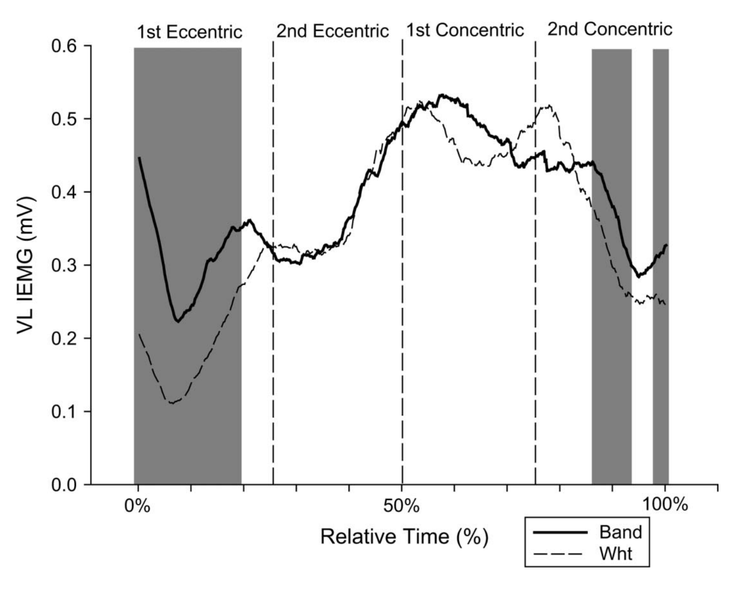

Figure 4. Vastus lateralis integrated electromyography (VL IEMG)-time curve for all subjects (averaged) comparing work-equivalent squats with bands (Band) and without bands (Wht). Shaded areas indicate statistical significance at $p \leq 0.05$.

DISCUSSION

To date, no investigation has reported a complete variable-time analysis (force, velocity, power, and EMG) of the eccentric and concentric phases during the squat with and without elastic bands (13). This investigation has shown that when equated for total work, squats with elastic bands elicit higher force, velocity, power, and muscle activity during the first part of the eccentric phase and latter portion of the concentric phase when compared with squats without elastic bands. This is not a surprising finding given that the elastic bands provide maximal resistance during these phases due to being stretched to a longer length (12).

As previously stated, it is known that external force output is higher at greater knee angle toward the top portion of the squat movement (8). Therefore, the findings of this investigation indicate that elastic bands provide additional resistance during this portion of the squat movement. Thus, elastic bands during the squat seem to provide a variable resistance pattern similar to that of the natural variance in force output during the squat from the bottom to the top of the movement. However, it should be noted that elastic bands did not provide maximal resistance at the bottom of the movement in comparison to the Wht condition (Figure 1). Power was higher during the first part of the eccentric phase and the latter portion of the concentric phase comparable to similar evaluations between the bench press and bench press throw (9). Thus, the squats with bands resulted in a kinetic and kinematic pattern similar to that of ballistic movement used for power training. This might indicate the benefit of elastic bands during the squat for maximizing power output, but this is speculative at this time.

No studies have shown that variable resistance training is more beneficial to strength gain in comparison to constant resistance training (7,10). Therefore, even though the elastic bands presented more loading during different phases of the squat in comparison to the Wht condition, this does not indicate its possible effectiveness for increased strength over conventional methods. However, the unique nature of the force-time, velocity-time, power-time, and muscle activity-time curves observed during the Band condition warrants further investigation.

PRACTICAL APPLICATIONS

The current investigation has demonstrated unique kinetic and kinematic characteristics between squats with and without elastic bands when work between the 2 conditions is equated. However, to date, only a limited number of investigations have studied the effects of squat training with elastic bands on performance (13). The current investigation, in itself, does not provide evidence that training with squats with bands would be more effective than squatting without bands for improving athletic performance. Further study, with equated work between conditions, is needed to determine whether training with elastic bands provides any additional training adaptations when compared with training without elastic bands.

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