Comparison of Tonal and Free Weight Back Squat Workouts on Muscle Activation, Muscle Oxygenation and Fatigue

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Abstract

Volume-load (VL), metabolic stress and muscular fatigue can lead to muscle hypertrophy when performing resistance training to failure. A smart digital-weight system (DWS) that utilizes dynamic loads throughout the concentric and eccentric phases of contraction may exacerbate these responses compared to traditional free-weight exercise by optimally stressing the muscle throughout the movement. **PURPOSE:** This study examined the VL, metabolic stress and muscular fatigue during a single set of back squats to failure using barbell free-weight (FREE) and dynamic resistance DWS. **METHODS:** Healthy adults (29.7 ± 7.1 yrs) who were not currently engaged in resistance training to failure participated. Prior to experimental conditions, a predicted one-repetition maximum (1-RM) for back squat was determined on the DWS. There were two experimental conditions (FREE and DWS) that were performed on separate days and assigned in a random order. In FREE, one set to failure of barbell back squat at 60% of 1-RM was performed. During DWS, one set to failure of back squats was performed on a DWS (Tonal Home Gym©, San Francisco, California) with dynamic load. During dynamic load, the load was 60% of 1-RM at the transition from eccentric to concentric phases and load increased during the concentric phase and decreased during eccentric phase. In FREE, VL was calculated (repetitions x load), but VL during DWS was determined by the DWS software, due to the dynamic loading. Muscle deoxygenation (HHb) was measured by near-infrared spectroscopy placed on the vastus lateralis. The magnitude of the metabolic stress was assessed as the greatest change in HHb from the cycle warm up (HHb_{max}). Also, HHb data from the first repetition to the last repetition were normalized to a cycle warm up and plotted against time. The area under the curve (HHbAUC) was calculated via the trapezoidal rule to assess overall metabolic stress in each condition. Change in jump height from pre to post squat assessed muscular fatigue. Three countermovement jumps were performed before and immediately after the set. Jump heights were measured via a positional linear transducer and averaged. Differences between FREE and DWS were compared using paired T-tests. Significant differences were established if $p < 0.05$. **RESULTS:** The predicted 1-RM for back squat was 174.0 ± 11.0 lbs and the load for each condition was 105.0 ± 5.5 lbs. There were no significance differences between DWS and FREE for the number of repetitions to fatigue (37.0 ± 12.6 reps vs. 39.2 ± 7.9 reps) or VL (4267.4 ± 1494.6 lbs vs. 4108.0 ± 795.3 lbs). There were no differences in HHb_{max} between DWS (-7.8 ± 3.3 au) and FREE (-8.2 ± 3.5 au). During HOME, the HHbAUC was 618.6 ± 330.0 au^2 and HHbAUC during FREE was 636.2 ± 463.5 au^2. The differences were not significant. Additionally, the change in jump height was similar between DWS (-5.2 ± 1.4 in) and FREE (-5.7 ± 1.6 in). **CONCLUSION:** The dynamic load during DWS did not affect VL, metabolic stress, or muscular fatigue compared to free-weight exercise during one set of back squats to failure. **PRACTICAL APPLICATION:** Acute responses during resistance exercise to failure suggests a dynamic load DWS could be as effective as free-weight exercise in promoting muscle hypertrophy. However, the dynamic load in DWS may not enhance muscle hypertrophy when training to failure. A home smart DWS could be a safe and effective at-home resistance training system for resistance training to failure.

Background

- Training to failure can be an effective strategy for building muscle mass and strength. Studies have shown that training to failure can lead to similar or greater increase in muscle hypertrophy compared to not training to failure.
- Mechanism of muscle hypertrophy from training to failure are thought to be from motor unit recruitment of Type II fibers as Type I fibers start to fatigue. EMG amplitude may increase as the muscle fatigues due to the greater muscle activation.
- Training to failure may also result in adaptation due to metabolic stress. During resistance training to failure, muscle oxygenation will decrease from a mismatch of oxygen demand and oxygen delivery. As muscle oxygenation decreases there is greater metabolic stress in the muscle.
- Digital-weight systems (DWS) that utilizes dynamic loads throughout the concentric and eccentric phases of contraction may exacerbate these responses by optimally stressing the muscle throughout the movement.
- The dynamic loads within repetitions could increase volume-load because of the add load during the repetition during resistance training to failure. Additionally, the added load could increase muscle activation and metabolic stress within the sets to fatigue. These acute responses could lead to similar or greater muscle hypertrophy compared to traditional resistance training.
- Training to failure is an effective alternative to high-load resistance training. Understanding the acute responses to training to failure a DWS compared to traditional resistance training could lead to a safe at-home training system.

Participant Characteristics

Age (yrs)	HT (cm)	WT (kg)	Predicted 1-RM (lbs)*	60% Predicted 1-RM**
29.7 ± 7.1	178.6 ± 9.1	80.5 ± 13.0	174.2 ± 11.2	105.0 ± 5.5

*Data presented as mean ± sd. *One RM prediction test was performed prior to experimental conditions and calculated from load and repetitions to fatigue. ** 60% Predicted 1-RM was rounded up to the nearest 5 lbs to use as load in experimental condition.*

Materials

Right Picture: The DWS was a Tonal Smart Home Gym©. This system is a dynamic weight system in which load varied during eccentric and concentric movement.

Left Picture: 1) A GymAware© linear positional transducer was used to measure jump height.

2) Delsys Avanti wireless electromyography (EMG) sensors were placed on the vastus lateralis of the dominant leg to measure muscle activation.

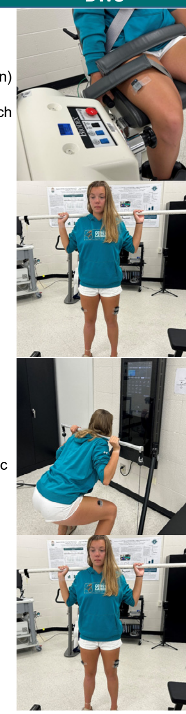
3) A Portamon© near-infrared spectroscopy device was placed on the vastus lateralis of the non-dominant leg.

Purpose

The purpose of this study is to examine muscle activation, metabolic stress, volume-load and fatigue between a dynamic resistance digital-weight system (DWS) and traditional free weights (Traditional) during one set of back squat to failure.

Methods

Experimental Condition TRADITIONAL | **Experimental Condition DWS**



Maximal Isometric Voluntary Contraction

- Three five-second maximal voluntary isometric (70° flexion) contractions (MVIC) using the dominant leg.
- EMG was collected and the highest amplitude for each contraction were averaged to determine MVIC

Maximal Dynamic Jump

- Three maximal jumps separated by a ten-second rest .
- A linear positional transducer measure jump height.
- Pre maximal jump height was averaged between the jumps.

Back Squat to Failure

- One set to voluntary fatigue when performing back squats following a cadence of 30 lifts per minute
- In Traditional, load was 60% of 1-RM.
- In DWS, load was 60% of 1-RM at the transition from eccentric to concentric phases. Load increased during the concentric phase and decreased during eccentric phase

Maximal Dynamic Jump

- Immediately following set to failure maximal jumps were performed using the same procedure as pre.
- Pre maximal jump height was averaged between the jumps.

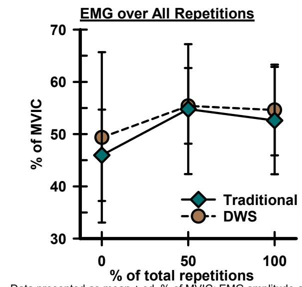
Data Analysis

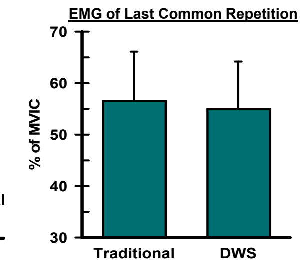
- **Muscle Activation –** All EMG amplitudes were normalized to the MVIC. EMG amplitude were averaged over 3 repetitions at 0%, 50%, and 100% of the total repetitions. Amplitude were average over the final three common repetitions of each set.
- **Metabolic Stress –** Muscle deoxygenation were normalized to an aerobic warm-up and plotted against time. Muscle deoxygenation area under the curve was calculated via the trapezoidal rule to assess overall metabolic stress.
- **Volume-Load** – In Traditional, volume-load was calculated (reps x load). In Tonal, volume-load was determined by the Tonal software due to the dynamic loading.
- **Fatigue** – Calculated as the change in jump height from pre- to post set to fatigue.

Conclusion

The dynamic resistance during DWS did not affect muscle activation, volume-load, metabolic stress, or muscular fatigue compared to free weight exercise during one set of back squats to failure.

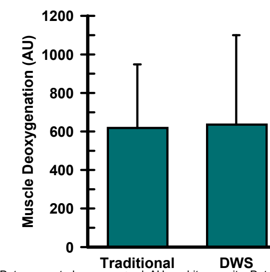
Muscle Activation





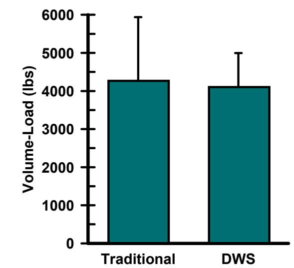
Data presented as mean ± sd. % of MVIC: EMG amplitude as a percentage of the maximal muscle activation. % of total repetitions based on the total repetitions complete in each set. Last common repetition: final similar repetition completed in both sets.

Metabolic Stress



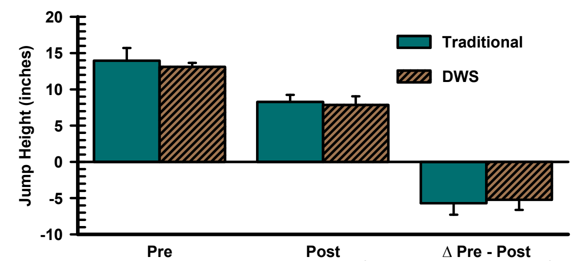
Data presented as mean ± sd. AU = arbitrary units. Data is area under the curve for muscle deoxygenation from the first repetition to the end of the final repetition.

Volume-Load



Data presented as mean ± sd.

Fatigue



Data presented as mean ± sd. Pre: jump height prior to sets to failure; post: jump height immediately following set to failure. Δ pre – post: difference in jump height from pre to post; negative jump height connotes a decrease from pre to post.

Practical Applications

- Acute responses during one set to failure suggests a dynamic resistance on the DWS could be as effective as free-weight exercise in promoting muscle hypertrophy.
- The additional load from dynamic resistance did not increase volume-load or augment acute responses, suggesting it may not be superior to traditional free-weights when training to failure.
- A home DWS could be a safe and effective at home resistance training system for resistance training to failure.