

The effects of moderate- versus high-load resistance training on muscle growth, body composition, and performance in collegiate women

Revision 1: JSCR-08-9131

Coastal Carolina University Smith Exercise Science Lab

Running Head: Moderate- versus high-loading in females

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No funding was received for this work.

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ABSTRACT

Twenty young women (20.3±1.5 years, 164±6 cm, 68.7±13.8 kg) without prior structured resistance training experience were recruited for this study. Body composition (BodPod), compartmental water (Bioelectrical Impedance), 7-site skinfold, and arm and thigh CSA were assessed pre- and post- 8 week training. Performance testing consisted of vertical jump, 3 kg chest pass initial velocity, squat 1RM and overhead press 1RM. Following 2 weeks of familiarization training, subjects were matched for body composition and relative squat strength, and randomly assigned to either a high- (HL: n=10; 4 sets of 5-7 repetitions) or moderate-load (ML: n=10; 2 sets of 10-14 repetitions) group that completed 6-7 exercises per day performed to momentary muscular failure. Training was divided into two lower and one upper body training sessions per week performed on non-consecutive days for 8 weeks. There were no statistically significant main effects for group or group x time interactions for any variable assessed. Both HL and ML resulted in similar significant increases in lean body mass (1.5 ± .83 kg), lean dry mass (1.32 ± 0.62 kg), thigh CSA (6.6 ± 5.6 cm²), vertical jump (2.9 ± 3.2 cm), chest pass velocity (0.334 ± 1.67 m/s), back squat 1 RM (22.5 ± 8.1 kg), and overhead press (3.0 ± 0.8 kg). HL and ML also both resulted in significant decreases in percent body fat (1.3 ± 1.3 %), total body water (0.73 ± 0.70 L), and intracellular water (0.43 ± 0.38 L). The results of this study indicate that both moderate- and high-load training are effective at improving muscle growth, body composition, strength and power in untrained young women.

Key Words: aesthetics, periodization, hypertrophy, heavy weight training, fat loss, muscle growth

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INTRODUCTION

Increasing muscular strength and hypertrophy are important to a variety of populations. Because muscle cross sectional area (CSA) is directly correlated to force output (23), increasing muscle hypertrophy may lead to enhanced performance in strength and power athletes (43). In the general population increasing strength may benefit the accomplishments of activities of daily living as reduced muscular strength is a predictor of mortality in older adults (42). Resistance training has been well accepted as the primary mode of exercise to enhance muscular strength and hypertrophy. The American College of Sports Medicine (ACSM) recommends performing 8-12 repetitions to muscular fatigue for general health (2), while the National Strength and Conditioning Association (NSCA) recommends performing repetitions of 10-12 with 65-85% of the one repetition maximum (1 RM) to maximize hypertrophy and repetitions of 1-5 with greater than 85% of the 1 RM to maximize strength development (5).

Although strength training among young women has increased since 1998 (18), Patterson et al. (31) reported that amongst a sample of 421 traditional undergraduate college women not engaged in varsity sports, only 33% of young women meet national strength training recommendations (> 2 days/week). The association between resistance training and appearing masculine has been identified as a potential barrier to adopting a resistance training program (30). Ratamess et al. (33) reported that 70% of young women engaged in resistance training at health clubs described "increased muscle tone" as motivation for resistance training; however, 38% of women who trained at health clubs expressed an adversity to resistance training due to the misconception that resistance training would lead to excessive muscular hypertrophy.

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A fear of becoming masculine or developing “large, bulky muscles” (33) may explain why many young women often train with sub-threshold intensities or abstain from resistance training altogether. Cotter et al. (8) investigated the difference in RPE response to imposed loads (40% and 70% 1 RM) and a self-selected load to be used for 3 sets of 10 repetitions that “would be comfortable, yet still provide a challenging workout” in recreationally trained females.

Women self-selected an intensity equal to approximately 57% 1 RM that corresponded with an RPE of 13-14 (“somewhat hard”). In contrast, 70% 1 RM resulted in an RPE of 15-16 (“hard”).

Ratamess et al. (33) reported recreationally trained women who trained with a personal trainer self-selected greater loads and worked at a higher RPE than women who trained alone; however, neither group self-selected loads for any of the exercises that exceeded 60% 1RM. In a recent meta-analysis, Schoenfeld et al. (39) demonstrated that low intensity loading (<50% 1RM) may promote hypertrophic adaptation similar to higher intensities (>70% 1RM) provided that sets in the lower intensity protocols are carried out with a high levels of effort (i.e.: sets should reach or approach momentary muscular failure). However, the results of the aforementioned studies, and similar findings in untrained women (12), suggest that women with shorter training histories (lower training status) often do not utilize a load of a high enough relative intensity and/or train with sufficient effort to maximize strength and hypertrophy adaptations during resistance training.

Volume and intensity are two variables that are commonly manipulated during a strength training program to induce a desired outcome. Based on the analysis of 15 studies, Fry (14) reported that higher loads account for 18-35% of the variance in hypertrophic responses as a result of resistance training. In contrast, several emerging studies suggest that training with

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lighter loads to failure will result in similar hypertrophy to using heavier loads when either total sets performed (18) or load volume (7,38) are matched between groups. A recent study by Schoenfeld et al. (37) demonstrated no significant differences in muscle growth between low- and high-loading conditions with greater strength gains in the high-load condition. A follow up study by Schoenfeld et al (36) compared 3 sets of 7 exercises using either a 2-4 RM or a 8-12 RM in trained young men. Greater strength gains were observed in the heavy group whereas greater increases in elbow extensor and quadriceps muscle thickness was observed in the moderate group. The larger volume accomplished by the moderate group likely explains the difference in results between these two studies. Although a number of studies conducted in male subjects have evaluated the effects of different loading schemes on muscle hypertrophy (39), there are very few studies that have evaluated these outcomes in young, healthy female subjects.

Schuenke et al. (40) compared 6 weeks of lower body training with 3 exercises (leg press, squat, leg extension) and 3 sets per exercise using either a high intensity (80-85% 1 RM, 6-10 repetitions) or a low intensity (40-60% 1 RM, 20-30 repetitions) loading scheme in untrained young women. While fiber CSA increased in both groups, a greater increase was observed in the high intensity group. In contrast, Alegre et al. (3) used a within subjects design in which subjects trained each leg with a different volume \times intensity protocol to reduce inter-individual differences in trainability in untrained young women. Subjects trained for 10 weeks with one leg performing high (80% 1 RM) and the other leg moderate (50% 1 RM) intensity unilateral lower body resistance exercise (leg press and knee extensions). Quadriceps muscle thickness, CSA, and static and dynamic torque increased similarly for both the high-load and moderate-load legs. The discrepancy in the results between these two studies may be the result of how muscular

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hypertrophy was measured (single fiber CSA via muscle biopsy vs. ultrasound muscle thickness); however, more research to elucidate the effects of varying the training load with more commonly employed intensities and sets × repetition training schematics on muscular hypertrophy outcomes in young (18-35 years old) women is warranted.

In addition to a lack of research in young women, most of the current studies investigating the effects of different loading schemes in men have compared very low-loads (i.e.: 30-50% 1 RM) with more moderately-heavy loads (70-80% 1 RM). These intensities do not reflect the loads often used in heavy strength training (85-90% 1 RM) nor the more moderate-loading approach (60-70% 1 RM) used by many novice trainers. Therefore, the purpose of this study was to compare changes in strength, body composition, and muscle hypertrophy between repetition-volume matched moderate- and high-load training in healthy young females over a 9 week period. We hypothesized that strength outcomes would be greater in the heavy loading group but that there would be no differences between groups for changes in arm and thigh CSA or lean body mass.

METHODS

Experimental Approach to the Problem

Subjects were pair-matched based on initial strength levels and body fat percentage and then randomly assigned to 1 of 2 groups: A heavy-load group that performed training within a 5-7 repetition maximum zone, and a moderate-loading group that performed training within a 10-14 repetition maximum zone. Training occurred over 9 weeks with the subjects performing two

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lower body and one upper body training sessions each week comprised of 4-6 exercises per session. Total repetition volume was equated between groups. Testing was carried out pre- and post-study for strength, power, body composition, and arm and thigh cross sectional area.

Subjects

Subjects were a convenience sample recruited from a university population of female volunteers between the ages of 18-35, without any existing musculoskeletal disorders, free from consumption of anabolic steroids or any other illegal agents known to increase muscle size within the past year, and not engaged in a structured resistance training program for the 6 months leading up to participation. Subjects were instructed to avoid taking any performance-enhancing supplements and to maintain their current diet during the study period. Subjects were instructed to continue their routine physical activities and not to begin any new physical training programs. A minimal adherence of 88% (completion 21 of 24 total training sessions) was set *a priori*. Subjects that missed a total of 4 training sessions or that missed 3 training sessions in a row were disqualified from the study.

A total of 24 subjects qualified for the study and were pair-matched according to baseline squat strength and body fat percentage. To pair match subjects were assigned a number and then placed into a groups that corresponded to “strong lean”, “weak lean”, “strong normal”, “weak normal”, “strong fat” and “weak fat”, whereby strong corresponded to a squat 1 RM > 60 kg and weak < 60 kg, and body fat percentages of 25% lean, 25-35% normal, and > 35%. A colleague outside of the research study then randomly assigned subjects based upon their pairing to either a

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high-load (HL) group that performed bilateral multi joint movements with a 5-6 rep range and assistance movements with a 6-7 rep range, or; a low-load (LL) group that performed bilateral multi joint movements with a 10-12 rep range and assistance movements with a 12-14 rep range.

Twenty subjects (Table 1) completed the study and were included in the final analysis as one dropped out due to an injury that occurred outside of training, one was disqualified for missing 4 training sessions and two more were disqualified for missing 3 training sessions in a row.

Approval for the study was obtained from the University Institutional Review Board (IRB) and informed consents were obtained from all subjects prior to data collection.

[Insert Table 1]

Procedures

Testing was conducted in the following order: anthropometrics, power, and strength testing. Anthropometrics were measured prior to any training and physical performance testing took place two weeks following anthropometric testing. All training was completed on a Friday, post-training performance testing took place the following Monday allowing for 96 hours rest, and final anthropometric testing took place 48-72 hours following post-training performance testing. Subjects performed five familiarization sessions over the course of two weeks separated by 48-96 hours of rest prior to power and strength testing. Subjects were asked to replicate their pre-treatment nutritional intakes the days of post-treatment strength and performance testing to reduce the influence of nutritional status affecting the results.

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Body Composition: Height was measured using standard anthropometry and body mass was measured using a calibrated scale (Cosmed, Concord, CA USA). Body composition was measured pre- and post-treatment and was determined by whole body densitometry using air displacement plethysmography (Bod Pod®, Cosmed, Concord, CA USA). All testing was performed in accordance with the manufacturer's instructions and subjects were tested while wearing only tight fitting compression shorts and a Lycra swim cap. The subjects were instructed to wear the same clothing for all testing procedures, to not consume food or drink 3 hours prior to testing, and to consume a similar quantity of food on both sessions. All testing was carried out at approximately the same time of day (± 1 hour) to account for circadian changes in fluid and fecal matter. Thoracic gas volume was estimated for all subjects using a predictive equation integral to the Bod Pod® software. The calculated value for body density was the Siri equation to estimate body composition. Data from the Bod Pod® included body weight, percent body fat, fat free mass and fat mass. After Bod Pod® testing skin fold measurements were taken with Lange skin fold calipers (Cambridge Scientific Industries Inc: Cambridge, MD) on the right side of the subject three times at seven sites: Triceps, Pectoral, Midaxilla, Subscapula, Abdomen, Suprailiac, and Quadriceps. The sum of the skin folds was used to analyze changes in subcutaneous adipose tissue. Based upon a small pilot study (n=6), the ICC and SEM from our lab are .998 and 0.56%, respectively.

Measurement of Compartmental Water: Total body water (TBW), intracellular water (ICW), extracellular water (ECW), lean dry mass (LDM) was assessed using the Quantum IV bioelectrical impedance analyzer and accompanying software (BIA: RJL Systems, Clinton Township, MI). The BIA was calibrated as per the manufacturer's recommendations the morning

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of each measurement session. Bioelectrical impedance spectroscopy has been shown to be a valid tool for assessment of TBW and its various compartments in young women (4,17,21,22,27). Prior to measurement, participants were instructed to remove all objects containing metal. A urine sample was collected and urine specific gravity was assessed. Subjects with a urine specific gravity greater than 1.025 were asked to sip water and return an hour later. Measurements were performed on a table free from electrical conductors, with subjects lying supine along the table's longitudinal centerline axis, legs abducted at an angle of 45° and hands pronated. After cleaning the skin with alcohol, two electrodes were placed on surface of the right hand and two on the right foot in accordance with procedures described elsewhere (16). A small pilot study (n = 7) with college aged females was conducted and *Chronbach's alpha* test-retest reliability and the standard error of measurement were $\alpha = 0.97$ and 3.0 L, respectively, for total body water.

Cross Sectional Area: Girth and skin fold measurements were performed on the right limbs to determine lean CSA via the method described by Moritani and DeVries (28). CSA of the arm was determined at the midpoint between the humeral greater tuberosity and lateral epicondyle, whereas CSA of the thigh was determined at the midpoint of the distance between the greater trochanter and lateral epicondyle of the femur. Skin fold measurements were performed three times at the four quadrants of the limb at the location where the circumference was measured. CSA was calculated via the following equation (28): $CSA = \pi \left[\frac{C}{2\pi} - \frac{\sum_{i=1}^4 f_i}{4} \right]^2$. All measurements were performed by the primary investigator to eliminate inter-rater variability. Distances from the proximal bony land mark (humeral greater tuberosity and greater trochanter) where measurements were performed were recorded and used again for post treatment

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measuring. DeFreitas et al. (10) demonstrated the Moritani and DeVries method is both sensitive ($SEE = 3.25 \text{ cm}^2$) and highly correlated ($r = .98$) to computed tomography (9). A pilot study ($n = 7$) with college aged females was conducted and *Chronbach's alpha* test-retest reliability and the standard error of measurement were $\alpha = 0.97$ and $SEM = 3.70 \text{ cm}^2$, respectively.

Lower Body Power: Vertical jump was assessed using the Just Jump! Mat (Probotics Inc.: Huntsville, AL). Leard et al. (19) demonstrated that the Just Jump! Mat is highly correlated ($r = .97$) with the 3-camera video analysis “gold standard” method of assessing vertical jump performance. The ICC, SEM, and CV of the Jump Jump! Mat has been reported as $\alpha = .93$, 1.6 cm, and 4.4%, respectively (29). Subjects were instructed to stand on the mat with feet hip-width apart and perform a rapid lower body eccentric movement followed immediately by a maximal intensity concentric movement. Subjects were instructed to jump straight up and minimize any in-air hip flexion. The best of the three trials separated by 1 min of rest was recorded as vertical jump height (cm). Based upon a small pilot study ($n=6$), the ICC and SEM from our lab are .991 and 1.50 cm, respectively.

Upper Body Power: The initial velocity achieved during a seated 3 kg medicine ball chest pass was used to measure upper body power. The Ballistic Ball (Assess2Perform: Steamboat Springs, CO) is a medicine ball with an accelerometer built in that links to a digital device via Bluetooth technology. Initial velocity was calculated via iOS technology provided by the manufacturer. Subjects sat with their backs against a 90° upright adjustable bench and held the medicine ball against their chests. When ready, subjects performed a chest pass and threw the ball forward with maximal exertion. Subjects were instructed to minimize throwing the ball such

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that it took the trajectory of an arch. The best of three trials separated by 1 min of rest recorded pass velocity (m/s). Hasegawa (15) reported that initial velocity was significantly related to rotational medicine ball throw distance with a correlation coefficient of $r = .64$ with the 3 kg ball.

Currently no data are available on the relationship between chest pass distance and initial velocity; however, we chose the seated chest pass since it more specific to the incline press and requires less skill than a standing rotational throw. Based upon a small pilot study ($n=6$), the ICC and SEM from our lab are .996 and 0.051 m/s, respectively.

Muscle Strength: Strength was assessed by 1 RM testing the parallel back squat (BS) and seated barbell overhead press (OHP) exercises. Subjects reported to the lab having refrained from any exercise other than activities of daily living for at least 48 hours prior to baseline testing and at least 48 hours prior to testing at the conclusion of the study. Pre- and post-study testing was scheduled for the same time of day as the subjects trained during the study to account for diurnal variation in performance. Repetition maximum testing was consistent with recognized guidelines as established by the National Strength and Conditioning Association (1). Subjects performed a general warm-up prior to testing that consisted of light cardiovascular exercise lasting approximately 5-10 minutes. A specific warm-up set of the given exercise of 5 repetitions was performed at ~50% 1 RM followed by one to two sets of 2-3 repetitions at a load corresponding to ~60-80% 1 RM. Subjects then performed sets of 1 repetition of increasing weight for 1 RM determination. Three to 5 minutes rest was provided between each successive attempt. All 1 RM determinations were made within 5 attempts. Subjects were required to reach parallel (iliotibial band parallel to the floor) in the BS for the attempt to be considered successful as determined by an NSCA Certified Strength and Conditioning Specialist. A 1 RM OHP attempt was deemed successful when subjects lowered the bar to their collar bone and then

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pressed the bar overhead finishing with the elbows fully extended. The BS 1 RM and OHP 1 RM were divided by the body mass in kg to obtain the relative BS 1 RM and relative OHP 1 RM, respectively. 1 RM testing has been shown to be a valid ($r = .88$) (41) and reliable ($ICC = .96$) (35) measure to assess changes in muscle strength following an exercise intervention. Based on results of a small pilot study ($n=5$), the test-retest ICC and SEM from our lab for BS 1RM testing was 0.961 and 2.37 kg, respectively. For OHP 1RM pilot testing ($n=6$) revealed an ICC and SEM of .984 and 1.01 kg, respectively.

Resistance Training Procedures

The resistance training protocol for each group can be found in Table 2. Training consisted of 3 weekly sessions performed on non-consecutive days for a total of 11 weeks. The first 5 sessions (2 weeks) were an acclimation phase where sets were terminated 2 to 3 repetitions short of failure and performed for both groups within a repetition range of 8-10. The acclimation phase also served to estimate the starting loads for all exercises with the exception of the squat and overhead press. Physical performance tests occurred on session 6 prior to group assignment. Thereafter, sets were carried out to the point of momentary concentric muscular failure—the inability to perform another concentric repetition while maintaining proper form—for the final 9 weeks of the study (Figure 1). A 9 week training period was selected since several similar studies have demonstrated changes in muscle growth and body composition following 8 weeks of resistance training (36–38). Since all subjects started the study at the same time week 5 corresponded with spring break and provided the subjects with a week of active rest between the transitions from mesocycle 1 to mesocycle 2. Cadence of repetitions was carried out in a

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controlled fashion, with a concentric action of approximately one second and an eccentric action of approximately two seconds. Subjects were afforded 2 minutes rest between sets of bilateral multi joint movements and 1 minute of rest between ancillary movement sets. The starting load for the squat and overhead press exercise was 85% and 65% 1 RM for the high- and moderate-load groups, respectively, and the load was adjusted for each exercise as needed on successive sets to ensure that subjects achieved failure in the target repetition range. Attempts were made to progressively increase the loads lifted each week within the confines of maintaining the target repetition range. All routines were directly supervised by the research team to ensure proper performance of the respective routines. Repetitions per set and their corresponding loads were recorded for all exercises and used to compare differences in volume-load (sets \times repetitions \times load) between groups and across time for back squat and overhead press. The average load used per session was used to calculate the relative intensity (% 1 RM) used.

[Insert Figure 1]

[Insert Table 2]

Dietary Adherence

Subjects were instructed to maintain their customary nutritional regimen and to avoid taking any supplements. Dietary intake was assessed by self-reported 3-day food records which were collected three times during the study: one week before the first training session (i.e. baseline), at week 4, and during the final week of the training protocol. Subjects were instructed on how to properly complete the logs and record all food items and their respective portion sizes consumed for the designated period of interest. All nutrition logs were scrutinized by the

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research team and clarification was obtained from subjects when there was confusion regarding the food item or portion consumed. Each item of food was individually entered into Diet Analysis Plus Version 10 (Cengage, USA) and total energy consumption, as well as the amount of energy derived from proteins, fats, and carbohydrates was assessed.

Statistical Analysis

All data is reported as means \pm standard deviations. Pre-intervention differences in body composition and strength were assessed using independent samples *t*-tests. A 2 x 3 mixed factorial ANOVA with repeated measures (group x time) was used to compare differences in pre-, mid- and post-intervention dietary intakes between groups. A 2 x 8 mixed factorial ANOVA with repeated measures (group x time) was used to compare squat and overhead press volumes. A series of 2 x 2 mixed factorial ANOVAs with repeated measures (group x time) was used to assess differences in strength, power, body composition, and limb CSA. When a significant main effect of group or interaction was found relative percent differences were calculated (percent difference = $([\text{post-intervention measure} - \text{baseline measure}] / \text{baseline measure}) \times 100$) and compared with independent samples *t*-tests with the Bonferroni correction. The normality of the data was checked and subsequently confirmed with the Shapiro-Wilk test. For all measured variables, the estimated sphericity was verified according to Mauchly's *W* test, and the Greenhouse–Geisser correction was used when necessary. Effect sizes were defined as small, medium, and large and are represented by Cohen's *d* of greater than 0.2, 0.5, and 0.8,

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respectively. All analyses was completed using SPSS Version 22 (IBM, USA) and an alpha level of $p < .05$ was set *a priori*.

RESULTS

There were no significant differences between groups at baseline for any of the dependent variables ($p > .05$). Adherence for the high-load group was $99.5 \pm 1.80\%$. One subject in the high-load group missed two sessions and one subject in the moderate-load group missed one session. Adherence in the moderate-load group was $99.5 \pm 2.55\%$; one subject missed a total of three sessions.

Body Composition

Body composition results are displayed in Table 3. There were no statistically significant ($p = .075$, $F = 3.56$) main effects of time, group ($p = .261$, $F = 1.35$) nor interactions ($p = .435$, $F = .64$) for body mass. There were no statistically significant main effects for time ($p = .837$, $F = .04$), group ($p = .591$, $F = .30$), or interaction ($p = .155$, $F = .04$) for sum of skinfold measures. There was a statistically significant ($p = .008$, $F = 8.82$) main effect of time for body fat percentage; however, there were no statistically significant main effects for group ($p = .854$, $F = .04$) or ($p = .899$, $F = .02$) interactions. There were no statistically significant ($p = .075$, $F = 3.57$) main effects of time, group ($p = .462$, $F = .51$), nor interactions ($p = .524$, $F = .42$) for fat mass. There was a statistically significant ($p < .001$, $F = 33.48$) main effect of time for fat free mass; however, there were no statistically significant ($p = .811$, $F = .06$) interactions.

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Compartmental Water

Compartmental water results are displayed in Table 3. There were no statistically significant main effects for time ($p = .902$, $F = .02$), group ($p = .783$, $F = .08$), nor interactions ($p = .153$, $F = 2.23$) for urine specific gravity. Mean urine specific gravity was $1.014 \pm .009$ and $1.014 \pm .008$ at pre- and post-testing, respectively. There was a statistically significant ($p = .004$, $F = 11.11$) main effect of time for total body water; however, there were no statistically significant main effects for group ($p = .145$, $F = 2.32$) nor interactions ($p = .422$, $F = .68$). There was a statistically significant ($p = .003$, $F = 12.30$) main effect of time for intracellular water; however, there were no statistically significant main effects for group ($p = .278$, $F = 1.25$) nor interactions ($p = .341$, $F = .96$). There were no statistically significant main effects of time ($p = .868$, $F = .03$), group ($p = .406$, $F = .72$), nor interactions ($p = .240$, $F = 1.48$) for extracellular water. There was a statistically significant main effect of time ($p < .001$, $F = 45.00$) and group ($p = .031$, $F = 5.48$) for lean dry mass; however, there were no significant ($p = .625$, $F = .25$) interactions. *Post hoc* analysis for percent change in lean dry mass revealed no statistically significant ($p = .751$, $t = .323$) differences between groups.

[Insert Tables 3-5]

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Limb CSA

Changes in limb CSA are displayed in Table 4. There was a statistically significant ($p = .002$, $F = 13.26$) main effect of time for thigh CSA; however, there were no statistically significant main effects for group ($p = .387$, $F = .789$) nor interactions ($p = .931$, $F = .01$). There were no statistically significant main effects of time ($p = .129$, $F = 2.53$), group ($p = .460$, $F = .57$), nor interactions ($p = .353$, $F = .91$) for arm CSA.

Performance

Changes in performance variables are displayed in Table 5. There was a statistically significant ($p = .009$, $F = 8.57$) main effect of time for vertical jump; however, the main effect for group ($p = .665$, $F = 0.19$) and interaction was not statistically significant ($p = .507$, $F = .46$). There was a statistically significant ($p = .042$, $F = 4.81$) main effect of time for chest pass; however, the main effect for group ($p = .585$, $F = .31$) and interaction was not statistically significant ($p = .469$, $F = .55$). There was a statistically significant ($p < .001$, $F = 78.13$) main effect of time for squat 1 RM; however, the main effect for group ($p = .106$, $F = 2.89$) and interaction was not statistically significant ($p = .107$, $F = 2.88$). There was a statistically significant ($p < .001$, $F = 75.93$) main effect of time for relative squat 1 RM; however, the main effect for group ($p = .759$, $F = .10$) and interaction was not statistically significant ($p = .154$, $F = 2.22$). There was a statistically significant ($p = .004$, $F = 11.12$) main effect of time for overhead press 1 RM; however, the main effect for group ($p = .549$, $F = .37$) and interaction was not statistically significant ($p = .862$, $F = .03$). There was a statistically significant ($p = .004$, $F =$

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11.00) main effect of time for relative overhead press 1 RM; however, the main effect for group ($p = .460$, $F = .57$) and interaction was not statistically significant ($p = .899$, $F = .02$).

Dietary Adherence

Total energy and macronutrient intakes are displayed in Table 6. There were no statistically significant main effects of time ($p = .761$, $F = .28$) or group ($p = .651$, $F = .21$) for total energy intake. A statistically significant ($p = .044$, $F = 3.40$) interaction for total energy intake was found. However, *post hoc* analysis revealed no statistically significant differences between groups at baseline ($p = .834$, $t = .21$), mid-training ($p = .500$, $t = .69$), or post-training ($p = .146$, $t = 1.51$), nor did a 1 way RMANOVA reveal any statistically significant differences between time points for high-load ($p = .117$, $F = 2.43$) or moderate-load ($p = .274$, $F = 1.39$) energy intake. There were no statistically significant main effects of time ($p = .428$, $F = 0.78$), group ($p = .499$, $F = 0.48$), nor interactions ($p = .266$, $F = 1.37$) for protein intake. There were no statistically significant main effects for time ($p = .594$, $F = .53$), group ($p = .709$, $F = 0.14$), nor interactions ($p = .218$, $F = 1.59$) for carbohydrate intake. There were no statistically significant main effects for time ($p = .851$, $F = .16$), group ($p = .657$, $F = 0.20$), nor interactions ($p = .101$, $F = 2.45$) for fat intake.

[Insert Table 6]

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Training Volume

The volume load and corresponding relative intensity for the squat exercise can be found in Table 7. A statistically significant ($p = .008$, $F = 9.13$) main effect of group was found for squat volume. The high-load group completed more weekly volume compared to the moderate-load group (1421 ± 212 vs. 1129 ± 210 kg, respectively). A statistically significant ($p < .001$, $F = 38.62$) main effect of time was also found for squat volume; however, the interaction was not statistically significant ($p = .713$, $F = .65$). The volume load and corresponding relative intensity for the overhead press exercise can be found in Table 8. A statistically significant ($p = .007$, $F = 9.74$) main effect of group was found for overhead press volume. The high-load group completed more weekly volume than the moderate-load group (516 ± 68 vs. 414 ± 70 kg, respectively). A statistically significant ($p < .001$, $F = 6.13$) main effect of time was also found; however, the interaction was not statistically significant ($p = .141$, $F = 1.60$).

[Insert Tables 7-8]

DISCUSSION

To the authors knowledge this was the first study to investigate the differences in body composition and performance outcomes between full body repetition-equated high-load and moderate-load resistance training in recreationally active females. The primary findings of the study elucidated both high-load and moderate-load training programs increased measures of muscular strength and power, lean body mass, and thigh CSA, with no statistically significant differences between groups.

Our results demonstrate that both high-load and moderate-load resistance training equally increases lean body mass and lean thigh CSA as evidenced by a $3.0 \pm 2.3\%$ and $3.3 \pm 2.7\%$ increase in LBM, respectively, and a 3.2 and 6.0% increase in thigh CSA, respectively. Despite a slightly greater hypertrophic response in the moderate-load training group (high load vs. moderate load thigh CSA ES: 0.24 vs. 0.43 and arm CSA ES: 0.07 vs. 0.27, respectively), no statistical between-group differences were found. These results agree with other studies investigating the effects of high- vs. moderate-loading. Alegre et al. (3) reported a 4.6% and 3.1% increase in thigh lean mass for high and moderate loading, respectively, following 12 weeks of unilateral leg press and knee extension exercise in untrained female subjects, and Chestnut and Docherty (7) also reported no significant difference between groups in thigh CSA following 10 weeks of high- (4 RM) and moderate-load (10 RM) resistance training in untrained men.

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Given that greater rates of post-exercise protein synthesis have been associated with higher total muscular work (6) it has been proposed that greater volume loads will lead to enhanced hypertrophy (38). Schoenfeld et al. (38) compared 8 weeks of volume-load equated high- (7 sets of 3 repetitions) and moderate-load (3 sets of 10 repetitions) training in young men and also reported no differences in biceps brachii thickness. In the current study the high-load group accomplished significantly more total volume-load, but no differences in limb CSA or lean body mass were found between groups. While this may seem to refute prior suggestions that volume-load and greater mechanical tension lead to superior hypertrophic adaptations, the repetition volume between groups was matched. By matching the repetition volume and maintaining the same repetition cadence, the time under tensions was similar between groups. Experimental studies in rodents have shown that greater the time under tension, the greater the phosphorylation of jun-N-terminal-kinase, an upstream activator of mTOR that acts as a mechanical stimuli sensor (20). Therefore, a higher possible metabolic stress combined with a similar time under tension may explain why similar improvements lean body mass and thigh lean mass occurred between groups despite the high-load group having performed a greater volume of total work.

Abe et al. (1) reported increases in muscle thickness in the upper body are greater and occur earlier in the training process compared to the lower body during the first 12 weeks of a resistance training program. Our results contrast with these reports, as we found significant increases in lean thigh CSA, but not arm CSA. This discrepancy in results is not surprising given that the lower extremities were trained twice as frequently and with approximately twice as much volume as the upper extremities in the present study, whereas Abe et al. employed full body

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resistance training three days per week. Our difference in CSA results between the upper and lower extremity further the training principal of specificity and lend evidence to the hypothesis that volume load, at least up to a certain point, is a major driver of hypertrophy (38). We chose this resistance training protocol because lab space limited training to three times per week and to increase subject adherence, as preliminary interviews with pilot subjects revealed a strong desire to improve lower body strength and aesthetics compared to the upper body.

There were no differences between groups for changes in total or compartmental body water. Both groups experienced decreases in total and intracellular, but not extracellular water. These results are in contrast with Ribeiro et al. (34) who reported increases in total body water as well as intra- and extracellular water following 16 weeks of resistance training in men and women. The authors noted that the greatest increases in intracellular water occurred during the final 8 weeks of training. It is possible that differences in training length may account for these changes. Additionally, the total energy (26.6 ± 9.0 kcal/kg) and carbohydrate (3.5 ± 1.3 g/kg) consumption in this study was low. Inadequate carbohydrate consumption may have led to reduced intramuscular glycogen concentrations over the course of the study which may have attenuated the osmotic effects of glycogen, and may explain the discrepancy in results between this study and Ribeiro et al.

Some caution should be taken when interpreting the body composition outcomes of this study. Subjects were instructed not to change their dietary habits and nutrient intakes were analyzed, but we did not standardize or recommend any particular dietary strategies since compliance could not be ensured. Although issues with under-reporting dietary intakes exist, the

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subjects in this study likely did not consume enough energy to support optimal muscular adaptations. In particular protein consumption was particularly low with an average of 0.94 g/kg and 1.13 g/kg consumed by the high- and moderate-load groups, respectively. These values are well below the higher (2.0 g/kg) protein recommendations of the NSCA (5) and International Society of Sports Nutrition (26) for individuals engaged in a resistance training exercise. As such, it is possible that a more robust hypertrophic response would have occurred with higher protein and energy intakes.

The NSCA (5) recommends higher loads and lower repetitions for the optimization of muscular strength. The results of a recent meta-analysis demonstrate that strength gains can be made training with both high- and low-loads, but that higher loading appears more favorable toward maximizing muscular strength (39). Schoenfeld et al. (37) reported greater increases in bench press and back squat 1 RM following 8 weeks of training with 3 sets of 10 repetitions compared to 3 sets of 20 repetitions in trained young men. While we found no statistical differences between groups for improvements in overhead press or back squat strength, nor vertical jump height or chest pass velocity, effect sizes for squat 1 RM were largely in favor of the high load group, and may represent a type II error given the small sample size. Alegre et al. (3) also reported no differences in strength outcomes between high- and moderate-load training in untrained young women. Differences in training status between this study and Schoenfeld et al. are likely to account for the divergence in results. The results of a meta-analysis exploring the dose-response relationship for strength reveal a linear relationship between the load (as a % of the 1RM) and strength outcomes in highly trained subjects, but display an inverted U in untrained subjects whereby strength gains are maximized around 60% 1RM and decline with

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increasing intensities (32). The results of this study and Alegre et al. suggest that, at least in untrained young women, strength can be gained by training at moderate intensities (50-70% 1RM) at a similar rate to training at higher intensities (> 85% 1RM); however, the results of our study with the large differences in effect size suggest that the utilization of higher intensities may optimize strength gains to a greater degree, especially as subjects acquire older training statuses.

Some limitations must be addressed when interpreting or applying these results. The study was short in duration compared to the long term training process many recreational weight lifters and athletes take part in. Additionally, these protocols were carried out in subjects with minimal resistance training experience. It is well accepted that with advanced training age, more complex and/or demanding training protocols are necessary to induce hypertrophy and strength gains (32). As such, caution should be taken when extrapolating these results to a long term training plan or subjects/athletes with greater training ages. Finally, comparing these results with a control group performing the same exercises and repetitions, but with self-selected loads, could strengthen the use of training protocols with higher intensities (>70% 1 RM) or higher intensities of effort to maximize muscular adaptations.

Practical Applications

The success of an exercise program depends heavily on adherence, and individuals with a low-affinity for training are more likely to drop out or not comply with resistance training prescription. A fear of becoming masculine is an obstacle to adopting a resistance training program in young women (30), and women who resistance trained with self-selected lower loads

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reported greater self-efficacy and intention to continue training compared to higher imposed loads (13). The results of this study lend support to a growing body of evidence that individuals with lower training status can make improvements in muscular strength and hypertrophy training with more moderate loads, and may be used by fitness professionals to further prescribe evidence-based resistance training protocols that also appeal to the individual's training preferences. The data obtained in this study also serves to further debunk some of the myths that may otherwise impede young women from strength training, including a fear of excessive hypertrophy (11,33). The exercises utilized in this program were selected to replicate training modalities commonly employed by young, healthy women interested in enhancing aesthetics. Given the similar small effect sizes for increases in lean body mass as well as limb CSA between groups, the results of this study suggest that fitness professionals can prescribe young women with either moderate or heavy loads to promote strength and hypertrophic adaptations without inducing a bulky appearance.

Acknowledgements

All authors declare no conflicts of interest. The authors wish to thank Jody Davis of the Coastal Carolina University student recreation center for providing space within the student gym to conduct training. The authors wish to thank Christian DeAngelis and Christopher Carney for their training assistance. The authors also wish to thank Laurin Conlin of LoCoFit, LLC., for providing the resistance training prescription. The results of the present study do not constitute endorsement of any product by the authors or the NSCA.

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Figure Legends:

Figure 1. Experimental Design Timeline

Table 1. Subject Baseline Characteristics*

	High Load (n=10)	Moderate Load (n=10)
Age (years)	20.8 ± 1.5	20.0 ± 1.7
Height (cm)	165.5 ± 6.1	162.0 ± 6.4
Body Mass (kg)	73.3 ± 17.3	65.8 ± 10.7
Body Fat Percentage	31.8 ± 9.4	31.0 ± 7.4
1 RM Squat (kg)	63.0 ± 10.4	58.5 ± 11.1
Relative Squat (1RM/kg body mass)	0.88 ± 0.13	0.91 ± 0.22

*No significant differences between groups for any variables ($p > .05$)

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Table 2. Resistance Training Program

Weeks 1-4

Monday		Group		TOTAL reps
A	Squat	Moderate	2 x 10-12	20-24 reps
		High	4 x 5-6	20-24 reps
B	Hip Thrust	Moderate	2 x 10-12	20-24 reps
		High	4 x 5-6	20-24 reps
C	Lunges	Moderate	2 x 12-14	24-28 reps
		High	4 x 6-7	24-28 reps
D	Leg Extensions	Moderate	2 x 12-14	24-28 reps
		High	4 x 6-7	24-28 reps
Wednesday				
A	Seated BB OHP	Moderate	2 x 10-12	20-24 reps
		High	4 x 5-6	20-24 reps
B1	Incline DB Press	Moderate	2 x 10-12	20-24 reps
		High	4 x 5-6	20-24 reps
B2	Seated Cable Row	Moderate	2 x 12-14	24-28 reps
		High	4 x 6-7	24-28 reps
C1	Cable Pressdown	Moderate	2 x 12-14	24-28 reps
		High	4 x 6-7	24-28 reps
C2	Cable Curls	Moderate	2 x 12-14	24-28 reps
		High	4 x 6-7	24-28 reps
Friday				
A	Leg Press	Moderate	2 x 10-12	20-24 reps
		High	4 x 5-6	20-24 reps
B	Romanian deadlift	Moderate	2 x 12-14	24-28 reps
		High	4 x 6-7	24-28 reps

C	Goblet Squat	Moderate	2 x 12-14	24-28 reps
		High	4 x 6-7	24-28 reps
D	Leg Curls	Moderate	2 x 12-14	24-28 reps
		High	4 x 6-7	24-28 reps

Week 5: Active Rest

Weeks 6-9

Monday				TOTAL reps
A	Squat	Moderate	2 x 10-12	20-24 reps
		High	4 x 5-6	20-24 reps
B	Hip Thrust	Moderate	2 x 10-12	20-24 reps
		High	4 x 5-6	20-24 reps
C	Step Ups	Moderate	2 x 12-14	24-28 reps
		High	4 x 6-7	24-28 reps
D	Leg Extensions	Moderate	2 x 12-14	24-28 reps
		High	4 x 6-7	24-28 reps
Wednesday				
A	Seated BB OHP	Moderate	2 x 10-12	20-24 reps
		High	4 x 5-6	20-24 reps
B1	Incline DB Press	Moderate	2 x 10-12	20-24 reps
		High	4 x 5-6	20-24 reps
B2	Lat Pull Down	Moderate	2 x 12-14	24-28 reps
		High	4 x 6-7	24-28 reps
C1	Lying DB Triceps Extension	Moderate	2 x 12-14	24-28 reps
		High	4 x 6-7	24-28 reps
C2	Dumbbell Curls	Moderate	2 x 12-14	24-28 reps
		High	4 x 6-7	24-28 reps

Friday				
A	Leg Press	Moderate	2 x 10-12	20-24 reps
		High	4 x 5-6	20-24 reps
B	Sumo Deadlift	Moderate	2 x 10-12	20-24 reps
		High	4 x 5-6	20-24 reps
C	Rumanian Deadlift	Moderate	2 x 12-14	24-28 reps
		High	4 x 6-7	24-28 reps
D	Leg Curls	Moderate	2 x 12-14	24-28 reps
		High	4 x 6-7	24-28 reps

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Table 3. Body Composition Outcomes

		Pre-Training	Post-Training	Effect Size	95% CI for Time Difference
Body Mass (kg)	HL	73.3 ± 17.3	73.8 ± 16.1	0.04	-0.09, 1.58
	ML	65.8 ± 10.7	66.9 ± 10.3	0.08	
Sum of Skinfolds (mm)	HL	187.6 ± 77.3	181.7 ± 68.7	-0.08	-8.02, 6.57
	ML	166.1 ± 62.6	170.5 ± 58.4	0.07	
Body Fat (%)	HL	31.8 ± 9.4	30.5 ± 8.7 ^a	-0.15	-2.26, -0.37
	ML	31.0 ± 7.4	29.8 ± 7.4 ^a	-0.14	
Fat Mass (kg)	HL	24.4 ± 12.5	23.3 ± 11.1	-0.10	-1.68, 0.09
	ML	21.0 ± 8.7	20.5 ± 8.4	-0.05	
Fat Free Mass (kg)	HL	48.9 ± 7.4	50.4 ± 7.5 ^a	0.26	0.98, 2.09
	ML	44.8 ± 4.0	46.4 ± 4.3 ^a	0.28	
Total Water (L)	HL	34.0 ± 5.8	33.1 ± 5.4 ^a	-0.11	-1.19, -0.27
	ML	31.5 ± 4.7	31.0 ± 2.7 ^a	-0.06	
Intracellular Water (L)	HL	17.5 ± 2.9	17.0 ± 2.4 ^a	-0.22	-0.69, -0.17
	ML	16.4 ± 1.6	16.1 ± 1.3 ^a	-0.13	
Extracellular Water (L)	HL	16.4 ± 3.1	16.1 ± 3.0	-0.13	-3.35, 1.42
	ML	15.2 ± 1.7	15.4 ± 2.2	-0.08	
Lean Dry Mass (kg)	HL	14.8 ± 1.4	16.2 ± 1.3 ^a	1.12	0.90, 1.73
	ML	13.6 ± 1.1	14.8 ± 1.5 ^a	0.96	

^a significantly different from pre-training
 HL: High Load; ML: Moderate Load

Table 4. Limb Cross Sectional Area Outcomes

		Pre-Training	Post-Training	Effect Size	95% CI for Time Difference
Thigh CSA (cm²)	HL	202.8 ± 32.1	209.2 ± 25.0 ^a	0.24	2.79, 10.42
	ML	192.7 ± 21.8	204.3 ± 23.3 ^a	0.43	
Arm CSA (cm²)	HL	100.8 ± 19.5	102.0 ± 17.7	0.07	-0.93, 6.75
	ML	93.6 ± 17.1	98.3 ± 10.5	0.27	

^a significantly different from pre-training

HL: High Load; ML: Moderate Load

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Table 5. Performance Variable Outcomes

		Pre-Training	Post-Training	Effect Size	95% CI for Time Difference
Vertical Jump (cm)	HL	41.6 ± 6.4	43.8 ± 7.8 ^a	0.34	0.82, 5.00
	ML	39.5 ± 6.4	43.1 ± 8.0 ^a	0.56	
Chest Pass (m/s)	HL	4.13 ± 0.50	4.35 ± 0.49 ^a	0.55	0.007, 0.325
	ML	3.95 ± 0.30	4.04 ± 0.42 ^a	0.23	
Squat 1 RM (kg)	HL	63.0 ± 10.4	89.8 ± 18.4 ^a	2.49	17.15, 27.85
	ML	58.5 ± 11.1	76.6 ± 10.1 ^a	1.68	
Relative Squat (1RM/kg body mass)	HL	0.88 ± .13	1.23 ± .19 ^a	2.00	0.23, 0.38
	ML	0.91 ± .22	1.16 ± .15 ^a	1.43	
Overhead Press 1 RM (kg)	HL	29.0 ± 7.3	31.8 ± 4.9 ^a	0.49	1.13, 4.92
	ML	27.5 ± 4.1	30.7 ± 3.4 ^a	0.56	
Relative Overhead Press 1RM/kg body mass)	HL	0.40 ± .09	0.44 ± .07 ^a	0.66	0.02, 0.07
	ML	0.42 ± .07	0.47 ± .08 ^a	0.83	

^a significantly different from pre-training
 HL: High Load; ML: Moderate Load

Table 6. Energy and Macronutrient Intake

		Baseline	Mid-Training	Post-Training
Energy (kcal)	High-Load	1767 ± 496	1904 ± 352	1674 ± 345
	Moderate-Load	1816 ± 565	1795 ± 352	1979 ± 523
Protein (g)	High-Load	68 ± 20	71 ± 19	68 ± 27
	Moderate-Load	72 ± 20	70 ± 18	82 ± 25
Carbohydrate (g)	High-Load	228 ± 71	247 ± 63	216 ± 48
	Moderate-Load	235 ± 81	237 ± 44	247 ± 72
Fat (g)	High-Load	65 ± 19	72 ± 23	62 ± 19
	Moderate-Load	68 ± 29	66 ± 18	76 ± 23

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Table 7. Weekly Squat Load Volume

		Squat Volume (kg)	% Baseline 1RM
Week 1	High-Load	1234 ± 224	83.3 ± 3.3
	Moderate-Load	947 ± 191	68.9 ± 2.6
Week 2	High-Load	1269 ± 185	86.9 ± 4.8
	Moderate-Load	1000 ± 211	73.4 ± 4.2
Week 3^a	High-Load	1349 ± 250	91.5 ± 6.7
	Moderate-Load	1082 ± 208	78.4 ± 5.2
Week 4^a	High-Load	1399 ± 229	95.0 ± 7.7
	Moderate-Load	1146 ± 209	83.2 ± 5.4
Week 5^b	High-Load	1444 ± 235	97.7 ± 10.4
	Moderate-Load	1178 ± 201	85.6 ± 6.8
Week 6^c	High-Load	1518 ± 253	102.5 ± 13.6
	Moderate-Load	1215 ± 199	88.7 ± 8.3
Week 7^b	High-Load	1559 ± 244	103.9 ± 13.0
	Moderate-Load	1197 ± 246	88.5 ± 15.5
Week 8^d	High-Load	1600 ± 243	106.6 ± 12.9
	Moderate-Load	1262 ± 251	93.0 ± 9.3

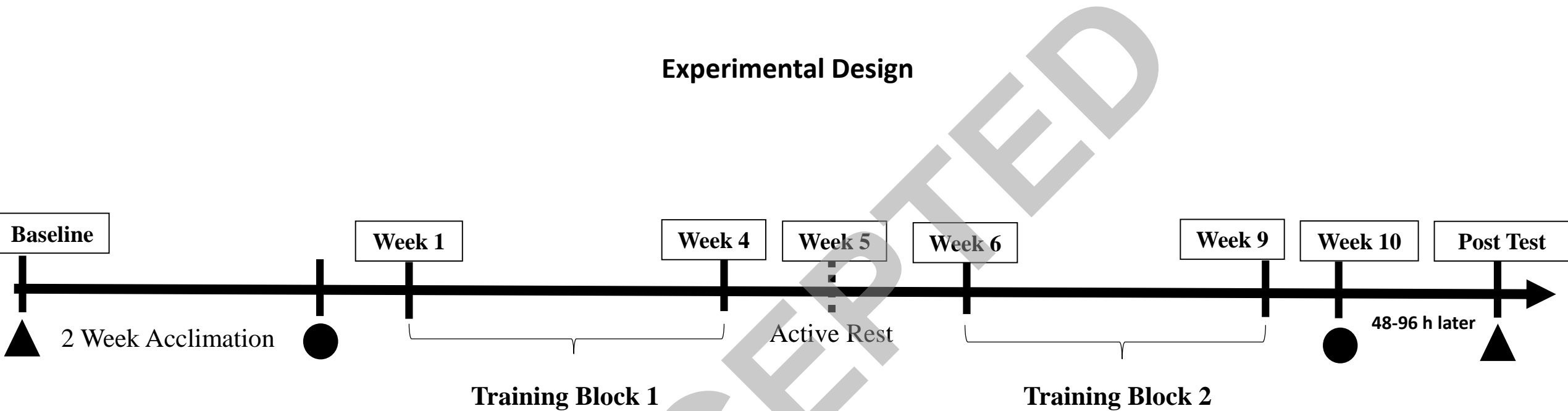
a: significantly different than week 2; b: significantly different than week 2 and 3; c: significantly different than week 1, 2, 3, and 4; d: significantly different than week 1, 2, 3, 4 and 5



Table 8. Weekly Overhead Press Load Volume

		Total Volume (kg)	% Baseline 1RM
Week 1	High-Load	479 ± 97	80.3 ± 6.2
	Moderate-Load	395 ± 75	66.2 ± 4.7
Week 2	High-Load	487 ± 86	78.4 ± 10.5
	Moderate-Load	410 ± 91	66.0 ± 3.9
Week 3	High-Load	480 ± 78	82.5 ± 21.1
	Moderate-Load	407 ± 65	64.8 ± 7.6
Week 4	High-Load	502 ± 84	83.6 ± 22.0
	Moderate-Load	406 ± 51	63.2 ± 7.5
Week 5	High-Load	532 ± 99	87.2 ± 19.6
	Moderate-Load	400 ± 68	68.2 ± 7.3
Week 6	High-Load	547 ± 85	86.8 ± 14.7
	Moderate-Load	416 ± 65	70.8 ± 10.9
Week 7 ^a	High-Load	550 ± 81	88.0 ± 16.4
	Moderate-Load	431 ± 80	70.6 ± 9.1
Week 8 ^a	High-Load	550 ± 51	89.1 ± 18.6
	Moderate-Load	444 ± 77	72.4 ± 8.6

a: significantly different than week 1, 2 and 3.

Figure 1



	Anthropometric and Body Composition Assessment
	Performance Testing