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Early Timeline of Lean Tissue Mass and Strength Improvements in Trained Men Following a High Volume/Frequency Resistance Training Program

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ABSTRACT

International Journal of Exercise Science 12(4): 1094-1109, 2019. The purpose of this study was to determine the early timeline effect of a systemic high volume/frequency resistance training intervention on lean tissue mass and strength in trained men. Twenty-two healthy resistance trained men, age (32.29 ± 9.75 years), training age (9.40 ± 6.18 years) were placed on a 4-week resistance training (RT) intervention with lean mass and strength assessed pre, mid, and post intervention. RT consisted of 6 exercises: flat smith chest press, pull ups, triceps pushdowns, dumbbell bicep curls, leg press or walking lunges, and standing calf raises, completing 5 sets of 6-12 repetitions, 6 days per week. One-way repeated measure ANOVA's were conducted to determine the impact of time on lean mass, leg press 1-RM, chest press 1-RM, and absolute/relative resistance training volume. Lean mass increased pre to mid 1.27 ± 1.18 kg, (2.03%), mid to post 1.14 ± 1.16 kg, (1.78%), and pre to post 2.41 ± 1.29 kg, (3.84%). Leg press 1-RM increased pre to mid 16.08 ± 34.90 kg, (6.09%), mid to post 27.53 ± 27.69 kg, (9.82%), and pre to post 43.61 ± 40.13 kg, (16.42%). Chest press 1-RM increased pre to mid 5.77 ± 5.51 kg, (4.45%), mid to post 6.70 ± 5.83 kg, (4.94%), and pre to post 12.47 kg ± 5.83 kg, (9.62%). High volume/frequency resistance training results in significant early improvements in lean mass and strength in trained men.

KEY WORDS: Early hypertrophy, strength training volume, exercise prescription

INTRODUCTION

Studies investigating the early timeline (less than four weeks) adaptations from resistance training (RT) demonstrates improvements in strength and hypertrophy of one muscle region in untrained participants. Seynnes et al. (26) demonstrated early quadriceps cross-sectional area (CSA) improvements of ~0.2% per day during the first 20 days of 3 times per week RT. Damas et al. (8) demonstrated an increase in CSA of 2.7% after three weeks of 6 sets of quadricep RT twice per week. DeFreitas et al. (10) revealed CSA increases of 3.46% following two quadriceps sessions that consisted of 9 sets each. Yasuda et al. (32) discovered significant improvements in CSA for the pectoralis major (16%), triceps brachii (8%), and bench press strength (6%) following a two week twice per day bench press routine. Stock et al. (27) demonstrated an increase of 109.3 g of shoulder and arm lean mass following 3 weeks of RT. Boone et al. (3) demonstrated significant improvements in knee extension strength of 45 kg and CSA improvements of ~22% for the quadriceps following four weeks of 3 times per week RT. Kim et al. (18) revealed significant quadriceps CSA improvements of 2.37% - 3.4% and knee extension strength of 29% following three weeks of 3 times per week RT. Fujita et al. (14) discovered significant increases in quadriceps CSA of 3.4% and 1-RM knee extension strength of 6.7% following six days of twice per day knee extension exercise. These results demonstrate early adaptations in response to a variety of RT programming in one muscle group. One muscle group RT does not represent RT that athletes and fitness enthusiasts perform that involves exercising all major muscle groups. Prior research represents the need for research investigating early adaptations from a high volume/frequency systemic RT program that is pragmatic. Another void is research that examines early adaptations in trained participants. Trained participants are closer to their genetic ceiling and their adaptive response to RT will likely be less than that of novice participants (21). Therefore, improvements in outcomes for trained participants may be considered more significant compared to novice trainees.

Ribeiro et al. (21) examined fat-free mass and strength changes in advanced trainees that resulted in significant improvements in about four weeks. Thomas and Burns (30) demonstrated no significant differences in lean tissue mass and strength comparing a muscle group frequency of 3 versus 1-time per week with a similar exercise volume of nine sets per muscle group per week. Thomas and Burns consisted of lower volume compared to Ribeiro et al. (21) that may explain the greater increases in outcomes in Ribeiro et al. Thomas and Burns conclude that higher training volume may be necessary to exceed lean tissue mass and strength gains presented in their study. This conclusion agrees with others that hypothesized that resistance training volume and associated frequency may be a significant determiner of outcomes especially hypertrophy (9, 24, 25). These results demonstrate the need for research assessing the impact of high volume and frequency RT on lean tissue mass and strength acquisition.

Resistance exercise has consistently demonstrated an ability to improve the strength and size of skeletal muscle. Investigators have hypothesized that high volume resistance exercise may improve the adaptive response and that muscle hypertrophy occurs during the early weeks of commencing RT (4, 6, 21, 25, 27, 30). However, published research examining early timeline adaptations is limited especially research that involves trained participants. The unique assessment performed here is data collected at two and four-week timelines for upper and lower body strength and lean tissue mass assessed via Dual Energy X-ray Absorptiometry (DXA). The purpose of this investigation was to measure early timeline adaptations of lean tissue mass and strength in trained men following a high volume/frequency intervention. We hypothesized that upper and lower body strength and lean tissue mass would improve significantly ($p < .05$) following the high volume/frequency four-week RT intervention. The uniqueness of this intervention is the high volume/frequency program that consisted of 30 sets per muscle group per week, 5 sets per exercise, performed 6 days per week.

METHODS

Participants

Participants were healthy, resistance trained men (> 1 year of experience), free of cardiovascular disease or major orthopedic injury, determined by completion of a health history questionnaire. None of the participants had a history of using anabolic steroids or performance enhancing medications. Participants did not consume performance enhancing supplements during the intervention. The study was approved via institutional review (IRB) at both Concordia University of Chicago and Missouri State University. All potential participants signed an IRB approved consent form prior to pre-testing (31). Prior to pre-testing participants attended a familiarization session to explain all study procedures. A priori sample size estimation with a power calculation of 0.80, effect size of d = 0.55, and a repeated measure design required a sample size of 7, exceeded with 22 completing the study (13). The training age for the 22 participants that completed the study was 9.40 ± 6.18 years and prior RT days per week was 3.61 ± 1.29. The study began with 26 participants with 22 completing all four weeks of resistance training and testing (Table 1).

Table 1. Initial participant characteristics: Means and standard deviations.

Variable	Mean ± SD (95% CI)
n	22 men
Age (y)	32.29 ± 9.65 (28.01 - 36.57)
Training Age (y)	9.40 ± 6.18 (6.65 - 12.13)
Training days per week prior to research	3.61 ± 1.29 (3.04 - 4.19)
Total Mass (kg)	88.73 ± 13.04 (82.95 - 94.51)
Lean Mass (kg)	62.86 ± 7.08 (59.71 - 66.00)
Height (cm)	176.99 ± 7.82 (173.52 - 180.46)
Body Fat Percent (%)	25.79 ± 6.48 (22.92 - 28.66)
Leg Press Strength (kg)	264.01 ± 73.70 (231.33 - 296.69)

Protocol

Participants were placed on a four-week high volume/frequency RT program. Dependent variables consisted of lean tissue mass assessed via DXA and strength assessed via 1-RM for the flat chest press and leg press all assessed pre, mid, and post-intervention. The independent variable was time, weeks 0 to 4. Additionally, absolute RT volume (load in kg · repetitions) and relative RT volume (absolute volume kg · kg^{-1} bodyweight) was recorded for the pre-training week and all four weeks of the intervention. One RM assessments were not included in absolute or relative training volume data. DXA is considered the gold standard for body composition assessment and provides valid and reliable assessment of lean tissue mass (r = 0.97, p > .0001) (15, 16).

To assess the effect of time on the dependent variables a within group time series design was conducted that involves one group with data collected at pre, mid, and post timelines (7). The benefits of a time series design are that internal validity is controlled with participants serving as their own controls. An additional benefit is that this design requires less participants which is beneficial considering the limited access to advanced trainees. This design also eliminates the ethical issue of selection and randomization (7). Advanced trainees come into an intervention with beliefs as to effective exercise programming and if they believe they are assigned to a control or group receiving a lesser treatment they may drop out.

To assess the effect of time in regards to increases in lean tissue mass, DXA scans were performed at three-time points: pre (the Friday prior to the RT intervention, mid (the Monday of Week 3), and post (the Monday following the intervention) (Table 2). DXA scans (GE-Lunar Prodigy) software (encore 13.60) occurred at the Body Composition Laboratory, Missouri State University. Prior to scans participants completed and signed the Missouri State University DXA waiver form and removed all metal objects. Height was measured with a wall mounted stadiometer to the nearest 0.1 cm and body mass measured via an electronic scale (Perfecto, Webb City, MO) to the nearest 0.1 kg. Scans were performed with participants lying supine along the center line. Participants weighed less than 159 kg and under 199 cm in height to fit on the DXA table. Feet were secured together and hands placed in the neutral position palms facing the hip within the scanning region. DXA scans were performed by a trained technician and calibration per manufacturer's recommendations.

Lower body strength assessment occurred at three-time points, pre (the Friday prior to the RT intervention), mid (the Sunday following week 2), and post (the Tuesday following the four-week intervention) (Table 2). Lower body strength assessment was measured on a horizontal leg press (Hammer Strength, Life Fitness, Schiller Park, Il). Warm up protocol consisted of one set of 10 repetitions with a load at 50% of participants predicted 1-RM followed by sets of 1 to 2 repetitions with increases in load of 10% requiring three to four sets to reach 1-RM attempts. Upon reaching ~90% of 1-RM, increases in load were 1% - 3% to attain a 1-RM with the smallest increment being 1.13 kg. Rest interval between 1-RM attempts was three min. Leg press range of motion consisted of beginning at 90 degrees of knee flexion followed by extension and return to the original position of 90 degrees of flexion. Seat position was recorded following the first 1-RM session for stable assessment throughout the study. Foot placement for the leg press consisted of the distal great toe placed at the top of the platform.

Upper body strength assessment occurred on the flat smith machine chest press (Keys Fitness, Garland, TX). Warm ups involved performing 10 repetitions at 50% of predicted 1-RM followed by three to four sets to reach a load for the attempted 1-RM, as described for lower body assessment. Range of motion consisted of commencing the repetition at elbow extension, eccentrically lowering the bar to the guards (setting 4) ~5 cm off participant's chest with a cadence of 2 s followed by a maximal concentric return to extension. Chest press was performed with hips and back positioned squarely on the bench with participant's feet placed flat on the floor. Distance between index fingers was measured to the nearest centimeter to insure reliable exercise performance. These strength testing procedures are identical to prior research (30).

Table 2. Timeline for testing and intervention.

Week	Day	Data
One week before week 0	Monday	Pre-Intervention Meeting Inform participants of intervention
Week 0	Monday – Saturday	Typical weekly training volume recorded
	Friday (pre-testing)	DXA pre-scan, 1-RM flat chest press and leg press
Week 1	Monday – Saturday	Resistance intervention
	Sunday	Rest
Week 2	Monday – Saturday	Resistance intervention
	Sunday (mid-testing)	1-RM flat chest press and leg press
Week 3	Monday (mid-testing)	DXA
	Monday – Saturday	Resistance intervention
	Sunday	Rest
Week 4	Monday – Saturday	Resistance intervention
	Sunday	Rest
Week 5	Monday (post testing)	DXA
	Tuesday	1-RM flat chest press and leg press

The resistance training warm up included performing 1-2 sets of 10 repetitions at 50% - 60% of the scheduled load on the chest press, latissimus pulldown or 2-3 repetitions of pull ups, and walking lunges or leg presses. The RT intervention consisted of 6 exercises all performed to concentric volitional fatigue completing 6-12 repetitions per set (load ~60-70% of 1-RM), 5 sets per exercise, six days per week for four weeks. Each week included a day of rest, that no exercise was suggested. Once a participant completed all 5 sets of 12 repetitions per exercise the load was increased 2-3%. The six exercises included: chest press, pullup or latissimus pulldown, triceps extension with high pulley, dumbbell curl, horizontal leg press (Hammer Strength, Life Fitness, Schiller Park, Il) or walking lunge (90 degrees of knee flexion) and standing calf raise. All exercises were performed in a controlled manner (~1 s concentric and eccentric cadence). The exercise intervention was performed in circuit fashion with one set performed of an exercise followed by a 45-s rest interval, followed by completion of the next exercise in the order listed in Table 3. Once all six exercises were completed, the routine continued back to the first exercise with the total daily routine completed after five rounds or 5 sets per exercise (Table 3). All data from exercise sessions was recorded in a training log (Excel, Microsoft Inc.). Data recorded included date, resistance, number of repetitions completed per set, and session time.

Table 3. Resistance training intervention.

Muscle Group	Exercise
Pectoralis	Flat Presses
Upper Back	Pullups/Pulldown
Triceps	Triceps Pushdown
Biceps	Seated Dumbbell Curls
Quadriceps/Hamstrings	Walking Lunges/Leg Presses
Gastrocnemius	Calf Raises

Note. Workouts were performed six days per week, in circuit fashion from top to bottom, with 45 s rest intervals between sets, completing 5 sets of 6-12 repetitions of each exercise.

Statistical Analysis

Descriptive statistics (means ± SD and 95% confidence intervals) were calculated for all dependent variables. Statistical analysis was completed using SPSS (version, 24, IBM, Armonk, NY). A one-way repeated measure analysis of variance was used to analyze the effect of time on lean mass, leg press 1-RM, chest press 1-RM, absolute and relative RT volume. Bonferroni's post hoc tests determined differences when significant effects of time were found. Statistical significance was set at a probability level of $p < .05$. Partial eta-squared (η^2) effect sizes were determined for time on the intervention using the following standards: 0.01 = small; 0.06 = medium; and 0.13 = large (5).

RESULTS

Lean Mass: There was a significant effect of time on lean mass, Wilks' Lambda = .216, F (2, 20) = 36.38, $p < .001$, $\eta^2 = .784$. Estimates of effect size reveal a strong effect of time on lean mass improvements. Bonferroni's post hoc tests revealed that following two and four weeks of RT, lean mass improvements were significantly greater than pre-intervention ($p < .05$). Lean mass improvements from pre to mid was 2.03% ($p < .001$), mid to post 1.78% ($p < .001$), and pre to post was 3.84% ($p < .001$) (Table 4).

Table 4. Lean mass changes following two and four weeks of RT.

Variable	Mean ± SD (95% CI)	F	p	Partial eta squared
Lean Mass (kg)		36.38	< .001	.784
Pre	62.85 ± 7.09 (59.7 - 66.00)			
Mid	64.13 ± 7.33* (60.88 - 67.38)			
Change Pre to Mid	1.27 ± 1.18* (1.93 - .61)			
% Change Pre to Mid	2.03			
Post	65.27 ± 7.28* (62.04 - 68.50)			
Change Mid to Post	1.14 ± 1.16 * (1.79 - .49)			
% Change Mid to Post	1.78			
Change Pre to Post	2.41 ± 1.29 * (3.13 - 1.69)			
% Change Pre to Post	3.84			

Note. CI = Confidence Interval. Multiple comparisons: Bonferroni. * Significant difference between Pre to Mid, Mid to Post, and Pre to Post ($p < .001$).

There was a significant effect of time on leg press strength, Wilk's Lambda = .400, F (2, 20) = 15.00, p < .001, η^2 = .60. Estimates of effect size reveal a strong effect of time on leg press 1-RM improvements. Bonferroni's post hoc tests revealed leg press 1-RM changes following two and four weeks of RT. Results reveal that leg press 1-RM improved from pre-to mid 6.09% (p = .127), mid to post 9.82% (p < .001), and pre to post 16.42% (p < .001) (Table 5).

Table 5. Leg press strength changes following two and four weeks of RT.

Variable	Mean ± SD (95% CI)	*F*	*p*	Partial eta squared
Leg Press 1-RM (kg)		15.00	<.001	.60
Pre	264.01 ± 73.70 (231.33 - 296.69)			
Mid	280.09 ± 83.27 (243.17 - 317.01)			
Change Pre to Mid	16.08 ± 34.90 (35.44 - 3.28)			
% Change Pre to Mid	6.09			
Post	307.62 ± 86.78* (269.14 - 346.09)			
Change Mid to Post	27.53 ± 27.69* (42.88 - 12.17)			
% Change Mid to Post	9.82			
Change Pre to Post	43.61 ± 40.13* (65.86 - 21.35)			
% Change Pre to Post	16.42			

Note. CI = confidence interval. 1-RM = one repetition maximum. Multiple comparisons: Bonferroni. *Significant difference between Mid to Post and Pre to Post (p < .001).

There was a significant effect of time on chest press 1-RM, Wilk's Lambda = .236, F (2, 20) = 32.393, p < .001, η^2 = .764. Estimates of effect size reveal a strong effect of time on the intervention and bench press 1-RM improvements. Bonferroni's post hoc tests revealed chest press 1-RM improvements following two and four weeks of RT. Chest press 1-RM improved significantly from pre to mid 4.45% (p < .001), mid to post 4.94% (p < .001), and pre to post 9.62% (p < .001) (Table 6).

A one-way repeated measure ANOVA was conducted to compare the effect of time on absolute training volume. Data was screened to ensure the assumptions for a one-way repeated measure ANOVA were met. Mauchly's test of sphericity was violated, ξ^2 (9) = 37.188, p < .05 resulting in a Greenhouse-Geisser correction. There was a significant effect of time on absolute training volume, Greenhouse-Geisser correction F (1.901, 39.921) = 292.592, p < .001, η^2 = .993. Estimates of effect size reveal a strong effect of time on the intervention and absolute training volume. Bonferroni's post hoc tests reveal absolute training volume increased significantly comparing week 0 to all four weeks of the intervention. Each subsequent week resulted in significantly greater absolute training volume with the exception being week 3 was not significantly greater than week 2 (p = .287). Percent improvements for absolute training volume from week 0 to week 1 was 614.86% (p < .05), week 1 to week 2 was 25.07% (p < .05), week 2 to week 3 was 4.84% (p = .287), and week 3 to week 4 was 6.06% (p < .05). Total percent increase from pre-week 0 to week 4 was 791.89% and from week 1 to week 4 was 39.08% (Table 7).

Table 6. Chest press strength changes following two and four weeks of RT.

Variable	Mean ± SD (95% CI)	*F*	*p*	Partial eta squared
Chest Press 1-RM (kg)		32.393	<.001	.764
Pre	129.69 ± 23.00 (119.49-139.88)			
Mid	135 ± 22.39* (125.09-145.83)			
Change Pre to Mid	5.77 ± 5.51* (8.77-2.77)			
% Change Pre to Mid	4.45			
Post	142.16 ± 23.20* (131.87-152.44)			
Change Mid to Post	6.70 ± 5.83* (9.94-3.47)			
% Change Mid to Post	4.94			
Change Pre to Post	12.47 kg ± 5.83* (8.54-16.41)			
% Change Pre to Post	9.62			

Note. CI = confidence interval. 1-RM = one repetition maximum. Multiple comparisons: Bonferroni.
* Significant difference between Pre to Mid, Mid to Post, and Pre to Post ($p < .001$).

Table 7. Absolute resistance training volume following four weeks of RT.

Variable	Mean ± SD (95% CI)	*F*	*p*	Partial eta squared
Absolute Volume (kg)		292.592	<.001	.993
Pre	20,133.83 ± 14,721.11 (13,606.85-26,660.81)			
Week 1	129,117.09 ± 56,793.20* (103,936.39-154297.78)			
% Change Pre to Week 1	614.86			
Week 2	161,489.21 ± 33,597.41** (146,592.95-176,385.46)			
% Change Week 1 to 2	25.07			
Week 3	169,305.89 ± 31,856.93 (155181.32-183430.46)			
% Change Week 2 to 3	4.84			
Week 4	179,571.76 ± 33,406.33*** (164,760.23-194,383.30)			
% Change Week 3 to 4	6.06			
% Change Pre to Week 4	791.89			
% Change Week 1 to 4	39.08			

Note. CI = confidence interval. 1-RM = one repetition maximum. Multiple comparisons: Bonferroni; * Mean difference between Pre and Week 1 ($p < .05$); **Mean difference between Week 1 and 2 ($p < .05$); ***Mean difference between Week 3 and 4 ($p < .05$).

A one-way repeated measure ANOVA was conducted to compare the effect of time on relative training volume (absolute volume kg · kg^{-1} bodyweight). Data was screened to ensure the assumptions for a one-way repeated measure ANOVA were met. Mauchly's test of sphericity was violated, ξ^2 (9) = 155.752, $p < .05$ resulting in Greenhouse–Geisser correction. There was a significant effect of time on relative training volume, Greenhouse-Geisser correction F (1.086, 22.816) = 20.434, $p < .001$, $\eta^2 = .493$. Estimates of effect size reveal a strong effect of time on the intervention and relative training volume. Bonferroni's post hoc analysis revealed that relative training volume increased significantly comparing week 0 to all four weeks of the intervention.

Each subsequent week of the intervention resulted in significantly greater relative training volume with the exception being that week 3 was not significantly greater than week 2 (p = .082). Percent improvements for relative training volume from week 0 to week 1 was 184.72 % (p < .05), week 1 to week 2 was 11.71 % (p < .05), week 2 to week 3 was 6.25 % (p = .082), and week 3 to week 4 was 5.98% (p < .05). Total percent increase in relative volume from pre-week 0 to week 4 was 258.15% and from week 1 to week 4 was 25.79% (Table 8).

Table 8. Relative resistance training volume following four weeks of RT.

Variable	Mean ± SD (95% CI)	*F*	*p*	Partial eta squared
Relative Volume ($kg \cdot kg^{-1}$)		20.434	<.001	.493
Pre	567.68 ± 1249.24 (13.799-1121.56)			
Week 1	1,616.30 ± 278.27* (1492.93-1739.68)			
% Change Pre to Week 1	184.72			
Week 2	1,805.62 ± 330.09** (1659.27-1951.98)			
% Change Week 1 to 2	11.71			
Week 3	1,918.51 ± 367.50 (1755.56-2081.45)			
% Change Week 2 to 3	6.25			
Week 4	2,033.15 ± 423.36*** (1845.44-2220.85)			
% Change Week 3 to 4	5.98			
% Change Pre to Week 4	258.15			
% Change Week 1 to 4	25.79			

Note. CI = confidence interval. 1-RM = one repetition maximum. Multiple comparisons: Bonferroni; * Mean difference between Pre and Week 1 (p < .05); **Mean difference between Week 1 and 2 (p < .05); ***Mean difference between Week 3 and 4 (p < .05).

DISCUSSION

The effects of time on lean mass demonstrate that this high volume/frequency RT intervention produces significant early adaptations. The hypothesis was that lean mass improvement would reach levels of significance following the four-week intervention. Early improvements in lean mass was not expected due to limited knowledge of early systemic adaptations from a high-volume intervention. Prior research resulted in improvements in lean tissue mass that were not significant following 8 weeks of RT (30).

Similar to the improvements in lean mass of this current study, Ribeiro et al. (21) demonstrated significant improvements in fat free mass following 4 weeks of RT. Ribeiro et al. placed male body builders on a four or six-day split routine. Fat free mass assessed via DXA increased significantly in both groups, 4.2% in four time per week and 3.5% in the six time per week group. Ribeiro et al. results are similar to the current study that resulted in pre to post lean mass improvements of 3.84%. Prior research revealed a 1.9% and 2.0% improvement in lean mass following 8 weeks of RT in trained participants (30). The current study resulted in almost twice the percent improvement in lean mass (2.0% vs. 3.84%) in half the time (8 vs. 4 weeks). The current investigation consisted of greater than three times the number of sets per week per

muscle group (30 vs. 9 sets) compared to Thomas and Burns (30). These results demonstrate that a relationship does exist between training volume and lean tissue mass adaptations.
Prior evidence exists of early muscular adaptations in response to RT that concurs with results presented here. Untrained participants demonstrate significant skeletal muscle hypertrophy from less than four weeks of RT (8, 10, 26, 32). Specifically, upper body lean mass improves significantly during the early weeks of RT (17, 20, 27). Diverse training volumes result in lean mass and CSA improvements in untrained participants (1, 3, 11, 18, 29). This investigation demonstrated early systemic lean mass adaptations in trained participants while the majority of published research examines adaptations of one muscle region in untrained participants.

Leg press 1-RM improved pre to mid 16.08 ± 34.90 kg, 6.09%, mid to post 27.53 ± 27.69 kg, 9.82%, and pre to post 43.61 ± 40.13 kg, 16.52%. Leg press 1-RM did not reach significance following the first two weeks and may have been a result of participant fatigue from two weeks of daily exercise. Mid 1-RM testing occurred with less than 24 hr. of recovery from the prior day's RT. Pre and post 1-RM were performed with 48 hr. of recovery that resulted in a 16.52% leg press 1-RM improvement pre to post.

Higher volume RT results in greater lower body strength improvements in trained men. Robbins et al. (22) assessed the impact of training volume comparing 1 vs. 4 vs. 8 sets per session. Following six weeks of RT, squat strength improvement was greater for the 8-set condition that was 19.5%. These results concur with the current study's 16.52% leg press 1-RM improvement after 4-weeks of RT. Sets per week in Robbins et al. was 16 compared to the 30 in the current investigation and both studies result in significant improvements in lower body strength. Thomas and Burns (30) resulted in lower body hack squat strength improvements in trained participants of 21 and 24 % following 8 weeks of RT. Thomas and Burns included 9 lower body sets per week while the current investigation consisted of 30. The current investigation assessed outcomes at two and four-week timelines and discovered significant lower body strength adaptions following four weeks of RT.

Chest press 1-RM improved significantly pre to mid 5.77 ± 5.51 kg, 4.45%, mid to post 6.70 ± 5.83 kg, 4.94%, and pre to post 12.47 ± 5.83 kg, 9.62%. Yasuda et al. (32) placed untrained men on a bench press routine of blood flow restricted or non-restricted twice per day for two weeks. Blood flow restricted bench press involved exercising with a compression cuff on both arms proximally with compression rates varying from 100 mmHg to 160 mmHg. Following two weeks of twice daily exercise, 1-RM increased 6% in the blood flow restricted group. The current investigation resulted in 1-RM chest press improvement of 4.45 % following two weeks of RT similar to the 6% in Yasuda et al. Yasuda et al. consisted of 48 sets of bench press exercise weekly vs. 30 sets of chest press in the current study. Ribeiro et al. (21) placed ten male body builders to a four or six-day split routine for four weeks that resulted in bench press 1-RM improvements of 8.4% - 11.4%. The current investigation resulted in similar improvement in chest press 1-RM of 9.62% following four weeks of RT. These results demonstrate the effectiveness of high-volume RT to improve upper body strength rapidly.

There was a significant effect of time on absolute training volume. Percent increase from week 1 to 4 within the intervention was 39.08%. Increases in absolute volume was significant comparing week 0 to all four weeks and each subsequent week was significantly greater than the week before except week 3 was not significantly greater than week 2 (Figure 1).

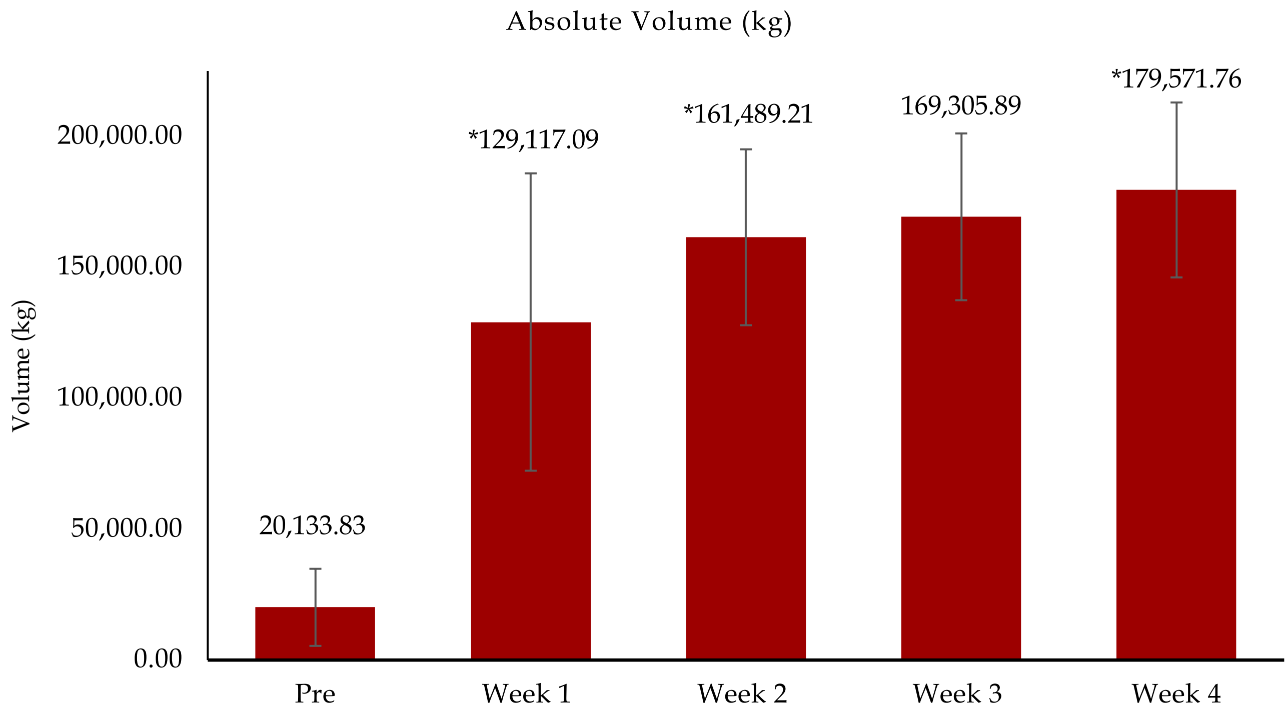

Figure 1. Mean absolute RT volume and standard deviation. *Significant from the week preceding ($p < .05$).

Absolute volume is rarely reported in RT research. Schoenfeld et al. (24) reported mean absolute volume for a week of resistance training at 56,820 kg in the strength routine and 51,283 kg in the hypertrophy routine. The current investigation reports absolute volumes from week 1 of 129,117.09 ± 56,793.20 kg to a high at week 4 of 179,571.76 ± 33,406.33 kg. Schoenfeld et al. (24) resulted in back squat 1-RM improvements of 18.9% and 22.2% and bench press 1-RM improvements of 8.1% and 10.9% following their 8-week intervention. The current investigation demonstrated increases in leg press 1-RM of 16.52% and chest press 1-RM of 9.62%. Both Schoenfeld et al. (24) and the current investigation represent similar strength adaptations however the current investigation was shorter in duration (4 vs. 8 weeks).

Schoenfeld et al. (23) reported weekly training volume for an eight-week intervention that compared high and low repetitions per set. Schoenfeld et al. reports training volume during week 8 in their 30 RM group as 102,037 ± 20,522 kg that was significantly greater than baseline. The current investigation presented absolute training volumes of 129,117.09 ± 56,793.20 kg during week 1 and week 4 of 179,571.76 ± 33,406.33 kg. According to Schoenfeld et al. RT volume is a primary variable responsible for hypertrophy. As with absolute volume few studies report relative volume (kg lifted · body mass kg $^{-1}$). The current investigation reports relative training volume at week 1 of 1,616.30 to week 4 of 2,033.15. The high relative volumes reported for the

current investigation mirror absolute volume that appear to be among the highest reported in published research.
Strengths of this study consists of the sample size of 22 trained men with a training age of 9.40 ± 6.18 years, pre-intervention lean mass of 62.86 ± 7.08 kg, and 1-RM chest press of 129.69 kg demonstrating the advanced status of these participants. A priori sample size estimation with a power calculation of 0.80, effect size (d = 0.55), and repeated measure design required a sample size of 7, exceeded in this study (13). These characteristics support the use of this intervention on an array of trained men. Participant attrition was four that implies the intervention was pragmatic. Participants enjoyed the brevity of the routine with daily exercise time ~35 min.

There is evidence to support the theory of early changes to skeletal muscle in response to RT (10, 19, 26). However, few studies have investigated systemic early adaptations in lean tissue mass at timelines of less than three weeks. This investigation discovered significant early improvements in lean tissue mass and chest press 1-RM following two weeks of RT. This investigation also demonstrates the efficiency of a total body RT program to improve outcomes at an early timeline with weekly exercise time ~3.5 hr per week.

Resistance training studies present many limitations and this investigation is no exception. Dietary control was a limitation here. Participants were asked to not consume performance enhancing supplements during the intervention. Participants were likely not consuming adequate nutrition to optimize outcomes. Nutrition was provided in Ribeiro et al. (21) set at 66 kcal · kg $^{-1}$ · day $^{-1}$, dietary protein 1.8 g · kg $^{-1}$ · day $^{-1}$, and the remaining calories allocated as 76% carbohydrates and 13% dietary fats. Fat free mass changes in Ribeiro et al. was 4.2% in the group that exercised four times per week and 3.5% in the six time per week group. The current investigation resulted in lean mass improvements pre to post of 3.84% similar to the mean value of the pooled fat free mass changes in Ribeiro et al. of ~3.85%. Future research should investigate outcomes from a high volume/frequency RT program with dietary control considering Ribeiro et al. or Tarnopolsky (28) suggestions of 6-8 grams carbohydrates · kg $^{-1}$ · day $^{-1}$ and protein intake 1.5 grams · kg $^{-1}$ · day $^{-1}$.

Future research may also consider assessing outcomes at timelines of six or more weeks. The first two weeks resulted in similar changes in lean mass (2.03%) vs. the final two weeks (1.78%) and strength improvements for bench press 1-RM were similar pre to mid and mid to post (4.94% vs. 4.45 %). Leg press improvements were greater from mid to post compared to pre to mid (9.82% vs. 6.09%). It is unknown if adaptations would continue linearly or if there would be a lessening of an effect over time. Figure 2 illustrates percent improvements for lean mass, chest press, and leg press 1-RM.

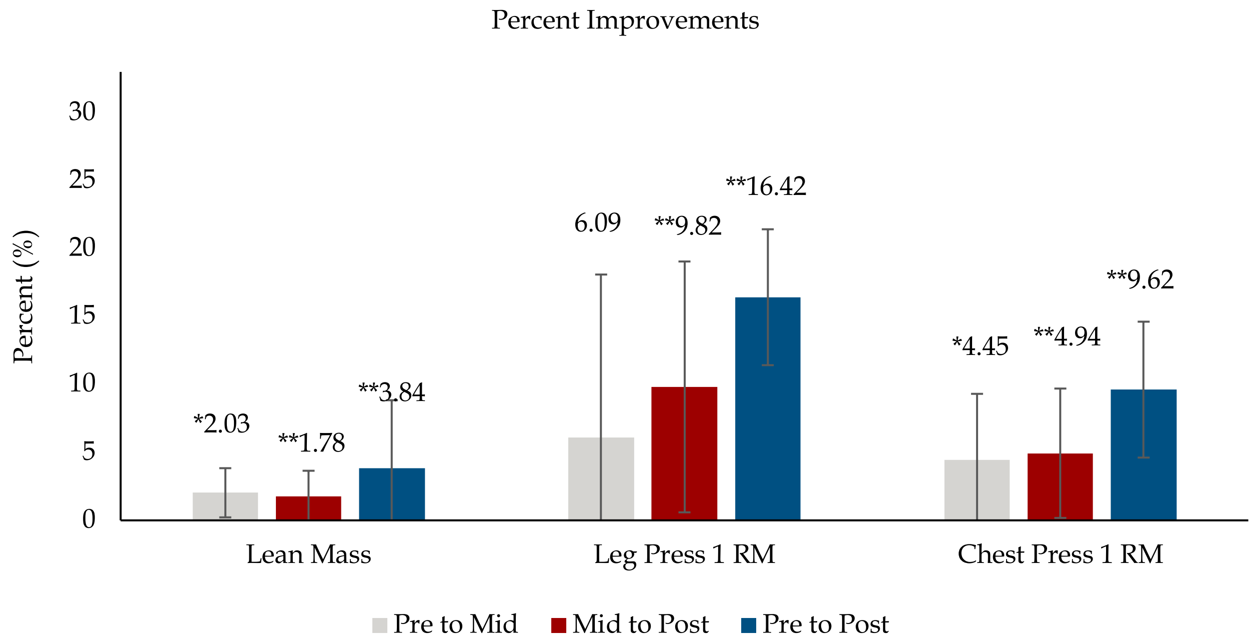

Figure 2. Mean percent improvements and standard deviation for dependent variables. *Significant from pre to mid ($p < .05$). **Significant from mid to post and pre to post ($p < .05$).

Future research could assess lean mass changes at an earlier timeline from a similar high volume/frequency program. There is evidence that muscular adaptations occur earlier than the two weeks assessed here. Fujita et al. (14) discovered that 6 days of twice daily blood flow restricted RT resulted in early quadriceps CSA improvements. Researchers could examine early adaptations from set totals of 30 or more per week per muscle group with sets spread over 6 sessions vs. 30 sets over 10 sessions. Increasing exercise frequency may result in higher training volumes, management of fatigue, and better outcomes. Greater RT volume should be considered in future work, perhaps 40 or more sets per muscle group per week. Adaptations of higher volume RT in untrained participants is unknown demonstrating the need for more research. Applying high volume RT to untrained participants should consider a periodized program with escalating RT volume.

The purpose of this investigation was to assess early timeline adaptations of lean tissue mass and strength in trained men. The novel aspect of this study was the focus on early adaptations from this high volume/frequency RT intervention. These results demonstrate significant early changes in lean mass and strength in trained men. These outcomes may benefit a variety of populations but perhaps the population most interested are coaches, athletes, and fitness professionals that seek to implement evidence-based exercise programming. Trained men adapted quickly with lean tissue mass and chest press 1-RM improvements that were significant following two weeks of RT and leg press 1-RM improvement was significant at four weeks. These results demonstrate the adaptation potential of the human body and skeletal muscle to high volume RT.

Adaptation is specific to the stress placed on the individual known as the theory of specificity (2). These results support this theory presenting significant early improvements in lean mass and strength in trained men. Weekly training volume exceeded the pre-training volume of participants to stimulate adaptations with pre-training volume being 20,133.83 ± 14,721.11 kg compared to week 1 volume that was 129,117.09 ± 56,793.20 kg. From pre-training to week 1 there was a greater than six-fold increase in training volume and volume increased significantly within the intervention. These training volumes effectively stimulated an adaptive response that resulted in specific early improvements in outcomes.

This intervention may be considered as part of a periodized plan for athletes or general populations seeking rapid improvements in outcomes. Periodization is based on designing phases of training integrated into a long-term plan to meet the specific goals of the individual (2). A theoretical training model may include a two to four-week phase of lower volume training. This lower volume phase may include three total body RT sessions per week, 3 to 4 sets per exercise, at a load of 60% - 75% of 1-RM. Following this lower volume phase one could implement two to four weeks of the current high-volume RT program. Following this higher volume phase, a reduction of both volume and frequency may be suggested for a period of four to 12 weeks. In this manner the current intervention may be repeated two to four times per year. Improving health and performance is a goal of fitness professionals and coaches. These results provide insight that high volume/frequency resistance exercise results in significant early improvements in outcomes.

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