THE BEST OF MASS

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MASS

MONTHLY APPLICATIONS IN STRENGTH SPORT

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The Reviewers

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Eric Helms is a coach, athlete, author, and educator. He is a coach for drug-free strength and physique competitors at all levels as a part of team 3D Muscle Journey. Eric regularly publishes peer-reviewed articles in exercise science and nutrition journals on physique and strength sport, in addition to writing for commercial fitness publications. He's taught undergraduate- and graduate-level nutrition and exercise science and speaks internationally at academic and commercial conferences. He has a B.S. in fitness and wellness, an M.S. in exercise science, a second Master's in sports nutrition, a Ph.D. in strength and conditioning, and is a research fellow for the Sports Performance Research Institute New Zealand at Auckland University of Technology. Eric earned pro status as a natural bodybuilder with the PNBA in 2011 and competes in the IPF at international-level events as an unequipped powerlifter.

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Letter from the Reviewers

Welcome to the 2017-2018 "Best Of" issue of MASS! Whether this is the first time you're getting a peek inside our research review or you've been subscribed since day 1, we think you'll love what you find in this special edition of MASS.

Since we launched MASS in April 2017, we've published 123 articles and videos, 1,154 pages of content, 60 audio roundtable episodes, 356 illustrative graphics, and 23 hours of video. We offer CEUs for two top organizations: NSCA and NASM. As of April 2018, we have more than 2,400 active subscribers. (Not a subscriber yet? Join here.)

And we're just getting started.

What you'll find in these pages is a glimpse at some of our favorite content from the first year of MASS, but you can be confident that *every* issue is packed with rigorously examined and visually stunning reviews of the research that's most relevant to strength and physique athletes, coaches, and enthusiasts.

If you (or your clients) want to build muscle, get stronger, and/or drop fat as efficiently and effectively as possible, MASS is for you. We know you want to stay on top of the research, but doing so can be time-consuming, expensive, and confusing. That's why we do all the heavy lifting for you and distill the most important findings into an easy-to-read monthly digest.

This free issue should give you an idea of what you can expect from MASS. In our written pieces, we cover the effectiveness of high-volume training for powerlifting, central fatigue of the deadlift, body fat spot reduction, the effects of pre-workout stretching on muscle growth, within-lifter velocity, diet breaks, and mental training. In our unique video content, Mike covers assistance work periodization and loading options, and Eric covers the real-world effects of low-carb, high-fat diets.

Each issue will tackle new questions, keeping you up to date with the current research, and giving you a thorough understanding of the best science-based practices. We hope you enjoy it, and we hope you'll subscribe so you can stay on the cutting edge of our field to get the best results possible for yourself or your clients.

Thanks so much for reading.

The MASS Team

Eric, Greg, and Mike

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Study Reviewed: Effect of Weekly Set Volume on Strength Gain: A Meta-Analysis. Ralston et al (2017)

How Much Does Training Volume Affect the Rate of Strength Gains?

BY GREG NUCKOLS

We know that training volume strongly influences hypertrophy, but low volume training is still quite popular when training for strength. Should powerlifters also jump on the high volume bandwagon?

KEY POINTS

1. The results of this meta-analysis (a quantitative overview of multiple studies) indicate that performing five or more sets per exercise per week was associated with larger strength gains than performing fewer than five sets per exercise per week.
2. While overall strength gains, strength gains in multi-joint exercises, and strength gains in single-joint exercises were significantly larger with higher training volumes, the effect sizes were "trivial" to "small" (0.14-0.23). Training volume doesn't seem to have the same relative impact on strength that it has on hypertrophy, but the absolute impact is actually similar.
3. This meta-analysis indicates that you can make strength gains with a variety of training volumes, but progress tends to be ~20-25% faster with higher volumes.

This is apparently meta-analysis season, which, incidentally, is my new favorite season. The recently reviewed meta-analysis about periodization, a meta-analysis on protein intake (2), and the study being reviewed in this article – a meta-analysis looking at the effects of training volume on strength gains – were all published within a few months of each other, and are all very relevant to MASS readers.

This isn't the first meta-analysis examining the effects of training volume on strength gains, but it does have the strictest inclusion criteria and most rigorous statistics of any meta-analysis on the topic. Also, since it's the most recent, it includes studies that weren't yet published when the last meta-analytic study of this topic – Kreiger's 2009 meta-regression (3) – came out. With eight more years of research in the books, this was a topic due for an updated meta-analysis.

This meta-analysis found that higher weekly set volumes (five or more sets per exercise per week) produced larger strength gains than lower weekly set volumes (fewer than five sets per exercise per week) in trained and untrained lifters. The difference in rate of strength gains was surprisingly (and perhaps deceptively) small, with effect sizes in the "trivial" and "small" range. From this meta-analysis, we can see that higher training volumes are required to maximize strength gains but that novice and intermediate lifters can still make good progress with training volumes that are quite low.

Purpose and Research Questions

The main purpose of this meta-analysis was to determine whether there's

Table 1 Inclusion Criteria

The training program used in the study needed to last at least 4 weeks
The training program needed to focus on at least one major muscle group (i.e. they excluded studies that may have looked at gains in finger muscle strength)
The subjects in the study needed to be adult males, aged 18-60 years old.
The study needed to compare single versus multiple sets of each exercise on a per-session basis
The subjects needed to be free from musculoskeletal injuries or physical limitations (i.e. they excluded rehab studies)
Strength needed to be measured with 1 rep max tests
The study needed to report descriptive characteristics of the subjects
The study needed to report enough data to determine the weekly volume and load of the exercises studied, and to calculate effect sizes for strength gains.

a dose-response relationship between training volume (measured in number of sets per week) and strength gains. Secondary purposes included determining whether the dose-response relationship was different for single-joint and multi-joint movements, and whether training age affected the dose-response relationship.

The authors hypothesized that there would be a dose-response relationship, with higher training volumes leading to larger strength gains than lower training volumes. They didn't offer hypotheses regarding the effects of training age or single-joint versus multi-joint exercises on the dose-response relationship.

Subjects and Methods

The studies included in this meta-analysis needed to meet eight criteria that can be seen in Table 1.

These were quite strict inclusion criteria, so even though the nine studies that made the cut included five studies that weren't yet published when Kreiger's meta-regression came out, Kreiger's meta-regression actually had more studies (14) included.

The authors didn't explicitly follow the PRISMA guidelines (considered the gold standard) for conducting and reporting meta-analyses, but the actual meta-analytic procedures themselves were thorough and appropriate, including some of the more important tests that are occasionally overlooked (i.e. heterogeneity, bias assessment, and screening for outliers).

The effects were grouped based on the number of sets per week the participants performed. Low weekly sets (LWS) was defined as ≤5 sets per week for the exercise being tested, medium weekly sets (MWS) was defined at 5-9 sets per week, and high weekly sets (HWS) was defined as ≥10 sets per week. For most of the analyses, MWS and HWS were combined, and there were no comparisons of MWS versus HWS. The reason is simple: All of the studies had at least one LWS group, but many of them had just one MWS or HWS group, so there were enough data for a robust comparison between <5 sets per week and ≥5 sets per week, but not enough to split out 5-9 sets per week and ≥10 sets per week for separate analyses. From here on out in this article, LWS will refer to <5 sets per week, and HWS will refer to ≥5 sets per week.

THIS META-ANALYSIS SUPPORTS THE CONVENTIONAL VIEW THAT TRAINING VOLUME SIGNIFICANTLY INFLUENCES STRENGTH GAINS.

Findings

Of the nine studies included in the meta-analysis, four used trained participants and five used untrained participants. The mean age of the subjects was 23.4±2.2 years old. Training periods of the studies included ranges from 8-26 weeks with a mean training frequency of 2.8±0.3 sessions per week, a mean intensity of 78.2±4.1% of 1RM, and weekly volumes ranging from 1-12 sets.

Two measures (elbow extension and shoulder flexion) from one study (4) were identified as outliers and were not included in further analysis. There was no evidence of publication bias – evidence that significant results were getting published more often than null results (p = 0.393 in Egger's test). Heterogeneity of effects was moderate in the main analysis with single-joint and multi-joint exercises, and trained and untrained participants all included (I2 = 45%) and tended to be larger in the

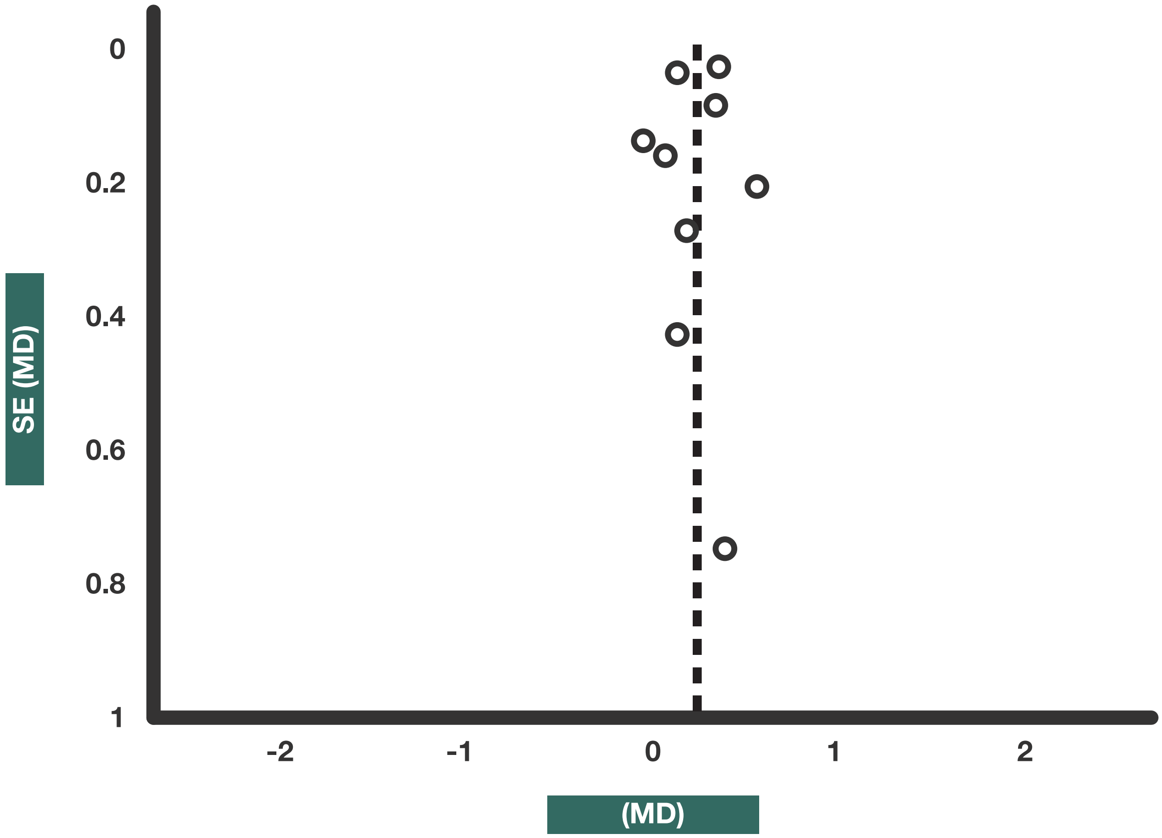
Look up this test

I2 look up score

review what standard error means

Figure 1

Funnel plot of standard error (SE) by mean difference (MD) for assessment of publication bias



Each open circle denotes a study included in the meta-analysis. The dashed vertical line represents the overall effect calculated with the random-effects model.

Since the differences in each individual study cluster around the mean difference and are evenly distributed on both sides of the mean difference, there's little evidence of publication bias.

review effect size

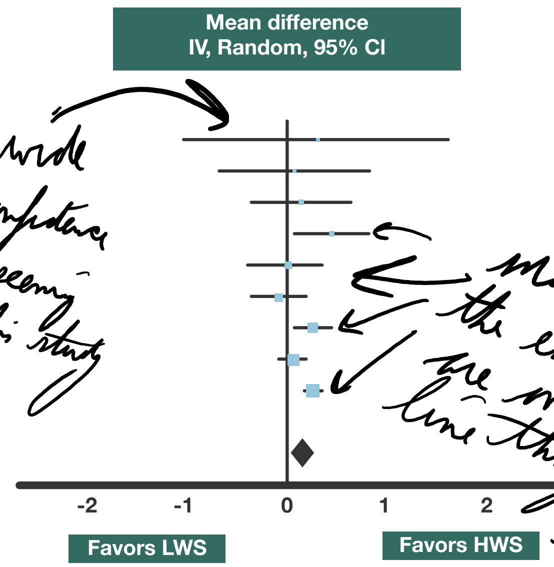
sub-analyses.

Overall, HWS led to significantly ($p = 0.003$) larger strength gains than LWS (ES = 1.01 and 0.82, respectively) This was considered a trivial effect (ES = 0.18±0.06). Sub analyses revealed very similar results. Comparing LWS to HWS, the ES for multi-joint exercises was 0.18±0.085 ($p=0.04$), the ES for single-joint exercises was 0.23±0.085 ($p=0.008$), and the ES for exercise-specific 1RM was 0.14±0.075 ($p=0.06$). All of these effects were classified as either trivial or small but were all significant ($p<0.05$), except for exercise-specific 1RM, which was nearly significantly ($p=0.06$). The authors didn't report ESs for studies using trained versus untrained subjects.

Figure 2
Forest plot of LWS vs. HWS (MWS and HWS combined) on multi-joint and isolation exercise by study

Day 1	Day 2
Sooneste et al [25]	0.34 [-1.14, 1.82]
Mashall et al [20]	0.09 [-0.77, 0.95]
Paulsen et al [19]	0.15 [-0.42, 0.72]
Rhea et al [13]	0.51 [0.07, 0.95]
Reid [24]	0.02 [-0.33, 0.37]
Baker et al [21]	-0.10 [-0.41, 0.21]
Bottaro et al [23]	0.29 [0.08, 0.50]
Ostrowski et al [18]	0.09 [-0.03, 0.21]
Radaelli et al [22]	0.30 [0.20, 0.40]
Total (95% CI)	**0.18 [0.06, 0.30]**

very wide confidence interval, seems to make this study a wash



Most of the estimates are over the line though

but differences don't seem large

review tau score

Heterogeneity. Tau^2 = 0.01; Chi^2 = 14.63, df = 8 (P = 0.07); I^2 = 45%
Test for overall effect: Z = 3.02 (P = 0.003)

*The **vertical line** indicates the overall estimate of combined multi-joint and isolation studies mean effect size. The **horizontal line** indicates 95% CI, **squares** indicate estimates, whereas **square size** is proportional to sample size, and rhombus indicates meta-analytically pooled estimates 95% CI. **95% CI** 95% confidence interval, **HWS** high weekly sets per exercise (≥10), IV inverse variance, **LWS** low weekly sets per exercise (≤5), **MWS** medium weekly sets per exercise (5-9)*

decent explanation here

Interpretation

This meta-analysis supports the conventional view that training volume significantly influences strength gains. However, the advantage of higher-volume training may not be as large as many people expect, at least in the short-to-medium term.

Before going any further, I need to explain a couple of things about effect sizes. An effect size helps tell you how large an effect is, as the name implies. You can calculate effect sizes in various ways, but what they all boil down to is a change or a difference divided by a measure of variability (generally a standard deviation). For example, if a training intervention is associated with an effect size of 0.5, that tells you that it makes people half a standard deviation better. In non-nerd speak, that means if someone was perfectly average before and better than 50% of people, after this training intervention, you could expect them to be better than ~70% of people. This website provides an interactive tool to help you visualize these differences and better understand effect sizes.

Come back to this

The classification system of "trivial," "small," "medium," and "large" effects helps to contextualize how important an effect is, and it generally does a pretty good job. If there's an effect size of 0.1 comparing two interventions, that means the "better" intervention only gave people an edge of 1/10 of a standard deviation, which is generally a truly "trivial" difference. On the other hand, an effect size of 1.0 would mean that the better invention boosted people by an entire standard more than the inferior intervention, which is generally a truly "large" difference.

However, you can't always put your faith in these classifications. For example, let's say you have a population of high-level sprinters who run a 100m sprint in 10.5±0.6 seconds. If you find an intervention that reliably decreases sprint time by 0.1 seconds, that would have an effect size of 0.17 (0.1/0.6). That's a "trivial" effect, but shaving a tenth off of a 100m sprint when you're already that fast is huge. On the other hand, sometimes a sample randomly has a very small standard deviation, so even a tiny, unimportant change could produce a large effect size.

Major key, worthwhile to consider absolute gains

In this meta-analysis, the difference between low volume and higher volume for strength gains may have been small or trivial by traditional effect size classifications, but the difference is still very practically meaningful. In a statistical model that pools effect sizes, the effect sizes are proportional to the actual observed change. In this case, the effect sizes for higher weekly volumes were

IN THIS META-ANALYSIS, THE DIFFERENCE BETWEEN LOW VOLUME AND HIGHER VOLUME FOR STRENGTH GAINS MAY HAVE BEEN SMALL OR TRIVIAL BY TRADITIONAL EFFECT SIZE CLASSIFICATIONS, BUT THE DIFFERENCE IS STILL VERY PRACTICALLY MEANINGFUL.

~20-25% larger than the effect sizes for lower weekly volumes, which means 20-25% faster strength gains. The traditional classification system may call that a "small" or "trivial" effect, but making progress 20-25% faster is pretty huge if you ask me, especially for competitive lifters.

what does "faster" mean here

I think it's helpful to compare the results of this meta-analysis to the results of the recent Schoenfeld et al (5) meta-analysis on the effects of volume on hypertrophy. When looking at all of the studies included in the analysis, 10+ sets per week was associated with an effect size of 0.52, while <5 sets per week was associated with an effect size of 0.31, for a difference of 0.21. After removing a

check out this study

noting that the effect sizes are between the treatment group & the control group

APPLICATION AND TAKEAWAYS

1. While a meta-analysis can never fill in all of the fine details, this does provide very strong evidence that higher training volumes are beneficial and necessary to maximize rates of strength gains.
2. It's still absolutely possible for most people to make strength gains with relatively low training volumes, at least in the short term, so you don't absolutely need to handle high training volumes all the time. This is invaluable knowledge for times when life gets crazy and for non-competitive lifters.
3. It's likely that higher training volumes become increasingly important as training status increases, since hypertrophy tends to play a progressively larger role in strength development as training age increases.

highly influential outlier (6), the difference was reduced to 0.40 versus 0.30, for a difference of 0.10. In other words, the absolute advantage of higher volumes for strength gains is similar to, if not larger than, the absolute advantage of higher volumes for hypertrophy. However, the relative advantage for hypertrophy is larger; higher volumes were associated with 33-60% larger effects. This disconnect between relative and absolute differences is due to the fact that all of the effects for hypertrophy were smaller (0.52 for 10+ sets per week with the outlier study included) than any of the effects for strength gains (0.8+ for <5 sets per week) in these metas. Basically, with low training volume, you'll gain quite a bit of strength (at least in the short term) but not much muscle mass. If you add training volume, both strength gains and rate of hypertrophy will increase to roughly the same absolute degree, but it may be the difference between good versus great strength progress, and minimal versus solid rates of hypertrophy.

I also think it's important to note that about half of the studies included in this meta-analysis were performed on untrained subjects. Early in the training process, neural adaptations explain the majority of the strength gains that occur, with hypertrophy playing an increasing role as training status increases (7, 8, 9). As such, I wouldn't anticipate that the absolute advantage of higher volumes would change much with increasing training age, but I'd expect the relative advantage to increase to more closely resemble the relationship between training volume and hypertrophy.

Furthermore, while this meta-analysis demonstrates that higher training volumes are superior for strength gains, it also shows that it's possible to make solid progress with lower training volumes as well. If your schedule curtails your ability to train as much as you'd like to, you can still probably make some strength gains (at least for a while) with lower training volumes.

Finally, I think it's important to keep the limitations of this meta-analysis in mind, along with the limitations of meta-analyses in general. The highest set grouping in this meta-analysis was 10+ sets. There are plenty of successful programs and coaches that prescribe more than 10 sets per week for each exercise (bench press and squat especially), but the scientific data don't adequately address higher levels of volume yet. We know that excessive volume can actually decrease rates of strength gains, but this meta-analysis can't tell us where that "tipping point" lies. Furthermore, training volume depends on individual responsiveness, capacity to recover from training, proclivity to resist injury, training age, and so much more – so any meta-analysis should be taken as a rough start point rather than a specific recommendation.

Next Steps

The past ~5 years have seen meta-analyses published on almost every facet of training that strength and hypertrophy nerds care about. What we really need now are more studies that move beyond group averages and that are designed to investigate ways to customize training programs to maximize results on an individual level.

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9. I promise I'm not trying to use MASS to shill my website, but I have an article that addresses this exact topic very thoroughly.

Study Reviewed: Acute Neuromuscular and Endocrine Responses to Two Different Compound Exercises: Squat Versus Deadlift. Barnes et al. (2017)

High-Intensity Deadlifts Do Not Cause Greater Central Fatigue Than High-Intensity Squats

BY MICHAEL C ZOURDOS

Does the deadlift really cause more "central fatigue" than the squat? And what does central fatigue even mean? This article tackles the often-asked, but rarely answered, questions.

KEY POINTS

1. High-intensity squats and deadlifts both cause significant central, peripheral, and neuromuscular fatigue; however, there is little difference in the amount of fatigue between exercises.
2. This study utilized well-trained lifters with a squat max of around 160kg and a deadlift max of around 190kg, which is a high training status for the available scientific literature.
3. This study provides excellent insight into the acute fatigue caused by high intensity squatting and deadlifting; however, we do not know if the same results would be found for high-volume hypertrophy-type training.

In general, I think it's safe to say that lifters deadlift with a lower frequency than they squat. This is usually the case because people believe the deadlift is inherently more fatiguing. It is often assumed that the deadlift causes greater "central fatigue" and neuromuscular fatigue, requiring longer recovery times and lower deadlift frequencies. While fatigue in this way has never been compared between the squat and deadlift, data have indicated similar increases in squat and deadlift one-repetition maximum (1RM) in the same study when squat was trained three times per week, while the deadlift was only trained once per week. Therefore, this study had trained lifters perform 8 sets of 2 reps at 95% of 1RM on the squat and deadlift in a crossover design. Maximal voluntary isometric contraction (MVIC) of the knee extensors, central fatigue and peripheral fatigue (voluntary activation-VA, surface electromyography-EMG, and control stimulus force), and salivary testosterone and cortisol (endocrine responses) were assessed at pre-training, 5 minutes post-training, and 30 minutes post-training. Most importantly, there were no significant differences between groups for any measure at any time point. Specifically, MVIC and VA decreased from pre- to post-training, but there were no group differences ($p>0.05$). Peripheral fatigue (control stimulus force) actually decreased from pre- to post-training in the squat, but not in the deadlift; however, again, there was not actually a significant difference between groups. There was decreased EMG activity five minutes after deadlift training with no change after the squat; however, the decline in EMG after deadlift was not significantly different than EMG activity post-squat training. There was no change in either condition at any time point for either endocrine marker ($p>0.05$). These results suggest that the acute central, peripheral, and neuromuscular fatigue of squat and deadlift train-

Table 1 Subject Characteristics

Number of Subjects	Age (years)	Height (cm)	Body Mass (kg)	Training Age	Squat 1RM (kg)	Deadlift 1RM (kg)
10	24.0 ± 3.6	176 ± 5.7	96.5 ± 22.2	At Least 2 Years	158.2 ± 23.4	191.5 ± 31.4

Data are Mean ± SD

Subjects characteristics from Barnes et al. 2017

ing are similar. However, it is essential to point out that this study did not analyze the time course of muscle damage and fatigue throughout a week. Thus, more data are needed to make definitive statements regarding the time course of recovery from squats and deadlifts.

Purpose and Research Questions

Purpose

The purpose of this study was to determine if there was a difference in the acute fatigue and endocrine responses to high-intensity training between squat and deadlift.

Research Question 1

Does acute central, peripheral, and neuromuscular fatigue differ between high-intensity squats and deadlifts?

Research Question 2

Is the acute endocrine response, as measured by salivary testosterone and cortisol, different between high-intensity squats and deadlifts?

Hypotheses

The authors hypothesized that significant fatigue would occur and that testosterone and cortisol would increase following both the squat and deadlift. Further, the authors hypothesized that the magnitude of both fatigue and the endocrine response would be greater after the deadlift session compared to the squat session.

Subjects and Methods

Subjects

There were 10 males in this study, all with a pretty solid training background. The specific descriptive statistics of the subjects can be seen in Table 1. All subjects had trained for at least two years and were training at least three times per week prior to the study. It was also explicitly stated that all subjects were used to squatting to

Table 2 Study Procedures

Day 1	Day 2	Day 3	Day 4
Familiarization and 1RM	Familiarization and 1RM	8 sets of 2 @95% on squat or dead-lift. All outcome measures tested pre-training, 5, and 30 minutes post-training	8 sets of 2 @95% on squat or dead-lift. All outcome measures tested pre-training, 5, and 30 minutes post-training

Note: There was an average of 2.7 days between days 1 and 2, and an average of 1.1 weeks between days 3 and 4.

depth. The subjects were not elite lifters by any means, but for the scientific literature, the training status of these subjects was relatively high.

Overall Study Procedures

The lifters completed this study over four days. The first two days were familiarization sessions and were used to test 1RMs – one day for the squat and one day for the deadlift. Then, a week later, subjects performed either squats or deadlifts for 8 sets of 2 reps at 95% of 1RM with five minutes of rest between sets. Then, one week after the first training session, the lifters repeated the training procedures, but for the other lift. All fatigue and endocrine measures (MVIC, VA, control stimulus force, EMG, and testosterone and cortisol) were tested during both training sessions at the following time points: 1) pre-training, 2) 5 minutes post-training, and 3) 30 minutes post-training.

Explanation of Outcome Measures

In this study, some of the outcome measures are unique to what we typically see in applied exercise science literature, so I'll briefly explain what these measures are and how they were obtained so we have a full understanding of terminology going forward. First, the more familiar measures: MVIC, EMG, testosterone and cortisol. A dynamometer was used for MVIC, which measured peak isometric force (strength). EMG (electrodes on the quadriceps) was determined as muscle activity during 200 milliseconds of peak MVIC. Testosterone and cortisol, in this case, were measured from saliva rather than from blood collection.

However, VA and control stimulus force were obtained in a unique way. For these measures, voltage was delivered via electrodes attached to the muscle. The muscle will then "pulse" or respond to the applied voltage. The voltage was applied at two points, first during a plateau in the MVIC and then five seconds after the conclusion of an MVIC test. The muscle's "response" at the time point five seconds post-MVIC was noted as the control stimulus force, which is an indirect measure of peripheral fatigue. The VA was measured as: (muscle response during MVIC plateau / control stimulus force) X 100, which was used as an indirect measure of central fatigue.

Dietary and Exercise Control and Log

Subjects did not exercise for 48 hours prior to each testing or training day in the study. Also, subjects were asked to not eat any food or take any stimulants for two hours before the start of each session. Subjects were allowed to train during the week between the squat and deadlift training sessions, but there was no control of this training.

Findings

MVIC and EMG

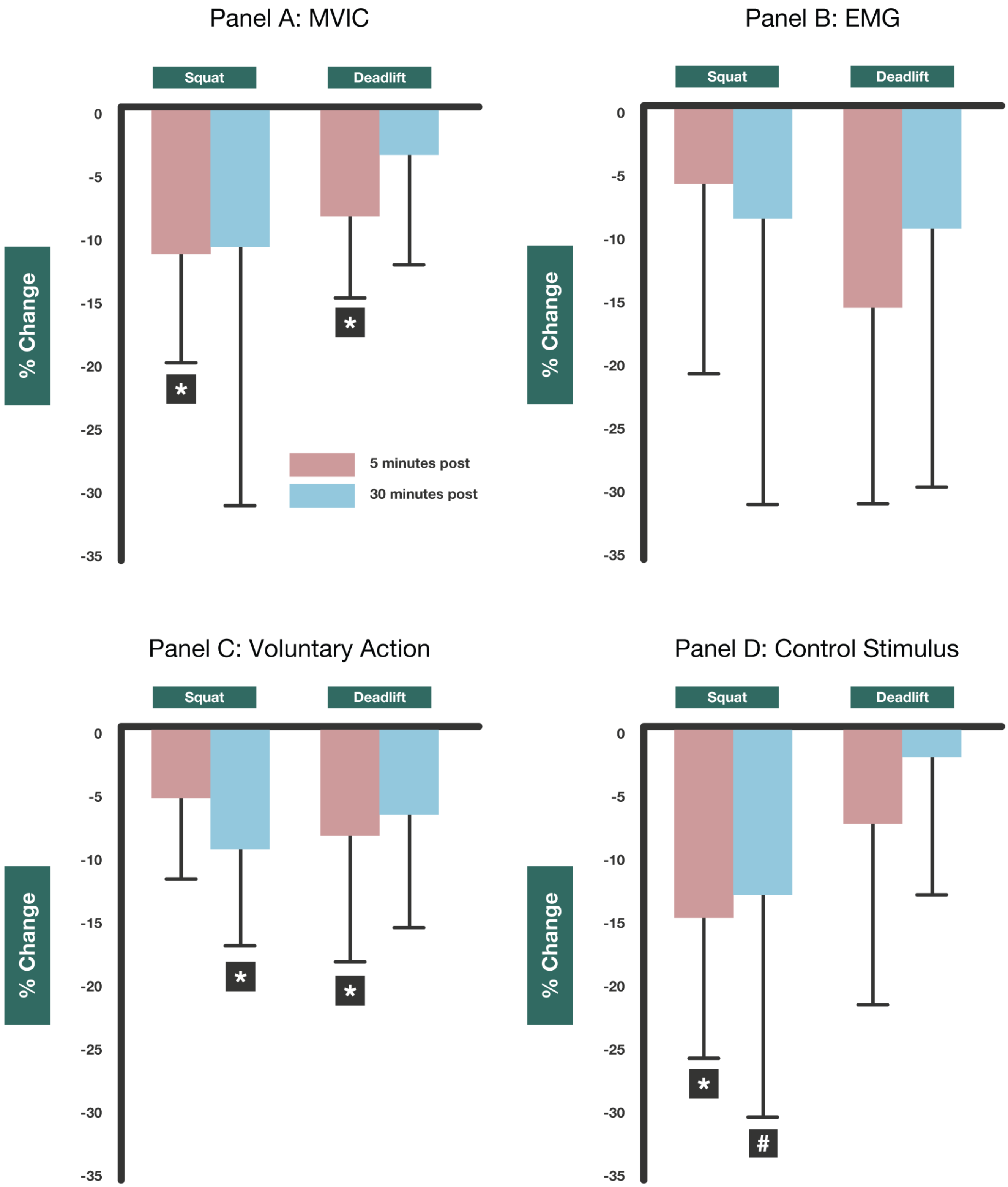
There was a significant decrease in MVIC at 5 minutes post-training in both exercises and at 30 minutes post-training for the deadlift, but not the squat. However, there were no significant differences between conditions for MVIC at either time point. For EMG, there was no significant change for the squat at 5 or 30 minutes post-training, but there was a decrease in EMG at 5 minutes post-training in the deadlift condition. However, there were no differences between conditions ($p>0.05$) for the decline in EMG. In summary, fatigue, as measured by MVIC and EMG, was the same after squat and deadlift training. Figure 1A and 1B show bar graphs with percentage changes from pre- to post-training from MVIC and EMG.

Voluntary Action and Control Stimulus Force

There was a decrease in VA in both conditions from pre-training to both 5 and 30 minutes post-training ($p=0.0001$), but there was no difference between groups ($p=0.765$). For control stimulus force, mean values decreased for the squat, but not for the deadlift; however, there was not a difference between groups for the mean change ($p=0.109$). However, in terms of percentage decrease from pre- to post-training, there was a significantly greater decline in squat at both time points compared to the deadlift ($p=0.034$). Bar graphs depicting percentage changes for VA and control stimulus force can be seen in Figure 1C and 1D.

Figure 1

Percentage decreases in all measures at 5 and 30 minutes post-training



MVIC = Maximal Voluntary Isometric Contraction, EMG = Electromyography

*, Significantly less than pre-training; #, Significantly greater decrease than deadlift

Testosterone and Cortisol

There were no significant changes or differences between groups for testosterone and cortisol. In fact, the pre- to post-training within-condition effect sizes (ES) were small in all cases except for a moderate effect (ES=0.79) for a cortisol increase at five minutes after deadlift training; however, this was not a statistically significant change. In short, high-intensity squat and deadlift training did not elicit a significant endocrine response.

Interpretation

Overall, the findings are pretty straightforward in that the acute neuromuscular fatigue, indirect markers of central and peripheral fatigue, and anabolic and catabolic hormone responses were not significantly different between high-intensity squat and deadlift training. Unfortunately, the lack of significant difference between groups doesn't shed too much light on training implications. However, these findings are in conflict with the commonly held belief that deadlift training is more fatiguing than squat training. Nonetheless, this study did not measure the time course of fatigue and recovery throughout the week; thus, we still do not know if it takes longer over the course of a week to recover from deadlift training than squat training. Ultimately, let's answer the following questions to help us decipher a practical benefit from these findings:

- What actually is "central fatigue"?

THESE FINDINGS ARE IN CONFLICT WITH THE COMMONLY HELD BELIEF THAT DEADLIFT TRAINING IS MORE FATIGUING THAN SQUAT TRAINING.

- Can we extrapolate the acute findings to predict the time course of fatigue?
- What are the implications of the lack of endocrine response?
- And why is there a scarcity of long-term deadlift data in the scientific literature?

Central and Peripheral Fatigue with Training

How many times have you heard someone say "my central nervous system is fried" after a training session? Probably a few times. However, how many times have you heard someone provide an accurate description of what that means? Probably never. It's one of those things people say without being prepared for a follow-up question. Peripheral fatigue, on the other hand, is more simply defined as reduced ability of muscle fibers to produce force (2), which could be due to a variety of reasons: metabolic, hormonal, cardiovascular, and neurological (3). Peripheral fatigue is influenced in part by central fatigue, but central fatigue is influenced by cortical transmissions (within the cerebrum) or within the spinal cord, rather than being dependent on local muscular factors alone (2). In truth, defining central fatigue is a huge undertaking since almost all fatigue is encompassed under central fatigue, but a simple definition is the decrease in strength and frequency of neuronal impulses, resulting in diminished muscle activity and force production (3). However, the measures in this study which assessed force production and muscle activity do not directly assess central fatigue because these measures do not directly measure cortical transmissions or the magnitude of neurotransmitter release. Thus, a decrease in strength could be directly related to central fatigue, or it could be due to one of the other factors mentioned above related to peripheral fatigue. In the present study, when voltage was delivered to the muscles to determine VA (as discussed in the methods) and a subsequent force was evoked from the muscle (control stimulus force), this happened because the applied voltage stimulated the motor cortex in the brain, which activated cortical impulses (4). Therefore, testing the magnitude of those evoked cortical impulses in the target muscle, in this case the quadriceps, is an indirect test of central fatigue. So, if VA and control stimulus force decrease (which they did from pre- to post-training in this study), then that indirectly shows lower activation of cortical neurons, and thus decreased central (and peripheral) fatigue.

OK, that's a long explanation, but hopefully it allows you to explain this concept (at least in part) next time someone asks. In short, this study showed that indirect measures of central fatigue were similar after squatting and deadlift, thus the deadlift does not cause greater acute central fatigue than the squat. However, this study only measured fatigue following high-intensity training (i.e. 95% of 1RM), so we do not know if high-volume training would have differential effects on cortical activity between the squat and deadlift.

Implications of Acute Changes for Weekly Programming

With any study that looks at an acute response, the ultimate question is: "How can this actually help with long-term programming?" Well, I'm not sure this study provides a lot of answers in that respect. As stated previously, it's commonly noted that the deadlift is more fatiguing than the squat (although this study is in disagreement); thus, the deadlift should be trained with lower frequency than the squat. In fact, the limited data that exist on this topic are in support of this notion. Specifically, powerlifters in a recent study increased squat 1RM by 9.21% and deadlift 1RM by 7.14% over eight weeks despite training the squat three times per week and the deadlift once per week (5). The authors of the present study note that periodization and tapering practices do not need to be different for the squat and deadlift, and while I do not disagree with this statement, it is possible to have different training frequencies, yet still have the same periodization strategy. In other words, periodization stipulates long-term changes in training variables (5, 6), but weekly frequency or configuration is a programming strategy. Thus, just because long-term trends in volume and intensity are the same between squat and deadlift throughout a macrocycle, that doesn't mean that training frequency has to be the same between the lifts.

POWERLIFTERS IN A RECENT STUDY INCREASED SQUAT 1RM BY 9.21% AND DEADLIFT 1RM BY 7.14% OVER EIGHT WEEKS DESPITE TRAINING THE SQUAT THREE TIMES PER WEEK AND THE DEADLIFT ONCE PER WEEK.

It is also possible that many people have a lower deadlift frequency simply because that is what they have adapted to. When training frequency is increased, the lifter will adapt over time despite significant muscle damage from the initial training session (7, 8). Therefore, as frequency and volume are gradually increased, it is likely the lifter will adapt over time. Also, the statement from this study that periodization strategies do not need to be different for the squat and deadlift does not mean that the deadlift should be mostly removed from a program. To illustrate, Hales et al., (2009) performed a kinematic analysis of the squat and deadlift during an actual powerlifting meet and noted important kinematic differences, including the observation that the knee, hip, and ankle joints were at different angles during the sticking point for the squat and deadlift. Hales et al., also observed that barbell velocity was different during the sticking point between lifts (9). This led the authors to note that the "crossover" effect of the squat to the deadlift was a "misconception" and that "the best way to improve the deadlift is to deadlift." While I certainly agree with the second point (in fact, that's one of the best lines ever written in a scientific paper), I think it is a stretch to say that a crossover effect between the lifts doesn't exist. Since the current study demonstrated similar acute fatigue and similar EMG activity of the quadriceps, there is likely a crossover to some degree. However, a limitation of the current study is that the back musculature and hamstrings were not analyzed to fully uncover if similar fatigue exists in all muscle groups trained.

For example, while the deadlift does activate the quadriceps, it is not typically known as a quad-dominant exercise, but the squat is a quad-dominant exercise. So the present results actually demonstrate that fatigue of the quadriceps is similar between the two lifts; therefore, it is still possible that the totality of fatigue due to the deadlift is greater than the squat when considering all muscle groups.

Future studies should analyze the time course of fatigue and recovery to high-volume squat and deadlift training. When this study is carried out, we can make recommendations regarding the amount of time someone should rest before repeating a deadlift and if it differs from the squat.

Endocrine Response

A simple look at the protocol – 8 sets of 2 at 95% – makes the lack of testosterone and cortisol increase unsurprising. As we know from a MASS video in the May 2017 issue, acute hormone elevations occur as a result of high-volume training with short rest intervals (10, 11). In the present study, only two reps per set were performed, and there was five minutes of rest between sets; thus, the protocol doesn't coincide with the typical criteria that would cause a transient testosterone or cortisol increase. Also, while this was a valid measure – only one previous study (12) (to my knowledge) has analyzed the acute endocrine response to the deadlift – it may not be all that important in the grand scheme of things since we now know that the acute hormonal response is not a causative factor of hypertrophy (13, 14).

Research Limitations of the Deadlift

As previously mentioned, long-term research is quite limited on the deadlift. While the lack of deadlift research isn't necessarily too important for analyzing the present data at hand, it is important for understanding why we can't make very specific recommendations regarding the time course of recovery from the deadlift. There is actually a decent amount of literature on acute deadlift analysis, such as looking at conventional versus sumo technique (15, 16) and kinetic and kinematic analyses (9, 17), but little long-term data exists. As a researcher, I have been a part of seven "long-term" training studies, between three and eight weeks. However, I have only included the deadlift in two of these studies. Most studies do not use strength athletes; rather, studies typically use university students, who have substantial experience with the bench press, decent experience with the squat, and little-to-no experience with the deadlift. Therefore, including the deadlift in a long-term training study is often problematic for three reasons:

The injury risk to subjects is high because they are not trained on it; thus, technique is usually poor.

If included, strength increases would

APPLICATION AND TAKEAWAYS

1. The deadlift does not cause greater acute central and peripheral fatigue than the squat.
2. High-intensity and low-rep squat and deadlift training do not elicit a significant testosterone and cortisol response.
3. Overall, long-term training data on the deadlift is scarce, so it is difficult to recommend if training frequency should be lower on the deadlift versus the squat (as commonly advocated), despite similar fatigue in the present study. Overarching periodization strategies can likely be similar between the squat and deadlift, but weekly programming (i.e. frequency and total volume) may vary between the two lifts depending on individual biomechanical considerations and what the lifter is adapted to.

be extremely rapid. If the study is designed to compare two different training programs, it would be hard to see if one is actually better for the deadlift. This is because the subjects would improve the deadlift rapidly in response to any programming because it's a novel exercise.

The deadlift adds further time commitment for both the subjects and investigators.

Next Steps

As noted earlier, a logical follow-up is a crossover design with high-volume training that also looks at fatigue and muscle damage at 24, 48, 72, and 96 hours following training to compare the time course of recovery between squat and deadlift. The next step beyond that is to have a group of lifters do two consecutive weeks of high-volume deadlifting and measure fatigue throughout both weeks, and then do the same with squat. This study would demonstrate if the repeated bout effect (RBE) – the attenuation of muscle damage when a stimulus is repeated (6) – occurs to the same magnitude in the deadlift as it does with the squat. Therefore, if the RBE does occur to the same extent in the deadlift as in the squat, perhaps lifters simply need to deadlift with greater volume and frequency for a few weeks to adapt to it, rather than to abandon a high-frequency deadlift strategy after the first sign of fatigue. To counter the previous statement, it must also be noted that different individual biomechanical considerations (i.e. limb lengths) or previous injury may subject some lifters to greater fatigue and injury risk on certain exercises, which is a good reason to use lift variations and be cautious regarding volume and frequency. Therefore, individual biomechanics, training age, availability to train, and preference should be taken into account when dictating a training frequency.

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Study Reviewed: Effect of Combined Resistance and Endurance Exercise Training on Regional Fat Loss. Scotto di Palumbo et al. (2017)

Body Fat Spot Reduction Isn't a Myth?

BY ERIC HELMS

Just when you thought you wouldn't hear the term "spot reduction" mentioned again, a study comes out that seems to show it's possible. Dive in to see the details of how this investigation fits into the puzzle of fat loss.

KEY POINTS

1. This study stands in contrast to previous research showing that localized fat loss adjacent to trained muscle does not occur. No study stands on its own, especially those with small sample sizes. It's possible the unique findings in this study are due to statistical chance or measurement validity. However, it's also possible the unique feature of this study – aerobic training performed after resistance training – produced the localized fat loss.
2. For MASS readers, these results may be applicable for weight class-restricted athletes or physique competitors attempting to reach lower levels of body fat. As one gets leaner, lean mass losses increase, which may occur in part due to the difficulty in mobilizing "stubborn body fat" for fuel. Thus, performing aerobic training after resistance training for specific regions (gluteal, lower abdominal, hip, and quadriceps fat seem to be the culprits depending on sex and individual genetics in most people) may be a viable strategy to aid fat loss at lower body-fat levels.
3. However, caution is advised when implementing this strategy, as excessive aerobic exercise can interfere with recovery, performance, and muscular adaptations to resistance training. Cardio done in excess when calories and body fat are low may do more to harm your physique than help it.

For years, educated personal trainers have been telling well-intentioned exercisers to stop doing daily 100-rep sets of crunches and to put that time and energy into nutrition and aerobic training that burns calories more efficiently (and rightly so). There is a sizable body of literature showing "spot reduction" of fat mass (losing extra fat adjacent to the muscles being exercised) does not occur to any greater extent than would be achieved by a different form of exercise resulting in similar caloric expenditure (2, 3, 4, 5, 6, 7). However, this study stands in contrast to previous findings. Inactive women were split into two groups: one that performed upper body resistance training followed by lower body cycling (UPPER, n = 8), and a group that performed lower body resistance training followed by upper body cycling (LOWER, n = 8). Both groups performed the same number of exercises, sets, and repetitions at the same relative intensity with the same rest periods. They both performed aerobic training after strength training for 30 minutes at 50% VO_2max, three days per week for 12 weeks. Regardless of similar total fat mass losses, UPPER lost more fat mass in their upper limbs (-12.1 ± 3.4%) compared to their lower limbs (-4.0 ± 4.7%; p = 0.02). Conversely, LOWER lost more fat mass in their lower limbs (-11.5 ± 8.2%) compared to their upper limbs (-2.3 ± 7.0%; p

Table 1 Subject Characteristics

	Age (years)	Body Mass (kg)	Height (m)	BMI (kg/m²)	VO_2max (mL·kg·min⁻¹)
Upper (n=8)	32 ± 4	70.3 ± 7.0	1.63 ± 0.04	27.7 ± 2.3	26.4 ± 2.7
Lower (n=8)	30 ± 4	71.7 ± 8.7	1.64 ± 0.09	27.4 ± 1.9	26.1 ± 3.0

Subjects characteristics from Scotto di Palumbo et al. 2018 (1).

= 0.02). Likewise, LOWER gained more lean mass in the lower limbs (+8.4 ± 5.8%) compared to their upper limbs (-2.7 ± 5.0%, $p < 0.01$), yet no differences between upper and lower limb lean mass changes were detected in UPPER.

Purpose and Research Questions

Purpose

The purpose of the present study was to examine the effect of combined circuit-based resistance training followed by steady state endurance exercise, performed separately in different body regions (lower body resistance training combined with upper body cardio), on body composition, with specific regard to fat-mass distribution.

Hypothesis: The authors hypothesized that the combination of exercise types performed in different bodily regions would likely induce diverse effects on regional body composition.

Subjects and Methods

Subjects

There were 16 inactive females with BMIs between 23 and 30kg/m² and ages between 25 and 40 who completed this study. (Inactivity was defined as less than one hour per week of physical activity.) Specific subject characteristics are provided in Table 1.

Training Protocol

A 12-week, machine-based resistance training program was performed three days per week by both groups. Resis-

Table 2 Resistance Training Protocol

	Exercises	Rest Period	Tempo	Scheme
Upper (n=8)	Chest Press, Low Row, Arm Curl, Deltoids Machine, Triceps Machine	30s between sets	Maximal intended concentric velocity	3 x 10 x 60% 1RM Performed twice (6 total sets per exercise)
Lower (n=8)	Gluteus Machine, Seated Leg Curl, Abductor Machine, Leg Extension, Adductor Machine			

tance training began after a ten-minute warm-up. While it was stated that resistance training was performed in a circuit fashion, upon reading the full text, it was apparent that three successive sets were performed for each exercise, and then the entire process (which I suppose could be considered a circuit) was repeated. Thus, my best guess is that three sets were performed on the same exercise before moving to the next, then once all five exercises were completed, the entire process was repeated again. While no specific progression plan was stated, they did specifically state that each repetition was performed explosively at maximum intended concentric velocity, and the training sessions were supervised by an exercise specialist. Thus, even though the load, sets, and reps did not change, maximum effort was given on each repetition, which can be considered a form of progression (or at least intent to progress). The known details of the training utilized in the intervention period are provided in Table 2.

Following resistance training (it was not indicated how soon after completion, so I assume immediately after), the participants performed low-intensity, steady -state cardio at matched intensities. The UPPER group performed 30 minutes of arm cycling at 50% VO_2max, while the LOWER group performed lower body cycling at the same intensity and duration.

maybe typo; the UPPER did lower body cycling

Aerobic and Resistance Training Performance

One-repetition maximum testing (1RM) was performed for each exercise in both groups at the start and end of the training protocol. However, as this was not a variable of interest, 1RM strength comparisons were not made within group pre to post, or between groups; no pre or post test means or standard deviations were provided. Similarly, VO_2max was tested at the start of this study with an incremental exercise test, but was not retested, as the researchers were not interested in fitness outcomes.

Dietary and Activity Control

Participants were asked to maintain normal dietary and activity patterns. This was confirmed with four-day food logs and physical activity questionnaires administered at the start, mid-way point, and conclusion of the study. Participants who altered their nutrition or activity were excluded from analysis. Make you wonder how many they started with

Body Composition Analysis

Total body mass, fat mass, and lean mass of the upper limb, lower limb, and trunk were measured by dual-energy X-ray absorptiometry (DXA) scans at the start and finish of the study. Additionally, skinfold thickness was measured at the triceps and anterior thigh at the beginning and end of the investigation.

Findings

Dietary and Training Compliance

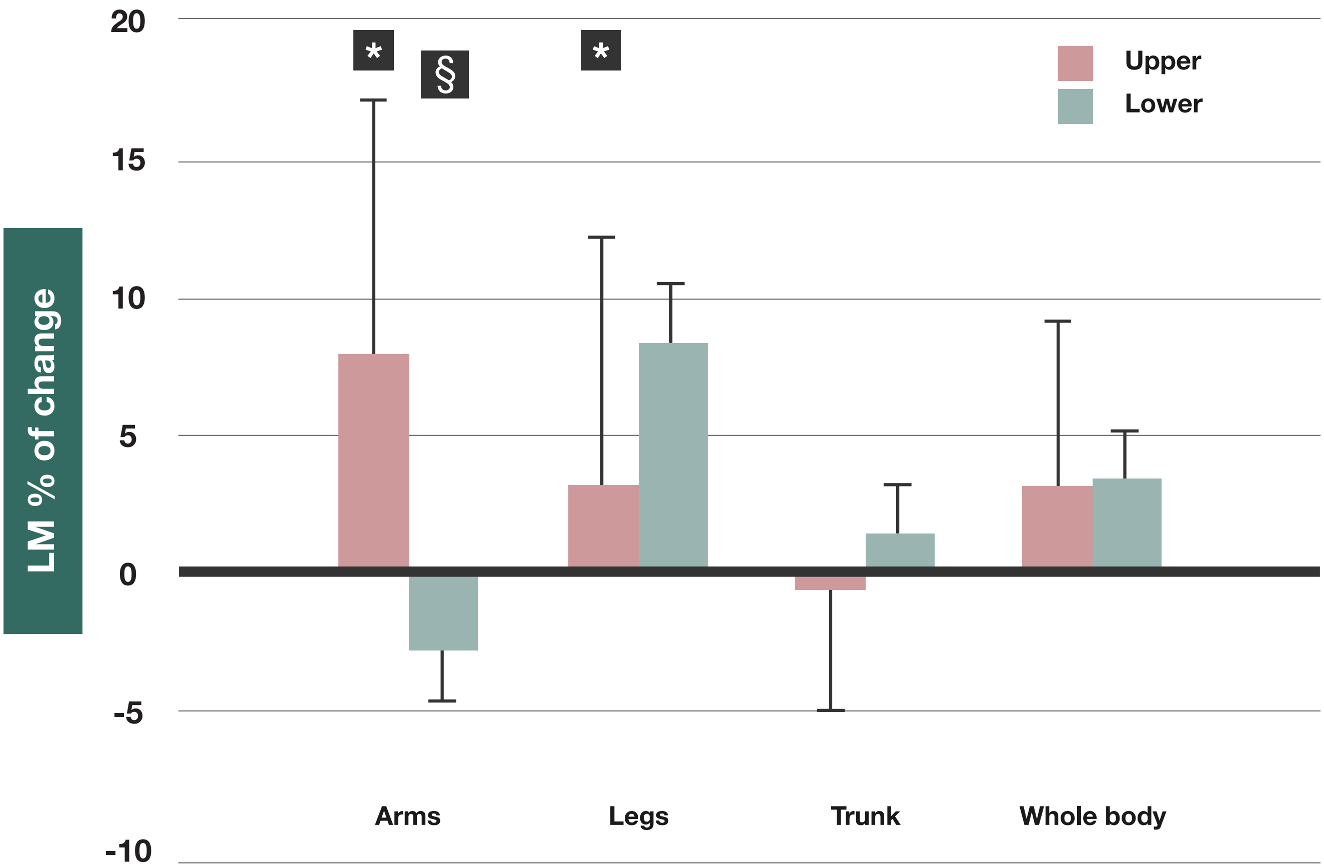
No significant nor meaningful changes occurred in the energy intake of either group from pre- to post-testing. Additionally, participants who did not complete at least 85% of all training sessions were excluded from analysis. Another exclusion filter

Body Composition

Neither group lost a significant amount of total body mass, largely due to variability between individuals; however, there was a moderate within-group effect size (ES) change in UPPER (ES=-0.68), but the between-group ES was trivial. Both UPPER ($p = 0.05$, ES=-0.32) and LOWER ($p = 0.04$, ES=-0.20) lost significant total fat mass without a significant or meaningful difference between groups ($p=0.75$, ES=0.15). Neither group gained significant total lean mass, but both groups had a small ES change in total lean mass and relatively low (but not significant) p-values.

However, both within- and between-group differences were found in lower and upper limb fat mass and lean mass. The only variable that was not statistically significant when comparing limbs was lean mass gain in UPPER group for the upper limbs. However, a moderate ES change did occur, and the change nearly reached significance ($p=0.06$, ES=0.54). Likewise, for skinfold thicknesses, there was a greater decrease in the anterior thigh skinfold thickness in the LOWER group compared to the UPPER group, and compared to their within-group change in triceps skinfold thickness. Similarly, the same outcome was observed for the triceps skinfold thickness reduction in the UPPER group compared to the LOWER group and their own anterior thigh skinfold thickness. A visual schematic of lean and fat mass changes within and between groups is shown in Figures 1 and 2.

Figure 1 Lean Mass Changes Between Groups



* indicates a significant between-group difference, and § indicates a significant within-group difference.

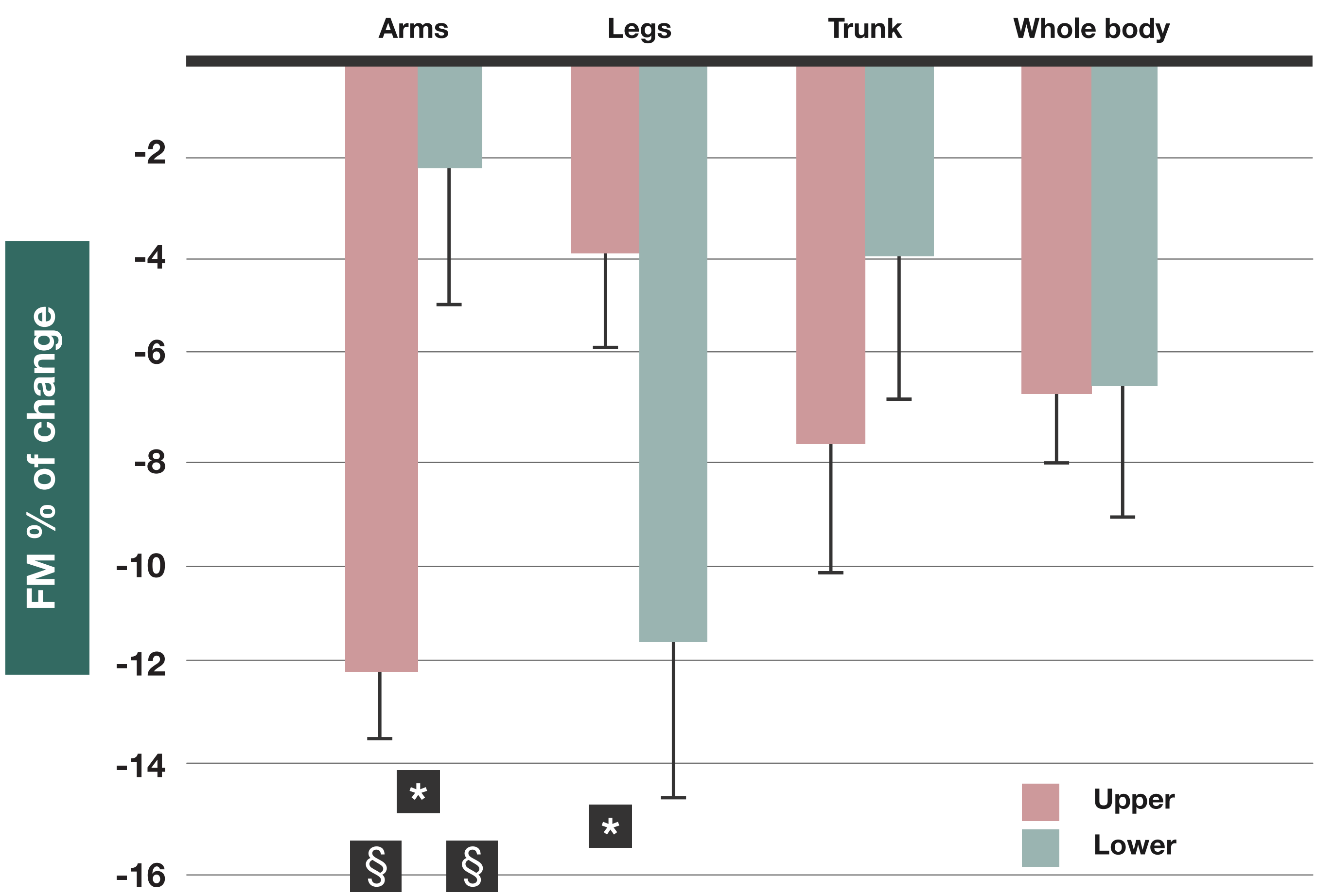
Interpretation

The primary finding of this study is that, in contrast to previous research, localized fat mass loss specific to the region of the body that was resistance-trained occurred, which was significant and meaningful when comparing regions within groups and between groups. This is actually quite surprising, as all the previous research I'm aware of on this topic is in opposition to this finding (2, 3, 4, 5, 6, 7). There are essentially two ways of looking at this outcome: 1) the findings are incorrect for some reason or, 2) the findings are correct, due to a unique aspect of the training protocol compared to prior research.

Let's explore both possibilities in depth.

First, it is certainly possible that the findings are due to chance. This is a study of a rather low sample size, and it's

Figure 2 Fat Mass Changes Between Groups



* indicates a significant between-group difference, and § indicates a significant within-group difference.

bound to happen that some findings are incorrect simply due to statistical odds. However, I highly doubt that is the case in this study, as the findings are so consistent with the hypothesis. It is not like the LOWER group lost more lower limb than upper limb fat while the UPPER group didn't lose more upper limb than lower limb fat (or vice versa). Rather, the outcome was very similar between and within groups, as you'd expect if the hypothesis was correct. Another possibility as to why these findings might be misleading is due to the way they were measured.

Believe it or not, site-specific reductions in skinfold thickness were observed in another 12-week resistance training protocol in the trained limb compared to the untrained limb (5). However, they also assessed fat mass changes in each limb with MRI, and found no significant difference in fat mass changes despite the decrease in subcutaneous tissue thickness. It is thought that this change in skinfold thickness may be due to geometrical factors secondary to hypertrophy of the underlying muscle (3); meaning, the muscle growth shifted the position of the subcutaneous fat at the skinfold site in such a way that it was lower when measured (but in actuality there was not a local reduction in fat mass, just position). Unlike MRI, where a cross-sectional image "slice" is analyzed by a researcher, DXA scans use equations to calculate body composition based on certain assumptions which are affected by changes in body segment thicknesses (8). Therefore, it's certainly a possibility that these findings are due to measurement validity issues.

The muscle just moved the fat around

However, taking this position with complete certainty is problematic, as two of the previous studies that found no spot reduction effect also used DXA to analyze changes in local fat mass (6, 7). For this reason, it would be inappropriate to dismiss the findings of this study purely based on the body composition analysis tool used. All of this means that we have to realistically entertain the possibility that spot reduction is possible and that it was achieved in this study due to its specific protocol. The only meaningful difference in this study compared to previous investigations was the combined use of resistance and aerobic exercise.

IN CONTRAST TO PREVIOUS RESEARCH, LOCALIZED FAT MASS LOSS SPECIFIC TO THE REGION OF THE BODY THAT WAS RESISTANCE-TRAINED OCCURRED, WHICH WAS SIGNIFICANT AND MEANINGFUL WHEN COMPARING REGIONS WITHIN GROUPS AND BETWEEN GROUPS.

Thus, we need to speculate as to how this could mechanistically make a difference. Most likely, the issue is blood flow. It has been hypothesized that fat mobilization is hampered to some degree when there is poor blood flow delivery to adipose tissue (9). Likewise, it has been demonstrated that exercising muscle increases blood flow to nearby adipose tissue (10). Thus, it is plausible that muscular work does indeed increase the mobilization of local adipose tissue stores to a greater degree than adipose tissue stores in other areas of the body. But, why haven't previous spot reduction studies resulted in the same outcome as

APPLICATION AND TAKEAWAYS

1. This is the only study to ever show that spot-reduction is possible; thus, its results should be interpreted with caution.
2. It is possible that performing steady-state cardio after resistance training could result in fat mass reduction proximal to the trained muscle due to enhanced blood flow, which could be useful for avoiding lean mass losses at the tail end of a diet when "stubborn fat" remains.

the present study? Well, just because fat is mobilized doesn't mean it's then oxidized and "burned off." After entering the bloodstream, if fat is not burned off, there is nothing to prevent it from being stored again. However, if one was to perform low-intensity aerobic exercise (which predominantly uses fat for fuel) after getting these "locally grown" free-fatty acids into the bloodstream, they would likely be used to fuel this activity. Therefore, it's possible that the key factor in realizing spot reduction in this study was the performance of cardio after training to burn off the fat that was mobilized.

Next Steps

First, let's be cautious before we confidently accept these findings as fact. This is one study, and it is a low sample size cohort with less-than-ideal measurement tools, so it is possible these findings are erroneous. But, as I said before, there is a distinct possibility they are not. That means we need to do two things before we start doing cardio after hip thrusts and leg raises on the daily. First, we need to replicate this study with a larger sample size of well-trained lifters who are reasonably lean (who might not have adipose tissue blood flow issues), using different methods (MRI would be a good choice). Then, if the results are replicated, we need a ton of applied research to assess how large the effect is in athletes looking to reach lower body composition levels (because honestly, spot reduction is not something you need to worry about when you have a lot of body fat everywhere). We would also need to assess whether spot-reduction is worth the potential downsides of performing a lot of steady state cardio (see the video series in this issue).

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Study Reviewed: Effect of the Flexibility Training Performed Immediately Before Resistance Training on Muscle Hypertrophy, Maximum Strength and Flexibility. Junior et al. (2017)

Does Stretching Before a Workout Decrease Muscle Growth?

BY GREG NUCKOLS

A lot of lifters still do traditional static stretching before they lift. Is that robbing them of some gains?

KEY POINTS

1. Static stretching directly before lifting may decrease rate of muscle growth, possibly due to a decrease in volume load.
2. However, static stretching before training may not compromise strength gains.
3. Adding static stretching to a strength training protocol increases gains in flexibility (duh).

Most lifters still perform static stretching before they lift, or, at least, they think they should stretch before they lift. However, there are plenty of studies showing that stretching can acutely decrease power output (though the magnitude of the decrease is often exaggerated [2]). Furthermore, a couple of studies show that stretching can decrease the number of reps you can do with a given load, at least when you lift immediately after stretching (3, 4). Since hypertrophy and strength gains are strongly influenced by training volume (5, 6, 7), we may assume that stretching before lifting would decrease rate of muscle growth and strength gains.

However, while studies had shown acute decrements in performance when stretching was performed immediately before a high-force or an explosive task, only two studies had actually examined the long-term effects on performance. One (8) found that untrained women who stretched immediately before lifting increased their 10RM just as much as women who didn't stretch before training. However, another (9) found that in trained women, stretching immediately before lifting led to smaller 10RM increases. So, the prior literature on strength gains was conflicting, and no study had yet investigated the effects of stretching immediately prior to lifting on hypertrophy or 1RM strength. Therefore, this study set out to test whether static stretching directly before resistance training would negatively impact rates of hypertrophy and strength gains.

Over 10 weeks of training, untrained subjects trained one quad without stretching first, and trained the other quad immediately after a pretty intense stretching session. The unstretched quad grew more, knee range of motion increased more on the side of the stretched quad, and strength gains were similar between legs.

Purpose and Research Questions

This study had four major questions:

1. Does static stretching immediately before strength training negatively impact training volume (reps performed and volume load)?
2. Does static stretching immediately before strength training decrease the rate of strength gains?
3. Does static stretching immediately before strength training decrease the rate of muscle growth?
4. Does static stretching immediately before strength training lead to larger increases in flexibility than strength training alone?

Subjects and Methods

Subjects

The subjects were nine untrained males, mostly in their 20s. Because of the small number of participants, this study used the subjects as their own controls to increase statistical power, opting for unilateral (i.e. single leg) knee extensions as the exercise to be trained and tested.

Training Program

After initial testing, each participant's legs were randomly assigned to one of two training interventions (i.e one leg did one intervention and the other did the other intervention): resistance training (RT), or resistance training following static stretching (FLEX-RT).

RT involved 4 sets of unilateral knee extensions to failure with 80% 1RM with 90 seconds between sets, twice per week. The strength training portion of the FLEX-RT was identical. However, before lifting, the leg assigned to the FLEX-RT protocol had partner-assisted quad stretches (lying face-down, with one of the researchers pushing the participant's heel toward their butt) performed on it for 2 sets of 25 seconds, with 60 seconds between stretches.

On a scale from 0 to 10 where 0 is "no pain" and 10 is "maximal pain," the stretches were between an 8 and a 10. In other words, this was a very intense stretch. The first set of knee extensions started 30 seconds after the second stretch was finished.

The participants alternated which leg they started with each day. For example, on the first training day of each week, they'd do all 4 sets with the RT leg before starting with the FLEX-RT leg, reversing the order for the second training day of each week. This was to ensure that the participants weren't always training one leg when they were already a bit fatigued.

The training program lasted 10 weeks. At week 5, they retested 1RMs to adjust the training load (i.e. they trained with the same load for the first 5 weeks, and a heavier load for the second five weeks,

Table 1 Mean Number of Repetitions and Total Training Volume During Weeks 1-5 and 6-10

	Week 1-5		Week 6-10	
	RT	FLEX-RT	RT	FLEX-RT
Mean number of repetitions	36.9 ± 8.1*	30.3 ± 6.1	46.4 ± 10.5*	39.3 ± 8.2
Mean total training volume (kg)	894.8 ± 168*	707.4 ± 129	1175.3 ± 206*	995.5 ± 170

Data are presented as mean ± SD

** = Significant difference between RT and FLEX-RT ($p < 0.001$)*

and simply tried to increase the total number of reps each week).

Pre- and Post-Study Measures

10 weeks before the start of the training intervention, vastus lateralis cross-sectional area (CSA) was measured via ultrasound, maximum active knee flexion was assessed via goniometry, and the participants performed two familiarization sessions with unilateral knee extensions to learn the exercise before testing. The familiarization sessions were two days apart. After familiarization, they tested their 1RMs twice; the first 1RM test was performed two days after the last familiarization session, and the second was performed three days after the first 1RM test.

Ten weeks later, just before the start of the training intervention, they repeated all of the testing (minus the familiarization sessions, and with only one 1RM test). All of the testing was performed twice to determine the test-retest reliability and average error of the measurements.

Training commenced after all of the initial testing was completed. After week 5 of training, they retested 1RMs only; after week 10, they retested 1RMs, vastus lateralis CSA, and knee range of motion.

Findings

Training Volume

Total reps performed and total volume load (sets x reps x load) were about ~15-20% higher for RT than FLEX-RT. As predicted, stretching directly before lifting decreased training volume when doing the same number of sets, and taking all sets to failure (Table 1).

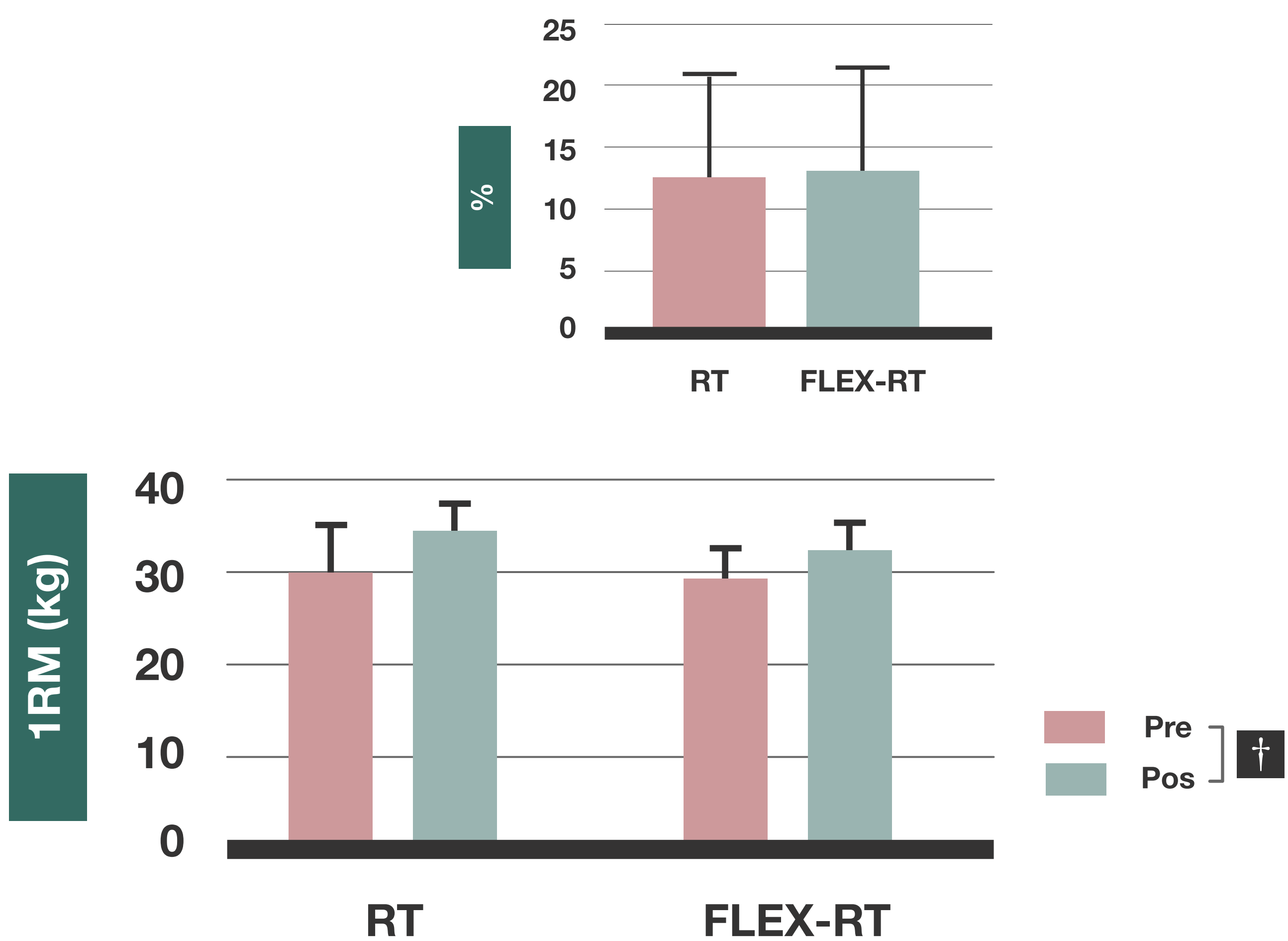
Strength Gains

Strength gains (increases in unilater-

the definition of long term here is 10 weeks

test 1RM twice to get a better reading

Figure 1 Effects on Strength Gains

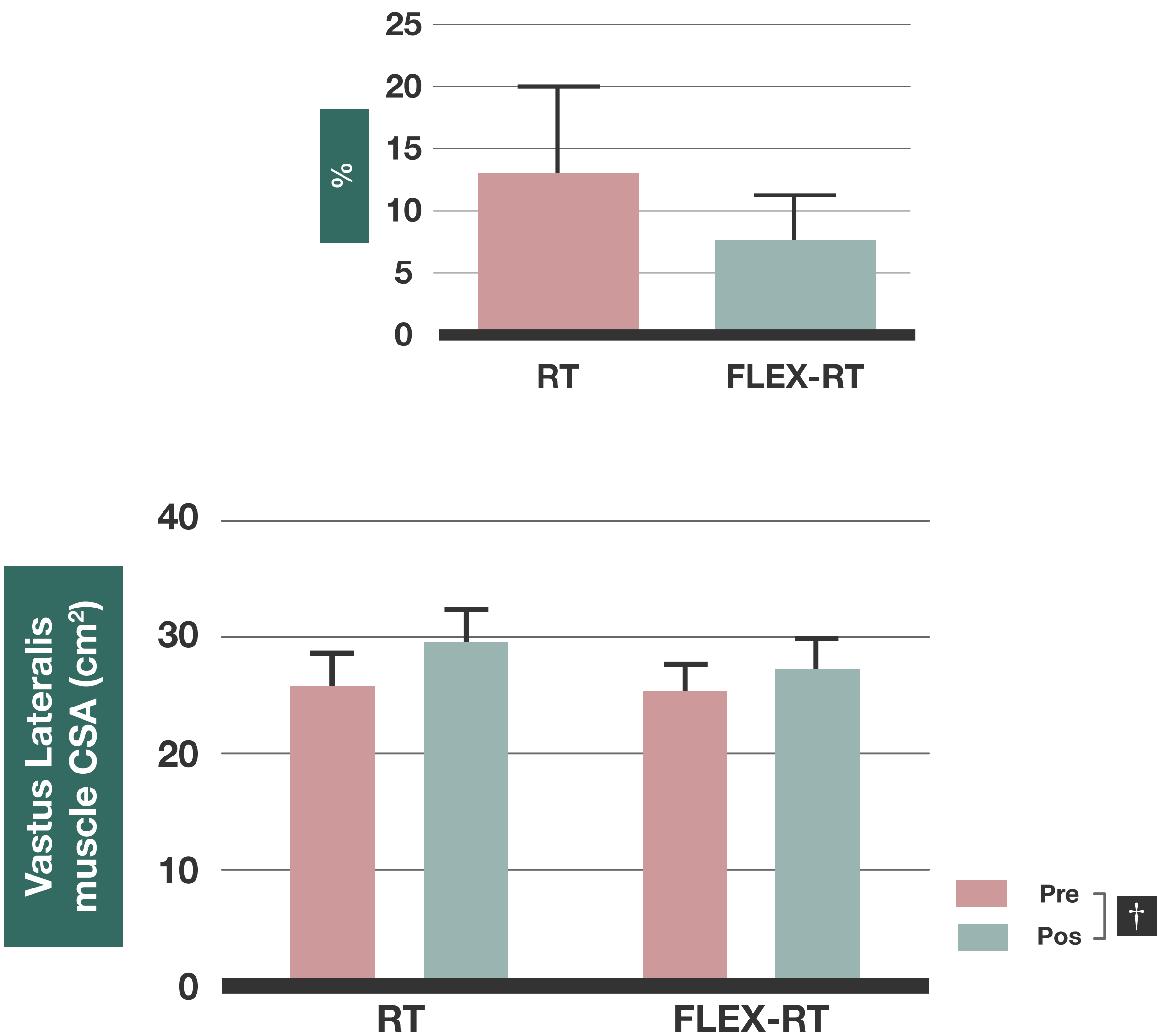


al knee extension 1RM) were essentially identical for the RT and FLEX-RT legs: 12.7 ± 7.4% for RT versus 12.9 ± 8.1% for FLEX-RT (Figure 2). Both of these were large increases, as assessed by effect size (ES = 0.90 and 0.96, respectively).

Hypertrophy

Vastus lateralis CSA increased more in the RT legs than the FLEX-RT legs: 12.7 ± 7.2% versus 7.4 ± 3.7% (Figure 3). The difference was nearly significant as assessed by an ANOVA (group x time interaction, $p = 0.075$), and a follow-up t-test revealed that the percent increase in the RT legs was significantly larger than the percent increase in the FLEX-RT legs ($p = 0.038$). Furthermore, effect sizes classify the increase in CSA to be large for the RT legs (ES = 1.17) and

Figure 2 Effects on Hypertrophy



only moderate for the FLEX-RT legs (ES = 0.75).

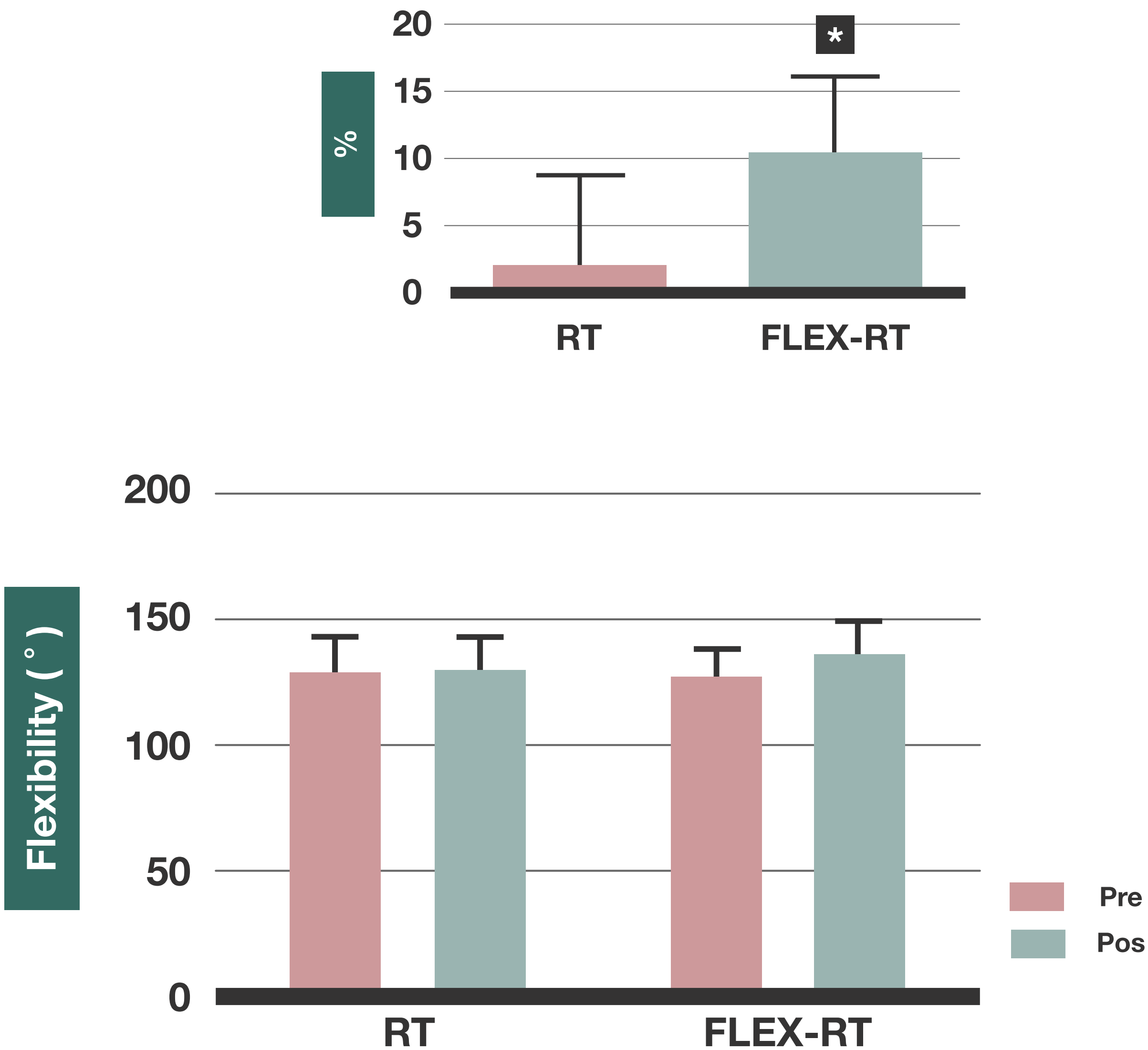
Flexibility

Maximum active knee flexion range of motion increased significantly for the FLEX-RT legs (10.1 ± 5.8%), but not for the RT legs (2.1 ± 6.5%), with significant differences between legs (p=0.001). This can be seen in figure 4. Effect sizes classified the increase in flexibility to be large for the FLEX-RT legs (ES=1.27) and trivial for the RT legs (ES=0.19).

Individual Responses

All nine people had larger increases in maximum active knee flexion range of motion for their FLEX-RT legs versus

Figure 3 Effects on Flexibility



their RT legs. Five people had larger strength gains in their FLEX-RT leg, while four had larger strength gains in their RT leg. Only eight participants were able to have their CSA measured after the training intervention. Of those eight, seven had larger vastus lateralis CSA increases in their RT leg, while only one had a larger CSA increase in their FLEX-RT leg.

Interpretation

In this study, untrained males gained more muscle when they didn't stretch before strength training. However, stretching was beneficial for gains in range of motion (again, duh), and it didn't compromise strength gains.

Those are the basic takeaways, but there's a bit more nuance to it than that.

Before you come away thinking that this study proves that stretching is bad for hypertrophy, but doesn't affect strength, there are a few things to keep in mind:

1) *The way hypertrophy was assessed.* The researchers measured cross-sectional area of the vastus lateralis at the midpoint of the thigh. However, it's possible that CSA at a single point in the muscle doesn't tell the entire story for hypertrophy in this case. Plenty of research shows that different exercises can cause activation of different regions of a muscle and can result in differing hypertrophy responses in different regions of a muscle (10). Since we know stretching can acutely affect the mechanical properties of a muscle, it's possible that stretching before lifting altered the way the stress was distributed throughout the muscle, perhaps affecting *where* hypertrophy took place. CSAs at multiple different regions or (even better) muscle volume would paint a more complete picture. Since training volume was lower after stretching, I do think it's very likely that stretching decreased the rate of muscle growth, but I'd like to see the finding confirmed by a study that measured muscle volume instead of CSA at a single point.

2) *When the stretching took place*. This is the same limitation we saw with the concurrent training paper from the last issue. Static stretching immediately before lifting pretty reliably decreases performance (force, power, reps with a given load, etc.). However, at least for force and power output, we know that waiting 10 minutes between stretching and lifting (i.e. how long it would generally take to get up to your working weight for something likes squats or deadlifts) can undo those performance decrements (11), as can a dynamic warmup (12, 13). It's possible (likely, I'd posit) that the decreases in training volume in this study may not apply in a real-world scenario … unless, that is, you warm up to squat, *then* stretch, then immediately start your first work set. Furthermore, stretching *on its own* was recently shown to independently cause hypertrophy (14), so it may be that stretching performed on off days or after training is actually beneficial for muscle growth.

3) *The intensity of the stretching.* The intensity of the stretching in this study may have played a larger role than the simple fact that stretching took place. The stretches only totaled 50 seconds in duration, but they were rated an 8-10 on a 0-10 scale where 10 is "maximum pain," perhaps inducing an inhibitory, protective response that compromised performance. A recent review (15) found that stretches lasting less than 60 seconds tend to not meaningfully affect performance, so it's striking to see such a marked acute decrease in performance here.

APPLICATION AND TAKEAWAYS

1. If you want to concurrently increase strength and flexibility, it would behoove you to add stretching to your normal training.
2. If you're going to do static stretching, don't do it directly before you start your main working sets, as this can decrease both performance and hypertrophy.

4) *Cross-education.* When you train one side of your body, the other side tends to get stronger as well (16). This is known as cross-education. The experimental protocol used in this study (unilateral exercise, with each person serving as their own control) is great for assessing hypertrophy: you can get plenty of statistical power with a smaller number of subjects, you can be very confident that your two "groups" are essentially identical, and cross-education doesn't apply to hypertrophy (as it seems to be a local phenomenon). However, for assessing strength, the cross-education effect muddies the water. Maybe RT was better for strength gains, but the FLEX-RT legs got a boost from cross-education that wiped out the difference (or vice versa). On the whole, hypertrophy findings with this sort of design are very trustworthy (more trustworthy than using two groups of completely different people, I'd argue), but you need to take strength findings with a grain of salt.

As you should know from Mike's presentation last week on the real effects of pre-exercise stretching, static stretching isn't the best way to warm up for a workout. This study adds one more piece of the puzzle to support that conclusion: If you do it directly before training, it can compromise training volume and probably reduce the rate of muscle growth. However, static stretching can still have its place. It reliably increases flexibility and range of motion, and *possibly* even causes muscle growth of its own (14). However, if you're going to do static stretching, you should save it for after your workout, off days, or you should do it far enough before training that it doesn't negatively impact performance in your workout.

Next Steps

Future studies should examine different populations (i.e. see if these findings apply to well-trained lifters), use measures of muscle size that provide a fuller picture of muscle growth such as CSAs at multiple different locations or muscle volume, and test the effects of timing to see if stretching after a workout or on off days has different effects on strength and hypertrophy.

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Study Reviewed: The Reliability of Individualized Load-Velocity Profiles. Banyard et al. (Published Ahead of Print)

The Future is Now: Within-Lifter Velocity is Reliable. Here's How You Can Use It

BY MICHAEL C. ZOURDOS

What was once the future is now the present. Velocity-based training is now a staple for many athletes. This study shows that velocities at submaximal intensities are reliable within an individual, but how can you actually use velocity in your training?

KEY POINTS

1. This study demonstrates that various measures of velocity are reliable (consistent) within the same individual from session-to-session at submaximal intensities.
2. Because velocity is reliable within individuals, this means that if somebody establishes their normative velocity profile, they can then use this to prescribe and progress training load.
3. Although velocity profiles are individual, we don't yet know what factors account for between-lifter differences in velocity at the same relative intensity.

Eventually, all long-standing practices come to an end, or at least see a challenge. For years, training load has been prescribed either as a percentage of one-repetition maximum (1RM), or by using an RM zone (i.e. 8-12 RM).

However, autoregulation for load prescription has become more popular in the last five years. In MASS, we have often talked about autoregulation through rating of perceived exertion (RPE); however, another common way to "rate" a repetition or set is by collecting average concentric velocity. The drawback of average concentric velocity is that unlike using RPE, it comes at a financial cost; however, a possible point in the column of average concentric velocity is that it's truly objective, whereas RPE is subjective. Despite the objectivity of velocity, we know that average concentric velocity varies between individuals; however, we don't yet know why this is the case. Therefore, to use average concentric velocity to prescribe load, a lifter must establish an individual velocity profile, and these established velocities must be determined to be reliable (consistent from session-to-session) if a lifter is to use velocity-based training (VBT) as their method of autoregulation. This study from Banyard et al. (1) examined the reliability of average concentric velocity along with peak concentric velocity and mean propulsive velocity in the back squat at 20, 40, 60, 80, 90, and 100% of 1RM over three different sessions. All velocity measures were sufficiently reliable at 20, 40, 60, 80, and 90% of 1RM. However, at 100% of 1RM, PV was sufficiently reliable, but average concentric velocity and mean propulsive velocity were not reliable. This suggests that the velocity at which someone can perform a 1RM is variable between sessions. In practice, this means that if you want to use average concentric velocity to prescribe training load, you can do so at submaximal intensities. While these results provide some useful information, they

Table 1 Subject Characteristics

Number of Subjects	Age (years)	Height (cm)	Body Mass (kg)	1RM Back Squat (kg)	Squat to Body Mass Ratio (kg)	Training Age
18 Males	27.2 ± 4.1	180.2 ± 6.1	80.5 ± 8.7	142.3 ± 28.3	1.74 ± 0.21	≥ 6 months

Data are Mean ± SD

Subjects characteristics from Banyard et al. 2017 (1)

still leave a lot to be desired; therefore, this article will not only explain these results, but will also provide various examples of how VBT training can be used in practice.

Purpose and Research Questions

Purpose

The purpose of this study was to determine if measures of velocity in the back squat were reliable within individuals from session-to-session at 20, 40, 60, 80, 90, and 100% of 1RM.

Research Question

Do lifters produce similar velocities in the back squat when lifting the same load across three different sessions?

Hypotheses

A direct hypothesis was not given. From reading the introduction, the authors seemed to indicate that previous evidence on this topic was equivocal. So it seems that the authors were unsure of what the outcome would be.

Subjects and Methods

Subjects

This study had 18 men with at least six months of resistance training experience. To be included, subjects had to squat at least 1.5 times body mass. The strength inclusion threshold is good, but is also a little confusing, as it's difficult to obtain a 1.5 times body mass squat in only six months of training. Obviously, most subjects had much more than six months of experience. The specific descriptive statistics of all subjects can be seen in Table 1.

Study Design

The subjects came to the laboratory four times, with each visit separated by

Table 2 Mean Velocity Values at 100% of 1RM from all Three Experimental Days

	Peak Concentric Velocity ($m \cdot s^{-1}$)	Average Concentric Velocity ($m \cdot s^{-1}$)	Mean Propulsive Velocity ($m \cdot s^{-1}$)
Experimental Day 1	0.84 ± 0.14	0.24 ± 0.07	0.26 ± 0.07
Experimental Day 2	0.82 ± 0.14	0.24 ± 0.07	0.26 ± 0.07
Experimental Day 3	0.83 ± 0.13	0.24 ± 0.04	0.25 ± 0.06
Average of All 3 Days	0.84 ± 0.13	0.24 ± 0.05	0.26 ± 0.06

There was no difference between days for values of any measure of velocity when all lifters velocities were averaged together. This means that the average values across all subjects were statistically reliable, this is evidenced by the almost identical values within each measure.

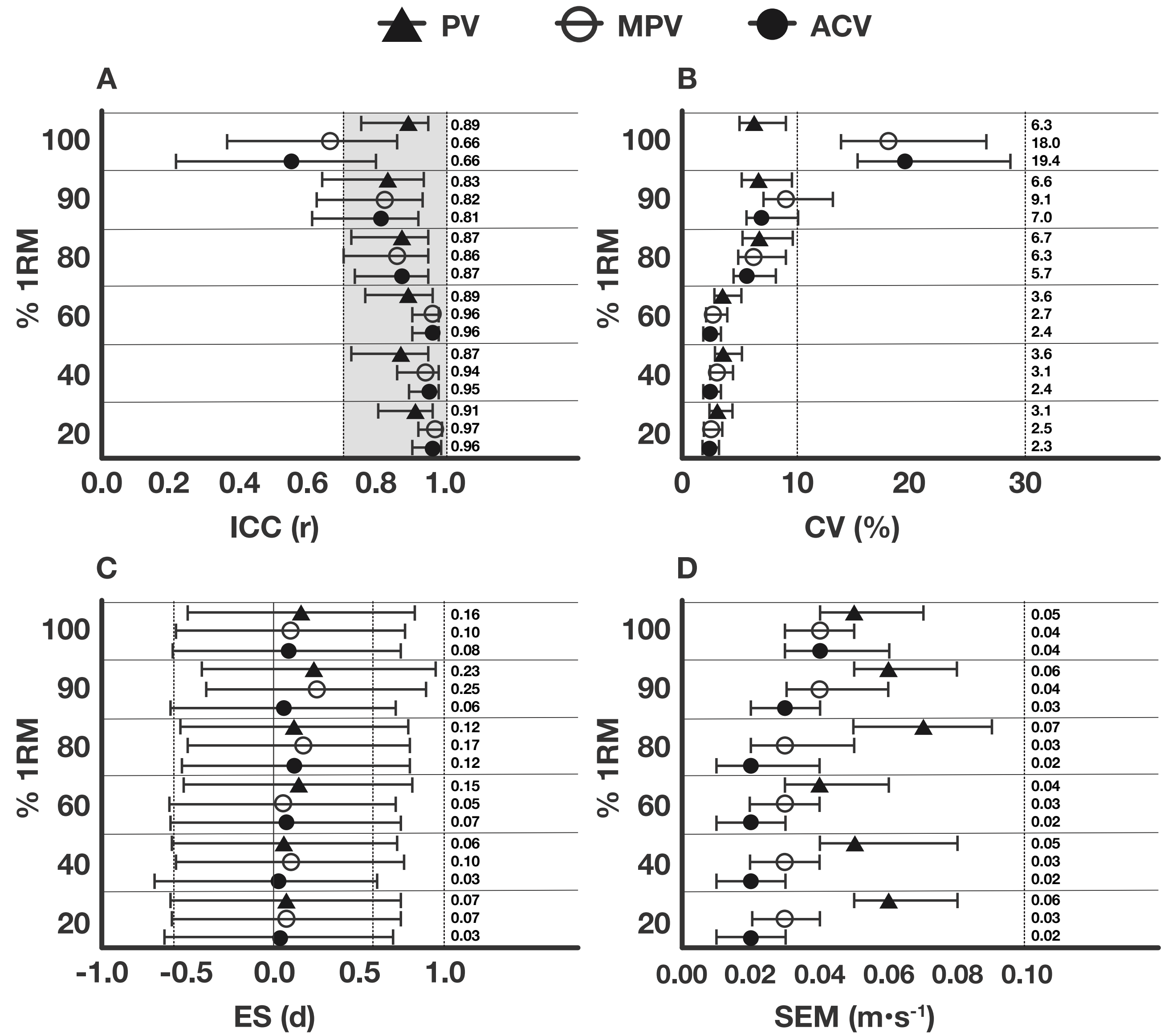
48 hours. The first time was to perform a baseline 1RM squat. During the next three visits, all lifters performed a 1RM in which average concentric velocity, PV, and mean propulsive velocity were recorded. Further, all subjects performed the exact same warm-up for the 1RM, which included three reps at 20, 40, and 60% of the baseline 1RM and one rep at 80 and 90% of the baseline 1RM. The fastest repetition at each 20, 40, and 60% was used for analysis, along with the velocities on each rep at 80 and 90%, and the velocities at 100% of 1RM. The velocities at all intensities were compared across visits two, three, and four to determine reliability. Measures of velocity were recorded during all reps by four position transducers.

Findings

The authors used reliability statistics to compare velocities between sessions. Overall, the mean values for all velocity measurements were reliable between the three experimental testing days. However, when looking at the reliability of each individual (which is most important here), PV was reliable at all intensities while average concentric velocity and mean propulsive velocity were reliable at 20, 40, 60, 80, and 90% of 1RM, but not at 100% of 1RM. To understand this a little more, let's present one table (Table 2) and one figure (Figure 1), and then present a brief breakdown of the statistical analyses since it's a bit different than what we're used to in MASS.

Despite the near-identical means (seen in Table 2) between experimental days at 100% of 1RM, only PV was reliable

Figure 1 Reliability of Statistics for all Velocity Measures Across all Intensities



This figure depicts the reliability statistics including Intraclass Correlation Coefficients (ICC - Panel A), Coefficient of Variation Percentage (CV% - Panel B), Effect Size (ES - Panel C), and Standard Error of Measurement (SEM - Panel D). On the right of each panel the average reliability at each intensity is presented in bold. PV = Peak Velocity, MPV = Mean Propulsive Velocity, ACV = Average Concentric Velocity, %1RM = Percentage of One-Repetition Maximum

when looking at individual reliability. Figure 1, a four-panel figure, presents intraclass correlation coefficients (ICC), coefficient of variation (CV%), effect sizes (ES), and standard error of measurement (SEM). The easiest way to visually see that individual average concentric velocity and mean propulsive velocity are not reliable at 100% of 1RM is by looking at the dot [which is the mean and is the colored-in diamond for average concentric velocity, and the open diamond for mean propulsive velocity in the ICC (panel A) and CV% (panel

B)] panels. On panel A, you can see that the ICC for average concentric velocity and mean propulsive velocity are to the left of the shaded region, which presents an ICC of 0.55 for average concentric velocity and 0.66 for mean propulsive velocity (an ICC = 1.0 is perfect and > 0.70 is acceptable), which the authors classify as "low" correlations. On panel B, you can see that the CV% for average concentric velocity and mean propulsive velocity are to the right of the shaded region between 15-20%. The CV% is the percentage difference or variation between sessions. This measure shows a large difference between sessions for average concentric velocity (19.4%) and mean propulsive velocity (18.0%) at 1RM, thus the individual reliability for these measures at 1RM is poor. Individual reliability for average concentric velocity and mean propulsive velocity at all other intensities was good, and reliability for PV at all intensities (including 100% of 1RM) was good. The criteria for acceptable reliability was: ICC > 0.70, CV < 10%, ES < 0.59, and the mean reliability statistic for each measure can be seen in bold at the right of each panel.

IF YOU HAVE A VELOCITY CALCULATOR AND WORK THROUGH A RANGE OF INTENSITIES ON A DAY WHEN YOU'RE FEELING PRETTY NORMAL, THOSE VELOCITIES ARE RELIABLE AT ALL INTENSITIES EXCEPT FOR 100% OF 1RM.

Interpretation

The most direct interpretation of the present results is simple: If you have a velocity calculator and work through a range of intensities on a day when you're feeling pretty normal, those velocities are reliable at all intensities except for 100% of 1RM. This can establish your individual velocity profile. You can now use this velocity profile to prescribe and progress training load. In other words, you can implement VBT. That's all well and good, but we have to dig far deeper than the present results and provide examples of how you can actually implement VBT. So, let's discuss what VBT actually is, how you can use velocity to examine progress, how RPE can be used within this concept, and what factors might affect an individual's velocity.

Table 3 Sample Training Weeks with Percentage, RPE, and Velocity Load Prescription

	Monday	Wednesday	Friday
Percentage	4 x 8 @ 70%	3 x 1 @ 80%	5 x 3 @ 85%
RPE	4 x 8 @ 5-7 RPE	3 x 1 @ < 5 RPE	5 x 3 @ 7-9 RPE
VBT	4 x 8 @ 0.40-0.70$m \cdot s^{-1}$	3 x 1 @ 0.55-0.75$m \cdot s^{-1}$	5 x 3 @ 0.30-0.45$m \cdot s^{-1}$

All percentages, RPEs, and velocities are based upon the squat, thus these values may vary slightly for other lifts. RPE = Rating of Perceived Exertion. VBT = Velocity-Based Training.

Velocity-Based Training Basics

In short, VBT is prescribing training load to fall within a predetermined velocity zone. This is simply a load prescription strategy as an alternative to using a percentage-based or RPE-based strategy. For example, previous data have indicated that for experienced squatters, one rep at 90% of 1RM has an average concentric velocity of 0.34 $m \cdot s^{-1}$, which corresponds to an RPE of 8-9 (2). Therefore, if you wanted to squat at a high intensity and leave a rep or two in the tank, you could prescribe 3 sets of 1 rep at 0.30-0.40 $m \cdot s^{-1}$. The load lifted may fluctuate in this case, but the effort per set will remain the same. The reason for the velocity range rather than an exact target is that it's highly unlikely you will hit the exact number you are looking for. As long as your velocity is within a close range, then you are putting forth the appropriate effort. This has utility over percentage-based load prescription because programming 3 sets of 1 at 90% may be too heavy if daily readiness is low. (You may have thought, "Well, RPE can already do this," and that's true. We'll compare velocity and RPE in a bit.)

Table 3 provides a training week using all three load prescription strategies to present an example. Also, note that the velocity ranges in Table 3 are where the last rep of the set should end up, which would likely correspond to the RPE range in the RPE example.

VBT and RPE Don't Have to Be Mutually Exclusive

In Table 3, the load prescription strategies are presented as mutually exclusive concepts, but if you think back to the programming series videos (part 1, part 2, part 3), you know we should always strive for a conceptual understanding and to integrate concepts. With that in mind, VBT and RPE can be used together. As previously stated, VBT is just a form of

Table 4 Mean Velocity Values at From Cooke Thesis Across the Intensity Spectrum

Intensity	ACV ($m \cdot s^{-1}$)	Associated Average RPE
30%	1.06 ± 0.13	1.5 ± 1
40%	1.00 ± 0.12	2 ± 1
50%	0.91 ± 0.10	3 ± 1.5
60%	0.82 ± 0.09	4 ± 1.5
70%	0.69 ± 0.08	5 ± 1.5
80%	0.55 ± 0.08	6.5 ± 1
90%	0.39 ± 0.08	8.5 ± 1
100%	0.26 ± 0.06	9.5 ± 0.5

ACV = Average Concentric Velocity. RPE = Rating of Perceived Exertion. Intensities are `expressed as a percentage of one-repetition maximum.

autoregulation. Some believe VBT is superior to RPE because it is objective, whereas the RPE scale itself is objective, but the rating is subjective. While this is true, ultimate objectivity has a drawback in that the average concentric velocity displayed on your position transducer or phone application cannot take into account a technique error. Consequently, if you make a technique error and an average concentric velocity registers lower than a predetermined velocity threshold, this might cause you to stop a set or lower the weight for the next set if you only pay attention to velocity. However, you can use RPE to subjectively estimate how many repetitions in reserve (RIR) you have (keeping in mind the technique error), which may be a more accurate representation of intensity than average concentric velocity in the moment. The human element can take the technique error into account.

Further, by using these methods in

conjunction, you can cross-reference your average concentric velocity at a given intensity with RPE and vice versa. While average concentric velocity is individual, that doesn't mean we can't provide mean values from research as a starting point. In Table 4, you'll see the mean average concentric velocity across 58 trained men and women in 10% increments from 20-100% of 1RM, which are data just recently collected from Cooke 2017 (3). The values in this table are for one repetition at each intensity in the squat, and they are cross-referenced with the associated average RPE across all lifters. Finally, even though velocity is individual, the mean average concentric velocity at some intensities is similar across studies with comparable populations. For example, Cooke (2017) (3), Helms et al. (2017) (4), Banyard et al. (2017) (1), and Zourdos et al. (2016) (2) all reported a mean average concentric velocity of 0.23-0.26 $m \cdot s^{-1}$ at 100% of 1RM.

Factors Impacting Individual Velocity

We know that velocity profiles should be individualized (although Table 4 is a good starting point for most), as Jovanovic and Flanagan (2014) observed different average concentric velocity at 60, 80, and 100% of 1RM in the bench press between two athletes despite each having the same 1RM (5). However, what factors account for the differing velocities between individuals? Well, I honestly don't know for sure. We thought femur length affected squat velocity; however, we (mostly me) were wrong. Specifically, two recent studies I've been a part of hypothesized that longer femurs would be related to faster average concentric velocity. Those studies are: 1) Fahs et al. (2018) (6), which showed no relationship between femur length and average concentric velocity at a 1RM squat ($r=0.02$, $p>0.05$); and 2) the Cooke thesis (3), in which we also showed no correlation ($p>0.05$) between femur length and squat average concentric velocity at any intensity between 20-100% of 1RM. So it's not femur length. What other factors might play a role? Some suggestions are stance width, fiber-type distribution, and training age. So far, the only one that seems to definitively play a role is training age, which was related to slower average concentric velocity at a 1RM in both the squat and bench (2, 7) and also 90% of 1RM in the squat (2). Ultimately, this is a question that cannot be fully answered at the moment, but what's most important is that if you can find your individual velocity, it should be reliable.

Velocity and RPE as Indicators of Readiness and Progress

Since an individual's velocity is reliable at submaximal intensities, this means we can use velocity as a readiness indicator in the warm-up. Therefore, once you have established your normative average

Table 5 Example of Using Velocity and RPE During the Warm-Up to Dictate Session Type

Average Concentric Velocity at 60% of 1RM During Warm-Up	Rating of Perceived Exertion	Corresponding Session-Type
< 0.76 m•s^{-1}	> 4	Light
> 0.76-0.88 m•s^{-1}	3-4	Moderate
> 0.88 m•s^{-1}	< 3	Heavy

The velocity ranges used in this table are taken from the 60% profile that was established by the Cooke thesis in Table 4. The ACV at 60% in the Cooke thesis was 0.82 m•s^{-1}, and the smallest worthwhile change in ACV is 0.06 m•s^{-1}, thus that is how these ranges were established. However, this is just as a guide, velocity profiles must be individualized.

concentric velocity values at submaximal intensities, you can then measure velocity during the warm-up as a readiness tool and adjust your daily volume or intensity (like a flexible template). Or, you could use those velocity values to help determine your attempt selection if it's a 1RM test day. Of course, RPE can accomplish this as well, and recent data have demonstrated RPE scores during the last warm-up set (85% of 1RM) to be more accurate at predicting daily 1RM performance than average concentric velocity (8); however, this was only in a three-person case series, so it can't be said with certainty if one is better than the other. In principle, though, you can use average concentric velocity and RPE on warm-up sets to assess readiness within a flexible template. If you have a heavy, moderate, and light day within a week, you would calculate velocity and RPE on warm-up attempts and, depending on the results, you would then choose the appropriate training session. An example of this is displayed in Table 5.

Lastly, since the current study shows that velocity is reliable within individuals, you can use it as a way to gauge progress from week to week or even following a taper. I think it's a good idea to occasionally test a 1RM, because practicing a lift at high intensity is a skill; however, you may not want to do this after every training block. A replacement for a 1RM test could be to assess velocity. Specifically, if you performed a 200kg back squat for one rep at 0.35 m·s^{-1} before a training block, then crushed

APPLICATION AND TAKEAWAYS

1. At all intensities except for 100% of 1RM, average concentric velocity is a reliable measure.
2. Since velocity is reliable, you can use it to program training load, progress training load, measure progress, and as a measure of readiness, if using a flexible template.
3. VBT and RPE are not mutually exclusive; in reality, they are both just methods of autoregulation, and you can cross-reference velocity with RPE to ensure accuracy of both.

200kg for a single at a velocity of 0.45 $m \cdot s^{-1}$ after the block, then you got stronger (and avoided the fatigue and mental stress of a 1RM or a highly damaging repetition test). Once again, RPE could accomplish this same principle from week to week and block to block, as well.

Next Steps

Recently, Dr. Helms' dissertation (9) demonstrated that a solely autoregulated load prescription method using RPE over eight weeks produced meaningfully larger increases in squat and bench strength than a percentage-based load prescription. With that said, there are two next steps: 1) Add a third group to Eric's study design, which uses VBT as a method of load prescription and compare it to RPE-based and percentage-based over the long-term and 2) Finally figure out what factors exactly make average concentric velocity different between individuals at the same relative percentage of 1RM.

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Study Reviewed: Intermittent Energy Restriction Improves Weight Loss Efficiency in Obese Men: The MATADOR Study. Byrne et al. (2017)

Diet Breaks Make an Energy Deficit More Effective and Less Costly

BY ERIC HELMS

This is the first study on diet breaks since 2003, and the results are very promising. Read on to learn how this strategy can aid not only fat loss efficiency, but also fat loss maintenance.

KEY POINTS

1. Despite the same energy deficit and the same total time spent in an energy deficit, a group taking two-week diet breaks after every two weeks of dieting lost ~50% more fat mass compared to a group dieting continuously for 16 weeks. However, due to the frequency of these breaks, the group performing diet breaks required 30 weeks to complete all 16 weeks of dieting.
2. Additionally, resting energy expenditure dropped only half as much in the diet break group compared to the continuous diet group when adjusted for body composition. This may be why the difference in groups favored the diet break group to a greater degree after a six-month follow-up, indicating diet breaks may help with the maintenance of weight loss after a diet concludes.
3. Diet breaks appear to reverse important physiological adaptations to an energy deficit, subsequently making the dieting period following a break more effective for fat loss. While increasing the time required to complete a diet as much as was done in this study is probably impractical, performing a diet break every 4-8 weeks versus every two weeks may be a useful strategy for physique competitors and weight class-restricted strength athletes to enhance fat loss and mitigate declines in resting energy expenditure.

To the best of my knowledge, the concept of taking a diet break in the bodybuilding world was originally popularized by Lyle McDonald in his 2005 book "A Guide to Flexible Dieting." Lyle's guidelines were inspired by a 2003 study by Wing and Jeffrey, in which they attempted to study the effects of weight loss relapses by prescribing diet breaks during a weight loss intervention (2).

Surprisingly, they found that planned breaks during a diet, unlike unplanned lapses, did not disrupt weight loss efforts. Despite these findings, no one has investigated the utility of diet breaks as a weight loss aid again… until now. In the present study, two groups of obese men either followed a 33% energy deficit diet (67% of maintenance energy) continuously for 16 weeks (CON), or took a two-week diet break at maintenance intermittently after every two weeks of dieting (INT) for a total of 30 weeks. During these diet breaks, there was no loss or gain of body weight. Additionally, while CON and INT had the same intended magnitude and total duration of energy deficit, INT lost ~50% more body weight and fat mass while losing a similar amount of lean body mass and experienced only half the reduction in resting energy expenditure (REE) compared to CON.

Table 1 Baseline Subject Characteristics

	Continuous Mean ± s.d.	Intermittent Mean ± s.d.	Difference Mean ± s.e.	P
Completed per protocol (Wk16)	N = 19	N = 17		
Age (years)	41.2 ± 5.5	39.5 ± 8.4	1.7 ± 2.3	0.46
Height (cm)	180.3 ± 6.1	177.8 ± 7.7	2.5 ± 2.3	0.28
Weight (kg)	110.9 ± 9.6	107.7 ± 13.3	3.3 ± 3.8	0.39
BMI (kg m^{-2})	34.3 ± 3.0	34.1 ± 4.0	0.2 ± 1.2	0.86
Body fat (%)	39.4 ± 5.0	39.7 ± 7.1	0.3 ± 2.0	0.89
Fat mass (kg)	43.9 ± 8.4	43.1 ± 11.3	0.9 ± 3.3	0.79
Fat-free mass (kg)	67.0 ± 5.3	64.5 ± 8.1	2.4 ± 2.2	0.29
Resting energy expenditure (kJ d^{-1})	9038 ± 762	8364 ± 875	674 ± 272	**0.02**
Completed per protocol (Wk16) and 6-month follow-up	N = 13	N = 15		
Age (years)	40.0 ± 5.2	40.3 ± 7.6	0.3 ± 0.8	0.72
Height (cm)	180.4 ± 5.6	178.9 ± 6.9	1.6 ± 0.7	**0.02**
Weight (kg)	110.2 ± 9.3	108.6 ± 13.5	1.6 ± 4.5	0.72
BMI (kg m^{-2})	34.0 ± 3.6	34.0 ± 4.3	0.0 ± 1.5	0.98
Body fat (%)	38.3 ± 5.4	40.4 ± 6.9	2.2 ± 2.4	0.36
Fat mass (kg)	42.5 ± 8.9	44.2 ± 11.0	1.7 ± 3.8	0.66
Fat-free mass (kg)	67.7 ± 4.8	64.4 ± 8.6	3.3 ± 2.7	0.23
Resting energy expenditure (kJ d^{-1})	9075 ± 892	8519 ± 804	557 ± 322	0.09

Purpose and Research Questions

Purpose

The purpose of this study was to examine the effect of repeatedly interrupting energy restriction with deliberate periods of energy balance on body weight, body composition, and energy expenditure.

Hypothesis

The authors hypothesized that, compared with continuous energy restriction, intermittent energy restriction (delivered as alternating two-week blocks of dieting and energy balance) would result in more efficient weight and fat loss (greater loss per unit of energy restriction), and that the compensatory reduction in energy expenditure typically associated with continuous weight loss would be reduced.

Subjects and Methods

Subjects

Eligible participants were males aged 25-54 years with a body mass index (BMI) classified as obese (30-45 kg·m^{-2}), weight-stable (± 2 kg for six months prior to participation), with a sedentary activity level (< 60 min of structured moderate to vigorous intensity physical activity per week). Baseline characteristics for both the participants who completed the protocol as intended and for those who completed the protocol as intended and were also available for a six-month follow up are displayed in Table 1.

Study Design

This was a parallel group design in which the participants were randomly assigned to either CON or INT groups. Both groups began the intervention with a four-week weight stabilization phase to determine energy needs and to help them acclimate to the diet's macronutrient composition before undertaking the energy restriction period. Following the CON or INT diet, participants completed an eight-week post-weight loss energy balance phase. Thus, including the 4-week baseline, the 16- or 30-week dieting phase, and the 8-week post-weight loss energy balance phases, the total length of the intervention was 28 and 42 weeks for the CON and INT groups, respectively.

Determination of Weight Maintenance Energy Requirements

Weight maintenance energy requirements were estimated for each participant by multiplying REE by an activity multiplier based on self-reported physical activity. Participants were prescribed an individualized diet to maintain body weight and were provided an electronic scale to record body weight at home. These weights were used to assess the accuracy of the weight maintenance diet and to adjust energy intake if needed. When participants gained or lost weight consistently over at least three days, energy intake was adjusted to maintain weight stability.

Body Weight, Composition and REE

Body weight was recorded at each lab visit with a high-grade digital scale and measured to the nearest 0.1kg. Body composition was assessed via Bodpod (air displacement), and REE was measured with a ventilated hood system after an overnight fast. Each variable was recorded at the start and finish of the dieting phase, at the start and end of the four-week baseline phase, after every four weeks of energy restriction, at weeks 1, 2, 4, and 8 of the eight-week post-diet energy balance phase, and at the follow-up six months later. During the dieting phase, measurements were taken after the same number of weeks of energy restriction for both groups. For example, the week four measure-

Table 2 Differences Between Groups

	Continuous Mean ± s.d.	Intermittent Mean ± s.d.	Difference Mean ± s.e.	P
Completed per protocol (Wk16)	N = 19	N = 17		
Weight (kg)	- 9.2 ± 3.7	- 14.1 ± 5.6	4.8 ± 1.6	**0.004**
Weight (%)	- 8.4 ± 3.3	- 12.9 ± 4.4	4.5 ± 1.3	**0.001**
Fat mass (kg)	- 8.0 ± 4.4	- 12.3 ± 4.8	4.3 ± 1.5	**0.009**
Fat-free mass (kg)	- 1.2 ± 2.4	- 1.8 ± 1.6	0.6 ± 0.7	0.42
Resting energy expenditure (kJ d^{-1})	- 624 ± 557	- 502 ± 481	121 ± 176	0.48
Resting energy expenditure (kJ d^{-1}; adjusted for FFM and FM)	- 749 ± 498	- 360 ± 502	389 ± 176	**0.03**
Completed per protocol (Wk16) and 6-month follow-up	N = 13	N = 15		
Weight (kg)	- 7.7 ± 3.1	- 13.9 ± 5.5	6.2 ± 1.7	**0.001**
Weight (%)	- 7.2 ± 2.9	- 12.6 ± 4.2	5.6 ± 1.4	**0.0004**
Fat mass (kg)	- 6.6 ± 3.4	- 12.3 ± 4.8	5.7 ± 1.6	**0.001**
Fat-free mass (kg)	- 1.1 ± 2.4	- 1.6 ± 1.4	0.5 ± 0.7	0.49
Resting energy expenditure (kJ d^{-1})	- 548 ± 590	- 452 ± 494	96 ± 205	0.65
Resting energy expenditure (kJ d^{-1}; adjusted for FFM and FM)	- 770 ± 523	- 255 ± 515	515 ± 213	**0.02**

FM, fat mass; FFM, fat-free mass.

Significant group differences are indicated by bolded text

ment was taken four weeks after baseline for the CON group, but six weeks after baseline for the INT group because a two-week diet break occurred before four weeks of energy restriction took place in the INT group. For the INT group, measurements were taken at the end of a two-week block of energy restriction to ensure a like-to-like comparison between groups.

Nutritional Intervention

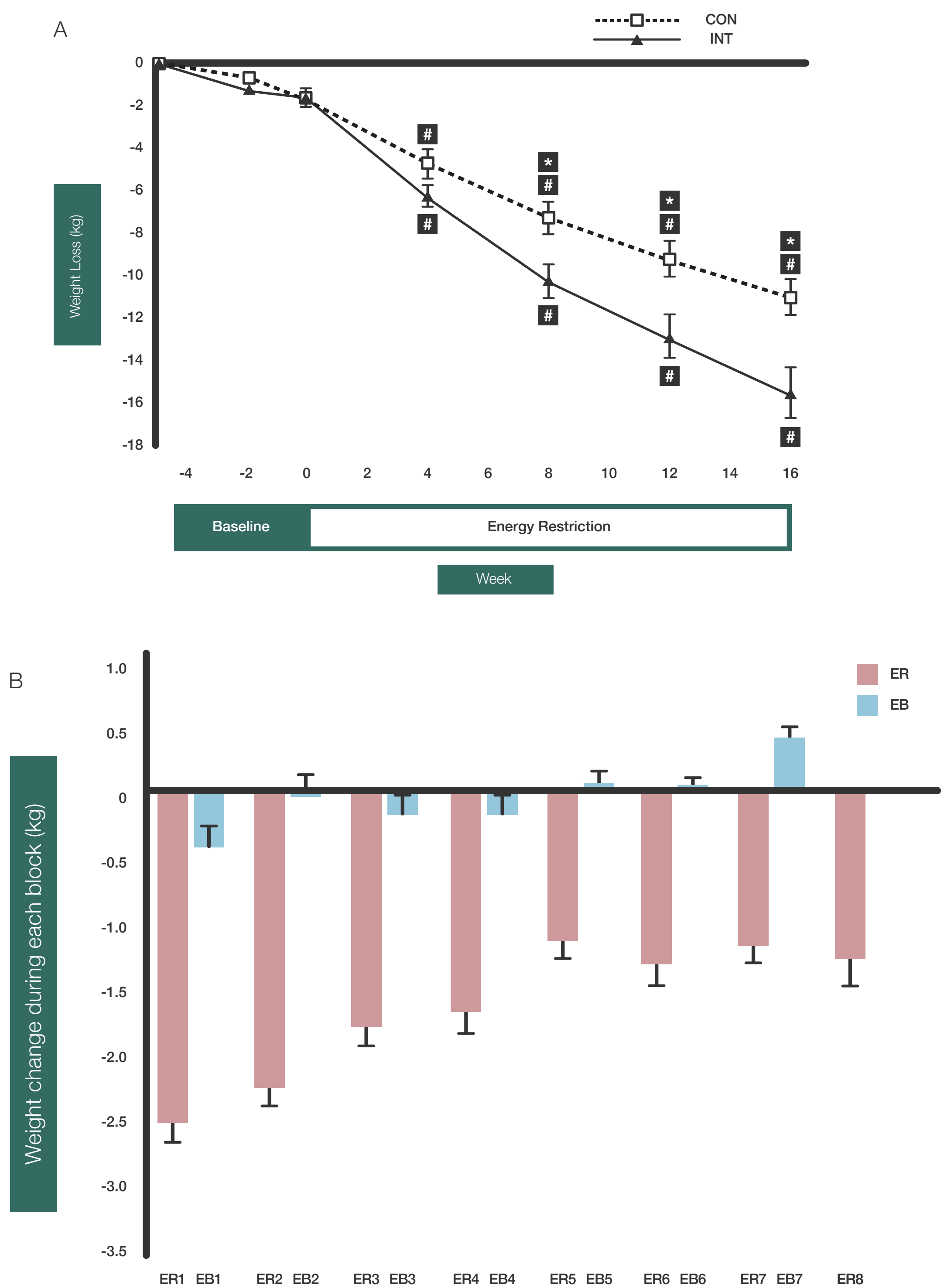
Energy restriction in both groups was equivalent to 67% of individual weight maintenance requirements (that is, a 33% deficit). Energy intake was adjusted to account for reductions in REE, which was measured after every four weeks of ER, in order to ensure that participants remained in the same relative energy deficit throughout the study. During diet breaks, participants were prescribed an energy intake matching their weight maintenance requirements. Participants were provided main meals and morning and afternoon snacks for the duration of the study. Meals were prepared under the direction of a dietitian and delivered to the participants' homes. The planned macronutrient distribution at all times in both groups was 25-30% of energy as fat, 15-20% as protein, and 50-60% as carbohydrate.

Findings

As seen in Table 2, among the participants who completed the diet protocol as intended, those in the INT group lost ~50% more body weight and body fat and had only about half the drop in REE when adjusted for body composition compared to CON. The differences at the six-month follow-up mark are even more impressive, as the gap between groups widened due to the CON group regaining more body fat than INT. Thus, at this point, INT maintained ~80-90% more weight and fat loss and had only one-third the reduction in REE compared to CON. As is shown in Figure 2, the pattern of weight loss remained much more linear in INT during energy restriction periods, while CON saw a progressive reduction in rate of weight loss throughout the diet, resulting in increasingly wider differences in weight loss between groups. Weight changes during both energy restriction and diet break periods in INT are shown in the second panel of this figure. Finally, Figure 2 shows that while both groups saw an initial decline in REE, this began to rebound in INT, eventually resulting in a significantly higher value than CON when adjusted for body composition.

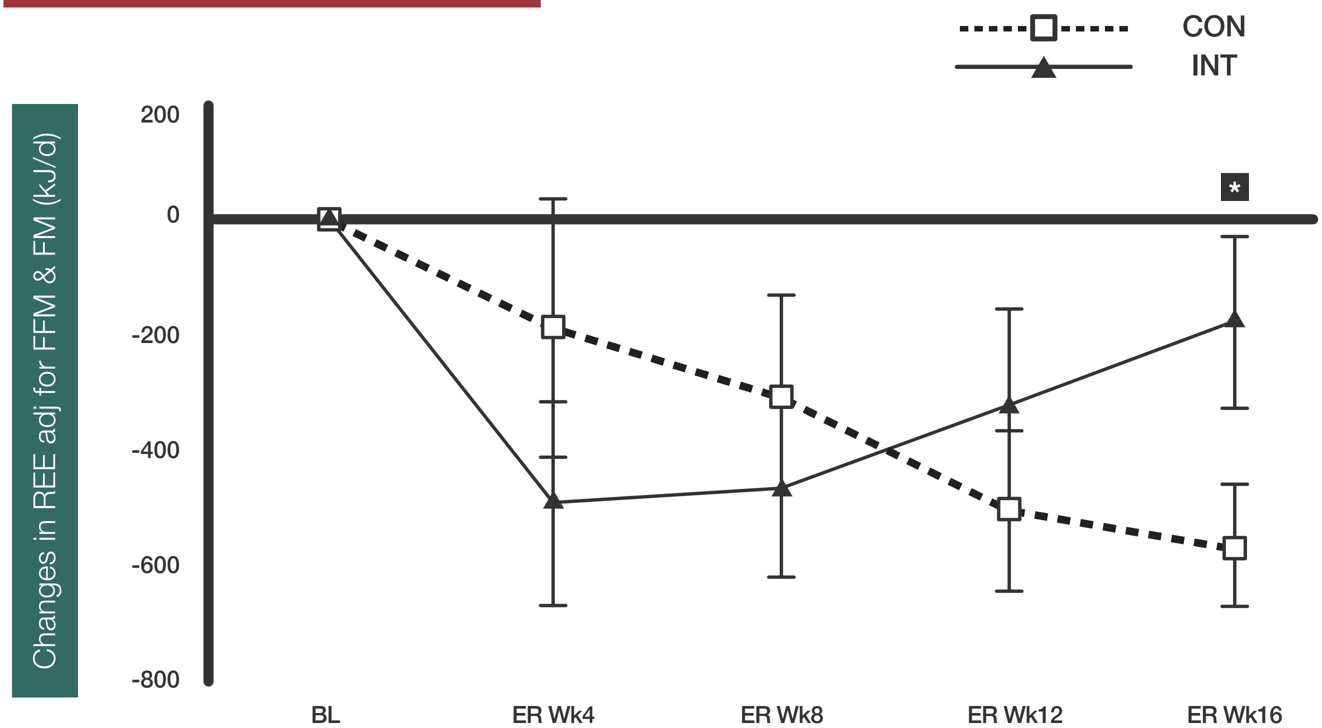
THE DIFFERENCES AT THE SIX-MONTH FOLLOW-UP MARK ARE EVEN MORE IMPRESSIVE, AS THE GAP BETWEEN GROUPS WIDENED DUE TO THE CON GROUP REGAINING MORE BODY FAT THAN INT. THUS, AT THIS POINT, INT MAINTAINED ~80-90% MORE WEIGHT AND FAT LOSS AND HAD ONLY ONE-THIRD THE REDUCTION IN REE COMPARED TO CON.

Figure 1 Weight Change



*Changes in body weight (kg; mean + s.e.m.) during baseline and 16 weeks of energy restriction (ER) in the continuous (CON; N=19) and intermittent (INT; N=17) groups. (a) Cumulative weight change (kg) over baseline (-4, -2, 0 weeks) and after 4, 8, 12, and 16 weeks of ER for the CON and INT groups. *Significant difference between groups; P < 0.05. #Significant difference from baseline within-group; P < 0.01. (b) Weight change (kg; mean + s.e.m.) in the intermittent energy restriction (INT) group during each of the 8 x 2-week energy restriction (ER) and 7 x 2-week energy balance (EB) blocks that comprised the 30-week intervention.*

Figure 2 Changes in Resting Energy Expenditure



** = Significant difference (p < 0.05) between groups*

Interpretation

In terms of clinical outcomes, the findings of this study are really impressive. When you read weight loss studies that compare macronutrient differences between diets (3), even when comparing high- versus low-protein conditions (4), differences of this magnitude are rarely seen. The same goes for studies on other forms of intermittent energy restriction, such as every-other-day fasting, and the 5/2 diet (2 days of very low or no calories, 5 days at maintenance or ad libitum intake); even in the rare case when there is an outcome favoring the intervention, the differences are relatively small (5, 6). So, are diet breaks just that awesome compared to other forms of intermittent energy restriction? I'd say the answer is both yes and no.

First let's take a step back and discuss the original study on diet breaks by Wing and Jeffrey back in 2003 (2). In that study, they had three groups; each provided a total of 14 weekly group sessions in which nutritional, behavioral, and exercise advice and support was provided while the individuals in the group followed a weight loss plan. This plan consisted of being told to follow an energy-restricted diet tailored to baseline body weight with instructions on how to do so, including a list of high-energy density foods to avoid. Additionally, they were prescribed a gradually increasing physical

Table 3 Wing and Jeffrey 20013 Diet Break Study Protocol

Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
No Break	1	2	3	4	5	6	7	8	9	10	11	12	13	14	x	x	x	x	x	x
2-Week Breaks	1	2	3	x	x	4	5	6	x	x	7	8	9	x	x	10	11	12	13	14
6-Week Breaks	1	2	3	4	5	6	7	x	x	x	x	x	x	8	9	10	11	12	13	14

activity plan and were instructed to log diet and exercise, take daily weigh-ins, and attend the 14 weekly group sessions (which began with a weigh-in). The only difference between groups in this study was that two groups took diet breaks: one group took three two-week breaks more or less evenly spread between the 14 weekly sessions, and the other took a single six-week break in the middle of the 14 weekly sessions. Thus, both diet break groups finished the program after 20 weeks (14 weeks of dieting, 6 total weeks of diet breaks), while the normal group finished after 14 weeks (this is displayed in Table 3).

What was interesting was that the group not taking diet breaks was instructed to continue with their weight loss efforts after the 14th week, carrying on with the behavior, exercise, and nutritional habits they had hopefully developed during the supervised intervention. Yet by week 20, all groups had lost a similar amount of weight, despite both the diet break groups getting to take "time off." This in and of itself is a cool finding, but the real question is: Why did the present study find an advantage when Wing and Jeffrey just found that you could take breaks without impeding your weight loss efforts?

The difference was that – unlike in Wing and Jeffrey's study – the present study's diet was tightly controlled. While Wing and Jeffrey conducted an out-patient study, the present study was much closer to an in-patient model. Additionally, the diet breaks were just as tightly controlled as the energy restriction periods. During these breaks, just like the dieting blocks, the researchers provided the meals and regularly checked compliance. The only difference between the breaks and the dieting blocks was that the caloric intake during the breaks matched weight maintenance energy requirements. Thus, it seems when left to one's own devices, if no control of food intake occurs, diet breaks likely result in compensatory overfeeding, washing out some of the potential weight loss benefits. However, when diet breaks are "by the numbers" and the individual eats maintenance calories, it seems you can essentially hit pause on your progress in order to accelerate it after you start up again.

Even more encouraging than the greater weight loss in INT observed in this study at the end of the energy restriction period is the even greater advantage for weight loss maintenance in INT compared to CON. While the researchers didn't pin down every single mechanism that could have caused this to occur, I have a feeling it doesn't just come down to a better maintenance of REE. In my personal experience as a competitor and as a coach, I have repeatedly seen that when diet breaks are implemented during a weight loss period, individuals feel less deprived when the diet concludes and subsequently partake in less post-diet overeating, leading to a smaller body weight rebound. In support of my coaching observations, there is a substantial body of research that I discuss here which shows that individuals who approach diets with a flexible restraint mindset tend to lose more weight, maintain more weight loss, and overeat less both during and after a diet concludes.

Finally, let's discuss why I said yes and no in response to my own question of "are diet breaks just that awesome?" at the start of this section. To get the benefits observed in this study, the participants essentially spent twice the length of time "in the intervention." Now for a casual dieter trying to lose weight, this really isn't an issue if you have a long-term view. If your goal is to live a healthier lifestyle and

> WHEN DIET BREAKS ARE "BY THE NUMBERS" AND THE INDIVIDUAL EATS MAINTENANCE CALORIES, IT SEEMS YOU CAN ESSENTIALLY HIT PAUSE ON YOUR PROGRESS IN ORDER TO ACCELERATE IT AFTER YOU START UP AGAIN.

maintain a lower body fat for the remainder of your life, then who cares if 10 years ago it took you 16 or 30 weeks to achieve the weight loss you desired. However, if you are a weight-class restricted strength athlete or physique competitor with a competition date, this becomes problematic. Certainly, you could just increase the length of your diet, which I actually recommend for physique competitors. Having more time to lose the body fat you need to lose will make the process better in almost every way, and it allows for the implementation of diet breaks (during which time, training is more effective and may help with lean mass retention). On the other hand, a strength athlete could make the argument that it would be better to lose the weight quickly, in

APPLICATION AND TAKEAWAYS

1. While intermittent diet breaks at maintenance energy intake will likely enhance the efficiency of fat loss, they will increase the length of time required to reach a weight loss goal.
2. The mechanism by which diet breaks exert this fat loss enhancing effect is at least in part due to mitigating losses in energy expenditure; however, there may be some post-diet psychological benefits as well given the superior weight-loss maintenance outcomes observed.
3. For physique competitors, in order to avoid increasing the length of your diet too much while still getting the benefits from diet breaks, I recommend implementing one-week diet breaks no more frequently than every 4-8 weeks.

advance of the competition, then come into the competition in a slight surplus or at maintenance, with months of good training under their belt, 1-2% over their weight class cut off, and do a mild water restriction to make weight. Unlike for the physique competitor, whether or not some body fat is regained during this process is inconsequential for the strength athlete. I actually completely agree with this approach, and I do think diet breaks have more utility for physique competitors than strength athletes. However, the application of diet breaks probably needs to be adjusted so that it doesn't increase the preparation length of a diet too much. In my experience, performing one-week diet breaks every 4-8 weeks or on an as-needed basis in response to some (but not all – often you will actually need to cut calories) weight-loss stalls is a very useful approach, which seems to result in many of the same benefits observed in the present study, without adding too much time to the preparation period so as to make it not worth it.

Next Steps

This was a fantastic study, and – on the whole – I have very little to critique. However, I would love to see this study replicated in a non-overweight cohort performing resistance training. It is my suspicion that, if anything, the physiological effects might be enhanced in a group that isn't overweight, as you would think decreases in energy expenditure would be more severe when moving from a normal to a low body fat level. On the other hand, perhaps the performance of resistance training would substantially mitigate any losses of lean mass and wash out differences in adaptive thermogenesis? I don't know, but that's why I would love to see a study like this carried out.

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Study Reviewed: Effects of Mental Training on Muscular Force, Hormonal and Physiological Changes in Kickboxers. Slimani et al. (2017)

Mind Over Matter: Mental Training Increases Strength Gains

BY GREG NUCKOLS

Everyone focuses on physical training, but mental training is a powerful, oft-overlooked tool that can boost your strength gains.

KEY POINTS

1. Two groups of high-level kickboxers performed the same lifting program over 12 weeks. One of the groups did additional mental training, including motivational self-talk and visualization.
2. While both groups experienced increased performance, the group doing additional mental training made larger gains. For our purposes here, their additional strength gains in the bench press and half squat are most relevant.
3. The group doing additional mental training also showed markers of decreased stress, including an elevation in testosterone:cortisol ratio and larger decreases in resting heart rate and blood pressure than the group not performing mental training.

When you talk to elite lifters, you'll notice that, in addition to discussing their training approach, a lot of them also talk about their mental approach to training and competing. This study set out to test the degree to which mental training could augment physical training.

Over 12 weeks, two groups of high-level kickboxers followed the same strength training program, but one group also performed additional mental training (self-talk and visualization). While both groups got stronger in the bench press and half squat, the group doing additional mental training experienced larger strength increases, along with decreases in heart rate and blood pressure, and increases in testosterone:cortisol ratio. Therefore, purposefully adding self-talk and visualization training to your lifting may help you make faster strength gains without incurring additional recovery demands.

Purpose and Research Questions

The authors of this study had three hypotheses:

1. Physical training plus mental training would lead to larger strength gains than physical training alone.
2. Physical training plus mental training would lead to larger increases in testosterone and a larger increase in testosterone:cortisol ratio than physical training alone.
3. Physical training plus mental training would lead to larger decreases in cortisol, heart rate, and blood pressure than physical training alone.

Subjects and Methods

Subjects

The subjects were 53 male elite (n=9)

or sub-elite kickboxers (n=44), meaning they competed in at least four national or international competitions per year. They were 24.2±4.4 years old, weighing 70.4±10.4kg, and all had at least one year of resistance training experience.

To be included in the study, they had to meet these criteria:

1. They'd never done any sort of dedicated mental training with the goal of improving sport performance.
2. They didn't use any drugs or dietary supplements.
3. They had no recent injuries.
4. They had no history of using drugs or medications that could affect the hypothalamic-adrenal-gonadal axis.
5. They had no history of chronic disease.
6. They had regular eating patterns.
7. They had no depressive illnesses.
8. They had no severe cognitive impairment.
9. They had to have at least moderate mental imagery ability, according to the Sport Imagery Ability Measure.

Testing

One week before the start of the study, the participants all tested 1RM bench press, 1RM half squat, max distance medicine ball throw, and max height countermovement jump to familiarize themselves with the tests.

At the start of training, after 6 weeks of training, and after 12 weeks of training, all groups completed those same physical tests again. In addition, the researchers measured the subjects' resting heart rate and blood pressure and drew blood to analyze testosterone and cortisol levels. All tests, measurements, and blood draws were performed at the same times of day (7-8 a.m. for blood draws, blood pressure, and heart rate and 5:30-7 p.m. for physical tests) at all three time points to minimize the effect of diurnal fluctuations in hormone levels, heart rate, blood pressure, and performance.

It's worth noting that the half squats used in this study were actually relatively close to legal squats in powerlifting. The participants were required to squat until the greater trochanter of the femur was parallel with the knee – probably ~2-3 inches above legal powerlifting depth, depending on quad size.

Training Protocol

The participants were split into three groups:

1. One group (n=20) performed only physical training (PT).
2. One group (n=18) performed physical training plus mental training (PT-MT).
3. One group (n=15) served as a control group, doing no physical or mental training.

Table 1 Training Program

	15 minutes	30 minutes	80 seconds	30 minutes	15 minutes
Physical Training	General and Specific Warm-up	Bench Press and Half Squat (4 x 8 @ 70% 1RM) Medicine Ball Throws and Counter Movement Jumps (4 x 10-12 each)	80 seconds of rest between sets	Neural Cognitive Tasks	Cooldown (Jogging, Stretching, Shadow Boxing)
Physical Plus Mental Training			80 seconds of Motivational Self-Talk (MST)between sets	First-Person Motor Imagery for Bench Press, Half Squat, Medicie Ball Throws, and Counter Movement Jump	

Training for the PT and PT-MT groups took place three days per week for 12 weeks, consisting of a 15-minute warm-up, 4 sets of 8 half squat and bench presses with 70% 1RM loads, and 4 sets of 10-12 medicine ball throws or countermovement jumps. They rested 80 seconds between sets of all exercises. Unfortunately, the authors don't explicitly state how load was progressed for the half squat and bench press.

In addition to the physical training, the PT-MT group also performed motivational self-talk between sets and performed mental imagery training at the end of each workout.

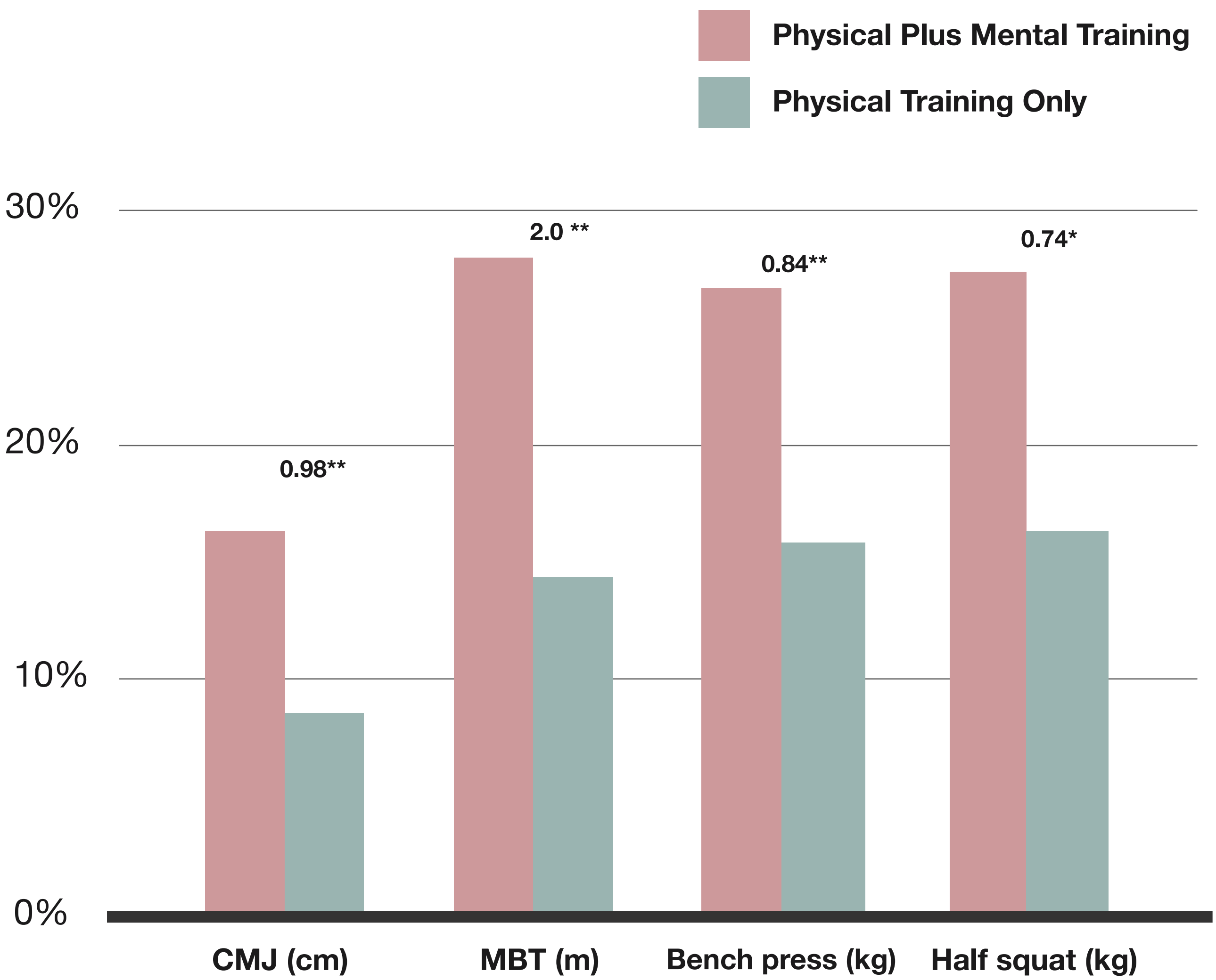
The motivational self-talk was self-selected, in accordance with self-determination theory. The athletes were told to identify negative self-talk before, during, or after training, write down the negative statement, and to restate that negative statement as a positive or motivating statement. For example, if an athlete caught himself thinking "I'm not sure I can lift this much weight," they'd instead be instructed to repeat something like, "I could lift more weight" between sets. The athletes were asked to change their motivational statements each time a new piece of negative self-talk arose.

Mental imagery consisted of internal kinesthetic imagery. This means that the participants were instructed to imagine themselves performing each exercise, looking out through their own eyes (i.e. a first-person view, instead of imagining watching themselves performing the exercise), and maximally exerting themselves through the exercise. The study also notes that they "urged the muscles to contract maximally," though it's unclear whether the participants actually maximally contracted their muscles, or just imagined their muscles contracting.

While the PT-MT group performed their mental training post-exercise, the PT group performed neural cognitive tasks. The study doesn't make the nature of those tasks clear, simply stating that they "never involved the abilities needed to form mental images." I honestly have no idea whatsoever what those tasks involved.

Finally, the PT and PT-MT groups performed two 90-minute sessions of kickboxing training per week, mostly focusing on technique and sport-specific training.

Figure 1 Relative Increases in Performance



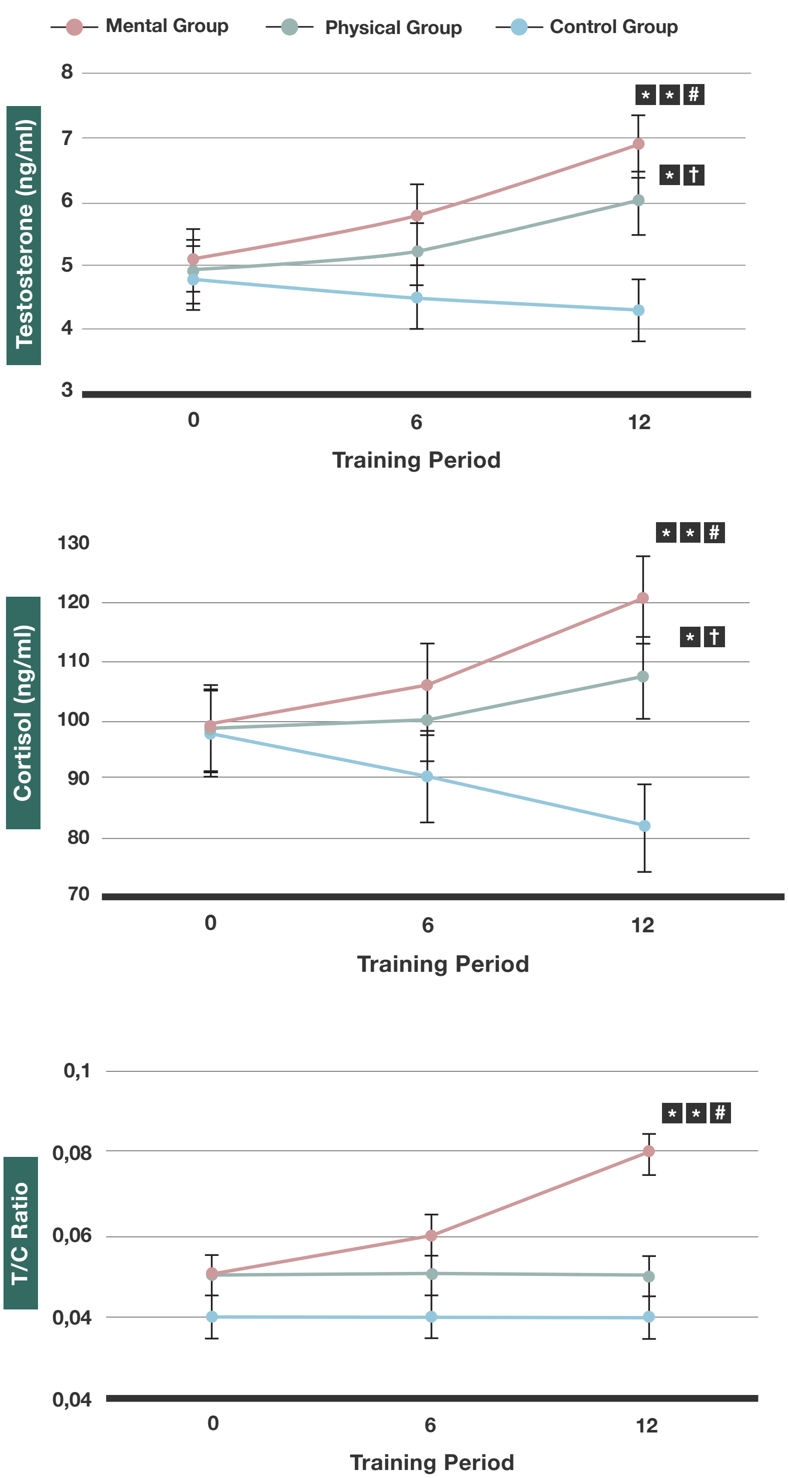
** = Medium between-group effect size; ** = Large between-group effect size*

CMJ = Counter-movement jump; MBT = Medicine ball throw

Findings

While the PT and PT-MT groups both improved significantly ($p<0.05$) in all measures of performance, improvements were larger in the PT-MT group across the board. Performance decreased non-significantly in the control group. The statistical tests reported didn't check to see if gains were significantly different, strangely (i.e. they reported that relative bench press was higher post-training for the PT-MT group than the PT group, but I don't think they ran tests to see if the actual increase itself was larger). However, between-group effect sizes can be seen in Figure 1.

Figure 2 Mean ± SD Values for Resting Testosterone, Cortisol Concentrations and T/C Ratio During 12-weeks of Mental Training in Male Trained Kickboxers



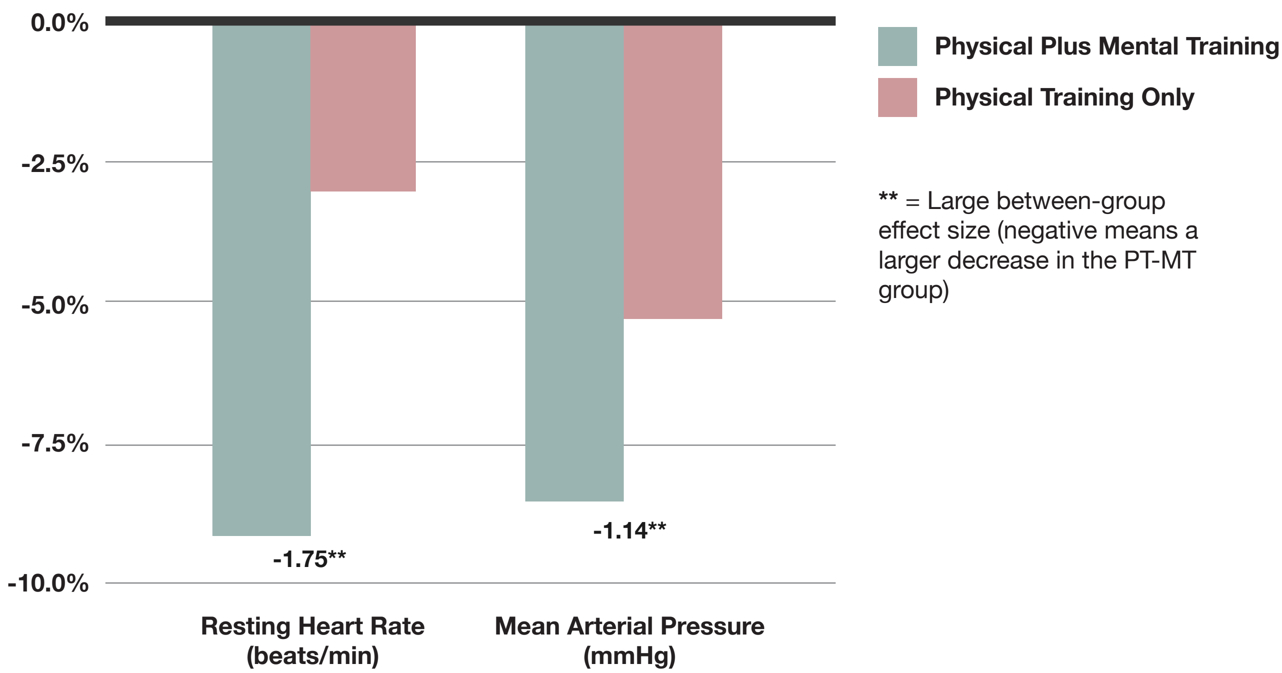
** = Significant difference at post-training compared with pre-training at $p < 0.05$; ** = Significant difference at post-training compared with pre-training at $p < 0.001$; # = Higher values for the mental group at post-training compared to physical and control groups at $p < 0.05$; † = Higher values for the physical group at post-training compared to the control group at $p < 0.05$*

When looking at the hormonal data, I think the authors had reporting issues. For testosterone, the authors report in the results section and in their figure that testosterone concentrations increased in both the PT and PT-MT groups, and they don't mention a significant change in the control group. So far, so good.

For cortisol, the authors report in the results section that cortisol was higher post-training in the PT-MT group than the PT or control groups. However, that doesn't match their figure, which shows significant increases in the PT and control groups and a non-significant decrease in the PT-MT group. In the discussion section, the authors report a decrease in cortisol in the PT-MT group.

Finally, for T:C ratio, the authors report that T:C ratio was higher post-training for the PT-MT group than the PT and control groups. That seems to indicate that the authors simply misstated the cortisol data in their results section, but correctly reported it in on their graphs and in their discussion (as a decrease in cortisol would increase T:C ratio). However, if we assume the graphs for testosterone and cortisol are accurate, we run into another problem with the T:C graph. Testosterone concentrations decreased non-significantly for the control group on the graphs, while cortisol levels increased sig-

Figure 3 Physical Plus Mental Training and Physical Training Only



*** = Large between-group effect size (negative means a larger decrease in the PT-MT group)*

nificantly. That would necessarily mean that T:C ratio would decrease over the course of the study. However, the T:C graph shows unchanged T:C ratios for the control group.

It's impossible to square this circle given the data reported. We can make the reported results for the PT and PT-MT groups add up if we assume the authors just made a typo in their results section, but even if we do that, there's no way we can wind up with a coherent picture for all three groups. As such, I'm not going to pay too much attention to the hormonal data for the rest of this review, as there seem to be unresolvable data reporting issues.

Lastly, resting heart rate and blood pressure decreased in both the PT and PT-MT groups, with larger decreases in the PT-MT group.

All pre- and post-training performance and physiological characteristics of the PT and PT-MT groups can be seen in Table 2.

Interpretation

The beauty of mental training is that it can increase strength gains without making it more challenging to recover from training. In fact, if you take the hormonal data reported in this study

Table 2 Results For Both Training Groups

	Physical Plus Mental Training Group	Physical Training Group
CMJ (cm)		
Pre	32.6 ± 2.6	33 ± 2.5
Post	37.9 ± 2.8	25.8 ± 2.7
MBT (m)		
Pre	4.3 ± 0.3	4.2 ± 0.3
Post	5.5 ± 0.3	4.8 ± 0.3
Bench Press (kg)		
Pre	60.2 ± 7.8	60.3 ± 7.7
Post	76.2 ± 8.7	69.8 ± 8.7
Half Squat (kg)		
Pre	89.2 ± 12.5	90.1 ± 13.4
Post	113.5 ± 14.1	104.8 ± 14.7
Resting HR (bpm)		
Pre	69.6 ± 2.5	69.7 ± 2.4
Post	63.2 ± 3.3	67.6 ± 2.8
MAP (mmHg)		
Pre	89.1 ± 2.3	90.2 ± 2.6
Post	81.5 ± 3.1	85.4 ± 3.5

at face value (which, again, may not be prudent), the mental training performed by the PT-MT group in this study may have put them in a hormonal state indicative of lower fatigue (increased T:C ratio). That's corroborated by the larger decreases in resting heart rate and blood pressure in the PT-MT group as well.

In this study, the PT-MT group performed two different types of mental training: motivational self-talk, and mental imagery.

The way they used self-talk – during rest periods to mentally prepare themselves for their next set – is something we can all implement. At the very least, it will keep you engaged and focused on your training instead of wasting time goofing off or checking Instagram. I think the way they determined the self-talk to use was instructive as well: the participants identified negative self-talk they already had and turned it around to make it positive. That shifts the focus from your perceived shortcomings to your ability to overcome those shortcomings. For example, if your speed off the floor is slow when deadlifting, you'll be in a much better mental space if you focus more on overcoming that issue ("I can pull these reps faster off the floor") rather than simply dwelling on it in a negative light ("well, my deadlifts are always slow, so I'm sure this next set will be slow too").

The way mental imagery was used in this study, on the other hand (for 30 minutes post-training), may be less convenient for most people to implement. I'd assume most people don't want to hang around the gym for another half hour when they're done training to do visualization exercises. However, I doubt that the timing of your mental imagery is crucially important. Furthermore, if self-talk (especially through the entire duration of a rest period) feels hokey to you, you could perform your mental imagery between sets as well. In a prior study, for example, people doing visualization exercises between their training sets gained more strength on the leg press than people not performing visualization exercises between sets (2).

THE BEAUTY OF MENTAL TRAINING IS THAT IT CAN INCREASE STRENGTH GAINS WITHOUT MAKING IT MORE CHALLENGING TO RECOVER FROM TRAINING.

The most effective form of imagery tends to be the first-person style used in this study (looking through your own eyes as you imagine the task, rather than observing yourself performing the task from a third-person point of view) (3). Furthermore, the more details you can evoke from the experience – the bar digging into your hands, the feeling of your muscles straining against the load, the music you listen to when you train, etc. – the more effective your mental imagery training will be. If the details of using mental imagery to enhance performance interest you, I'd highly recommend this review (4). The nitty gritty details are outside the purview of this article, but the linked review is very well-written.

APPLICATION AND TAKEAWAYS

Adding mental training to your current program will likely boost your strength gains and may even decrease markers of physiological stress. Positive self-talk and first person kinesthetic mental imagery absolutely don't replace slinging around heavy iron, obviously, but they can help you get larger gains from your training program.

Next Steps

One drawback of this study was that it was performed on people who were prescreened to have at least moderate mental imagery ability. It would be interesting for future studies to address 1) the degree to which that skill is trainable and 2) the relationship between mental imagery ability and the additive strength benefits one can expect from mental training.

Furthermore, while this study used participants with some degree of training experience, they were far from elite lifters. Future studies should determine the degree to which high-level lifters benefit from added mental training.

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Assistance Work in Periodization and Loading Options

BY MICHAEL C. ZOURDOS

Assistance work can be programmed in a myriad of ways, but how does it follow within the periodized construct, and what are the various loading options? This video lays out some strategies and allows you to get inventive with assistance work prescription.

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Real-World Effects of Low Carbohydrate, High Fat Diets in Strength Athletes

BY ERIC HELMS

The debates on low carb diets are dizzying at times, and useful information is often lost in the confusion. In this video, Eric details the outcomes of a low carb, high fat diet case study on powerlifters and weightlifters that cuts through the noise.

Click to watch Eric's presentation.

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