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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.

Greg Nuckols

Greg Nuckols has over a decade of experience under the bar and a B.S. in exercise and sports science. Greg is currently enrolled in the exercise science M.A. program at the University of North Carolina at Chapel Hill. He's held three all-time world records in powerlifting in the 220lb and 242lb classes. He's trained hundreds of athletes and regular folks, both online and in-person. He's written for many of the major magazines and websites in the fitness industry, including Men's Health, Men's Fitness, Muscle & Fitness, Bodybuilding.com, T-Nation, and Schwarzenegger.com. Furthermore, he's had the opportunity to work with and learn from numerous record holders, champion athletes, and collegiate and professional strength and conditioning coaches through his previous job as Chief Content Director for Juggernaut Training Systems and current full-time work on StrongerByScience.com.

Michael C. Zourdos

Michael (Mike) C. Zourdos, Ph.D., CSCS, has specializations in strength and conditioning and skeletal muscle physiology. He earned his Ph.D. in exercise physiology from The Florida State University (FSU) in 2012 under the guidance of Dr. Jeong-Su Kim. Prior to attending FSU, Mike received his B.S. in exercise science from Marietta College and M.S. in applied health physiology from Salisbury University. Mike served as the head powerlifting coach of FSU's 2011 and 2012 state championship teams. He also competes as a powerlifter in the USAPL, and among his best competition lifts is a 230kg (507lbs) raw squat at a body weight of 76kg. Mike owns the company Training Revolution, LLC., where he has coached more than 100 lifters, including a USAPL open division national champion.

Letter from the Reviewers

Believe it or not, we've just entered year three of releasing MASS issues. Time certainly flies when you're having fun, and we want to once again thank you all for nerding out with us on a monthly basis.

We'll start with the videos in this issue. First, Mike drops the second Q&A video based upon your questions. This Q&A specifically bridges-off a question that came in response to his first Q&A video from last month. In this video, Mike covers the nuances between body part versus exercise-specific weekly training frequency for hypertrophy. If you've wondered how to balance muscle-group specific training frequency with lift-specific training frequency, this video is for you.

Likewise, Eric starts a new multi-part series on managing fatigue during contest prep. In this video, he takes a high-level look at all the factors that go into the fatigue physique athletes accumulate while dieting, and some of the often-overlooked ways they can be mitigated. He's fresh off his first successful show this season, so he's able to use some of his own experiences as an example, in addition to the experiences of the many 3DMJ clients that he and his colleagues work with.

In our written articles, we also have a lot of cool stuff to share. Greg reviews a recent meta-analysis on citrulline malate that, at least for now, answers the question of whether or not this is a worthwhile supplement to consider for MASS readers. Greg also covers a recent study that examines how the menstrual cycle affects lifting performance among female lifters. Finally, he reviews a study that dives into the factors that differentiate bench press performance among elite powerlifters of differing weight classes.

Mike reviews two interesting studies this month. The first examined whether resistance training can be used as a form of active rest to speed the time course of strength recovery, and the second study compared intuitive rest intervals and fixed rest intervals during heavy strength training, answering the question of whether you need a stopwatch in the gym.

Finally, Eric reviews a study on the effects of breakfast omission on lifting performance in trained lifters who habitually consume breakfast, and also a study on the placebo effect of supplements. In the latter, Eric uses the study to launch a meta-discussion of how psychology, personality, and expectancy can impact the use of supplements, the likelihood of experiencing a placebo effect, and long-term success among individuals seeking to improve their fitness and adopt lifestyle changes.

We think you're really going to enjoy this issue. We certainly enjoyed writing it, and we look forward to plowing ahead into year three with you all!

The MASS Team

Eric, Greg, and Mike

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Study Reviewed: Factors Underlying Bench Press Performance in Elite Competitive Powerlifters. Reya et al. (2019)

What Factors are Related to Relative Bench Press Performance?

BY GREG NUCKOLS

While prior research has examined factors related to absolute bench press strength, few studies have looked at factors related to relative strength. A recent study fills in that gap, examining structural, technical, and neuromuscular factors.

KEY POINTS

1. Proxies for muscle size (lean mass and arm circumferences) seemed to be most strongly associated with relative bench press strength (Wilks score).
2. Isolated joint torques were also significantly associated with relative bench press strength, whereas technical factors (arch height, leg drive force, horizontal displacement, etc.) weren't. Having relatively long humeri was negatively associated with relative bench press performance.
3. We need to be a little skeptical of some of these associations, as Wilks scores are likely biased in favor of heavier lifters.

The bench press is probably either your favorite lift (if you're a good bencher), or your most frustrating lift (if you're a bad bencher). But, if you're involved in gym culture at all, you probably care at least a little bit about how your bench stacks up against your peers.

If you're a powerlifter, you especially care about how your bench compares to other people in your weight class. While prior research has looked into the factors contributing to absolute bench press strength, the presently reviewed study (1) is the first to look at factors contributing to *relative* bench press performance, assessed in this study using Wilks scores.

The researchers assessed structural, technical, and neuromuscular factors that may be related to bench press performance. They found that proxies for muscle mass (i.e. lean mass and limb girths), isometric triceps strength, and concentric isokinetic shoulder flexion and shoulder horizontal flexion torque were most strongly associated with Wilks score.

Purpose and Research Questions

The purpose of this study was to identify the structural, technical, and neuromuscular variables most strongly associated with relative bench press performance (assessed via Wilks score) in competitive powerlifters. No research questions or hypotheses were directly stated.

Subjects and Methods

Subjects

The subjects were 13 competitive male powerlifters. With the exception of one 53-year-old subject, all participants were between 18 and 26 years old. To be included in the study, the lifters needed

Table 1 Subjects' training and competition history

	Mean (95% CI)
General strength training experience (years)	7.5 (4.9-9.9)
Powerlifting specific training experience (years)	3.6 (1.4-5.8)
Powerlifting competition experience (years)	3.2 (1.1-5.3)
Best competition result (squat + bench + deadlift; kg)	621.9 (565.8-678)
Best competition results (Wilks points)	402.5 (365.8-439.2)
Best competition bench press result (kg)	155.0 (142.2-167.8)
Best competition bench press result (Wilks points)	99.1 (92.1-106.1)

to have a competition bench press that scored at least 90 Wilks points. Further details about the subjects can be seen in Table 1.

Study Design

The study took place over two visits per participant. The first session just included anthropometric and ultrasound measurements. The second session included all other testing (discussed below), including electromyography (EMG), 1RM bench press, kinetics and kinematics of the lift, and single-joint isometric and isokinetic strength. Researchers then examined relationships between each of these measures and the lifters' Wilks scores.

Measures

The researchers took *a lot* of measurements in this study. Most of them should be pretty self-explanatory, and they can be seen in tables below. However, it's worth a little information about some of the less common assessments.

Lean body mass and fat mass: Matiegka – These are estimates based on numerous anthropometric measurements. This probably isn't a great way to assess body composition, as it was developed in the 1920s and was largely abandoned when better methods became available.

Brugsch index – Chest circumference divided by height

Ilio-acromial index – Iliac width (hip width) divided by acromial width (shoulder width)

Brachial index – The length of the forearm divided by the length of the humerus

Voluntary activation – A ratio of how much force a muscle can contract with

Table 2 Descriptive statistics (mean and 95% confidence intervals) and correlations (*r*) between structural factors and the dependent variable (Wilks points)

Independent variable	Mean (95% CI)	Pearson's *r* (95% CI)
Lean body mass: bioimpedance (kg)	77.7 (73.6-81.8)	0.64 (0.14 to 0.86)†‡
Lean body mass: matiegka (kg)	79.4 (75.1-83.6)	0.7 (0.24 to 0.9)†
Lean body mass: ultrasound (kg)	68.9 (64.6-73.1)	0.74 (0.32 to 0.92)†
Fat mass: bioimpedance (kg)	16.1 (12.9-19.3)	-0.05 (-0.59 to 0.52)
Fat mass: matiegka (kg)	14.5 (10.6-18.4)	-0.14 (-0.64 to 0.45)
Fat mass: ultrasound (kg)	24.9 (19.1-30.8)	-0.12 (-0.63 to 0.46)
CSA triceps (mm)	119 (108-130)	0.58 (0.04 to 0.86)†
Bone mass: bioimpedance (kg)	3.8 (3.6-4)	0.65 (0.15 to 0.88)†
Forearm circumference (cm)	32.1 (30.9-33.3)	0.7 (0.24 to 0.9)†
Upper arm circumference (cm)	38.7 (37.1-40.3)	0.58 (0.04 to 0.86)†
Flexed upper arm circumference (cm)	41.3 (39.5-43.1)	0.59 (0.06 to 0.86)†‡
Chest circumference (cm)	110.7 (107.3-114.1)	0.15 (-0.44 to 0.65)
Chest depth (cm)	20.0 (18.5-21.6)	0.15 (-0.44 to 0.65)
Arm span (cm)	182.7 (178.4-187)	-0.02 (-0.57 to 0.54)
Brugsch index	0.62 (0.6-0.64)	0.32 (-0.28 to 0.74)
Ilio-acromial index	0.69 (0.67-0.72)	-0.2 (-0.68 to 0.39)
Brachial index	0.81 (0.79-0.83)	0.6 (0.07 to 0.87)†
Arm length:height index	0.45 (0.44-0.45)	-0.31 (-0.74 to 0.29)

CI = confidence interval; CSA = cross-sectional area
† = $p < 0.05$
‡ = Spearman's ρ due to non-normal distribution of data

when under conscious control, and how much force it can contract with when additionally exposed to electrical stimulation.

Findings

The findings can be seen in Tables 2-4. The structural variables significantly positively associated with Wilks score were: lean body mass, triceps CSA, bone mass, forearm circumference, upper arm circumference, and brachial index. No technical factors were significantly associated with Wilks score. The neuromuscular factors associated with Wilks score were maximal isometric elbow extension force, isokinetic concentric shoulder flexion force, isokinetic concentric shoulder horizontal flexion force, and isokinetic eccentric shoulder flexion force.

A simplified multiple regression mod-

Table 3 Descriptive statistics (mean and 95% confidence intervals) and correlations (Pearson's *r*) between technical factors (obtained at the point of minimal barbell velocity during the lifting phase) and the dependent variable

Independent variable	Mean (95% CI)	Pearson's *r* (95% CI)
Vertical bar displacement (cm)	26.7 (23.4-30)	-0.31 (-0.74 to 0.29)
Horizontal bar displacement (cm)	11.4 (8.4-14.4)	0.24 (-0.36 to 0.7)
Shoulder flexion angle (°)	43.1 (31.7-54.4)	0.49 (-0.08 to 0.82)
Shoulder abduction angle (°)	71.6 (64.9-78.2)	0.47 (-0.11 to 0.81)
Shoulder horizontal adduction angle (°)	28.4 (22.6-34.1)	0.25 (-0.35 to 0.7)
Elbow flexion angle (°)	48.7 (39.9-57.6)	-0.4 (-0.78 to 0.19)
Ground force by the feet per kg/body mass (N)	9.4 (8-10.7)	0.12 (-0.46 to 0.63)
Lumbar arch height (cm)	10.4 (8.4-12.3)	0.2 (-0.39 to 0.68)

el found that lean body mass, brachial index, and concentric isokinetic shoulder flexion force could explain 59% of the variability in Wilks score within this sample.

Interpretation

One thing makes this study really hard to interpret: as their performance metric for bench press, the authors used Wilks score rather than actual bench press 1RM. The Wilks formula was a popular formula used to normalize lifts based on the lifter's body mass in order to crown a meet's "best lifter" across all weight classes. However, it was recently replaced by a new formula, in part because Wilks scores seemed to favor heavyweight male lifters. With that being said, I don't know if Wilks scores were biased in favor of heavier lifters for the bench press specifically (since Wilks scores are generally just used for totals); a previous study (2) found that Wilks scores *weren't* biased for the bench press, but I'm very confident that the study was conducted with equipped powerlifters (i.e. benching with bench shirts). I ran a quick regression on the dataset from openpowerlifting.org, to see whether Wilks score for the bench press tended to increase as body weights increase for raw lifters in drug-tested organizations. It *did*, but the association was pretty weak (though that's to be expected, since there's a *huge* dispersal of both body weights and Wilks scores). However, when I compare the lighter lifters (75kg and below) and the heavier lifters (110kg and above), the average bench Wilks score for the heavier lifters is about 10 points higher (80.3 vs. 90.2), so it appears that Wilks is probably still biased in favor of heavier lifters for the raw bench press.

Table 4 Descriptive statistics (mean and 95% confidence intervals) and correlations (r) between neuromuscular factors and the dependent variable

Independent variable	Mean (95% CI)	Pearson's r (95% CI)
MVC elbow extension (N·m)	378.2 (342.2-414.2)	0.66 (0.17 to 0.89)†
MVC elbow extension (N·m·kg^{-1})	4.04 (3.70-4.38)	0.54 (-0.02 to 0.84)
Voluntary activation (%)	98.3 (97.2-99.4)	0.18 (-0.41 to 0.66)
Isokinetic shoulder flexion CON (N·m)	156.2 (135.2-177.1)	0.71 (0.26 to 0.91) †
Isokinetic shoulder flexion CON (N·m·kg^{-1})	1.66 (1.49-1.82)	0.64 (0.14 to 0.88) †
Isokinetic elbow extension CON (N·m)	129.7 (116.1-143.3)	0.3 (-0.3 to 0.73)
Isokinetic elbow extension CON (N·m·kg^{-1})	1.39 (1.23-1.55)	0 (-0.55 to 0.55)
Isokinetic horizontal shoulder flexion CON (N·m)	244.2 (223.5-265)	0.57 (0.03 to 0.85) †
Isokinetic horizontal shoulder flexion CON (N·m·kg^{-1})	2.61 (2.41-2.81)	0.36 (-0.24 to 0.76)
Isokinetic shoulder flexion ECC (N·m)	183.5 (160.9-206)	0.57 (0.03 to 0.85) †
Isokinetic shoulder flexion ECC (N·m·kg^{-1})	1.95 (1.77-2.12)	0.44 (-0.15 to 0.8)
Isokinetic elbow flexion ECC (N·m)	164.3 (147.3-181.3)	0.11 (-0.47 to 0.62)
Isokinetic elbow flexion ECC (N·m·kg^{-1})	1.77 (1.55-1.98)	0.15 (-0.44 to 0.65)
Isokinetic horizontal shoulder flexion ECC (N·m)	275.8 (247.6-303.9)	0.09 (-0.48 to 0.61)
Isokinetic horizontal shoulder flexion ECC (N·m·kg^{-1})	2.96 (2.64-3.28)	-0.17 (-0.42 to 0.66)
EMG pectoralis major (%)	129.1 (96.8-161.5)	-0.09 (-0.61 to 0.48)
EMG triceps brachii (%)	159.8 (139.2-180.4)	-0.17 (-0.42 to 0.66)
EMG anterior deltoid (%)	143.6 (123-164.1)	0.22 (-0.38 to 0.69)
EMG latissimus dorsi (%)	51.8 (36.7-66.9)	-0.26 (-0.71 to 0.34)
Pennation angle (°)	14.7 (13.5-15.9)	-0.46 (-0.81 to 0.12)‡
Muscle fascicle length (mm)	82.7 (70.2-93.2)	0.27 (-0.33 to 0.71)

CI = confidence interval; MVC = maximal voluntary contraction; EMG = electromyography
† = $p < 0.05$
‡ = Spearman's ρ due to non-normal distribution of data

The aim of the study wasn't necessarily to see what factors contribute to making someone a *stronger* bencher; it was to see what factors are associated with being a better, more competitive bencher. That's important for two reasons:

1. If Wilks *is* biased in favor of heavier lifters for the bench press, that will color our interpretation of the results
2. We should expect the associations in this study to be weaker than those seen in previous research.

The first point should be fairly obvious. If bigger people tend to be stronger in an absolute sense, and if Wilks tends to favor heavier lifters, then it should come as no surprise that other measures of strength (i.e. isometric and isokinetic torques) are positively associated with Wilks scores. However, that doesn't necessarily mean that those relationships would still hold if the authors instead used the new, less biased formula (IPF points). The second point may be less obvious, but it should make more sense if we think through it for a moment. If person A has 15kg more lean body mass than person B, person A is VERY likely to out-bench person B, even if person B is a very skilled bencher, especially if person A is also a powerlifter. You simply don't see many 75kg lifters out-benching similarly well-trained 90kg lifters. However, person A may have more fat than person B, or just not be as skilled of a bencher, so person B could still have a higher Wilks score. Thus, it's obvious that larger, stronger lifters tend to bench more than smaller, weaker lifters, and that you should anticipate a strong association between muscle/strength measures and absolute bench press performance; however, the potential bias of Wilks scores notwithstanding, it's less obvious that larger, stronger lifters are *better, more competitive benchers*, so using a formula to normalize for body size is likely to decrease the strength of the associations.

The first point is important, because *most* of the factors associated with Wilks scores in this study (lean body mass, bone mass, limb circumferences, and measures of single-joint strength) would also be associated with the subjects' weight. Larger lifters will tend to have more lean body mass, larger muscles, and greater absolute strength; if those things are associated with body mass, *and* Wilks is independently associated with body mass, all of those associations may just be influenced by a clear confounder behind the scenes. However, it may also be that the heavier lifters were *also* just the best lifters in this sample, and their greater lean body mass is reflective of a longer training career, smarter training, and a better genetic draw for building muscle and getting stronger. If skill as

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TAKING A BIG PICTURE VIEW OF THESE RESULTS, IT WOULD APPEAR THAT YOUR BEST BET IF YOU WANT TO IMPROVE RELATIVE PERFORMANCE IN THE BENCH PRESS IS TO GAIN MUSCLE.

a bencher is *also* associated with body mass, then you've got two competing confounders behind the scenes, and interpretation just becomes a mess.

The second point is important, just to make sure we don't see the results of this study as a huge departure from the previously published literature. In prior research on highly trained strength athletes, various measures or proxies of muscle mass have been very strongly (r>0.8, and often 0.9+) associated with absolute 1RM strength (3, 4). The strongest association in this study is between Wilks score and lean body mass (assessed via ultrasound), but the r-value was still only 0.74, meaning variations in lean body mass only explain about half of the variation in Wilks score (r^2 = 0.55). We know that muscle mass is very strongly associated with *absolute* strength in trained populations; I just don't want you coming away from this study thinking that the relationship is considerably weaker than it actually is.

So, with all of that being said, I think that it's borderline impossible to interpret the significant associations; we don't know how the measures in this study relate to absolute strength, and it's likely that the formula they used to normalize performance across body weights was biased (at least a bit) in favor of the heavier lifters.

However, the interesting results are the associations that *weren't* significant. Arm length and chest circumference, even when normalized to height, weren't associated with Wilks score. Nor were arch height, leg drive force, or bench stroke length (vertical bar displacement). That doesn't necessarily mean that none of those things matter – it just means they're not predictive of Wilks score in a systematic way. For example, Eddie Berglund's huge arch may help him bench more, but in general, if all you know about two people is their arch height, that information wouldn't be very useful for predicting which person will have the higher Wilks score. In terms of isokinetic variables, concentric shoulder flexion and shoulder horizontal torque were significantly associated with Wilks score, but concentric elbow extension torque wasn't. This *may* suggest that pec and anterior delt strength are

APPLICATION AND TAKEAWAYS

Since technical factors weren't related to Wilks score, that suggests that lifters can be successful with an array of different bench techniques. However, the best predictor of relative performance seems to be jacked-ness. If your bench has stalled, you could probably benefit from dedicated hypertrophy work.

more important for bench press performance than triceps strength, though we obviously can't draw causal inferences from cross-sectional research. However, isometric elbow extension torque was significantly associated with Wilks score; since bench press clearly isn't an isometric exercise, I would think that isokinetic measurements would be more closely associated with bench press performance than isometric measurements.

Taking a big picture view of these results, it would appear that your best bet if you want to improve relative performance in the bench press is to gain muscle. Since Wilks may be biased in favor of heavier lifters, and since the sample in this study included only male lifters, I also wanted to see if the relationship between lean mass and relative bench press performance held true in female lifters, and when using a less biased formula. As luck would have it, I just finished up data collection for my thesis, which included bench press 1RM and arm lean mass measurements (assessed via DEXA) in 20 trained men and 20 trained women. Since this isn't one of my primary outcomes, I feel comfortable sharing these results: the relationship between arm lean mass and IPF points for both men and women is similar to the relationship between lean mass and Wilks points in this study (r = 0.65 for men, and r = 0.72 for women). And if you're curious about the relationship between arm lean mass and absolute strength (bench press 1RM), the relationship is even stronger (r = 0.81 for both men and women independently, and 0.91 for the entire sample). So, it's clear that people with more arm lean mass bench more, and bench more relative to their weight; thus, it's most likely the case that your best bet for increasing your bench (assuming technique is ironed out) in the long run is to gain muscle.

Next Steps

I'd really like to re-analyze the data from this study using IPF points (or my personal favorite method of normalizing performance – allometric scaling) to make sure the relationships were legit and not potentially an artifact of the Wilks formula being biased. To reiterate, the bias isn't particularly large, so I don't *think* the choice of Wilks as their scaling formula substantially impacted the results, but I'd feel a little better about them if another formula was used.

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Study Reviewed: Upper-Body Resistance Exercise Reduces Time to Recover After a High-Volume Bench Press Protocol in Resistance-Trained Men. Bartolomei et al. (2019)

Should You Train to Recover?

BY MICHAEL C. ZOURDOS

So you're beat up from yesterday's tough training session? Cool, just rest today. On second thought, maybe you should actually train again to recover faster. This study shows that light training of the damaged muscle group can aid recovery.

KEY POINTS

1. This study had trained men perform 8 sets of 10 on bench press at 70% of 1RM. One group of those men then performed 6 sets of 10 at 10% of 1RM at 6 and 30 hours post-training, while another group just rested.
2. Recovery was measured at 15 minutes, 24 hours, and 48 hours post-training, and some indices of fatigue recovered more quickly in the light training group compared to the just-resting group.
3. We are a long way from stating that training in the recovery period is an amazing recovery strategy, but it is a practical one, as training at 10% of 1RM is quite easy and takes little time. Although the recovery benefit in this study was not large, it may be enough to give this practical strategy a shot.

What do you use for recovery? The common responses might be: foam rolling, walking, low-intensity cycling, massage, cryotherapy, cold water immersion, or simply resting. But, have you considered training again for recovery? This study (1) had 25 trained men perform 8 sets of 10 at 70% of one-repetition maximum (1RM) on the bench press, then had indices of recovery (strength, power, muscle thickness, and soreness) tested at 15 minutes, 24 hours, and 48 hours post-exercise. 11 of the men simply rested between the training session and the recovery test periods. The other 14 men performed active recovery at 6 and 30 hours post-exercise, which consisted of 6 sets of 10 on the bench press at 10% of 1RM. The results tended to show faster recovery in the active rest (i.e. light training) group compared to just resting for the power and swelling measurements. So, it is possible that performing really light training in a fatigued state can enhance recovery. This article will discuss the practicality of this recovery strategy and examine why light training may work.

Purpose and Research Questions

Purpose

The purpose of this study was to examine if training the fatigued muscle group in the days following a damaging training session can speed recovery versus simply resting.

Hypotheses

The authors hypothesized that performing the bench press with a really light load in the first two days after a

Table 1 Subject characteristics

Group	Subjects	Age (years)	Body mass (kg)	Height (cm)	Bench press 1RM (kg)	Relative bench press 1RM (kg·BM^{-1})
Active Recovery	11 men	25.7 ± 4.0	86.0 ± 10.5	177.7 ± 5.4	115.2 ± 14.1	1.3 ± 0.2
Resting	14 men	25.7 ± 3.4	88.0 ± 13.5	177.1 ± 4.7	113.0 ± 18.0	1.3 ± 0.2

Data are mean ± SD
Subject characteristics from Bartolomei et al. 2019 (1).

damaging bench press workout would speed recovery compared to simply resting.

Subjects and Methods

Subjects

25 young men with a training experience of 6.5 ± 3.1 years and an average training frequency of at least three times per week participated. The available subject details are in Table 1.

Protocol

Subjects came to the lab four times. The first visit tested their free-weight barbell bench press 1RM. For the second visit, the researchers assessed all recovery outcome measures (isometric bench press strength, muscle thickness, bench press throw power, and soreness, as shown in Table 2) prior to exercise. Subjects performed the damaging exercise (8 sets of 10 at 70% of 1RM with 75 seconds between sets), then all recovery outcome measures were tested again 15 minutes after training. Next, subjects came back to the lab at 24 (visit 3) and 48 hours (visit 4) following training to have outcome measures tested again. The only difference in protocols between the active-recovery group and the resting group is that the 11 subjects in the active-recovery group were asked to perform 6 sets of 10 reps at 10% of 1RM on the bench press 6 and 30 hours following the 8X10 session. A limitation of this study is that the light benches in

Table 2 Recovery outcome measures

Muscle soreness	Soreness of the chest and triceps
Isometric bench press force	Obtained using 50% of 1RM on the Smith Machine bench press
Bench press throw power	Obtained using 50% of 1RM on the Smith Machine bench press
Swelling	Muscle thickness via ultrasound

Although the bench press force and power tests were performed on a Smith Machine the actual training protocol used a free weight barbell bench press

Table 3 Recovery outcome measures findings

Measure	Result	Difference between groups
Muscle soreness	Both Chest and triceps soreness were still elevated at 48 hours in both groups	No
Isometric bench press force	Decreased at 15 min and 24 hours in rest group, only decreased at 15 min in active recovery group	No
Bench press throw power	Decreased at 15 min and 24 hours in rest group, only decreased at 15 min in active recovery group	Yes
Chest swelling	Chest swelling was elevated at 15 min, 24, and 48 hours in the rest group, but only elevated at 15 min in the active recovery group	Yes
Triceps swelling	A main time effect (i.e. overall increase, but no increase at a specific time point) in both groups, but at 24 hours triceps swelling had clearly recovered	No

the active recovery group were *not* performed in the lab; rather, the subjects were just asked to do it on their own.

Findings

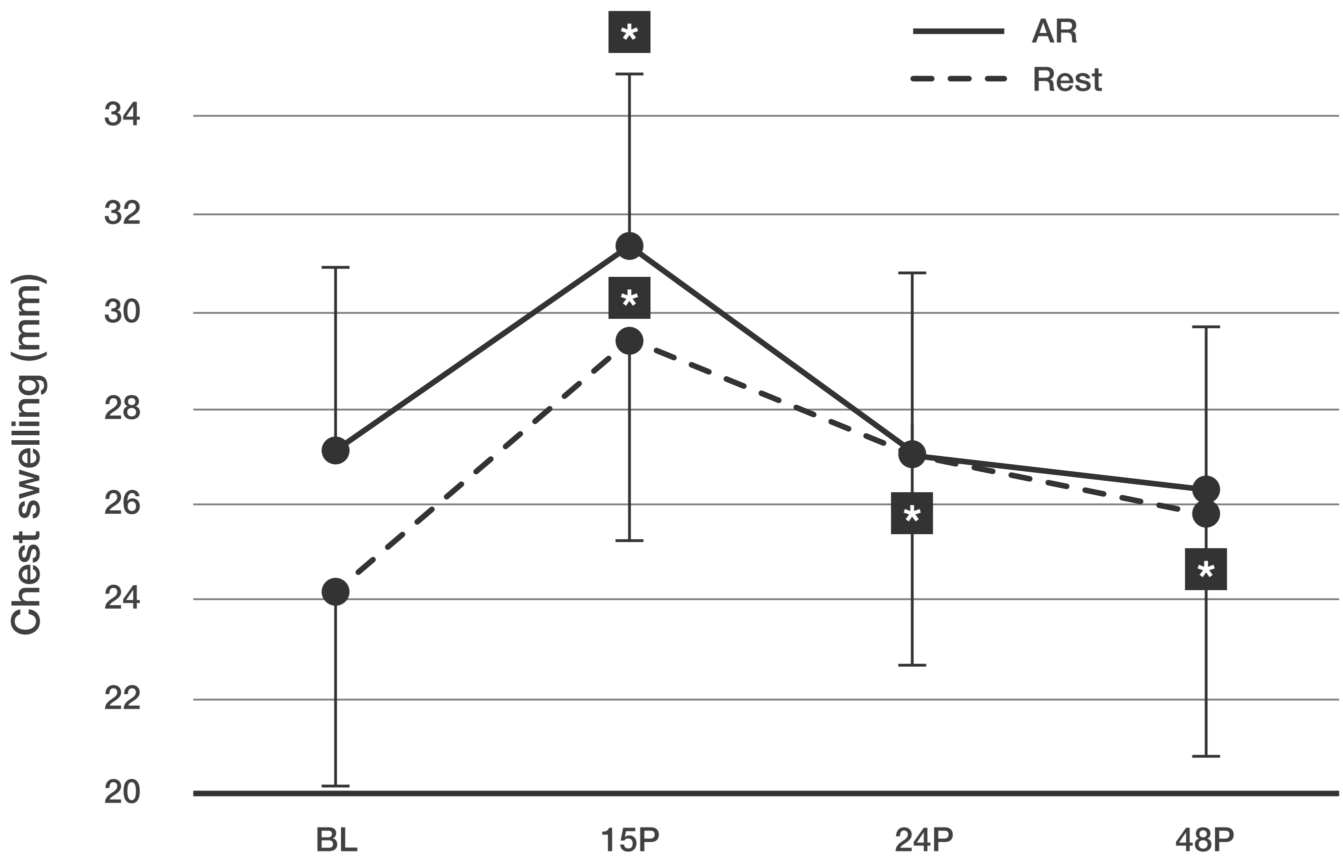
Overall, some measures recovered more quickly in the active recovery group, and there were group differences for two measures (power and chest swelling). So, performing light bench presses within the first two days after a damaging bench press session seemed to provide quicker recovery in some measures; however, the findings are not overwhelmingly convincing. The findings are summarized in Table 3, and a graph of the chest swelling results is in Figure 1.

Interpretation

The premise behind a lot of practical recovery strategies is to increase blood flow to the damaged muscle while not causing any additional muscle damage. Most common recovery strategies such as massage, foam rolling, low-intensity walking or cycling accomplish this task. Among these methods, massage actually seems to be the most effective (2) at accelerating recovery, as previously written about by Greg. Although it may initially seem counterintuitive to directly train a muscle during the recovery period, training that muscle with only 10% of 1RM is pretty consistent with the premise of increasing blood flow and not causing additional damage. So, what is really different about training a muscle really light versus using one of the more traditional recovery modes mentioned above? Not much.

Based on the present results (1), there's a potential benefit to training the same exercise to recover from that exercise, but it's not overwhelming. Much of the recovery literature shows modalities don't confer a huge recovery benefit, or there are feasibility limitations which limit their application. Foam rolling, for

Figure 1 Time course recovery of chest swelling



** = Significantly elevated compared to BL (Baseline); P = Post-Exercise; AR = Active Rest Group*
Data are mean ± SD.

example, does have some benefit, but it seems to be quite small (3). Although massage, if performed right after training, has a clear benefit to alleviate soreness (2), it can be expensive to continually get massages. Compression garments are also beneficial for soreness (2) and may provide a potential performance benefit (4) but can be cumbersome to wear for long periods of time. Due to the practical limitations of massage and compression garments, foam rolling, low-intensity walking, and light training can be attractive. Of those three options, light training might be the best way to target the upper body for recovery.

If you are training another exercise the day after you bench press, then it would be pretty easy to do sets of 10 at 10% on the bench while you are already at the gym. You could easily superset the light training with something else or just knock it out at the end of your workout. On the other hand, while something like cold-water immersion (read more) may have some benefit (2, 5), it is impractical for most and probably shouldn't be used all the time anyway due to attenuating anabolic signaling when used frequently (6). Besides, 10% is really light. It is benching exactly the bar for a 200kg bencher. So, if you can barbell bench less than 200kg, you would in fact be using really light dumbbells to get to an equivalent of 10%. I don't think the load has to be as low as 10%; most people could probably just use the bar unless your working weight is fairly close to the bar. It's also probably not necessary to use 10 reps; someone could probably do the bar for sets of 5 reps. The main point is that really light training can be done quickly and practically and with little effort and possibly confer a recovery benefit.

I don't want the above paragraph to sound like I am shilling for performing light training as a recovery modality, as I don't think the present results are that impressive. I just don't think recovery modalities as a whole are overly impressive (at least the really practical ones). So, if you can take just a few minutes and perform some really light bench reps (or whatever exercise you are recovering from) while you are at the gym, this takes little effort. Overall, it's more important to structure daily volume appropriately. In other words, if you always feel that you need some sort of magic in

REALLY LIGHT TRAINING CAN BE DONE QUICKLY AND PRACTICALLY AND WITH LITTLE EFFORT AND POSSIBLY CONFER A RECOVERY BENEFIT.

the recovery period, then it's likely that you should trim your daily volume to allow you to recover more quickly, which may actually enhance your weekly training volume and frequency as we've covered before.

In summary, light training did cause swelling of the chest, isometric strength, and power production to recover more quickly than simply resting. However, we don't yet know if light training has an effect on recovery of dynamic strength (i.e. actual bench press performance). Further, a point against light training is that it did not aid soreness in the reviewed study. So, just as foam rolling isn't a standalone recovery modality, light training probably isn't either. However, I would stay tuned on this one, as I suspect more studies will come out on this in the near future since it's a new topic, the method is practical, and the mechanism (blood flow) makes sense.

APPLICATION AND TAKEAWAYS

1. Trained men who bench pressed with only 10% of 1RM in the two days following a hard bench workout recovered more quickly than men who just rested.
2. Although light training potentially aids recovery, the benefit in this study seemed to be small, and it is the first study to show this effect. We should be on the lookout for future research in this area.
3. Despite the recovery benefit of light training only being small, we should consider the practicality of this method. There is potential gain for very little effort. Performing an exercise for a few sets of 10 at only 10% is really easy and could be done if you are already at the gym training another muscle group. So while we don't want to overstate the benefits, this is probably worth a try as long as you are not so fatigued that performing light training would risk injury.

Next Steps

First, I'd like to see replication of this study. The next questions would be: Does light training work on the lower body (i.e. squats) as a recovery modality? Do other volumes and intensities have an effect similar to 6X10 at 10%? Also, how long following damaging training should light training be performed if recovery is the goal? The presently reviewed study used light training and assessed recovery at 6 and 30 hours post-exercise, but we don't yet know how that protocol would compare to others. Lastly, the effectiveness of light training for recovery may depend on the individual and the magnitude of damage incurred in the original training session. There are lots of questions to be explored in this new area of research.

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Study Reviewed: Breakfast Omission Reduces Subsequent Resistance Exercise Performance. de Bin Naharudin et al. (2019)

Breakfast, the Most Important Meal of the Day ... for Gains?

BY ERIC HELMS

It's generally accepted that eating a pre-training meal, at least in a non-dieted state, doesn't improve lifting performance on average. However, after an overnight fast, especially in habitual consumers of breakfast, eating before training may meaningfully improve performance.

KEY POINTS

1. Male, resistance-trained, habitual breakfast consumers completed four sets of squats and four sets of bench press to failure in a crossover design two hours after either consuming breakfast or just drinking water. In the water-only group, significantly fewer repetitions were performed overall for both exercises, and during sets one and two.
2. While there are other data showing that pre-resistance training feeding may not improve performance, skipping breakfast may reduce resistance training volume after an overnight fast – especially in habitual consumers of breakfast.
3. While the mechanisms driving these differences were not measured, it is likely a combination of slightly higher muscle glycogen levels – considering more reps were performed only in sets one and two – and primarily, other factors such as blood glucose stability due to liver glycogen depletion and central fatigue mediated by low glycogen.

There are mixed data regarding whether or not lifting performance can be reliably improved by consuming carbohydrates before training. The present study (1) adds another piece to this puzzle by comparing breakfast omission to high carbohydrate breakfast consumption prior to resistance training in trained males who were habitual breakfast consumers. In this crossover trial, the participants either drank only water or had a high carbohydrate breakfast two hours prior to performing four sets to failure on the squat and bench press using their 10RM on each set. Both appetite and performance were measured, and unsurprisingly, appetite was predictably higher during the water-only condition. However, less predictably (given the mixed data in the broader literature), more total repetitions were performed during the breakfast consumption condition on both the bench press and squat, which was largely driven by differences in sets one and two between conditions for both exercises. Why have so many previous studies on pre-exercise carbohydrate reported non-significant effects on lifting performance while this one shows an effect? Also, what mechanisms might be driving this outcome, and how should they influence practical application? In the following article, I'll do my best to answer these questions.

Purpose and Research Questions

Purpose

Table 1 Macronutrient, energy, and water intake during each trial*†

	Breakfast meal	
	BO	BC
Protein (g)	0 ± 0	14.7 ± 1.4
Carbohydrate (g)	0 ± 0	116.3 ± 10.7
Fat (g)	0 ± 0	8.4 ± 0.8
Fiber (g)	0 ± 0	3.8 ± 0.4
Energy (kcal)	0 ± 0	600 ± 55
Water (ml)	514 ± 72	514 ± 72

**BO = breakfast omission; BC = breakfast consumption*
† = values are mean ± SD, n = 16

The purpose of this study was to determine if a high-carbohydrate breakfast two hours prior to training impacted reps performed during 4 sets of 10 to failure on the squat and bench press in trained males who habitually consume breakfast.

Hypothesis

The authors hypothesized that performance would be better with breakfast consumption versus without eating breakfast.

Subjects and Methods

Subjects

Sixteen resistance trained men participated in this study (age 23 ± 4 years, body mass: 77.56 ± 7.13 kg, height: 1.75 ± 0.04 m, and body mass index: 25.3 ± 2.3 kg/m^2). The participants were required to be habitually consuming breakfast at least three times per week and performing resistance training at least twice per week for at least the last two years. Their training must have included the bench press and back squat.

Study Design and Assessments

This study was performed as a crossover, meaning all volunteers participated in both conditions in a randomized order. The participants had their 10RM tested on the squat and bench 48 hours prior to each phase of the crossover. Additionally, their habitual diets and activity were recorded so that they could be replicated for whichever phase they did second. In one phase of the crossover, the participants consumed a standardized breakfast consisting of rice cereal, milk, bread, butter, jam, and orange juice, providing 20% of their estimated caloric intake and 1.5g of carbohydrate/kg body mass (details shown in Table 1). Then, two hours later, they performed four sets of back squat and bench press to failure with their 10RM load. In the other phase of the crossover, they performed the same training two hours after drinking only water.

Breakfast or water was consumed by each participant at their time of habitual breakfast consumption. Using a visual analogue scale (a horizontal line of 1-100 mm that they point to), they rated their hunger, fullness, desire to eat, and predicted food consumption immediately prior, immediately after, one hour after, and two hours after drinking water or eating breakfast.

Two hours after water or breakfast, training commenced following a standardized cycling and barbell warm up. Bench press was performed with a full range of motion such that the bar touched the chest and the elbows locked out on each rep, and squats were performed until the thighs were parallel to the ground (just a bit higher than powerlifting legal depth). Three-minute rest intervals were administered between sets, and the investigators ensured all sets were taken to failure.

Table 2 Subjects' appetite sensations of hunger, fullness, desire to eat (DTE), and prospective food consumption (PFC)*†

Appetite sensation	BO	BC
Hunger (mm)		
Pre-meal	62 ± 17	51 ± 20
Post-meal	63 ± 20‡	12 ± 9§
1 hour after meal	72 ± 17‡	31 ± 19§
2 hours after meal	78 ± 15‡§	45 ± 27
Fullness (mm)		
Pre-meal	25 ± 21	30 ± 18
Post-meal	44 ± 23‡§	81 ± 10§
1 hour after meal	24 ± 15‡	62 ± 17§
2 hours after meal	19 ± 14‡	45 ± 22§
DTE (mm)		
Pre-meal	67 ± 11	61 ± 19
Post-meal	65 ± 20‡	18 ± 18§
1 hour after meal	76 ± 18‡	39 ± 23§
2 hours after meal	79 ± 17‡§	49 ± 25§
PFC (mm)		
Pre-meal	65 ± 18	63 ± 20
Post-meal	64 ± 18‡	25 ± 19§
1 hour after meal	76 ± 18‡	45 ± 20§
2 hours after meal	79 ± 13‡	54 ± 23

**BO = breakfast omission; BC = breakfast consumption*
† = values are mean ± SD, n = 16; ‡ = significantly different from BC;
§ = significantly differetn compared with a pre-meal

Findings

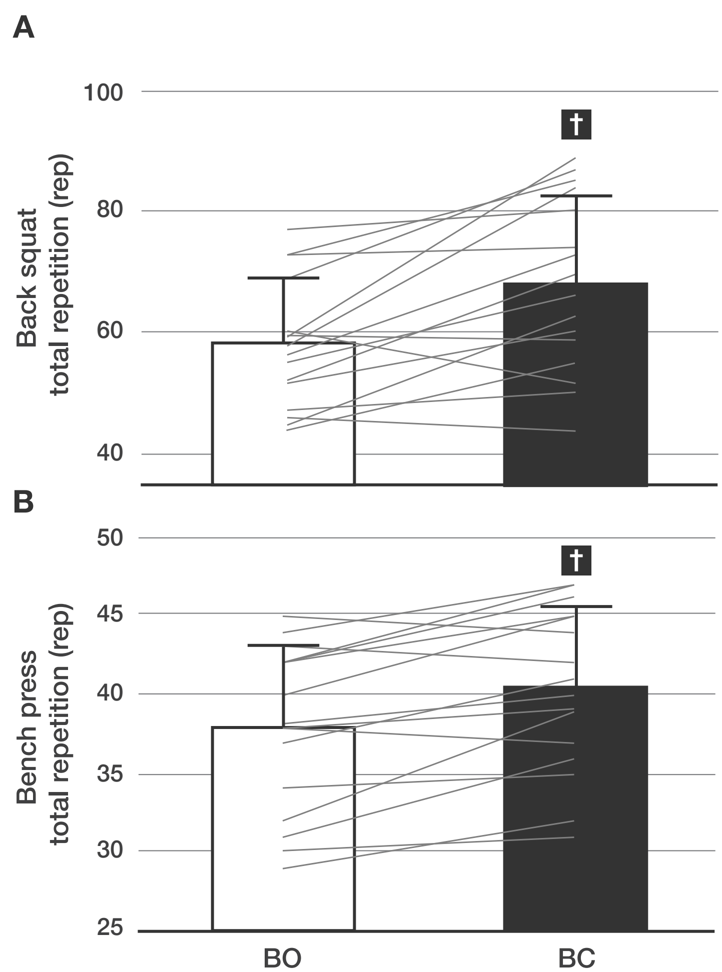
Appetite

During the breakfast omission condition, the participants were significantly hungrier at all time points compared to after eating breakfast (Table 2). Likewise, during the breakfast consumption condition, the participants were fuller, had a lower desire to eat, and predicted they would eat less food later in the day at all time points after eating, compared to when only drinking water. Additionally, during the omission phase, the participants felt significantly fuller immediately after drinking water, but had no less desire to eat, felt no less hungry, and their predictions of how much food they would eat later in the day did not decrease. By the two hour post-water time point, the participants were significantly hungrier during breakfast omission and had a significantly higher desire to eat compared to before drinking water. Finally, during the breakfast consumption condition, compared to before eating, the participants reported lower hunger levels and predicted they would eat less food later in the day right after and an hour after eating. They were fuller and had a lower desire to eat all the way up to the two-hour mark after breakfast was consumed.

Performance

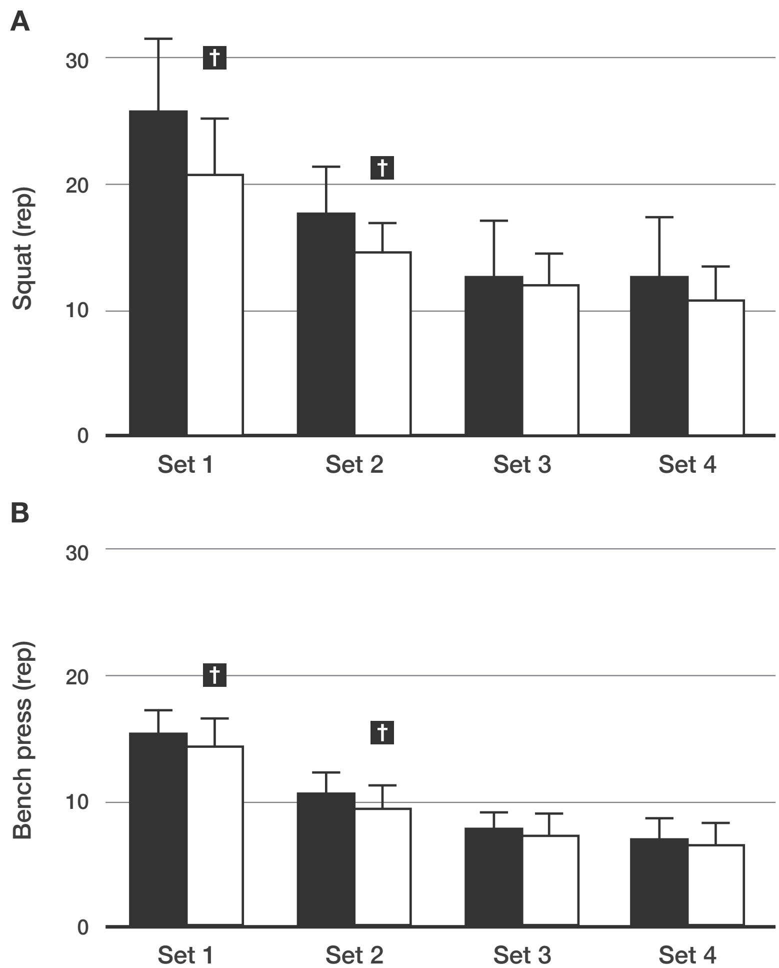
Figure 1 shows the total repetition differences between groups for the bench press and squat with individuals represented by lines. Overall, the subjects completed significantly more repetitions for both exercises in the breakfast consumption condition. Specifically, the breakfast omission condition performed 15% fewer or ~10 fewer reps in total over the four sets of squats (breakfast omission: 58 ± 11 repetitions vs. breakfast consumption: 68 ± 14 repetitions; between-group effect size = 0.98; $p < 0.001$). Similarly, the breakfast omission condition performed 6% fewer or ~3 fewer reps in total over the four sets of bench press (breakfast omission: 38 ± 5 repetitions vs. breakfast consumption: 40 ± 5 repetitions; between-group effect size = 1.06; $p < 0.001$). As a side note: Using the standard effect size formula, the effect sizes were 0.79 and 0.4 for squat and bench press, respectively

Figure 1 Total repetitions over the 4 sets for the back squat (A) and bench press (B)



Bars are mean values, vertical error bars represent SD, and lines represent individual subject data, n=16.
† = Significantly different from BC ($p < 0.05$); BO = breakfast omission; BC = breakfast consumption

Figure 2 Repetitions performed in each set for back squat (A) and bench press (B)



Bars are mean values, and vertical error bars represent SD, n=16.
† = Significantly different from BC ($p < 0.05$); BC = breakfast consumption

(they used the standard deviation of the change score versus pre-test mean). This changes the results only slightly such that the effects would be classified as moderate and small for squat and bench press rep differences, rather than large in both cases (and actually just shy of large and moderate, respectively).

These differences between conditions in total reps performed were largely driven by differences in the first two sets of both squats and bench presses. More reps were performed in sets one and two during the breakfast consumption condition, as shown in Figure 2.

Interpretation

This isn't the first time we've covered carbohydrates in MASS. For the most part, our articles center on chronic intakes of carbohydrate and longitudinal effects on performance, hypertrophy, and fat loss (check out Cliff Harvey's guest article on low-carb diets here and my article on "keto gaining" here). However, this study is specific to the acute effects of consuming or skipping a high carbohydrate breakfast on lifting performance in habitual breakfast consumers. While the results are pretty straightforward – 1) habitual breakfast consumers are hungrier when they don't eat breakfast and 2) can't perform as many reps per set – the second finding is actually not the norm. For example, in a classic crossover trial by Mitchell and colleagues back in 1997, the participants did a quadriceps glycogen-depleting cycling session, then for the 48 hours following, consumed matched-calorie diets consisting of either 0.37g/kg of carbohydrate (that's just under 40g of carbs per day for someone who weighs 220lb), or 7.7g/kg of carbohydrate (just under 800g for the same 220lb person). Following the 48 hours of low or high carbohydrate intakes, the participants performed 5 sets with 15RM loads to failure on the squat, leg press, and leg extension (2). Based on what was known at the time, the authors hypothesized that the participants would perform worse during the low carbohydrate condition, as they believed the participants couldn't have replenished their muscle glycogen. To the authors' surprise, there were no significant differences in the volume load or repetitions performed between conditions.

THE BODY IS REMARKABLY ADEPT AT MAINTAINING MUSCLE GLYCOGEN LEVELS AT WHAT IT DEEMS ACCEPTABLE LEVELS.

Today, from more recent research (3), we know the body is remarkably adept at maintaining muscle glycogen levels at what it deems acceptable levels. Athletes consuming ample calories maintain muscle glycogen levels between 100-150 mmol/kg. When muscle glycogen levels are low (below ~70mmol/kg), not only is endurance performance inhibited, but so is muscle force and power, as calcium release from the sarcoplasmic reticulum becomes impaired (4). However, the mistake researchers made in prior decades was *assuming* muscle glycogen was depleted following low carbohydrate protocols, without actually measuring it. Believe it or not, even in a fasted state, glycogen levels recover at a rate of 1.3 to 11.1 mmol/kg/hr depending on the type of exercise that caused depletion (5). While fasted repletion of glycogen cannot occur indefinitely without consuming energy, the fact that it can occur at all means that on a low carbohydrate diet, where the glycerol backbones of

EATING CARBOHYDRATES PRIOR TO TRAINING DOESN'T JUST COME DOWN TO THE ACUTE EFFECT ON MUSCLE GLYCOGEN LEVELS. RATHER, PROLONGED ENERGY BALANCE STATUS, LIVER GLYCOGEN LEVELS, BLOOD GLUCOSE STABILITY, METABOLIC HABITUATION TO MEAL PATTERNS, AND FEEDBACK EFFECTS FROM LOW GLYCOGEN LEVELS ON CENTRAL FATIGUE MAY ALL BE CONTRIBUTING FACTORS.

fatty acids are available in abundance, and the transporters to convert lactate to glycogen are upregulated, the body has the means to restore muscle glycogen levels effectively with enough time (4). Thus, it seems that at least in the short term, especially considering that high volume resistance training only depletes muscle glycogen by up to ~40% (6), carbohydrate intake – *specifically as it relates to muscle glycogen restoration* – is not a limiting factor for lifting performance in most cases.

So, the question becomes: What happened in this study? Well, as we just discussed, muscle glycogen pretty much stays put unless actively depleted by muscular contractions. If depleted, the body works hard to replenish it to acceptable levels with available carbohydrate or other endogenous and exogenous substrates if no carbohydrate is available. In the Mitchell study cited above (2), 48 hours seemed to be ample time on a non-energy restricted, low-carb diet for muscle glycogen levels to replenish, given the lack of differences in performance. However, an overnight fast might not have been long enough for muscle glycogen levels to return to peak levels after their normal end-of-day level of depletion among the participants in the present study. Given that the first and second sets were negatively impacted by breakfast omission and then subsequent sets were similar between conditions, I think a reasonable conclusion is that some small degree of superior muscle glycogen repletion occurred in the breakfast consumption condition that may have contributed in part to the better performance observed during sets one and two. By sets three and four, glycogen may have been depleted to a similar level as the breakfast-skipping phase.

With that said, I don't think a difference in muscle glycogen was the *primary* mechanism driving poorer performance in the present study. During sleep, you need to maintain blood glucose levels in the brain and other tissue, which is largely supplied by liver glycogen. Subsequently, liver glycogen levels are often

APPLICATION AND TAKEAWAYS

If you habitually train a couple of hours after eating a carbohydrate-dominant breakfast, skipping breakfast might negatively impact your performance. While stimulants, a scoop of whey, and/or carbohydrate mouth rinsing are all potentially viable strategies in a pinch, (and worth considering when dieting, if you can make it work), I would recommend retaining some carbs in your pre-training morning meal to help ensure glycogen levels aren't too low and blood glucose remains stable.

depleted after an overnight fast (7). On top of this, habitually consuming breakfast alters the blood glucose response to food in the morning (8), such that it is not unreasonable to speculate that blood glucose levels were less stable in these habitual breakfast consumers when they skipped their first meal. Without ample liver glycogen availability to help stabilize blood glucose or exogenous fuel, performance can be negatively affected.

This might also be the case during prolonged dieting phases. If you recall my MASS article way back in our third issue, I reviewed a study where a group consuming pre- and post-training carbohydrate performed better on a muscular endurance test during a dieting phase compared to a group that consumed protein pre and post. You might also recall the recent MASS article by Mike on carbohydrate mouth rinsing, in which a swig of water with glucose in it – *even when you spit it out* – maintained performance better than placebo during a higher volume resistance training session after an overnight fast, even when breakfast *was consumed*. The point being, the role of eating carbohydrates prior to training doesn't just come down to the acute effect on muscle glycogen levels. Rather, prolonged energy balance status, liver glycogen levels, blood glucose stability, metabolic habituation to meal patterns, and feedback effects from low glycogen levels (in various compartments to include muscle, liver, and the brain) on central fatigue (7) may all be contributing factors that can impact resistance training performance.

Next Steps

In my mind, the next step is to see how much of the observed effects were due to the overnight fast and subsequent two hours of only consuming water before training in isolation, or due to the fact that the participants in this study habitually consumed breakfast. Can habituation to a 10-hour, pre-training fast (actually longer depending on when they ate dinner the night prior) completely, or even partially, eliminate the negative effects on resistance training performance? To find out, you'd need to repeat this study protocol but have two groups doing the crossover: those adapted to training after 12+ hour long fasts (like many in the intermittent fasting community), and those who habitually train after consuming breakfast.

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Study Reviewed: Menstrual Cycle Associated Modulations in Neuromuscular Function and Fatigability of the Knee Extensors in Eumenorrheic Females. Ansdell et al. (2019)

Does Neuromuscular Performance Change Throughout the Menstrual Cycle?

BY GREG NUCKOLS

Do the hormonal changes associated with the menstrual cycle affect strength, strength endurance, or neuromuscular function? Strength seems to be unaffected, while strength endurance may be higher during the second half of the cycle.

KEY POINTS

1. Quad strength does not seem to vary significantly, on average, over the course of the menstrual cycle.
2. Strength endurance, on the other hand, seems to be highest during the luteal phase of the menstrual cycle and lowest during the early follicular phase.

Many women report that they have noticeable fluctuations in physical performance throughout the menstrual cycle, while other women report that performance is steady. But what does the objective data say?

The presently reviewed study (1) tested maximal knee extension force, strength endurance, and various measures of neuromuscular function near the start of the menstrual cycle, near the midpoint of the cycle, and 21 days into the cycle. The most important findings for MASS readers were that maximal strength didn't change (on average) throughout the cycle, but strength endurance was significantly greater at day 21 than at the start of the cycle (the second day of menses).

Purpose and Research Questions

Purpose

This paper was based on the results of two different studies. The purpose of the first study was to see if the measurements used in the second study were reliable. The focus will be on the second study for the rest of this article.

The purpose of the second study was to examine neuromuscular function and fatigability of the quads across the menstrual cycle. This is the study that this article will focus on.

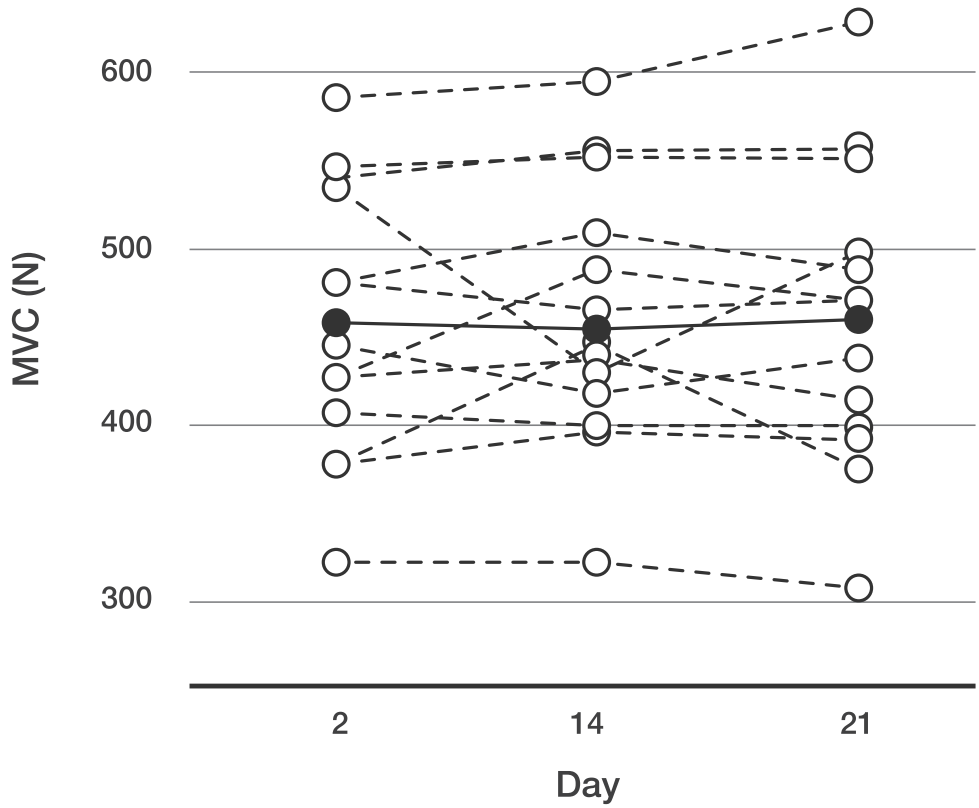
Research Questions

1. Would neuromuscular function of the quads vary throughout the menstrual cycle?
2. Would fatigability of the quads vary throughout the menstrual cycle?

Hypotheses

It was hypothesized that neuromuscular function would be greater (higher maximum force, less neural inhibition, and greater voluntary activation) on day 14 of the cycle than on day 2 due to increasing estrogen levels. It was also hypothesized that neuromuscular function would decrease from day 14 to day 21 due to an increase in progesterone, but that fatigability would decrease (i.e. strength endurance would increase).

Figure 1 Changes in individual (white) and group mean



Subjects and Methods

Subjects

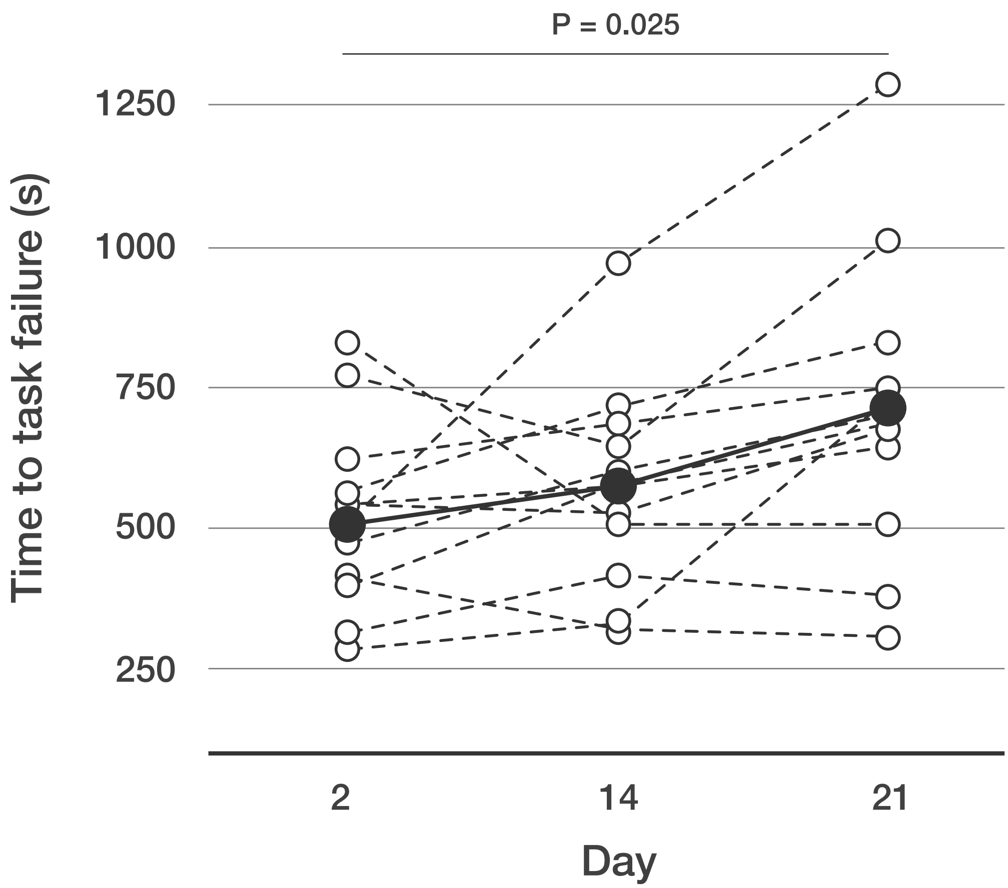
There were 15 subjects in study 2. They had normal monthly cycles and hadn't used any form of hormonal contraception in at least six months. Since training status is not listed, I assume they were untrained.

Study Design

Each subject visited the lab four times for this study. The first visit was a familiarization session, followed by three experimental visits. The experimental visits took place during the early follicular phase (2 days after the onset of menses), the late follicular phase, around the time of ovulation (14 days after the onset of menses), and the mid-luteal phase (21 days after the onset of menses).

On the morning of each experimental session, the participants had a fasted blood draw, which was used to verify menstrual cycle phase (based on fluctuations in estrogen and progesterone). The experimental sessions started with

Figure 2 Changes in individual (white) and group mean



pre-exercise neuromuscular assessments, including maximal voluntary isometric torque, followed by a fatiguing exercise protocol, and post-exercise neuromuscular assessments immediately after the subjects reached the point of failure.

The neuromuscular assessments were extensive, and they're not really worth explaining in detail since this isn't a research review targeted at neuromuscular researchers. However, the researchers included assessments that would be able to tease out whether the fatigue the women experienced was primarily peripheral (i.e. the brain is still sending strong signals, but muscle contractile force is still decreased) or central (i.e. a decrease in central motor drive).

The exercise protocol consisted of intermittent isometric contractions with 60% of maximal contractile force. Each cycle of contractions consisted of a three-second isometric hold, followed by two seconds of rest. After 11 cycles, the 12th contraction was a maximal voluntary contraction. The participants maintained this contraction-relaxation cycle until they could no longer reach a

THERE'S EVIDENCE THAT WOMEN TAKE LONGER TO RECOVER FROM TRAINING DURING THE LUTEAL PHASE , AND THREE DIFFERENT STUDIES HAVE FOUND THAT INCREASING TRAINING VOLUME DURING THE FOLLICULAR PHASE LEADS TO MORE HYPERTROPHY AND LARGER STRENGTH GAINS THAN INCREASING TRAINING VOLUME DURING THE LUTEAL PHASE

60% voluntary isometric contraction for at least 3 reps during each round of 11 cycles.

Findings

Most relevant for us is that maximal isometric quad strength did not significantly differ across the menstrual cycle. However, time to task failure during the fatigue protocol was significantly longer during the mid-luteal phase than the early follicular phase (p=0.025; +36% during the mid-luteal phase).

Two neuromuscular assessments differed between menstrual cycle phases. One was voluntary activation, assessed via transcranial magnetic stimulation (VA_{TMS}), and the other was short-interval cortical inhibition. Short-interval cortical inhibition was shown to not be a very reliable measurement (post-exercise ICC = 0.42), so I won't focus on that. VA_{TMS} is a measure of central fatigue; if VA_{TMS} is high, central drive is high, and signals from your brain are making their way to your muscles efficiently. In this study, VA_{TMS} decreased more pre-to-post exercise during the late follicular phase (-12%) than during the other two phases (-6% for early follicular, and -7% for mid-luteal), though the difference was only statistically significant for the mid-luteal phase.

Interpretation

The first thing I want to point out is that maximal strength didn't differ across the menstrual cycle (at least at the three time points tested). Every so often, I'll see an article claiming that women are considerably stronger around the time of ovulation. While there's some evidence to back that up (2, 3), some of the studies supporting that contention test the strength of finger muscles, which *may* not respond the same way as large muscle groups (one example here: 4). This is something I've discussed with

APPLICATION AND TAKEAWAYS

If you want to benefit from the boost in strength endurance during the luteal phase, you could schedule your lighter, higher rep training during that time period. However, you should be careful about going overboard on total volume (doing a bunch of sets), as recovery capacity also seems to be limited during the luteal phase.

female lifters and my female clients, and the feedback I've gotten is that about 50% of women don't notice any strength fluctuations throughout their cycle, and for the other 50%, the time they think they perform best is all over the place. You can see that in this study; if you look at Figure 1, you can see that while the group mean is flat across all three time points, individual measures fluctuate considerably, with no clear pattern in favor of one menstrual cycle phase over another.

The fact that time to task failure was greatest during the mid-luteal phase in this study honestly surprised me. Most of the research on fatigability across the menstrual cycle finds that women fatigue quicker during the luteal phase, though most of that research is on endurance performance or repeated sprint ability. However, it may make sense that these findings don't carry over to resistance exercise. The primary reason endurance performance may be lower during the luteal phase is that elevations in progesterone slightly impair thermoregulation (3). That's a big deal for runners, but probably isn't the primary mechanism limiting strength endurance. Furthermore, other research has found that strength endurance doesn't vary much across the menstrual cycle (5).

So, since time to task failure (and thus, *possibly* strength endurance and work capacity) may be greater during the luteal phase, does that mean women should take advantage of that fact and ramp their training volume up? Probably not. In fact, the opposite may be true. There's evidence that women take longer to recover from training during the luteal phase (6), and three different studies have found that increasing training volume during the follicular phase leads to more hypertrophy and larger strength gains than increasing training volume during the luteal phase (7, 8, 9). The likely reason is that estrogen protects against muscle damage and promotes recovery, while progesterone largely counteracts the beneficial effects of estrogen (10). Thus, when progesterone starts ramping up during the luteal phase, women are more susceptible to muscle damage, take longer to recover, and can't adapt quite as fast. So, if you want to take advantage of the increased strength endurance during the luteal phase, your best bet would probably be to do more reps per set, rather than doing a bunch of extra sets.

Next Steps

I'd like to see a study similar to this one using more ecologically valid measures of strength and strength endurance. Something like 1RM squat and bench press, and reps to failure with 50% of 1RM would help make me a bit more confident that the findings in this study would carry over to "real world" performance.

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Study Reviewed: Variability and Impact of Self-Selected Interset Rest Periods During Experienced Strength Training. Ibbott et al. (2019)

Ditch the Stopwatch and Rest Intuitively Between Sets

BY MICHAEL C. ZOURDOS

I'm sure we've all sat on a bench with a stopwatch timing our rest intervals between sets. This study suggests that you can intuitively gauge your rest intervals to be able to successfully complete your prescribed training.

KEY POINTS

1. This paper examined how long rest intervals would be during heavy squats when they were self-selected by subjects.
2. The individuals in this study intuitively rested for an average of 4-5 minutes when self-selecting their rest during 5 sets of 5 at a 5RM load. This rest time was enough to allow nearly 100% of subjects to complete the prescribed sets and reps without failing. Rest times increased during the latter intervals compared to the rest interval between the first two sets.
3. Overall, it is good practice to rest enough that you don't have to continually decrease load from set to set. Resting enough typically means about 3-5 minutes for compound movements, and this study shows that lifters can intuitively do this without timing rest periods.

We've previously covered research showing that the old adage of short rest periods (30-90 seconds) being superior for hypertrophy has not stood the test of time (2). In brief, short rest periods were long thought to be ideal for hypertrophy due to stimulating a larger acute hormone response (3), but it is now understood that the relationship between hormonal release and hypertrophy was correlational and not causal (4, 5). Recent data has shown that longer rest periods (i.e. 3 minutes) on the major lifts are probably the way to go to maximize hypertrophy (2). The benefit of long rest periods stems from the lifter being able to recover more between sets, allowing for a higher load or a greater amount of reps on subsequent sets compared to short rest periods. However, do we really need to time our rest periods? What if we just intuitively rest and do the next set when we *feel* ready? This study (1) had 16 adult, male rugby players perform two sessions of a 5X5 squat protocol with their 5-repetition maximum (5RM). In both sessions, the subjects were told: "Choose a rest period you feel will allow you to complete a maximal effort during your next set." The researchers found that except for one subject missing one rep, all other sets and reps were completed successfully. The near 100% successful completion of the 5X5 protocol suggests that lifters can accurately gauge their own rest intervals for volume performance. Rest periods were shorter in session two (249 ± 76 seconds) than in session one (283 ± 101 seconds), and rest periods were longer after sets three and four compared to after set one. In short, lifters rested 4-5 minutes on average, and it seems that lifters can appropriately gauge their own rest intervals during heavy squat training since there was nearly 100%

Table 1 Subject characteristics				
Subjects	**Age (years)**	**Body mass (kg)**	**Height (cm)**	**Resistance training age (years)**
16 male rugby players	23 ± 3	98.8 ± 15.5	179.4 ± 5.4	4 ± 2

Data are mean ± SD
Subject characteristics from Ibbott et al. 2019 (1)

successful completion of the prescribed sets and reps. So, is there an ideal rest interval length? And, can intuitive rest be used all the time? This article will explore those questions.

Purpose and Research Questions

Purpose

1. The purpose of this study was to examine if individuals can self-select rest intervals and still successfully complete pre-determined training volumes.
2. The researchers also examined how self-selected rest intervals would affect power output, pre-set readiness, and session RPE.

Research Questions

1. How long do lifters rest when they self-select rest periods during heavy squat training?
2. Can lifters intuitively select rest intervals and maintain performance?
3. How do self-selected rest intervals affect pre-set readiness and post-set perception of fatigue?

Hypotheses

The researchers did not predict how long the self-selected rest intervals would be. The only hypothesis given was that there would be a high reliability of all measures between the two experimental testing sessions.

Subjects and Methods

Subjects

Sixteen male rugby players, presumably from Australia (as that's where the authors reside), participated. The athletes had played rugby for an average of 10 years and had performed 4 years of resistance training under the direction of a strength coach. Strength levels were not provided. The available details of the athletes are in Table 1.

Protocol

Subjects came to the laboratory four times with each visit separated by at least

Table 2 Outcome measures in experimental sessions

1. Rest period time	The actual time that subjects took for their self-selected rest periods.
2. Volume Completion	The amount of the prescribed protocol that was successfully completed.
3. Average power output	GymAware linear position transducer calculated average power during each set,
4. Readiness to lift	Likert scale indicating how "ready" the subjects were to lift that was administered before every set
5. Rating of perceived exertion (RPE)	Measured via the 0-10 Borg RPE scale, which is self-perceived general effort, not the repetitions in reserve scale. This was administered after every set.

48 hours. The first session tested a 5RM back squat. Sessions two, three, and four were the exact same, except session two was considered a familiarization session, so only the data from sessions three and four were used for analysis.

In the experimental sessions (sessions three and four), subjects were scheduled to complete 5 sets of 5 reps at their 5RM load. No guidance regarding rest periods was given, except each athlete was read the script: "Choose a rest period you feel will allow you to complete a maximal effort during your next set." The researchers aimed to see if there was a change in outcome measures as the sets went on in each session, and they aimed to compare if there was a difference in outcome measures between each session. The specific outcome measures are in Table 2.

Findings

Rest Period Times

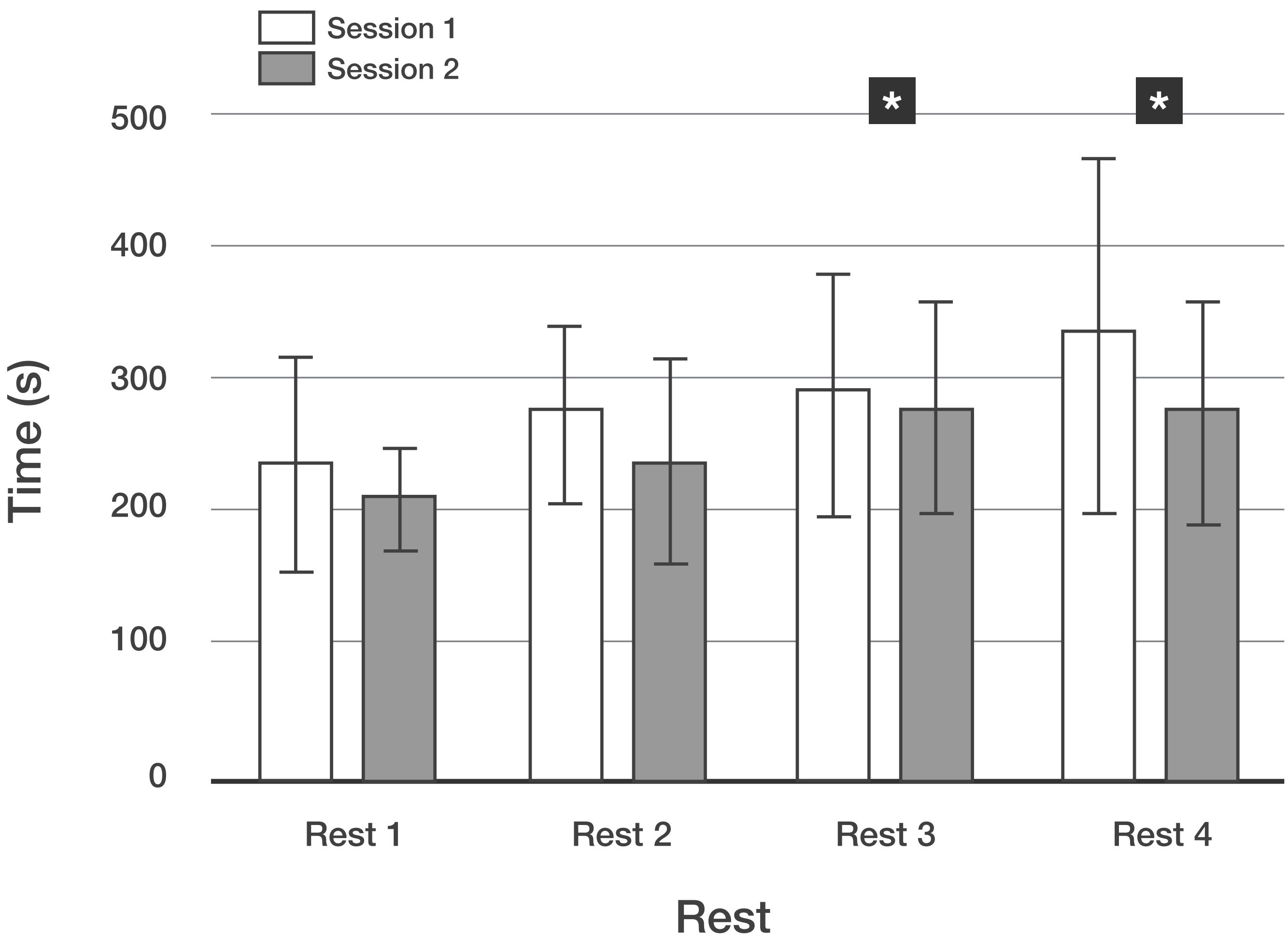
In both sessions, subjects rested more following sets three and four than after set one. Average rest periods were shorter in session two (249 ± 76 seconds or 4:09 on average) than in session one (283 ± 101 seconds or 4:43 on average). Rest periods for individual sets are in Figure 1.

Volume and Power Performance

15 of the 16 subjects completed all of the prescribed sets and reps successfully. Only one subject failed on the last rep of set four during the first session, so this subject was not permitted to perform the fifth set. Therefore, out of 800 possible reps in the study, 794 reps or 99.3% of the prescribed volume was successfully completed.

Average power output was statistically greater in session one than in session two (although I'm not sure this is meaningful) and, in both sessions, power output was greater in set one than in sets 3-5 (Figure 2).

Figure 1 Time of self-selected rest intervals

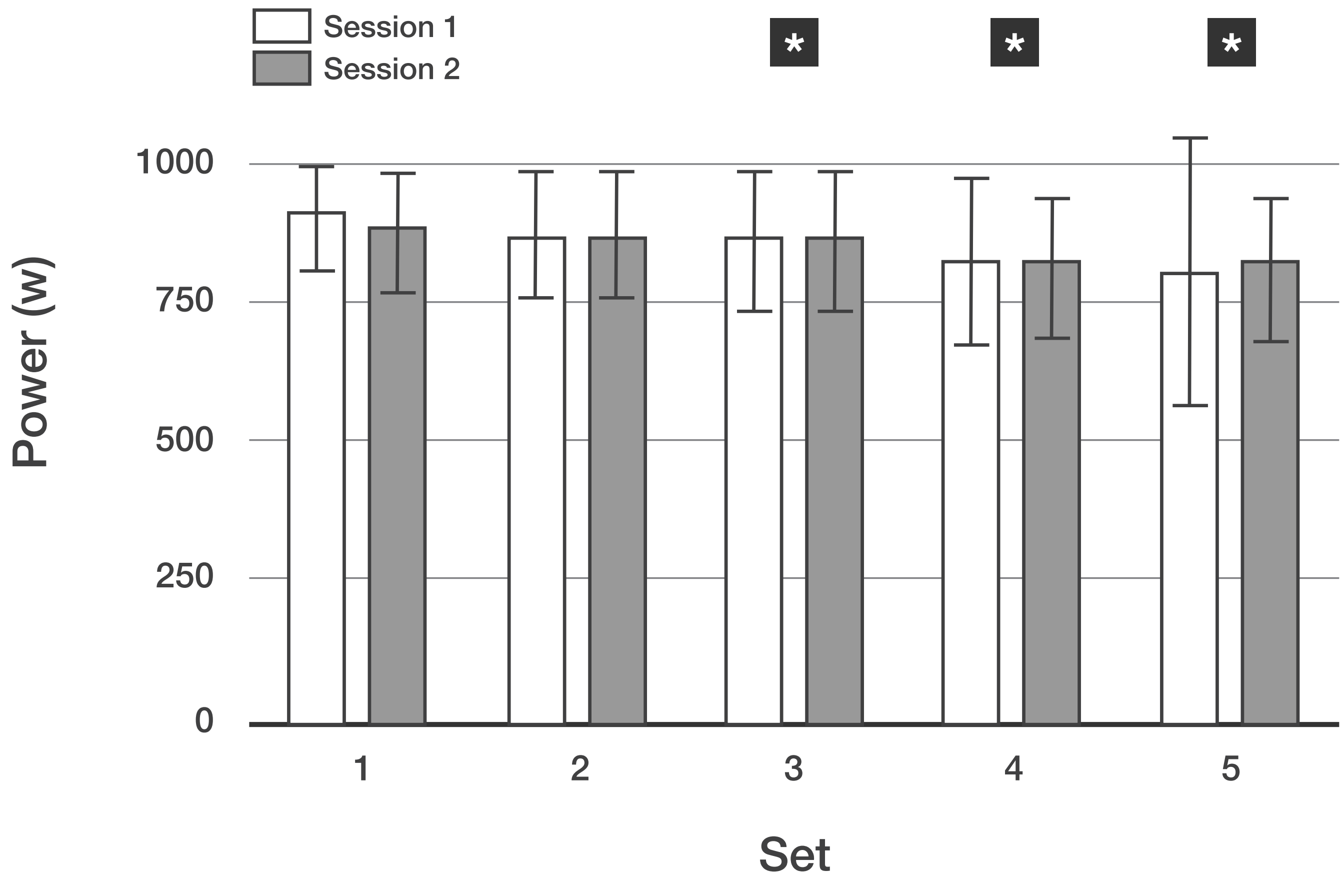


**Significantly longer rest interval in rest interval 3 and 4 compared to rest interval 1*
Rest 1 = Rest between sets 1 and 2; Rest 2 = Rest between sets 2 and 3; Rest 3 = Rest between sets 3 and 4;
Rest 4 = Rest between sets 4 and 5
Data are mean ± SD

RPE and Readiness to Lift

The average session RPE was identical (7 ± 1) between sessions, and the average readiness to lift score was also quite similar between sessions (session 1: 7.1 ± 1.3 vs. session 2: 7.2 ± 0.8). Taken together, the session RPE and readiness to lift scores indicated greater fatigue and lower readiness in sets three, four, and five compared to set one ($p<0.05$) in both sessions. The session RPE and readiness to lift values are in Table 3.

Figure 2 Average power output in all sets



**Significantly lower power output in that set compared to set 1 in both sessions*
Data are mean ± SD

Interpretation

The last few years of research have shown that longer rest periods (i.e. ≥3 minutes) may be superior to shorter rest periods (~60 seconds) for hypertrophy (2). This is probably due to the fact that longer rest intervals allow for more recovery and potentially better volume performance when sets and load are pre-determined. For example, if someone is aiming to complete 5 sets of 8 on squats at 100kg with 60 seconds rest, and the first set is at an 8RPE, it is likely that a short rest interval will result in failure to perform 8 reps on one of the next few sets, while a longer rest (3-5 min) would probably allow successful completion of the predetermined training prescription. The presently reviewed study (1) found that subjects rested between 4-5 minutes, on average, when they were allowed

Table 3 RPE and readiness to lift scores in each session

	Session 1					Session 2				
	Set 1	Set 2	Set 3	Set 4	Set 5	Set 1	Set 2	Set 3	Set 4	Set 5
Average RPE	6	6	7	8	8	6	7	7	7	8
Average RTL	8.5	8.0	7.3	6.4	5.7	8.2	7.8	7.2	6.6	6.3

RPE = Rating of Perceived Exertion; RTL = Readiness to Lift
Both the RPE and RTL scales were 0-10 scales. A higher RPE values indicates more fatigue post-set, and a higher RTL value means greater readiness pre-set.

intuitive rest intervals. Further, the intuitive rest intervals led to a near 100% completion rate of the predetermined training prescription; thus, it does seem that lifters can effectively gauge their own rest intervals to maximize volume performance.

Rest intervals in the second experimental session were 34 seconds shorter than the first session. This shows one of two things: 1) The subjects' intuitive ability to gauge rest intervals improved or 2) The subjects got a training adaptation from the first session and simply didn't need to rest as long in session two. I think both explanations are appropriate here, but the training adaptation one takes a more prominent role in this study. If you recall from the methods, the subjects also did the 5 sets of 5RM protocol in a familiarization session. Although the data from the familiarization session wasn't used, the same protocol was performed; thus, the second experimental visit was actually the third time the subjects performed the protocol, so they likely got a training adaptation. The session RPE and readiness to lift scores also suggest a training adaptation as these scores were similar between sessions despite an average of 34 fewer seconds of rest in session two. A training adaptation from the familiarization session is also apparent, as most people would fail on the later sets if asked to do 5 sets at a 5RM load. Even though rest times increased from just a shade over three minutes to over five minutes on average in the first session and about 4.5 minutes on average in the second session, I don't think that simply resting longer would help most people successfully complete the latter sets of 5X5 at a 5RM with 100% success.

One question I have is how these findings would hold up with lower weight and higher reps. If someone was training with a 10RM for multiple sets, I think the intuitive rest times would be longer than in the present study. I also highly doubt 5X10 at 10RM would be completed with success no matter the rest interval. I do think that intuitive rest can be used at other intensities; however, it is unlikely that most can maintain a certain RM for multiple sets during a high-repetition set. As a general training note, and as we've discussed in MASS various times (one, two, and three), it's probably a good idea to train a few reps shy of failure for the most part. In that case, intuitive rest intervals would probably work just fine for maintaining a predetermined number of reps across all sets.

I don't believe the finding that power output was greater in session two than in session one to be meaningful or important. First, I calculated an effect size between sessions for power output, which came to 0.16 – a trivial effect. Further, it makes sense that in each session, power would be lower in the last couple of sets, as force output and velocity would be lower, meaning that time to complete reps was longer (Power = Work / Time). If the goal is to maximize power output, it's a good idea to take long rest intervals, and if training for power or explosiveness, a significantly lower load (i.e. 30-60% of 1RM) would be used anyway.

Overall Rest Period Recommendations

So, how long should rest intervals be? In general, the intuitive rest times used in this study are pretty consistent with the previous recommendations, which suggest >3 minutes between sets for the compound lifts to maximize progress. You can probably get away with 1-3 minutes for assistance movements. Despite these recommendations, it's always important to keep in mind that the data showing longer rest to be better than shorter rest always equate for number of sets performed between long and short rest groups. Therefore, the short rest group can potentially accumulate more sets in less time than a long rest group. I'm not saying that you should take short rest; I am indeed firmly in the long rest camp. However, it's worth pointing this out: If you are short on time one day, then I would simply recommend you do your first set at the top load to reach your prescribed peak intensity (peak session intensity matters more than average intensity for strength) and then reduce the load for the remainder of the sets and reduce your rest interval to complete the session in the time that you have that day. In fact, we've covered this concept before in program troubleshooting.

IT DOES SEEM THAT LIFTERS CAN EFFECTIVELY GAUGE THEIR OWN REST INTERVALS TO MAXIMIZE VOLUME PERFORMANCE.

Next Steps

As said above, the same study could be done at other intensities (i.e. 10RM). I'd also like to see another study without the familiarization session. Familiarization sessions are a good idea in research if subjects are unfamiliar with a protocol

APPLICATION AND TAKEAWAYS

1. These results show that during heavy squats, people can self-select their rest times (rest intuitively, in other words) and still effectively complete 5 sets of 5 at a previously tested 5RM.
2. The intuitive rest times were pretty predictable, in that rest times increased between the later sets compared to earlier sets. Rest times averaged between 4 and 5 minutes, which is in line with the >3-minute recommendation for hypertrophy and strength adaptations.
3. Ultimately, resting 3-5 minutes between compound movements is probably a good idea for hypertrophy and strength adaptations. However, when time constraints are an issue, short rest intervals may be needed. In that case of short rest, I would still keep peak intensity the same. In addition, monitoring rest times is probably a good idea if you are deliberately using rest intervals due to time constraints, just to make sure that you aren't late to whatever you have scheduled post-training.

or testing procedures, but I'm not sure it was necessary in this case, and it likely produced a training adaptation. Further, I'd like to see how intuitive rest plays out when not training to failure.

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Study Reviewed: Effects of Placebo on Bench Throw Performance of Paralympic Weightlifting Athletes: A Pilot Study. Costa et al. (2019)

The Placebo Effect in Supplement Research

BY ERIC HELMS

This study is one of many examining the placebo effect of a supplement on some element of performance. While the placebo effect and the need to control for it are nothing new, learning when it works, for whom, and why it occurs provides interesting insight into psychology.

KEY POINTS

1. This study is one of many to demonstrate that a placebo can have a measurable, real impact on performance, physiology, or body composition. When Paralympic weightlifters took an inert capsule, believing they'd consumed caffeine, velocity was higher versus consuming nothing during bench press throws at 50% of 1RM.
2. A potential benefit of giving an athlete a placebo is that doing so eliminates the chance of a tainted supplement producing a positive drug test. In the specific case of caffeine, it also eliminates any potential negative effects on sleep.
3. However, the broader literature suggests there can be unexpected negative consequences from taking placebos – or supplements, in general. If individuals focus less on their own actions and behaviors and instead rely externally on the power of a pill, it may harm self-efficacy. Additionally, some evidence suggests those with a lower self-esteem may be more likely to experience a placebo effect.

For MASS readers, the placebo effect is probably something you are familiar with. A placebo in supplement research is a pill or powder that does nothing, but the group taking it is told it is or may be the real supplement. In a "double blind" study, neither the researchers nor the participants know which pill the participants received, and the groups are randomized to receive the real deal or an inert substance. Including a placebo group is necessary when testing supplements because the simple belief that you are taking an ergogenic substance can often produce a measurable quantitative change – i.e., the placebo effect. Quite incredibly, belief is often powerful enough to produce an effect when no supplement is provided; thus, to ensure that a supplement actually does something *beyond* what simple belief can produce, the best trials compare an intervention group consuming a supplement, a control group consuming nothing, and a placebo group. In the present study, only a control group and a placebo group were compared without an intervention group, meaning the researchers were actually studying the placebo effect itself. Specifically, in this crossover trial, a group of Paralympic weightlifters were randomized to receive either nothing or an inert capsule, which they believed was caffeine, prior to performing bench throws at various percentages of their bench press 1RM. While taking the placebo, the athletes produced higher velocities at 50% 1RM compared to when they were given nothing. While this finding is interesting and has direct applications that I'll go into in this article, I'll primarily discuss the intriguing aspects of the placebo effect as they relate to supplement research more generally.

Table 1 Subject characteristics					
Group	Age (years)	Weight (kg)	Height (m)	Body mass index ($kg \cdot m^2$)	1 repetition maximum load (kg)
Mean	40.25 ± 9.91	60.6 ± 8.36	1.61 ± 0.16	23.83 ± 4.48	69 ± 19.46
Minimum	26	49.0	1.36	19.38	40
Maximum	54	71.2	1.78	30.82	92

Purpose and Research Questions

Purpose

The purpose of this study was to evaluate if performance during bench press throws would change in Paralympic weightlifting athletes after taking a placebo when they were informed they were taking caffeine.

Hypothesis

The authors did not propose a hypothesis.

Subjects and Methods

Subjects

Four male Paralympic weightlifters completed this study (age: 40.25 ± 9.91 years, weight: 60.5 ± 8.29 kg, height: 1.60 ± 0.15 m). Athletes trained regularly five days per week for the purpose of competition. All previously used caffeine but had not taken caffeine *supplements* in the prior six months. Regarding their competitive status, two of the athletes were medal winners at the national level. Subject characteristics are shown in Table 1.

Study Design and Assessments

This study was performed as a randomized crossover trial, meaning all volunteers participated in both conditions in a randomized order. The athletes were tested three times with 72 hours between tests. During the first lab visit, they performed a standardized 1RM bench press test. Then, in the second and third visits, they performed the same bench press throw testing after ingesting either a placebo or nothing, in a randomized order. During the placebo condition, the athletes consumed a starch capsule that they were told contained 6mg/kg of caffeine one hour prior to testing. The athletes were told to avoid caffeine for a week prior to the study.

Bench press 1RM testing and bench throws were conducted on a Smith machine with a linear position transducer attached to the bar to measure velocity. During testing, the athletes were instructed to accelerate the bar with maximum intended velocity on all reps. Bench throw testing consisted of three

Table 2 Comparison between the placebo and control group on velocity of displacement of the bar in bench press

Variable	Condition	50% 1RM	ES	60% 1RM	ES	70% 1RM	ES	80% 1RM	ES
Mean velocity (m/s)	Control	0.76 ± 0.08	0.36*	0.70 ± 0.07	0.19	0.61 ± 0.10	-0.26	0.47 ± 0.10	-0.31
	Placebo	0.84 ± 0.12		0.74 ± 0.12		0.56 ± 0.08		0.41 ± 0.08	
Mean velocity to peak (m/s)	Control	0.79 ± 0.09	0.33	0.72 ± 0.07	0.18	0.61 ± 0.11	-0.19	0.48 ± 0.10	-0.31
	Placebo	0.87 ± 0.13		0.76 ± 0.13		0.57 ± 0.09		0.42 ± 0.08	
Mean propulsive velocity	Control	0.81 ±0.09	0.46*	0.74 ± 0.09	0.19	0.63 ± 0.12	-0.27	0.48 ± 0.10	-0.36
	Placebo	0.92 ± 0.12		0.79 ± 0.15		0.57 ± 0.09		0.41 ± 0.08	
Peak velocity (m/s)	Control	1.16 ± 0.11	0.37	1.06 ± 0.13	0.14	0.91 ± 0.19	-0.27	0.72 ± 0.19	-0.32
	Placebo	1.27 ± 0.16		1.11 ± 0.21		0.82 ± 0.11		0.61 ± 0.12	

*ES = Effect Size; positive values indicate a high velocity for the placebo condition; RM = Repetition maximum; * = a significant difference between placebo and control.*

reps at 50, 60, 70, and 80% of 1RM, with five minute rest intervals between sets.

Findings

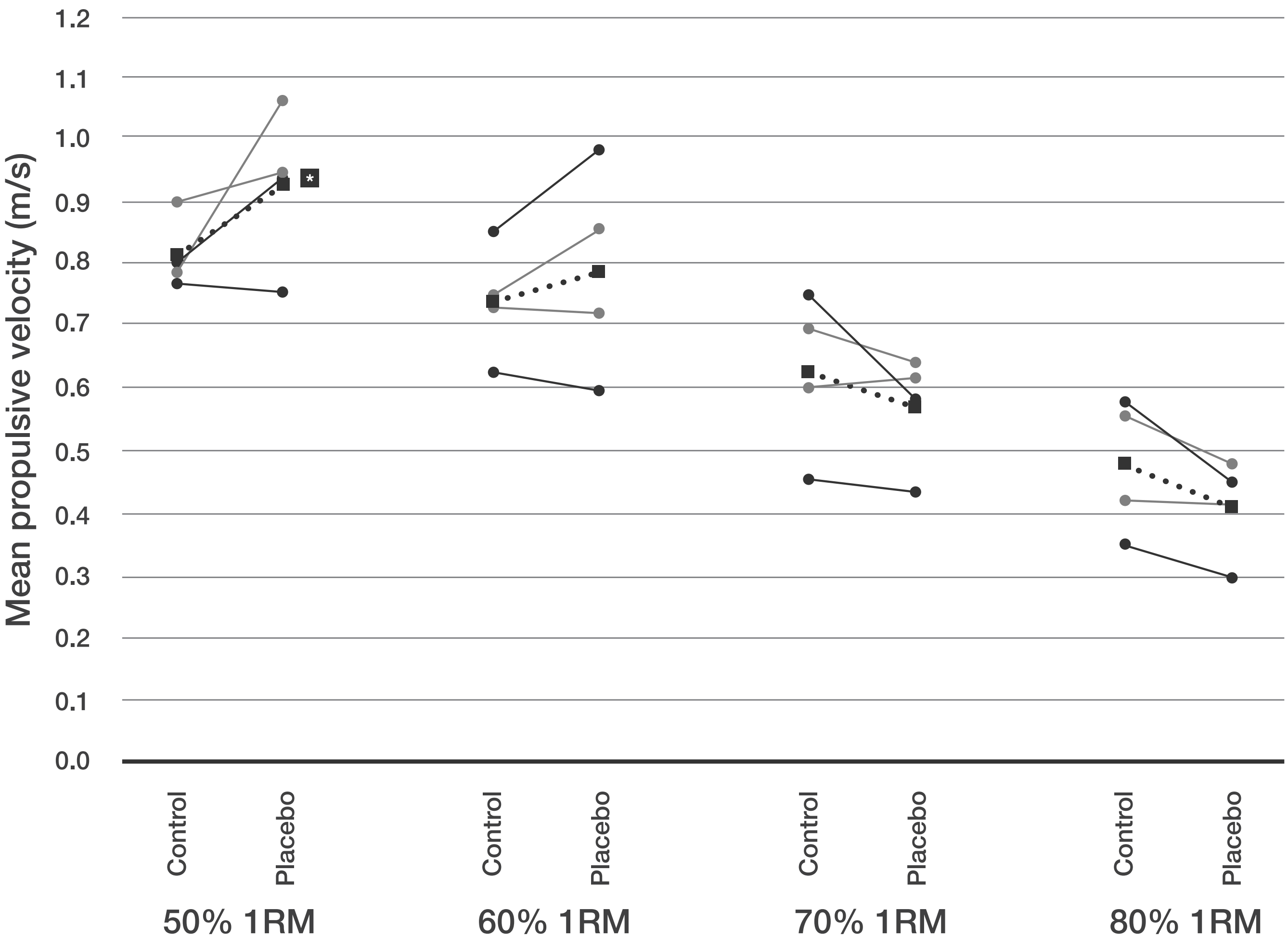
There were no significant differences between the velocity of bench press throws between conditions at 60, 70, and 80% of 1RM; however, bench press throws were performed significantly faster at 50% of 1RM during the placebo condition. Means, standard deviations, and between-group effect sizes of the velocities are shown in Table 2. Effect sizes were calculated relative to the faster velocity, meaning there were actually small effect sizes (greater than 0.2) favoring the control, rather than the placebo, during the 70 and 80% throws. With that said, this was a trial of only four individuals, and the differences in velocity at 70 and 80% were not significant, so this may or may not be statistically "real" (discussed further in the interpretation).

Individual comparisons of mean propulsive velocity at each load are shown in Figure 1, indicated by straight lines with the overall effect shown as the dashed line. In the figure, you can see that the majority of throws were faster for the athletes during the placebo condition at 50%, half were faster at 60%, and while non-significant, three quarters of the athletes were slower during the placebo condition at 70 and 80%.

Interpretation

First, I'll start with the interesting parts of this specific study. Then, I'll branch out and discuss the broader literature. As I noted in the findings, the only significant outcome was that velocity at 50% of 1RM was significantly higher during the placebo condition versus control. Now, even that should be taken with a grain of salt in a study with only four individuals, but given this is a crossover trial, odds are the placebo effect *probably* produced this outcome. Likewise, the nonsignificant differences

Figure 1 Mean propulsive velocity (m/s)



with small effect sizes should be interpreted even more cautiously due to the sample size. However, they are worth discussing because they *may* point to how the placebo effect played out in this study. As you saw in the results, velocity was slightly lower on average as the sets progressed during the placebo condition after 50 and 60%. What may have happened is that during the initial sets, the placebo effect caused the participants to push harder than they otherwise would have (or knew they could have); subsequently, they were a bit fatigued, which slowed down their last two sets at 70 and 80%. Again, the differences were nonsignificant after 50%, and I don't know if much fatigue could truly occur with triples at 50 and 60% 1RM with 5 minutes of rest, but if I were to speculate as to how the placebo effect played out (i.e. they pushed harder on the 50% set), that would be my guess as to what occurred. But again, the nonsignificant differences at 70 and 80% could just be statistical noise.

The placebo effect is real. It's a cool phenomenon inherent to the reality of being human, and it's something we have to control for in research. In this study, the authors framed that positively, pointing out that placebos could be given to improve performance without risks of failing a drug test due to a contaminated supplement (as a side note, it's worth pointing out that just because a placebo does something once, doesn't mean the placebo effect will continue to manifest every single session over time). Also, in the specific case of caffeine, you could make the argument that there's no chance sleep could be negatively impacted with a placebo, but this could be said about the side effects of any supplement. Unfortunately, the broader literature also points to some potential downsides you might not be aware of related to the placebo effect and supplements in general.

In a 2014 study on weight loss (2), participants were given weight loss counseling and guidance to lose weight and also randomized into groups that were either 1) given a placebo for 12 weeks and told it was a weight loss supplement, 2) given a placebo for 12 weeks and told they had a 50% chance of it being a supplement or placebo, or 3) given nothing. Across all groups, the participants who believed more strongly in the effectiveness of supplements tended to lose a smaller proportion of weight. Additionally, the group told they were given the weight loss supplement reported a decline in self-efficacy over the course of the study while increasing their belief in supplements' effectiveness. The group told they had a 50% chance of receiving the active supplement remained somewhat stable in their self-efficacy scores and did not change their level of belief in supplements. Finally, those taking nothing increased their self-efficacy and reduced their belief in the value of supplements.

THE PARTICIPANTS WHO BELIEVED MORE STRONGLY IN THE EFFECTIVENESS OF SUPPLEMENTS TENDED TO LOSE A SMALLER PROPORTION OF WEIGHT. ADDITIONALLY, THE GROUP TOLD THEY WERE GIVEN THE WEIGHT LOSS SUPPLEMENT REPORTED A DECLINE IN SELF-EFFICACY OVER THE COURSE OF THE STUDY WHILE INCREASING THEIR BELIEF IN SUPPLEMENTS' EFFECTIVENESS.

THE VERY PEOPLE WHO PROBABLY SHOULDN'T BE BUYING SUPPLEMENTS ARE THE ONES WHO MOST OFTEN DO.

Importantly, there were no significant differences in weight loss between groups. Meaning, in this study (2), giving people a weight loss placebo pill, in addition to counseling and guidance on nutrition and weight loss, not only didn't help them lose weight, but actually hurt their long-term likelihood of success by reducing self-efficacy. This outcome unfortunately speaks to the nature of supplement marketing and psychology, in that the uneducated consumer can delay true behavior change and instead rely on the belief that some external factor, like a weight loss supplement, will do the job for them.

Behavior change is difficult. Changing your eating habits and following an exercise plan requires a significant restructuring of your life, priorities, and goals and forces you to face aspects of your behavior you might find embarrassing, shameful, or difficult to alter. Sure, if you have the education to know that 99% of weight loss is achieved through nutrition, training, and adopting a new, healthy lifestyle, you might know that supplements can *maybe* help you 1% more, and taking a supplement won't be harmful. But if you don't have this knowledge, there's a chance taking a supplement can harm your self-efficacy by nudging your locus of control externally.

The unfortunate nature of this psychology is that the very people who probably shouldn't be buying supplements are the ones who most often do. If you have low self-esteem, you probably want to change something about yourself; unfortunately, this often goes hand in hand with low self-efficacy (the belief that you have the power to change yourself or accomplish things). Meaning, a supplement looks more attractive than diet or exercise, because if you don't believe you have the power to change, then you need something external to change you. The common marketing behind supplements often reinforces these perceptions. The "get fixed fast" messaging tells you that "yes, only this supplement can get you to your goals, and it will be quick, easy, and will amaze you." This messaging signals that something external is more powerful than you, and what you've been missing is this supplement, rather than belief in your own capacity to change. Indeed, this psychology played out in a 1983 study in which low self-esteem mediated the suggestibility of placebo effects in insomniacs told they were taking either "arousal" or "relaxation pills" (3).

APPLICATION AND TAKEAWAYS

Supplements sometimes work, but the placebo effect often does too. Thus, we have to control for the placebo effect in research. But as practitioners, we should pay close attention to clients who are consistently sucked in by supplement marketing, especially when they *should* know better. Such behavior could be indicative of deeper issues related to low self-esteem or efficacy. Following these behavioral threads might lead to important opportunities for self-discovery and behavior change.

To close, belief is a powerful thing, and it is not contained to supplements. Recall Greg's recent article on genetics and belief, where in some cases, *believing* you possessed or lacked a specific gene variant related to diet or exercise had a greater effect on diet or exercise outcomes than actually having or not having the gene! So what does this mean for us as athletes, coaches, and trainers? Well, it means we really need to nurture self-efficacy, esteem, and meet people (and ourselves) where we are at currently. Despite the ease of placing faith in something external when faced with self-doubt, we must look internally and try to cultivate self belief.

Next Steps

I think it would be worthwhile to study how exposure to the supplement industry affects people in the long run. One interesting thing I see among bodybuilders is the funny combination of strong self-efficacy and strong beliefs in the effectiveness of supplements. I think this is because the bodybuilding industry is saturated with supplement marketing (steroid-like gains!), and it is financially intertwined with sponsorships, fitness expos, and supplement companies. It would be interesting to see how supplement industry exposure impacts long-term outcomes among bodybuilders, and how and if this is intertwined with their self-efficacy, esteem, or education.

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Study Reviewed: Acute Effects of Citrulline Supplementation on High-Intensity Strength and Power Performance: A Systematic Review and Meta-Analysis. Trexler et al. (2019)

Citrulline Supplementation Increases Strength Endurance

BY GREG NUCKOLS

The body of citrulline research has grown dramatically in the past few years, so there are finally enough studies to warrant a meta-analysis. This meta-analysis found that citrulline supplementation improves strength endurance significantly, though the effect is quite modest.

KEY POINTS

1. Citrulline supplementation significantly improves strength endurance and power endurance, though the overall effect is quite modest.
2. In studies just looking at strength endurance, the effect is a bit larger, putting its effects in line with other supplements generally believed to be effective, including creatine and caffeine.
3. Other moderating variables (sex, funding source, training status, etc.) didn't seem to meaningfully impact the results.

Citrulline is a supplement that's supposed to improve strength endurance and work capacity. Once citrulline is absorbed, it's converted to arginine, which can then be converted to nitric oxide. Nitric oxide causes vasodilation, thus increasing blood flow to active muscles. Citrulline is preferred to arginine because citrulline supplementation increases blood levels of arginine more effectively than arginine itself does (2).

Eric previously wrote a great MASS article about citrulline supplementation, covering a study where citrulline failed to increase reps performed across multiple sets (3), though he noted that most of the research still leaned in favor of citrulline increasing strength endurance. The presently reviewed meta-analysis helps us determine whether citrulline does actually tend to improve performance, and quantifies the impact you can expect it to have (1).

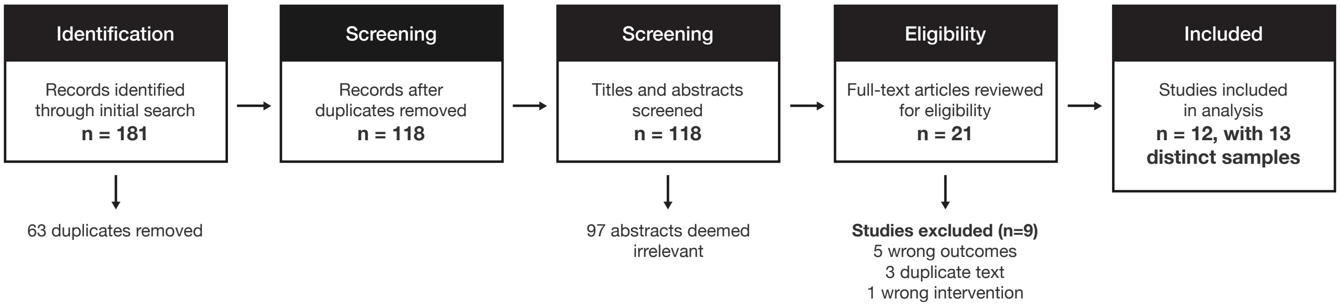
This meta-analysis found that citrulline supplementation does significantly increase strength endurance and power endurance, relative to placebo. For strength and power together, the effect is trivial-to-small (hedges g = 0.20), but it's slightly larger for just measures of strength endurance (g = 0.30). As such, while it doesn't have a huge effect, its effects seem to be similar in magnitude to those of other generally effective supplements like creatine, caffeine, and beta-alanine.

Purpose and Research Questions

Purpose

The purpose of this meta-analysis was to evaluate whether citrulline supplementation improves "high intensity exercise performance" relative to placebo. "High intensity exercise performance" was defined as "strength and power variables from performance tests involving multiple repetitive muscle actions of large muscle groups, consisting of either

Figure 1 Study inclusion process



resistance training sets or sprints lasting 30s or less." We can think of this more like "work capacity" or "strength and power endurance" rather than maximal strength and/or power.

Research Questions

1. Does citrulline supplementation improve high intensity exercise performance relative to placebo?
2. Do the effects of citrulline depend on other factors, such as sex, training status, strength performance versus power performance, or the funding source for the studies?

Subjects and Methods

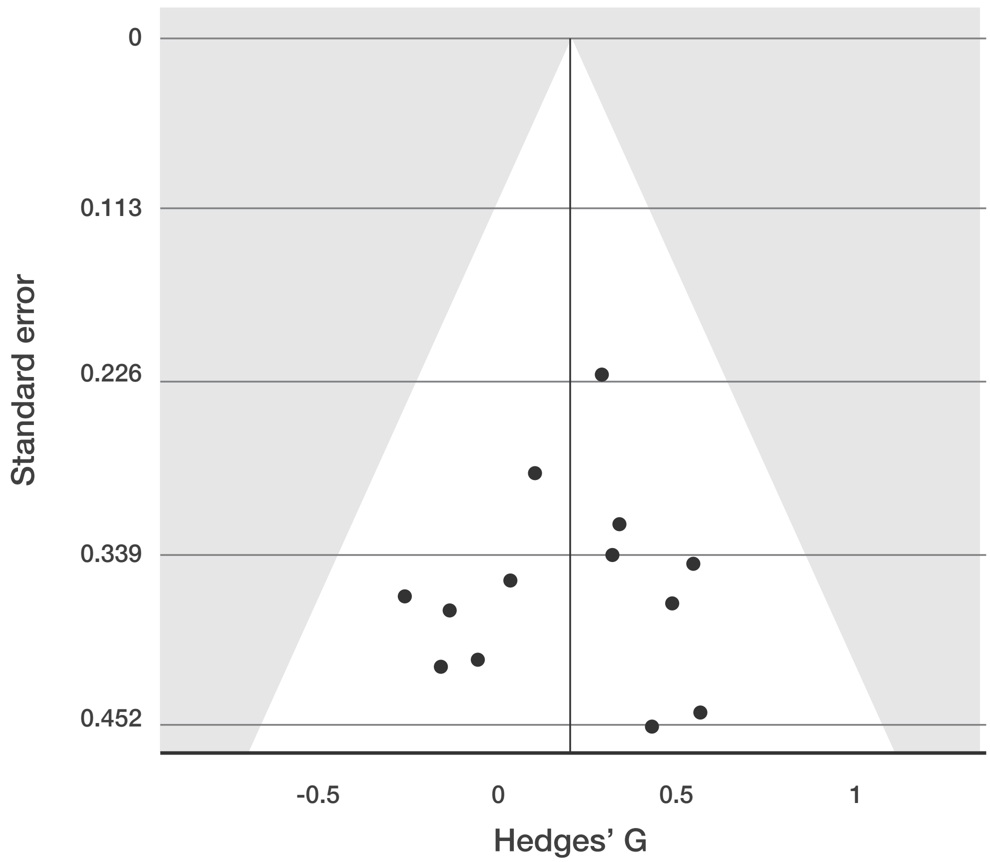
Since this was a meta-analysis, the "subjects" were the individual studies that met the inclusion criteria. The inclusion criteria were:

1. The study had to be published in an English language journal.
2. The subjects had to be healthy (i.e. no research in clinical populations).
3. The study had to compare citrulline versus a placebo for some measure of high intensity strength or power performance.
4. The study had to use exercises that tested large muscle groups (i.e. not something like handgrip strength).
5. The study had to provide a dose of at least 3g of citrulline at least 30 minutes prior to testing.
6. The study couldn't test other ergogenic ingredients along with citrulline, except for malate (citrulline malate is the most common form of citrulline powder on the market).

Once the inclusion criteria were set, the authors searched three databases for studies about citrulline. They initially identified 118 potentially relevant papers after duplicates were removed and screened them down to 12 studies that met all inclusion criteria.

The authors ticked all of the boxes for methodological rigor in a meta-analy-

Figure 2 Funnel plot (standard error vs. Hedges' G) for studies meeting inclusion criteria



A symmetric funnel plot (like this one) suggests low risk of publication bias.

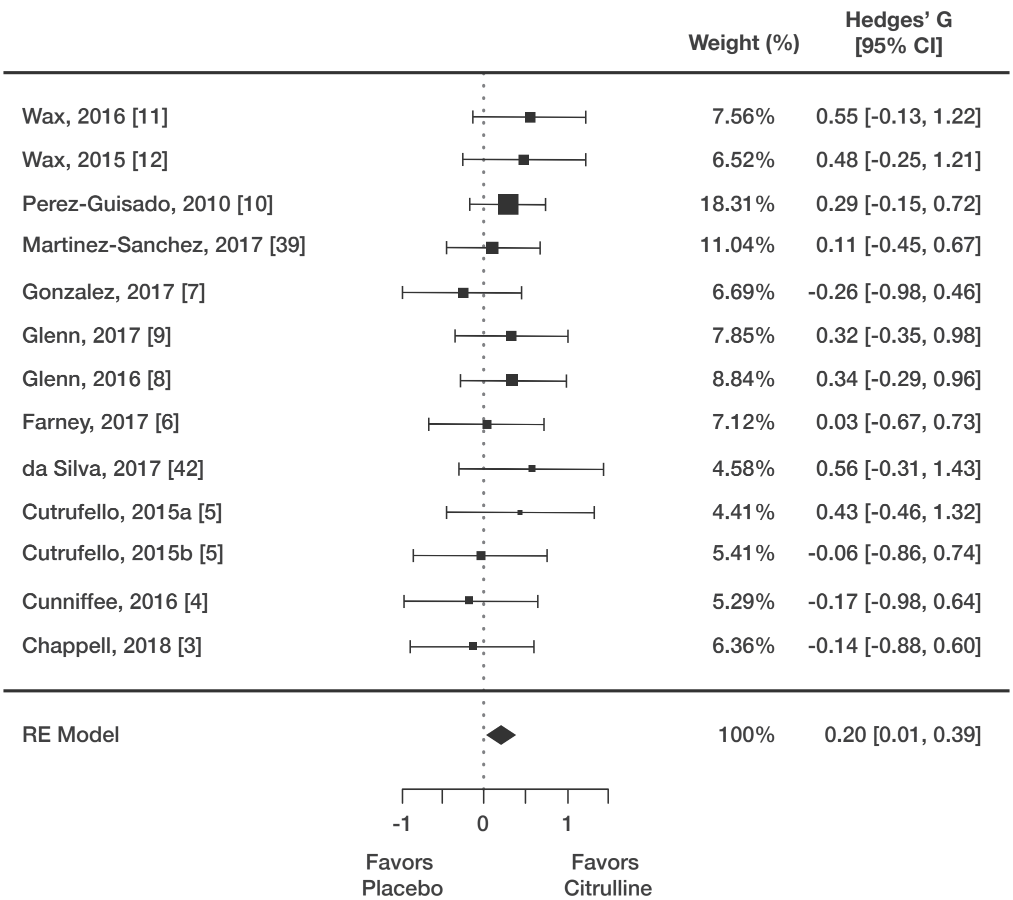
sis, including testing for heterogeneity, assessing risk of bias, and performing robustness checks on their model. The actual analysis was done using a random effects model (which is appropriate for a body of research like this one where the outcome variables aren't all identical), and the authors performed additional analyses to see whether sex, resistance training status, musculature tested (upper vs. lower body), type of outcome (strength vs. power), mode of exercise (traditional resistance exercise vs. resisted cycling), or funding source modified the outcome.

Findings

There was low heterogeneity and risk of bias within this body of literature, both of which are good signs.

For the main analysis including all outcomes from all included studies, citrulline supplementation did have a significant effect ($p = 0.036$) on high intensity exercise performance. However, the effect size straddled the line between

Figure 3 Forest plot of studies meeting inclusion criteria



CI = confidence interval; RE model = random effects model

small and trivial (Hedges g = 0.20), and the confidence intervals almost scraped 0 (meaning the effect almost wasn't statistically significant; 0.01-0.39).

There weren't any statistically significant differences between any of the subgroups in the moderator analyses. However, there were a couple of comparisons worth noting. Citrulline supplementation seemed to have similar effects on both trained (g = 0.21) and untrained (g = 0.18) participants. The effect was also pretty similar for both lower body (g = 0.17) and upper body (g = 0.23) exercise. However, the mode of exercise may matter; when comparing strength versus power outcomes, the effect size was larger for strength outcomes (g = 0.30 vs. 0.04), and the within-subgroup effect was significant for strength outcomes (p=0.01) but not power outcomes (p=0.77). It's unclear whether the form of citrulline matters; citrulline malate is the most popular form used in research and practice, so it's tough to compare it

Table 1 Subgroup analyses

Subgroups	*n* studies	SMD	95% CI	p value
Sex				
Male-only	7	0.23	-0.01 to 0.47	0.06
Females included	6	0.16	-0.14 to 0.45	0.29
Training status				
RT	7	0.21	-0.02 to 0.44	0.08
Non-RT	6	0.18	-0.13 to 0.49	0.26
Citrulline form				
Citrulline malate	10	0.22	0.01 to 0.43	**0.04**
Other	3	0.13	-0.28 to 0.54	0.53
Musculature tested				
Lower-body only	7	0.17	-0.10 to 0.43	0.21
Upper-body included	6	0.23	-0.03 to 0.49	0.08
Type of exercise outcome				
Strength only	8	0.30	0.06 to 0.54	**0.01**
Power included	5	0.04	-0.25 to 0.34	0.77
Modality of exercise				
Resistance exercise	11	0.21	0.01 to 0.41	**0.04**
Cycle ergometry	2	0.15	-0.35 to 0.64	0.56
Funding source				
Industry/undisclosed	5	0.23	-0.04 to 0.50	0.10
Other	8	0.17	-0.08 to 0.43	0.19

Bold p values indicate statistical significance ($p < 0.05$)
n studies = number of studies; SMD = standardized mean difference (Hedges' G);
95% CI = 95% confidence interval; RT = resistance trained

to other forms (including plain L-citrulline), as there were only three studies on all other forms. Finally, funding source didn't seem to make too much of a difference. In studies that were funded by industry, or that didn't disclose their funding source, the effect size was g = 0.23, vs. g = 0.17 in studies that weren't industry funded (a difference of 0.06 points is pretty inconsequential).

Interpretation

There's one thing in the results section that may jump out immediately as a cause for concern for people who know a reasonable amount about stats: The confidence interval for the main analysis almost crossed zero, which means the results almost didn't cross the magic "statistically significant" threshold. As we've discussed in MASS before, barely significant p-values deserve a bit more scrutiny, because they're sometimes hints that the authors fiddled with their analysis to p-hack their way to significance. However, that's not the case here. As mentioned, the authors performed several robustness checks on their results (which you wouldn't do if you knew you were cheating the system, as robustness checks would expose your trickery), and I've discussed this result with the lead author (full disclosure: he's my close friend and employee). He said that they decided on a very conservative set of assumptions for their statistical model on the front end (which means a higher p-value and wider confidence intervals), but that if he went with parameters that would have been less conservative but arguably more appropriate, the confidence interval would have been narrower (and not scraped so close to zero). In other words, they consistently erred on the side of conservative assumptions, which lowered the risk of erroneously finding a statistically significant result. If they had made some more aggressive (but very common and widely accepted) statistical assumptions, the p-values would have been much lower. If anyone would like to discuss the stats further, we can do so in the Facebook group, as this is probably already a longer stats discussion than most MASS readers care for. However, for once, we can probably be slightly more confident in the results than the stats presented in the text would suggest.

DON'T TAKE IT AND EXPECT TO HIT A NEW PR TODAY, AND BE CAUTIOUS ABOUT ASSUMING THAT IT WILL NECESSARILY LEAD TO LARGER STRENGTH GAINS OR MORE HYPERTROPHY IF YOU CONSISTENTLY TAKE IT BEFORE TRAINING.

I enjoyed this meta-analysis because it almost perfectly mirrors a conversation Eric Helms and I had during peer review on one of his past articles on citrulline. He made the point that, after a few promising early results, there had been a rash of citrulline studies finding it didn't lead to significant increases in performance. I fiddled around in the program GPower for a while and determined that the number of significant versus null findings was consistent with what you'd expect from a supplement that had an overall small-to-medium effect, but mostly underpowered studies. It turns out that I was barking up the right tree; Eric was only interested in the studies on strength endurance, and the effect

CITRULLINE SUPPLEMENTATION SEEMS TO BE A NO-BRAINER FOR ATHLETES WHO COMPETE IN SPORTS WHERE STRENGTH ENDURANCE MAY BE A LIMITING FACTOR (LIKE STRONGMAN), AND IT MAY BE WORTH THE COST FOR OTHER STRENGTH AND PHYSIQUE ATHLETES WHO ARE LOOKING FOR A SMALL (FAIRLY AFFORDABLE) EDGE.

size for the strength endurance studies in this meta-analysis was 0.3 (I was thinking it would be around 0.4-0.5). I just wanted to point this out so that you know that as a MASS subscriber, you not only hear about the results of newly published studies; you sometimes hear about the results of studies nearly a year in advance.

I also enjoyed the discussion section of this meta-analysis because it did a good job of contextualizing the results. Sure, the effect size was 0.2 (or 0.3 if you just want to pay attention to the strength endurance studies), but what does that actually mean? The authors contextualize the results by comparing them to other popular supplements with meta-analyses. The effect size for the impact of creatine on upper body exercise is 0.42, and for lower body, it's 0.21 (4). Caffeine's impact on acute strength and power is associated with a similar effect size (0.20 and 0.17; 5). When looking at short-duration exercise tasks (45 seconds to 8 minutes), the effect size for caffeine is 0.41, for bicarbonate it's 0.40, for nitrate it's 0.19, and for beta-alanine it's 0.17 (6). All of which is to say, the effect sizes for citrulline in this meta-analysis are right in line with the effect sizes seen from other supplements that we typically consider to be effective. Now, there are still few enough citrulline studies (12 with either strength or power endurance outcomes, and 8 with strength endurance outcomes) that one negative result might bring the effect back above the "statistically significant" threshold (which the authors acknowledge in their discussion), but the point estimate for the effect size is right in line with what you'd expect from a generally effective supplement.

One final thing I'd like to reiterate is that this meta-analysis was looking at strength endurance/work capacity outcomes (i.e. total reps completed during multiple sets to failure). It wasn't looking

APPLICATION AND TAKEAWAYS

If you're looking for a supplement that improves strength endurance and acute work capacity, citrulline seems to be a safe bet. However, before recommending it more widely, I think we should wait on longitudinal studies to test whether the small boost in training volume actually affects strength gains and muscle growth.

at maximal strength, nor was it looking at gains in performance following training. Don't take it and expect to hit a new PR today, and be cautious about assuming that it will necessarily lead to larger strength gains or more hypertrophy if you consistently take it before training. That's a logical assumption (if you can handle more volume, maybe you'll grow more and gain more strength), but it's an as-of-yet untested assumption.

Citrulline supplementation seems to be a no-brainer for athletes who compete in sports where strength endurance may be a limiting factor (like strongman), and it *may* be worth the cost for other strength and physique athletes who are looking for a small (fairly affordable) edge. If you want to take citrulline, don't rely on pre-workouts, which are typically underdosed; most of the pre-workouts with citrulline have 3g of citrulline malate (and thus, less than 3g of actual citrulline). A better – and cheaper – way to get citrulline is to buy from a wholesaler. That way, you can know exactly how much you're taking. Furthermore, if you want citrulline to help you in your workouts, you should take it 1-2 hours before the start of your workout, since that's when it's approaching peak bioactivity. The dosing that's typically found to be more effective is 8-9g of citrulline malate (or 4.5-5g of plain L-citrulline). Citrulline malate is the most common type of citrulline powder on the market, but plain L-citrulline is probably fine as well.

If you want to learn a lot more about citrulline, I'd strongly recommend this article. It's from the author of this meta-analysis, and it goes way further into mechanisms than would be appropriate for MASS.

Next Steps

I'd love to see a longitudinal placebo-controlled training study on citrulline supplementation. We assume that if something increases your ability to tolerate higher training volumes that it will also increase strength gains and/or lead to more hypertrophy. That line of reasoning worked out well for creatine, but not for bicarbonate. If the performance bump from citrulline *does* improve training outcomes, then it instantly becomes a no-brainer supplement. If it doesn't, then its only clear use would be for circumstances in which your acute strength endurance really matters (i.e. before and during a CrossFit competition, or potentially a strongman competition).

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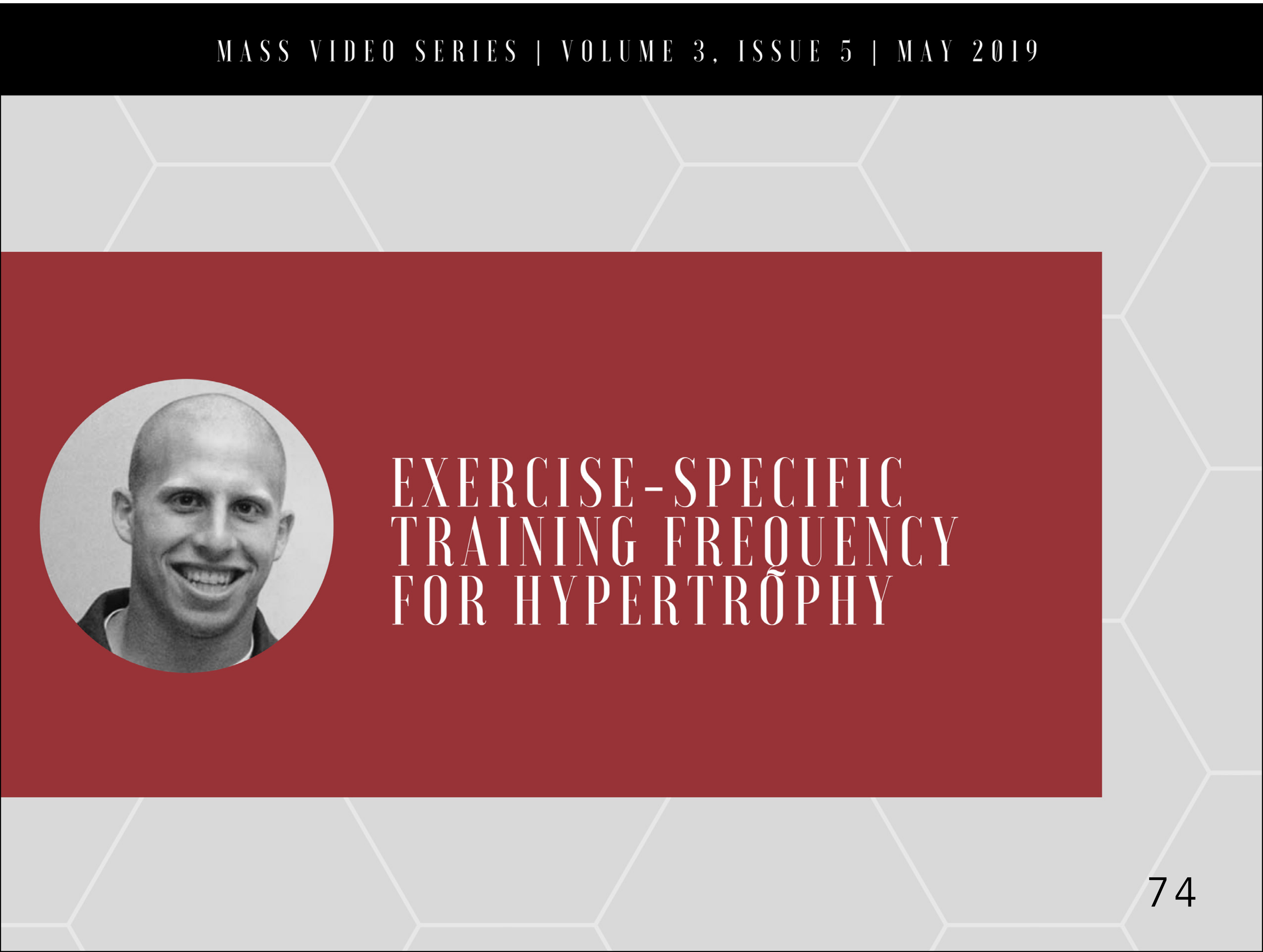
VIDEO: Exercise-Specific Training Frequency for Hypertrophy

BY MICHAEL C. ZOURDOS

Our second Q&A video, in part, examines the old adage that the deadlift is more demanding than the squat and bench press. Is this really the case? Whatever the answer, how can we determine training frequency on the main lifts when hypertrophy is the goal?

Click to watch Michael's presentation.



Relevant MASS Videos and Articles

1. Improving 1RM Strength for Hypertrophy (Volume 3, Issue 4)
2. Mesocycle Construction for Bodybuilding (Volume 1, Issue 9)
3. Program Troubleshooting (Volume 2, Issue 7)
4. Details Matter When Setting up a Full-Body Training Program (Volume 2, Issue 5)
5. Body Segment Lengths Don't Affect Forward Lean in the Squat? (Volume 2, Issue 1)

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VIDEO: Global Contest Prep Fatigue Management, Part 1

BY ERIC HELMS

The demands, requirements, barriers to prep success, their causes, and anecdotal experiences of competitors give us insights for improvement. In part 1 of this series, Eric covers the realities of prep and discusses training modifications to help manage fatigue.

Click to watch Eric's presentation.

Relevant MASS Videos

1. Implementing Deloads Part 1
2. Implementing Deloads Part 2
3. Sustainable Motivation for Sport and Fitness
4. The Structure of Flexible Dieting Part 3

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Just Missed the Cut

Every month, we consider hundreds of new papers, and they can't all be included in MASS. Therefore, we're happy to share a few pieces of research that just missed the cut. It's our hope that with the knowledge gained from reading MASS, along with our interpreting research guide, you'll be able to tackle these on your own.

- O'Bryan et al. Do multi-ingredient protein supplements augment resistance training-induced gains in skeletal muscle mass and strength? A systematic review and meta-analysis of 35 trials
- Schofield et al. Resting metabolic rate prediction equations and the validity to assess energy deficiency in the athlete population
- Bonafiglia et al. Gene expression variability in human skeletal muscle transcriptome responses to acute resistance exercise
- Wilke et al. Acute Effects of Resistance Exercise on Cognitive Function in Healthy Adults: A Systematic Review with Multilevel Meta-Analysis
- Barbalho et al. Evidence for an Upper Threshold for Resistance Training Volume in Trained Women
- Chen and Power. Modifiability of the history dependence of force through chronic eccentric and concentric biased resistance training
- Haun et al. A Critical Evaluation of the Biological Construct Skeletal Muscle Hypertrophy: Size Matters but So Does the Measurement
- Wilk et al. The Effects of Eccentric Cadence on Power and Velocity of the Bar during the Concentric Phase of the Bench Press Movement
- Neto et al. Barbell Hip Thrust, Muscular Activation and Performance: A Systematic Review
- Pareja-Blanco et al. Time Course of Recovery Following Resistance Exercise with Different Loading Magnitudes and Velocity Loss in the Set
- Murach et al. Muscle Fiber Splitting Is a Physiological Response to Extreme Loading in Animals
- Boerner et al. Is What You See What You Get? Perceptions of Personal Trainers' Competence, Knowledge, and Preferred Sex of Personal Trainer Relative to Physique
- Pérez-Castilla et al. Reliability and Concurrent Validity of Seven Commercially Available Devices for the Assessment of Movement Velocity at Different Intensities During the Bench Press
- Dinsdale and Bissas. Eliciting Postactivation Potentiation With Hang Cleans Depends on the Recovery Duration and the Individual's 1 Repetition Maximum Strength

Thanks for reading MASS.

The next issue will be released to subscribers on June 1.

Graphics by Katherine Whitfield, and layout design by Lyndsey Nuckols.