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MASS

MONTHLY APPLICATIONS IN STRENGTH SPORT

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The Reviewers

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Letter from the Reviewers

This issue marks two full years of MASS. Our thanks to every person reading this, as it is only because of you that we have had such a successful two years and that MASS has such a bright future.

We are especially excited about this issue as it covers many new topics for the MASS audience. One of the new topics is heart rate variability. While you may have heard of heart rate variability before, there is surprisingly no evidence regarding its usage as an indicator of readiness for long-term resistance training. In one of his written articles, Eric has covered the first study to examine if heart rate variability is an effective readiness indicator to use as a part of a flexible training template. Eric has also covered a new systematic review on probiotic supplementation. Probiotics have been supported by a large marketing wave over the past few years, but this article tells you if they are actually worthwhile for strength sports.

Greg expands on this issue's array of new topics by covering a study that examined how many calories lifting can burn. Greg has also tackled a new paper demonstrating that your tolerance to caffeine may indeed diminish with habitual use; thus, it may be advisable to restrict the intake to certain training sessions. Greg's third article poses the question: "Do heeled squat shoes really help?" The answer may surprise you.

Mike also brings a new topic to this issue by reviewing a recent study which evaluated the efficacy of different 1RM prediction methods. Included in this article is a link to a video Mike made which shows you exactly how to predict your 1RM using submaximal velocities. Additionally, Mike examines the concept of programming introductory training weeks to avoid significant muscle soreness based upon a recent study, which suggests that really light training is effective at eliciting the repeated bout effect.

In the video content, Eric continues his deload series, in which he walks you through sample deloads and introductory cycles that you can put into practice. Finally, Mike has delivered our first ever Q&A video based upon your questions. This Q&A discusses if improving 1RM strength is beneficial for hypertrophy, and if so, how you can train for it without sacrificing hypertrophy-type training.

To ask a question for a future Q&A video, just go to the Facebook group. In the search bar on the left side of the page, search "Q&A" and the official thread will pop up. Then, go ahead and ask a question on the thread, and we'll be sure to get to it in the future. Also, don't forget to give the audio roundtables a listen.

Thank you for being a part of the first two years of MASS. We plan on seeing you for many more.

The MASS Team

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Welcome to our very first question and answer video. One of our subscribers has asked if increasing 1RM with low rep work is beneficial for hypertrophy or if you are better off just training in the moderate to high rep ranges. This video tackles that question and lays out practical strategies for how strength and hypertrophy training don't have to be mutually exclusive.

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VIDEO: Implementing Deloads, Part 2

Deloads, often referred to as light weeks, recovery weeks, or unloads are a fundamental part of training periodization and programming. In part 2 of this series, Eric builds on the rationale, tenets, and periodization concepts of part 1 by giving specific examples you can use as templates to build on.

Study Reviewed: Predicting the Energy Expenditure of an Acute Resistance Exercise Bout in Men and Women. Lytle et al. (2019)

How Many Calories Do You Burn Lifting Weights?

BY GREG NUCKOLS

When people exercise specifically to burn calories, they tend to turn to traditional cardio, but lifting weights obviously burns calories as well. How many? That's what this study aimed to find out.

KEY POINTS

1. A mixed-sex cohort completed a workout consisting of seven exercises for 2-3 sets of 8-12 reps with 70% of predicted 1RMs.
2. During the workout, researchers measured gas exchange, which allowed them to estimate caloric expenditure.
3. Lifting may burn anywhere from 75-300+ calories per workout, based primarily on work performed; volume load is our best proxy for work.

How many calories do you burn lifting weights? I think that question has at least flashed into most people's minds, but there's surprisingly little research on the topic. Anecdotally, I've found that most lifters tend to massively overestimate the caloric cost of their training. In the present study (1), subjects completed a workout consisting of seven exercises for 2-3 sets of 8-12 reps with 70% of predicted 1RMs, while researchers estimated their caloric expenditure based on analyzing gas exchange (indirect calorimetry). With that data, they constructed a regression model to predict the energy cost of a single training session. They also assessed excess post-exercise oxygen consumption (EPOC) and found that the additional caloric expenditure after training due to EPOC is a scant 7-8 calories.

Purpose and Research Questions

Purpose

The purpose of this study was to quantify the energy cost of a single resistance training session, and to develop regression equations to predict energy expenditure during resistance training.

Research Questions

1. How many calories are expended during a full-body resistance training bout?
2. What equations can be used to predict energy expenditure during resistance training on an individual basis?

Hypotheses

The researchers hypothesized that aerobic capacity, height, weight, body composition, age, and total exercise volume would be included among the variables that would predict energy expenditure during a resistance training session.

Subjects and Methods

Subjects

The subjects were 52 healthy, active

Table 1 Subject characteristics

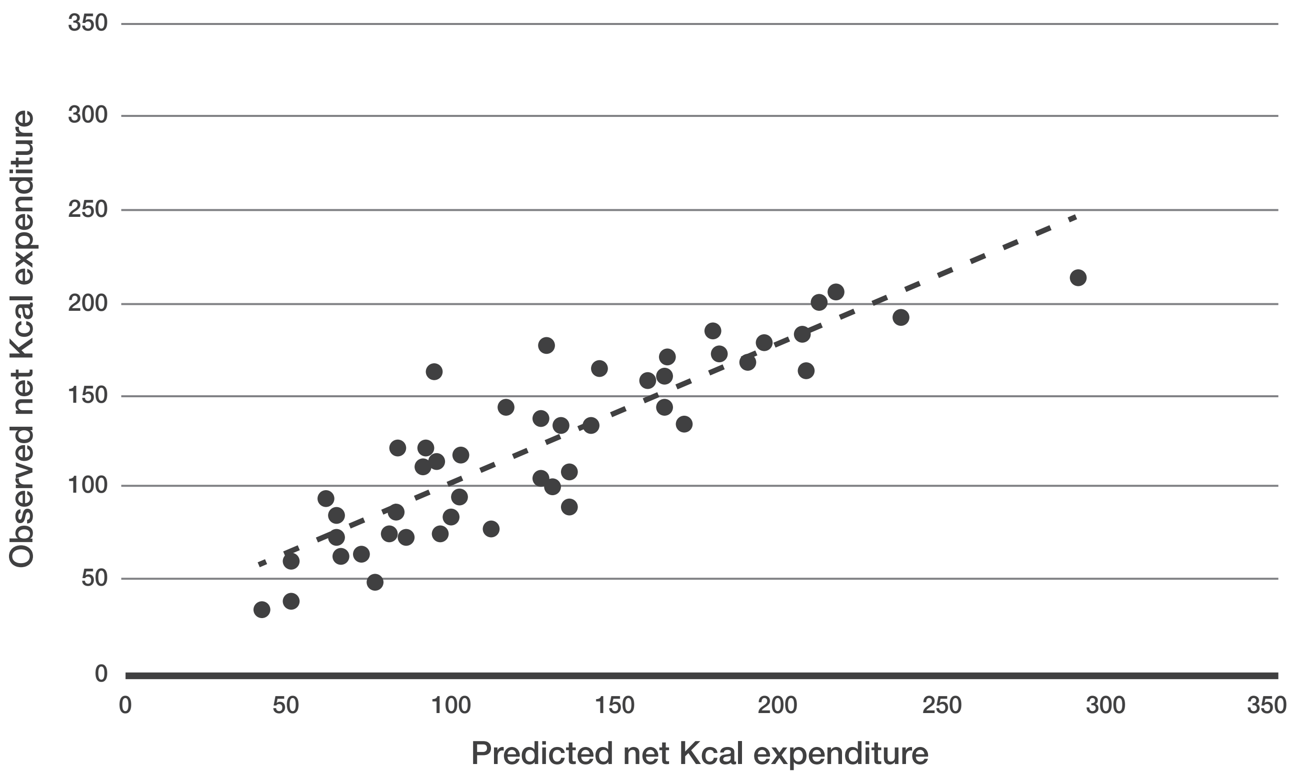
Subjects (n=52)	Males (n=27)	Females (n=25)
Height (cm)	181.9 ± 6.1	165.4 ± 6.8
Weight (kg)	94.0 ± 18.0	76.4 ± 16.7
Age (years)	30.0 ± 11.3	36.0 ± 13.2
VO_2max (L/min)	3.7 ± 0.6	2.37 ± 0.42
VO_2max (mL/kg/min)	40.6 ± 8.6	32.6 ± 8.0
DEXA fat %	27.2 ± 8.7	38.8 ± 10.3
DEXA fat mass (kg)	24.9 ± 11.0	29.0 ± 13.0
DEXA lean mass (kg)	64.0 ± 8.9	42.6 ± 5.6

adults aged 20-58. The sample included 27 men and 25 women. More details about the participants can be seen in Table 1.

Study Overview

This study took place over three visits. In the first visit, the researchers collected basic anthropometric and body composition data (via DXA), and the participants performed a VO2max test on a treadmill. In the second visit – at least 72 hours after the first visit, and at least one week prior to visit three – the researchers determined the subjects' 3-5RM for all of the exercises used in the study (leg press, chest press, leg curl, pull-down, knee extensions, triceps push-downs, and

Figure 1 Comparison of observed vs. predicted net Kcal expenditure



Total net Kcal = 0.874(Height, cm) - 0.596(Age, years) - 1.016(Fat mass, kg) + 1.638(Lean mass, kg) + 2.461(Total volume [sets·reps·weight], kg·10^{-3}) - 110.742
Adj. R^2 = 0.773
R^2 = 0.879
SEE = ±28.465

biceps curls). The 3-5RMs were used to predict 1RMs for each exercise. Of note, all of the exercises were machine-based, and the machines used in this study all employed pneumatic resistance.

During the third visit, subjects completed a full-body resistance training session, performing the aforementioned exercises for 2-3 sets to failure with 70% of their predicted 1RMs, with approximately 90 seconds between sets. For all exercises, if the subjects completed at least 8 reps on their second set, they performed a third set; if they got fewer than 8 reps on their second set, they just moved on to the next exercise. During the workout, gas exchange was measured using a metabolic cart, allowing energy expenditure to be estimated for each exercise and for the entire session. The researchers estimated *excess* calorie expenditure. In other words, if a subject burned 250 calories during the session, but they would have burned 100 calories at rest, the excess calorie expenditure was 150 calories.

A subsample of nine participants underwent further testing to estimate excess post-exercise oxygen consumption (EPOC). The researchers estimated EPOC by measuring the subjects' RMR (again, using the metabolic cart) at rest, and then measuring energy expenditure again for 30 minutes following the resistance training session during visit three. EPOC was defined as the cumulative difference between caloric expenditure at rest and caloric expenditure following the training session.

Findings

The male subjects burned approximately twice as many calories as the female subjects (161.2 ± 65.9 vs. 87.6 ± 39kcal), but energy expenditure was similar when normalized to lean mass (2.8 ± 1.0 vs. 2.4 ± 1.3 kcal per kg of lean mass). For predicting energy expenditure during the entire session, height, weight, age, sex, lean body mass, fat mass, and total volume load (sets × reps × load) were significant predictor variables, and a regression equation based on these variables did a good job predicting energy expenditure during the session (adjusted $r^2 = 0.77$). Different regression equations were also developed for each individual exercise, with each exercise having a different mix of predictor variables (2). A statistically significant but practically meaningless amount of EPOC took place following the session, as EPOC only accounted for an additional 7.43 calories burned, on average.

Interpretation

I was excited to review this article this month, simply because I see so many hot takes regarding the number of calories burned during strength training. Some people think it burns basically no calories, and others seem to think that lifting consistently will let you eat 4,000 calories per day. The truth is much more boring, lying somewhere in between.

Now, regarding the actual regression

Table 2 Experiment results

Exercises	Regression coefficients								Model Fit	
	Height (cm)	Age (years)	Gender (m=1, f=0)	Fat mass (kg)	Lean mass (kg)	Weight (kg)	Volume m3 (kg)	Constant	R square	SEE
Total	0.874	-0.596		-1.016	1.638		2.461	-110.742	0.773	28.465
Leg press	0.120	-0.093		-0.252	0.297		1.169	-13.837	0.830	4.400
Chest press	0.186	-3.173		-0.198	0.271		4.211	-28.468	0.680	4.700
Leg curl		-0.129			0.245	-0.100	5.189	6.633	0.620	5.360
Lat pull down		-0.165		-0.128	0.187		4.725	8.483	0.670	4.960
Leg extension		-0.08	-1.635	-0.185	0.394		4.252	1.444	0.700	5.310
Triceps pushdown	0.255		-5.124	-0.239	0.390		0.919	-44.891	0.720	4.990
Biceps curl	0.292	-0.091	-7.068		0.351	-0.156	15.059	-44.262	0.620	5.603

equations provided in this paper, I'm not sure we should put *that* much stock in them. If you want to play around with a calculator, I made one here (Note: download it or make a copy to your Google Drive. *DO NOT* request editing access), but I'm not sure it would be all that accurate for most MASS readers' workouts. Although resistance is fairly similar using free weights and pneumatic machines, they're not identical (3). Furthermore, as you can see from the different regression equations for each exercise, not all exercises are created equal. They used three compound and four isolation machine exercises in this study; if you just do a bunch of free weight compound exercises, the equation probably wouldn't be super accurate.

I'm also a little irked that the authors only reported the r^2 values for the full multiple regression models and didn't report the relationships between caloric expenditure and each of the independent variables. In theory, volume load should be a pretty good predictor by itself, and I can't think of a good *a priori* reason to assume that some of the other variables (fat mass, height, sex, and age) would directly affect caloric expenditure during lifting independent of volume load. During exercise, caloric expenditure is primarily driven by work performed (force × distance / time). To actually calculate work, you'd need to know the range of motion for each exercise in addition to the load and total reps, but volume load serves as a pretty good proxy. Several of the other variables were likely correlated with volume load (sex, lean body mass, and possibly age), so I'm not sure how much they actually improve the model. Now, my hunch may be wrong, and maybe volume load was only moderately associated with caloric expenditure by itself, and all of the other variables really did substantially improve the model, but I'd at least like to see the independent effect of just volume load.

SOMEWHERE AROUND 75-100KCAL SEEMS TO BE A DECENT ESTIMATE FOR A LOWER VOLUME SESSION IN WOMEN, ~150KCAL SEEMS TO BE A DECENT ESTIMATE FOR A LOWER VOLUME SESSION IN MEN OR A HIGHER VOLUME SESSION IN WOMEN, AND A HIGHER VOLUME SESSION IN MEN WOULD PROBABLY BURN 300KCAL OR SO.

Just to contextualize the results of this

> IF YOU'RE PURELY INTERESTED IN MAXIMIZING CALORIC EXPENDITURE, LIFTING DOESN'T HOLD A CANDLE TO TRADITIONAL FORMS OF CARDIO.

study, its estimates of calorie expenditure were pretty much in line with the other research on the subject. For example, a prior study in women found an average caloric expenditure of 155kcal after a somewhat higher volume lifting session (10 exercises for 3 sets of 10 at 70% 1RM; 4), while another study found an average caloric expenditure of 135kcal in men and 82kcal in women after a somewhat lower volume session (8 exercises for one set of 15 with a 15RM load; 5), and another study found that deadlifting 175kg for 8 reps burns about 10kcal per set (6). So, somewhere around 75-100kcal seems to be a decent estimate for a lower volume session in women, ~150kcal seems to be a decent estimate for a lower volume session in men or a higher volume session in women, and a higher volume session in men would probably burn 300kcal or so. However, keep in mind that total caloric expenditure will ultimately depend on the total amount of work performed. In other words, if two people both do 3x10 at 70% of 1RM for a given exercise, but the second person lifts twice as much weight as the first, the second person will probably burn about twice as many calories. If you adjust your training to increase volume load (doing 10s instead of triples, for example, or doing more total sets), the caloric expenditure will likely increase proportional to the increase in volume load. A high volume session for a very strong lifter can probably burn 500+ calories, but that's not the norm.

So, the next logical question is, "is lifting actually *good* at burning calories." And the answer is … well, not really. If you're purely interested in maximizing caloric expenditure, lifting doesn't hold a candle to traditional forms of cardio. For example, as a decent rule of thumb, a 150lb person burns about 100kcal jogging one mile over flat ground. Even if you run that mile in a leisurely 10 minutes, you're still burning about 10kcal per minute. If you're around 200lbs and run a mile in seven minutes, you're burning closer to 135kcal, at a clip of over 19kcal per minute. Average caloric expenditure in this study was about 1.7kcal per minute for women, and 3.1kcal per minute for men. In a previous study, average caloric expenditure was about 2.4kcal per minute for women (4). Sure, you could increase your kcals burned per minute by doing more reps and taking shorter rest

APPLICATION AND TAKEAWAYS

Just keep in mind that energy expenditure during lifting depends on the total amount of work done. In general, that shouldn't affect much outside the gym, but you may want to decrease or increase your food intake if you're about to dramatically decrease or increase training volume.

intervals, but the rate of energy expenditure will never hold a candle to traditional cardio. Now, if you're not primarily lifting weights specifically to burn a bunch of calories, that may not matter to you, but it's still useful information to contextualize these findings.

The final question we should ask is, "am I going to be burning enough calories during training to warrant preemptive nutrition adjustments with changes in training volume?" In general, I think the answer is probably no … at least if you're making smart training adjustments. Increasing volume too quickly can increase injury risk (7), so a safe rule of thumb is to not increase volume faster than about 10-20% per week. Even if you're super strong and your training volume is already high, so you're burning 500kcal per session, a 10-20% increase would only increase caloric expenditure by about 50-100kcal, which will barely be noticeable across an entire day of eating. Now, if you're dropping from a very high volume program to a very low volume program (maybe for peaking aggressively), and we assume your per-session caloric expenditure is decreasing from 400 to 100, and we assume your training frequency is dropping from five sessions per week to three, then it may be worth making some preemptive adjustments, since that's a pretty large change (weekly caloric expenditure would decrease by about 1700kcal). Conversely, if you throw caution to the wind and triple your training volume overnight (don't do this), you may need to preemptively eat more to account for the increase in caloric expenditure. But under normal circumstances, as long as you're making sane training adjustments, the difference in caloric expenditure you'll experience due to changes in training volume is probably negligible.

One final note about this study: there was some EPOC, but it wasn't anything to write home about. Now, the 7kcal figure is lower than what's been reported elsewhere in the literature (8), but you're not going to find any studies showing EPOC accounts for hundreds of additional calories burned. Thankfully that idea has fallen out of fashion, but several years ago, everyone and their brother seemed to be claiming that lifting burned a ton of extra calories through EPOC.

That's just not the case. Now, it is true that resistance training may elevate your metabolic rate by ~5% for 24-72 hours after a training session (9; primarily to repair muscle damage, in all likelihood), but that's distinct from EPOC, which primarily refers to the additional energy that must be expended just to get the body back to a metabolic baseline (metabolizing lactate, resynthesizing phosphocreatine, etc.).

Next Steps

I'd love to see a study estimating caloric expenditure in a single cohort of people performing three training sessions with the same exercises and numbers of sets, but with different intensities (and thus volume loads) just to check my bias that total work performed is the primary driver of caloric expenditure when lifting. This study comes close (10), but I'd prefer to see a regression-based approach that accounts for strength differences between individuals rather than just prescribing different fixed volume loads.

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Study Reviewed: Validity of Different Velocity-Based Methods and Repetitions-to-Failure Equations for Predicting the 1 Repetition Maximum During 2 Upper-Body Pulling Exercises. Perez-Castilla et al. (2019)

Practical and Effective Ways to Predict Your 1RM

BY MICHAEL C. ZOURDOS

There are many equations to predict 1RM, but which one is the most accurate? This study shows that just two velocity points can predict a 1RM with pretty good accuracy. This article will walk you through exactly how to do this and examine other popular 1RM prediction methods.

KEY POINTS

1. This paper compared using submaximal velocity methods and formulae based on reps performed at 80% of 1RM to predict 1RM in the seated row and lat pull-down.
2. While all methods of 1RM prediction were reasonably accurate at predicting 1RM, velocity-based equations provided more accurate 1RM predictions than the reps-performed formulas for the seated row.
3. Although the 1RM prediction methods used in this study were fairly accurate, lifters should always remember that a 1RM prediction equation is unlikely to be perfectly accurate, so appropriate precautions should be taken if using a predicted 1RM to guide training or powerlifting attempt selection.

Sometimes you hit a rep personal record and immediately go to the phone calculator and plug your numbers into an online formula to predict your 1RM. The Epley equation (2) is one of the first equations to do this and is quite similar to the popular equation: 1RM = [(Reps X Weight Lifted X 0.0333) + Weight Lifted]. The problem is that these equations are not always accurate. One reason predicting 1RM based upon reps performed is inaccurate is because the amount of reps that can be performed at a specific percentage of 1RM is highly individual (3). Two people could squat 175kg for 10 reps but could have considerably different 1RMs. More recently, researchers have found average velocity at submaximal intensities to accurately predict 1RM on the bench press (4), but little data exists related to other lifts. This study (1) had 23 collegiate men and women work up to a 1RM on both the lat pull-down and seated row, and the researchers collected average velocity on all warm-up sets. After the 1RM, all subjects performed one set to failure using 80% of their 1RM. Velocity was then used to predict 1RM using 4-point (40, 55, 70, and 85% of 1RM) and 2-point (40 and 85% of 1RM) methods, and the number of reps performed with 80% of 1RM was used to predict 1RM using both the Mayhew (5) and Wathen equations (6). While all equations had acceptable accuracy, both velocity equations tended to be better at predicting 1RM than both reps-performed methods for the seated row; however, all equations provided similar accuracy on the lat pull-down. Additionally, the reps-performed equations seemed to underrate an individual's 1RM. This article will not only discuss the evidence surrounding 1RM prediction equations but will walk you through how to use a linear regression forecast to predict 1RM using the 2-point velocity method so that you can do it yourself.

Table 1 Subject characteristics

Subjects	Age (years)	Body mass (kg)	Height (cm)	Lat-pulldown 1RM (kg)	Seated cable row 1RM (kg)
12 men	20.8 ± 2.5	78.9 ± 10.7	179.6 ± 6.1	78.1 ± 14.0	74.4 ± 14.2
11 women	20.2 ± 1.1	65.3 ± 4.4	172.2 ± 4.9	46.1 ± 7.3	44.1 ± 6.2

Data are mean ± SD
Subject characteristics from Perez-Castilla et al. 2019 (1).

Purpose and Research Questions

Purpose

The purpose of this study was to examine the accuracy of predicting 1RM in the lat pull-down and seated row using 2- and 4-point velocity equations and reps-performed equations.

Research Question

1. Can 1RM on the lat pull-down and seated row be accurately predicted using velocity during the warm-up sets?
2. Can 1RM on the lat pull-down and seated row be accurately predicted by the amount of reps performed at 80% of 1RM?
3. Are velocity equations more accurate than reps-performed equations for predicting 1RM in the lat pull-down and seated row?

Hypotheses

No hypotheses were provided

Subjects and Methods

Subjects

Twenty-three college students (12 men and 11 women) participated. All students were "sport sciences" students, but no training experience was given. Full subject details are in Table 1.

Protocol

Subjects completed this crossover design study over two days, which were 48-72 hours apart. Each day was the same except one day was for the lat pull-down and the other for the seated row. Subjects worked up to a 1RM on the day's lift and velocity was collected during all warm-ups and 1RM attempts using both a linear position transducer (Real Power Pro Globus) and a phone application (Powerlift). After the 1RM test, subjects rested 10 minutes and then performed reps to failure at 80% of the 1RM.

Six different 1RM predictions were made; these are laid out in Table 2. Predictions were made with a linear regression forecast (this is explained in the interpretation), then each prediction was compared against the actual 1RM for accuracy using various statistics (t-test, effect size, correlations, and Bland-Altman plots).

The Mayhew (5) and Wathen (6) equations can be seen and automatically calculated by simply plugging in your relevant numbers here.

Table 2 List of 1RM prediction methods

1. 4-Point Velocity using values obtained at ~40, 55, 70, and 85% of 1RM from the linear position transducer during the warm-up
2. 2-Point Velocity using values obtained at ~40 and 85% of 1RM from the linear position transducer during the warm-up
3. 4-Point using values obtained at ~40, 55, 70, and 85% of 1RM from the phone application during the warm-up
4. 2-Point Velocity using values obtained at ~40 and 85% of 1RM from the phone application during the warm-up
5. The Mayhew equation using reps performed at 80% of 1RM
6. The Wathen equation using reps performed at 80% of 1RM

Findings

Main Points

In short, the velocity methods tended to be better than the reps-performed methods, and the velocity methods predicted 1RM with similar accuracy. Statistically, the velocity methods predicted seated row more accurately than the reps-performed methods (p=0.004); however, there was no statistical difference between methods for prediction of 1RM in the lat pull-down (p=0.20).

Agreement of Prediction Methods

Correlations were very high (r≥0.96) between predicted 1RM and actual 1RM for all methods; however, two sets of values can highly correlate yet still disagree (7), so we turn to the Bland-Altman plots to determine agreement of the predictions with the actual 1RM. The Bland-Altman plots showed better agreement between the velocity-based 1RM predictions and actual 1RM for the seated row (compared to reps-based methods and actual 1RM), but there was not much difference for the lat pull-down.

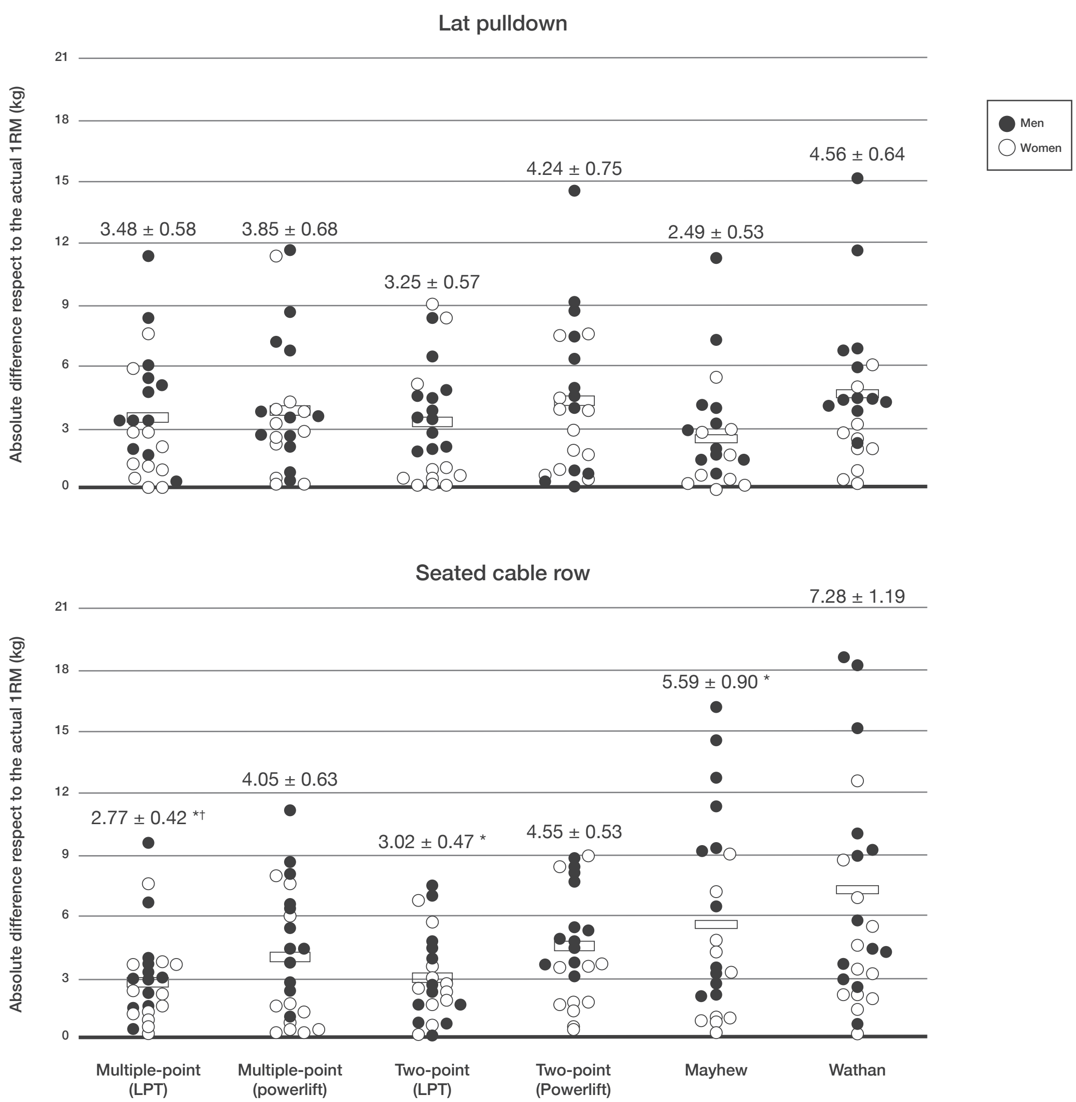
Effect Sizes

Effect sizes for agreement studies are interpreted a bit differently, with anything over 0.1 being small (normally that is 0.2). In this study, the effect sizes between the reps-performed methods and actual 1RM for both exercises were all between (-0.10 and -0.32); they are negative because the predictions were underestimations. Across all velocity methods, the effects sizes between the predicted and actual 1RMs were smaller than reps performed and ranged from -0.08 to 0.09.

Mean Differences

In Figure 1, each dot represents an individual subject, and the distance between each dot and the x-axis is the difference between the actual and predicted 1RM. The values on top of each dot are the mean and standard deviation for the difference of each equation between

Figure 1 Mean difference for each prediction versus the actual 1RM



*LPT = Linear Position Transducer; * = Significantly different than the Wathen equation according to the ANOVA; † = Significantly different than the Mayhew equation according to the ANOVA*

the actual and predicted 1RM. Despite the Mayhew equation actually having the lowest mean difference for lat pull-down, there was no difference between means of any prediction method for the lat pull-down.

For the seated row, velocity equations were statistically better than the reps-performed equations. All mean values on these figures show an underestimation of 1RM in kilograms.

Interpretation

The main points are as follows: 1) Both velocity methods had better accuracy than the reps-performed methods, especially for the seated row; and 2) The reps-performed methods tended to underestimate the 1RM. The underestimation could be due to the reps to failure sets being performed after the 1RM test. Therefore, fatigue from the 1RM test could have caused fewer reps to be performed at 80% of 1RM than an individual could have done prior to the 1RM test, but this is speculative. It's not surprising that the velocity predictions were better than reps-performed predictions. There are quite a few reps-performed equations out there, most of which you can see at this link. The two equations used in this study, Mayhew and Wathen, were both previously shown to be the most accurate of the reps-performed equations for predicting bench press 1RM, with the Wathen most accurate for the squat (2). The one other equation worth mentioning is the Epley equation, as it is one of the earliest developed and is simple to calculate (2). The Epley equation is as follows: 1RM = Weight * (1+ Reps Performed / 30). For example, if someone squatted 205kg for 5 reps, the Epley formula would predict a 1RM of 239kg. Reps-performed equations do seem to get more accurate as the reps performed gets lower. Specifically, in the Epley equation 225kg X 2 would estimate a 1RM of 240kg, which seems pretty accurate for most. As a side note, if you've read the 5/3/1 Manual, the equation used there is essentially the Epley equation just stated this way:

BOTH VELOCITY METHODS HAD BETTER ACCURACY THAN THE REPS-PERFORMED METHODS.

1RM = [(Weight X Reps X 0.0333) + Weight].

A main problem with reps-performed equations is that there is a large between-individual variation in the amount of reps performed at a given intensity. Cooke et al reported that well-trained men and women were able to perform 14 ± 4 reps on the squat at 70% of 1RM with a range of 6-26 reps among the lifters (3). Two people may be able to perform 10 reps at 175kg on the squat, but could have considerably different 1RMs; however, the reps-performed equation would predict the same 1RM. The between-individual difference in reps performed at higher intensities is likely lower, which is one reason these general equations may be more accurate at higher intensities. Another drawback of reps-performed equations is that doing a rep-max test can be fatiguing. So, one way to avoid performing a fatiguing rep-max test and to individualize your prediction is to simply work up to a pretty heavy load and record an RPE value after a single rep. If you work up

A MAIN PROBLEM WITH REPS-PERFORMED EQUATIONS IS THAT THERE IS A LARGE BETWEEN-INDIVIDUAL VARIATION IN THE AMOUNT OF REPS PERFORMED AT A GIVEN INTENSITY.

to a squat single at 225kg at an 8RPE (that means you could do three reps total), then you could use 225 X 3 with one of the prediction equations. Obviously, the accuracy of that is predicated on the RPE being correct, but if the lifter is experienced, it's probably going to be pretty accurate.

Since the 4-point and 2-point velocity equations in this study provided similar prediction accuracy, let's focus on the 2-point one because it's simpler. The 2-point equation used roughly 40 and 85% of 1RM because they corresponded to velocities of ~1.0 and 0.5 $m{\cdot}s^{-1}$, which were the velocities used in a previous study showing the 2-points method to accurately predict Smith machine bench press 1RM (4). To actually use this method, you need to do a linear regression forecast. To do this, you would take the two loads lifted (x values or independent variables) and the velocities (y values or dependent variables) and calculate the intercept and slope. Then, you would multiply the slope by the load lifted and then add the intercept. Next, if you provide a new load (x value), this equation will then predict a velocity (y value) for that load. So, how do you know what the 1RM prediction is? Well, you get the prediction based upon the velocity. For a trained individual, if a squat 1RM velocity is about 0.24 $m{\cdot}s^{-1}$ (8), then whatever load corresponds with that is your predicted 1RM. The best way to do this would be to know your own average velocity at a 1RM since velocity profiles are individualized (9), as that would certainly improve this prediction. I realize that may have been just a bit confusing to read, so I made a video that you can watch here that walks you through this process step-by-step. Additionally, courtesy of Greg, here is a downloadable calculator with the formula already entered (to enter your data, just go to File → Download As, and download a copy for yourself). If using the calculator, you can alter the 1RM velocity for a specific lift and to be specific to you. Then, enter your own values for load and velocity, and the 1RM prediction will change accordingly.

Overall, no method of 1RM prediction is going to be perfectly accurate, but

APPLICATION AND TAKEAWAYS

1. These results demonstrate that although reps-performed equations can predict 1RM with reasonable accuracy, a 2-point submaximal average velocity method was better for predicting 1RM in the seated row.
2. Although the velocity methods were accurate, they are not as easy to calculate as the reps-performed methods. Please refer to the video along with this article for clarity on this method.
3. With any 1RM prediction equation, lifters should always understand that the prediction is unlikely to be perfectly accurate. Therefore, if you are calculating percentages for load prescription off of a predicted 1RM, it is advisable to use a slightly lower (i.e. 2.5-5kg lower) working 1RM in the first week of the training block just to ensure that the predicted 1RM is not too heavy.

hopefully this article helps you get pretty close. Predicting 1RM can be a useful tool for the following reasons: to gauge progress over time without always doing an actual test, getting a 1RM to calculate percentages, or even predicting a 1RM in your warm-up to help with attempt selection if you are testing your lifts in the gym. Also, sometimes you just need to calculate your 1RM off of a rep PR because, well, you just feel like you have to know immediately.

Next Steps

I'd like to see four things in this area: 1) Use of individual 1RM velocities to make predictions using the 2-point method; 2) Use of the 2-point velocity method in the squat, bench press, and deadlift; 3) Testing the method using RPE that I described above; and 4) More studies on the deadlift because, to date, no equation seems to be particularly accurate for predicting deadlift 1RM (2) from reps performed.

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Study Reviewed: Effect of Individualized Resistance Training Prescription with Heart Rate Variability on Individual Muscle Hypertrophy and Strength Responses. de Oliveira et al. (2019)

Heart Rate Variability-Guided Resistance Training

BY ERIC HELMS

Heart rate variability is an established autoregulation tool for endurance training. However, this is the first study examining its utility for guiding a flexible resistance training model. At first glance, this heart rate variability-guided training program seems to be no better than fixed training, but in actuality, it may allow you to make gains at a faster pace.

KEY POINTS

1. Heart rate variability is a measurement of how much variance there is in the timing between beats of your heart. Even if your resting heart rate is unchanged day-to-day, there may still be differences in the time intervals *between* beats. This is your heart rate variability, which represents your autonomic nervous function, reflecting your global state of fatigue, readiness, and recovery.
2. In this study, young male participants were split into two groups who performed the same full-body resistance training program consisting of 20 sessions. In one group, they simply trained three days per week for seven weeks. In the other group, they trained at a frequency dictated by when their heart rate variability had returned to baseline.
3. While there were no significant nor meaningful differences between groups in hypertrophy or strength, the heart rate variability-guided group was able to complete their prescribed 20 sessions in 5.1 weeks, while the fixed training group completed the protocol in 7 weeks.

We've discussed many methods of autoregulation in MASS previously, including autoregulating session configuration, exercise selection, and RPE- and velocity-based manipulations of load and volume. This article continues that theme, looking once again at flexible training templates. Mike provided an in-depth discussion of flexible training templates guided by RPE, perceived recovery status, velocity, and jump height in this video. However, one method of implementing a flexible training template that we haven't yet addressed is the use of heart rate variability. You are probably familiar with the concept of your heart rate, expressed in beats per minute. Heart rate variability is simply a way to quantify the variability of the time interval *between* heart beats. Interestingly, this metric has been shown to mirror the recovery status of your autonomic nervous system. This is the first study in which heart rate variability was used to manipulate resistance training (1); however, it has been successfully used to autoregulate endurance training previously (2). In the present study, untrained males were randomized into two groups, both performing 20 full-body resistance training sessions. One group – the fixed frequency group – trained on Monday, Wednesday, and Friday, finishing the 20 sessions after 7 weeks. The other group, however, trained only when their heart rate variability score had at least returned to baseline, allowing a variable, individualized frequency. While both groups experienced similar changes in strength and vastus lateralis cross-sectional area, the heart rate variability group completed the 20 sessions in just 5.1 weeks on average. In the following article. I'll discuss the findings and their implications.

Purpose and Research Questions

Purpose

The purpose of this study was to determine if a heart rate variability-guided training frequency would lead to superior strength or hypertrophy gains compared to a fixed training frequency. In addition, the authors wanted to determine if the variability in strength and hypertrophy could be reduced by providing an individualized training frequency based on heart rate variability.

Hypothesis

The authors hypothesized that heart rate variability-guided training would lead to higher volumes of training, and subsequently would result in greater strength and hypertrophy. Additionally, they hypothesized that the heart rate variability-guided group would have less variability in their strength and hypertrophy responses among the participants (i.e. the response would be more homogeneous).

Subjects and Methods

Subjects

Twenty young males who had not performed resistance training in the prior six months participated in this study (age: 22.7 ± 3.8 years; body mass: 77.5 ± 11.6 kg; height: 176 ± 0.7 cm). While the participants were effectively untrained, which arguably limits the application of this study to trained individuals, using untrained participants also controls for the potentially confounding variable of participants performing wildly different training protocols (high or low frequency, volume, and/or intensity) prior to starting the study, which can influence results but is rarely discussed.

Study Design and Assessments

The participants were randomized into two groups that performed identical resistance training programs. Each session was the same and consisted of knee extension, 45 degree leg press, hamstrings curl, bench press, lat pulldown, triceps pushdown, biceps curl, and shoulder press, in that order. Three sets were performed to failure on each exercise for 9-12 reps, and load was increased whenever more than 12 reps were performed, and reduced when fewer than 8 reps were performed. Two minute rest intervals were administered between sets and exercises. The training

Table 1 Total training volume in first and last training session

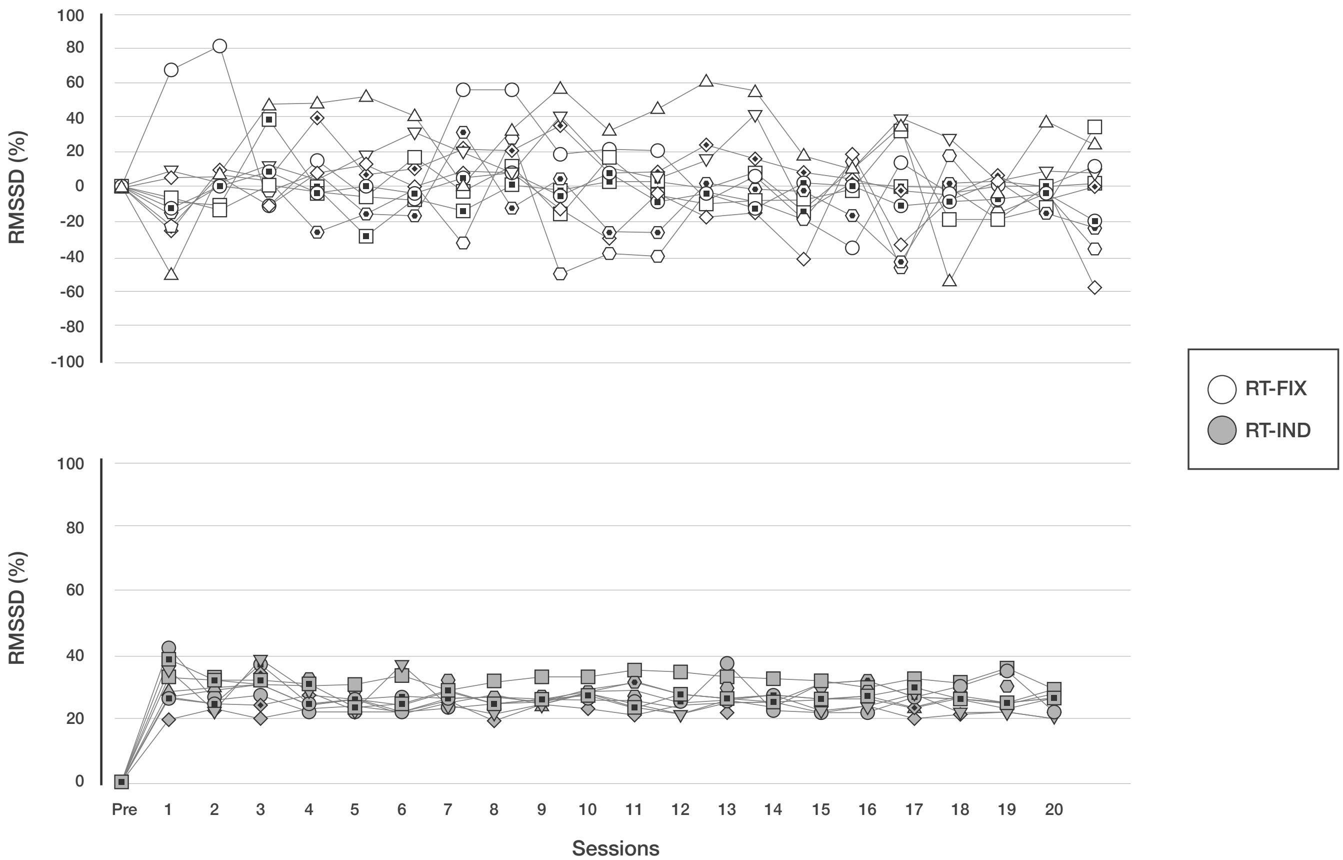
	RT-FIX		RT-IND	
Exercises	**First session**	**Last session**	**First session**	**Last session**
Leg extension (kg)	2847.5 ± 520.4	4237.0 ± 794.5*	3097.6 ± 680.3	4417.5 ± 780.2*
45° leg press (kg)	7445.0 ± 1296.0	14896 ± 1888.7*	9458.0 ± 2507.6	16677.5 ± 3482.7*
Leg curl (kg)	1255.3 ± 292.3	2234.5 ± 311.6*	1456.5 ± 341.7	2362.5 ± 601.2*
Bench press (kg)	949.8 ± 209.1	1420.2 ± 209.0*	1195.6 ± 338.7	1674.8 ± 384.9*
Lat pulldown (kg)	1132.5 ± 145.0	1467.8 ± 214.5*	1203.6 ± 303.1	1707.3 ± 303.6*
Shoulder press (kg)	503.0 ± 120.0	970.5 ± 209.5*	582.5 ± 1987.0	1095.5 ± 276.5*
Triceps push (kg)	943.0 ± 139.4	1389.0 ± 149.6*	1142.5 ± 385.0	1575.4 ± 505.4*
Arm curl (kg)	500.8 ± 80.7	656.4 ± 115.2*	483.2 ± 163.8	680.8 ± 195.7*

RT-FIX = resistance training with constant recovery interval; RT-IND = resistance training with individualized recovery interval
** = Significant difference compared to first session (main time effect, P < 0.0001). Values presented as mean ± SD.*

sessions were performed in the fixed group on Monday, Wednesday, and Friday, and in the heart rate variability group they were performed on weekdays, but only if the metric for heart rate variability (the root mean square of successive heartbeat interval differences; for a deeper understanding see this article) had returned to baseline. If heart rate variability hadn't returned to baseline, training was "delayed" until the next day when variability was measured again. Meaning, a participant could train five days per week if every day their heart rate variability had recovered. Likewise, a participant could plausibly train far less frequently if heart rate variability took a long time to return to baseline.

Before the start of the resistance training protocol, participants in the heart rate variability group had their baseline heart rate variability measured daily to establish their baseline. Additionally, cross-sectional area of the vastus lateralis was measured by ultrasound, and a 1RM knee extension test was administered prior to and at the end of the study. To provide a comparison to the heart rate variability group, the fixed frequency group also had their heart rate variability measured daily.

Figure 1 RMSSD values measured before RT-IND and RT-FIX groups individually



Baseline RMSSD value is represented by the number zero (Pre), and the number of sessions is represented as a percentage of the pre value
RT-FIX = Resistance Training Fixed Schedule Group; RT-IND = Resistance Training Individual Schedule Group;
RMSSD = Root Mean Square of Successive Differences (a metric of heart rate variability)

Findings

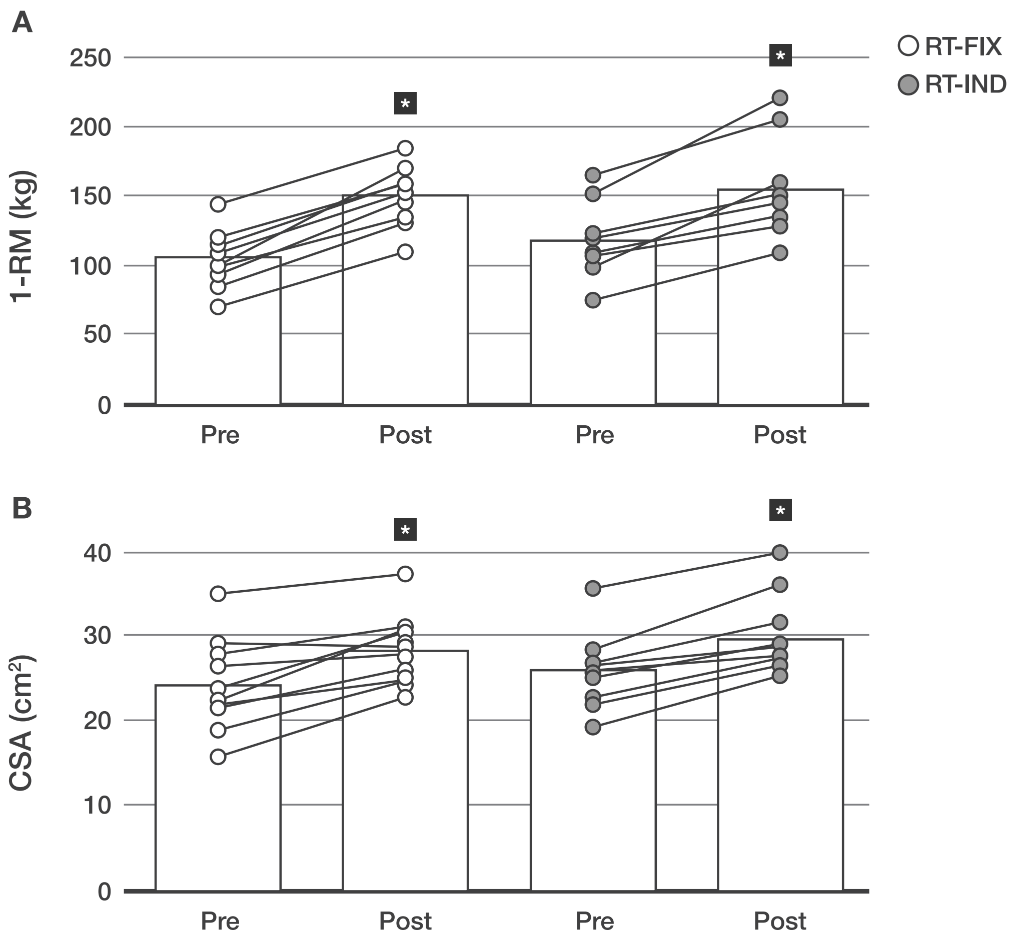
Volume Load

As shown in Table 1, volume load was not significantly different between groups. However, for every exercise, there was a within-group increase in volume load, indicating that the participants had increased the number of reps and/or load they could use over time with each movement.

Recovery Time Course

Figure 1 shows the individual heart rate variability score measured before each session, relative to baseline, which is represented by zero in the figure. Thus, any score at or above zero indicates heart rate variability had recovered. Of course, in the heart rate variability-guided group, all the scores are above zero. However, in the fixed frequency group you can see that sessions were performed regardless of the

Figure 2 Maximum dynamic strength and muscle measured at baseline (pre) and after 20 sessions of resistance training



*RT-FIX = resistance training with constant recovery interval; RT-IND = resistance training with individualized recovery interval; * = Significant difference from Pre (main time effect, P < 0.0001). Values presented as mean ± SD.*

relationship of the heart rate variability score to baseline and that much higher peak values were achieved.

On average, the fixed frequency group performed 45% of training sessions (9 out of 20) in an under-recovered state, and subsequently 55% (11 out of 20) in a recovered state. As designed, the fixed frequency group completed 20 sessions in 7 weeks. However, the heart rate variability group completed their 20 sessions in 5.1 weeks on average.

Hypertrophy and 1RM

While both groups got significantly bigger and stronger relative to baseline, there were no significant or meaningful differences between groups in strength or cross-sectional area changes. Group and individual changes are displayed in Figure 2. Additionally, variability in the individual responses did not differ significantly between groups, as there was only a single non-responder, and only for hypertrophy in the fixed frequency group.

Interpretation

I found this study fascinating, as it is the first study to use heart rate variability as a readiness indicator for implementing a flexible training template. We've talked a lot about programming in MASS, and ensuring that the stress imposed in a single session is not so high that it drives frequency and volume down so far that training is suboptimal in the long run. For this reason, we've emphasized various strategies for training configuration (2), use of failure (3), exercise selection (4), and recovery (5) in the context of optimizing your ability to produce overload efficiently long term. In this study, heart rate variability was used as a global metric of recovery to perhaps manipulate frequency to a similar end.

Looking at the results in black and white terms, they seem lackluster. Both groups did 20 sessions, and both groups made very similar gains. Autoregulation, at least using heart rate variability, didn't pan out this time through that lens. But, if you consider that the heart rate variability group achieved the same gains in roughly ~70% of the time, completing four full-body sessions per week on average versus three per week in the fixed group, the story changes. That said, strictly, we can't know that heart rate variability-guided training actually allowed faster gains. It's entirely possible that if the fixed frequency group had trained four days per week in a fixed manner, regardless of their heart rate variability score, they would have still achieved the same gains. Likewise, it's possible that if you had tested the fixed frequency group at the five week mark, they would have still had similar gains to the heart rate variability-guided group. In the end, we don't know, and we'd need more research

CONSIDER THAT THE HEART RATE VARIABILITY GROUP ACHIEVED THE SAME GAINS IN ROUGHLY ~70% OF THE TIME, COMPLETING FOUR FULL-BODY SESSIONS PER WEEK ON AVERAGE VERSUS THREE PER WEEK IN THE FIXED GROUP.

APPLICATION AND TAKEAWAYS

We aren't yet at a point where I'm comfortable recommending heart rate variability as an autoregulation tool. I'm intrigued for sure, but many of the factors that impact resistance training performance are peripheral in nature (e.g. muscle damage), while heart rate variability is a more global metric. Thus, more research is needed using heart rate variability for resistance training prescription and regulation before definitive statements can be made.

to find out.

However, what I find intriguing is that in the fixed frequency group, about half the sessions were performed in an "under-recovered" state (if we assume heart rate variability accurately represents recovery status). At face value, that doesn't indicate that they could have trained with a higher frequency very effectively. For comparison, by design, the heart rate variability group performed all their sessions in a "recovered" state, but finished early. This indicates that the ability to recover improved in the heart rate variability group. Take a second to consider that concept. We talk about individual differences and needs in programming a lot, but we forget that our ability to recover *itself* can adapt.

If you look at Figure 1, you can see all the individuals in the heart rate variability group had scores between 20 to 40 before they trained, while the fixed frequency group had scores from -50 to 80. This is a function of one group only training once they'd reached a state of "recovery," and the other just training on a fixed schedule. To further explore the concept of enhancing your ability to recover, consider that it's very likely that on days you scored 50-80, you would have also scored a positive number the day prior (given the heart rate variability group was between 20-40 prior to all sessions). Meaning, by training in a "just-enough recovered" state to trigger a training session, you'd likely improve your ability to recover for subsequent sessions, and thus, over time, you'd be able handle a higher frequency.

I think that's exactly what we see here, and why the fixed frequency group was "under recovered" almost half the time, despite taking two more weeks to finish the program than the heart rate variability group. Again, to bring some caution to my interpretation, it's very possible the fixed frequency group also could have improved their ability to recover by training more frequently, even if not guided by heart rate variability, but I suspect it would have come at the cost of more fatigue. In the end, we can't know until more research is performed, especially given how sensitive and potentially "noisy" heart rate variability can be. Case in point, the authors required participants not to use "anti-inflammatory, analgesic, antihypertensive, beta-blockers, central nervous system depressant drugs or caffeine throughout the experimental protocol," because they can notably impact heart rate variability, along with things like anxiety, stress, sleep, and other stressors that may or may not have notable effects on resistance training capacity, performance, or recovery.

Next Steps

A simple way to resolve the question of whether it was just the number of training sessions performed – regardless of the time it took to perform them (~5 vs. 7 weeks) – or if the heart rate variability group gained an advantage and was more efficient is to have the fixed frequency group go through the study second. First, you'd have the heart rate variability group complete the training protocol, taking as long as it takes so that all sessions are performed in a recovered state. Then, following completion by this group, the fixed frequency group is assigned the same average number of training days per week so that they finish in the same time frame. If it is the case that higher frequency while disregarding recovery status results in an imbalance of stress and fatigue, you'd expect to see lesser strength or hypertrophy gains.

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Study Reviewed: Time Course of Tolerance to the Performance Benefits of Caffeine. Lara et al. (2019)

Is Caffeine Still Ergogenic After Repeated Use?

BY GREG NUCKOLS

A lot of people drink a caffeinated beverage or use a caffeinated supplement before every workout. Are they still getting an ergogenic boost from the caffeine, or have they built up a tolerance and lost the performance boost with repeated use? This study provides us with the best evidence yet to answer this question.

KEY POINTS

1. In this crossover trial, subjects spent 20 days taking 3mg/kg of caffeine or a placebo, and then received the other treatment after a washout period.
2. Throughout each 20-day period, performance was monitored via VO2max tests and half-Wingate tests (an all-out 15 second resisted cycle sprint).
3. VO2max changes showed clear, progressive tolerance and loss of the ergogenic effects of caffeine. The ergogenic effects on peak power during the half-Wingate test, on the other hand, may have decreased for six days and plateaued thereafter.

If you're like most lifters, you probably drink some type of caffeinated beverage or supplement before most workouts. After all this time, is it still actually helping your performance, or have you fully developed a tolerance to it?

In the presently reviewed crossover trial (1), subjects spent 20 days taking 3mg/kg of caffeine or a placebo, and then received the other treatment after a washout period. Researchers monitored performance during each 20-day block using both aerobic (VO2max testing) and anaerobic (half-Wingate; a 15 second all-out cycle spring against resistance) tests. They found that the subjects *did* progressively develop a tolerance for some measures (VO2max and half-Wingate mean power), such that caffeine had lost its ergogenic effects after just 20 days of continuous use. However, for other measures (wattage at VO2max and half-Wingate peak power), it's hard to tell whether we're seeing a progressive loss of ergogenicity or a plateau in tolerance.

Purpose and Research Questions

Purpose

There were two purposes of this study: a) to investigate whether progressive caffeine tolerance mitigates the ergogenic boost that caffeine-naive people experience when consuming pre-exercise caffeine, and b) to describe the time course of caffeine tolerance on both aerobic and anaerobic performance.

Research Questions

1. Do people get a smaller ergogenic boost from caffeine after they've built up a tolerance to it?
2. What is the time course of developing caffeine tolerance?

Hypotheses

The researchers hypothesized that caffeine would be ergogenic for caffeine-naive subjects, but that the bene-

Table 1 Subject characteristics (N=11)

Activity level	Age (years)	Body mass (kg)	Height (cm)	Body fat (%)	VO_2max (mL/kg/min)
>4 days of exercise; >45 min/day	32.3 ± 4.9	66.6 ± 13.6	171 ± 8	16.6 ± 5.0	48.0 ± 3.8

ficial effects on performance would progressively decrease over time.

Subjects and Methods

Subjects

The subjects were 11 healthy, active individuals. More information about the subjects can be seen in Table 1.

Study Overview

This study employed a crossover design, effectively allowing the subjects to serve as their own control. The study was also placebo-controlled and double-blinded, meaning neither the researchers nor the subjects knew when the subjects were taking caffeine or the placebo.

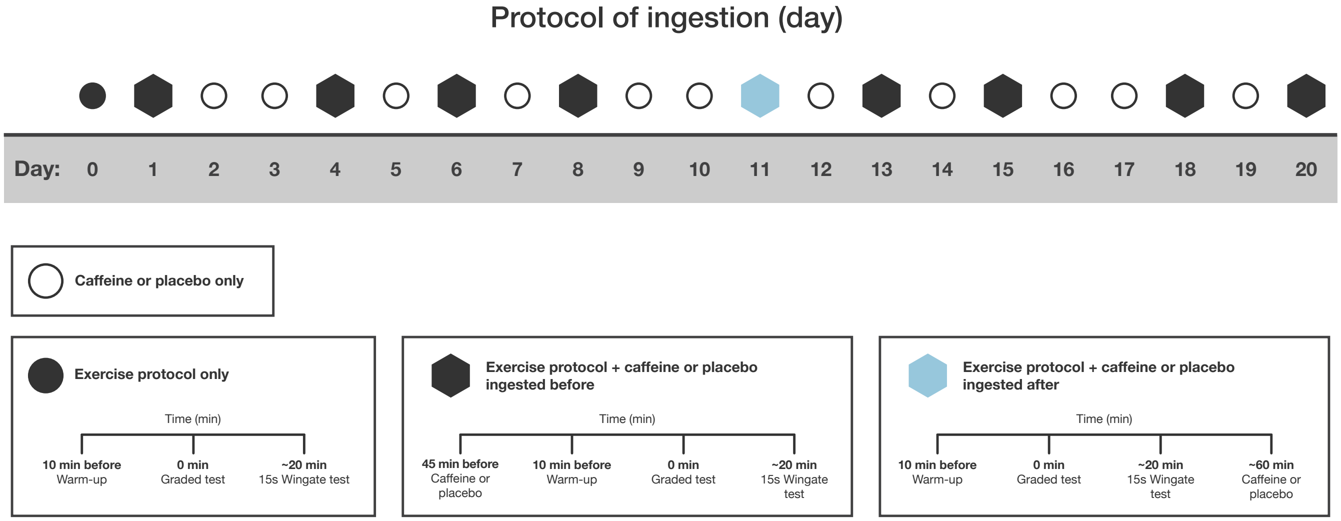
Each subject completed two 21-day blocks of testing. On the first day, the subjects completed a VO2max test and a half-Wingate test (15-second, all-out resisted sprint) on a cycle ergometer without being given a caffeine or placebo pill. Then, for the next 20 days, the subjects took a pill each morning (either caffeine or placebo). Roughly every other day, the subjects completed additional VO2max and half-Wingate tests 45 minutes after taking their daily pill. The only exception was day 11 of each testing period, when the subjects completed their VO2max and half-Wingate tests *before* taking their daily pill.

The caffeine was dosed at 3mg/kg, which is approximately the lowest dose that has been found to consistently have ergogenic effects. The order of the two blocks was randomized and counterbalanced, meaning half of the subjects took caffeine for their first block, and half of the subjects took a placebo for their first block. There was a wash-out period of at least seven days between blocks. The subjects were instructed to maintain their normal exercise habits throughout the study and to avoid consuming caffeine for one month prior to the start of the study and for the duration of the study (except for the caffeine pills they were given during the study).

Findings

Caffeine had similar effects on VO2max, wattage at VO2max, Wingate mean power, and Wingate peak power. On the first day of caffeine supplementation, caffeine had a clear ergogenic effect ($d \approx 1.0$-2.25) when compared to the first, non-supplemented session of the block and when compared to the subjects' first day taking the placebo pill. However,

Figure 1 Experimental design



Caffeine (3mg/kg/day) or a placebo was administered for 20 consecutive days in a randomized order. Exercise performance was measured on day 0 (48 hours before treatment) and on days 1, 4, 6, 8, 11, 13, 15, 18 and 20 with each protocol. Exercise performance assessment included a graded exercise test on a cycle ergometer to volitional fatigue and the 15-s Wingate test 45 minutes after the ingestion of the assigned capsule. Only on day 11 during each treatment, participants ingested the capsule after the end of the exercise.

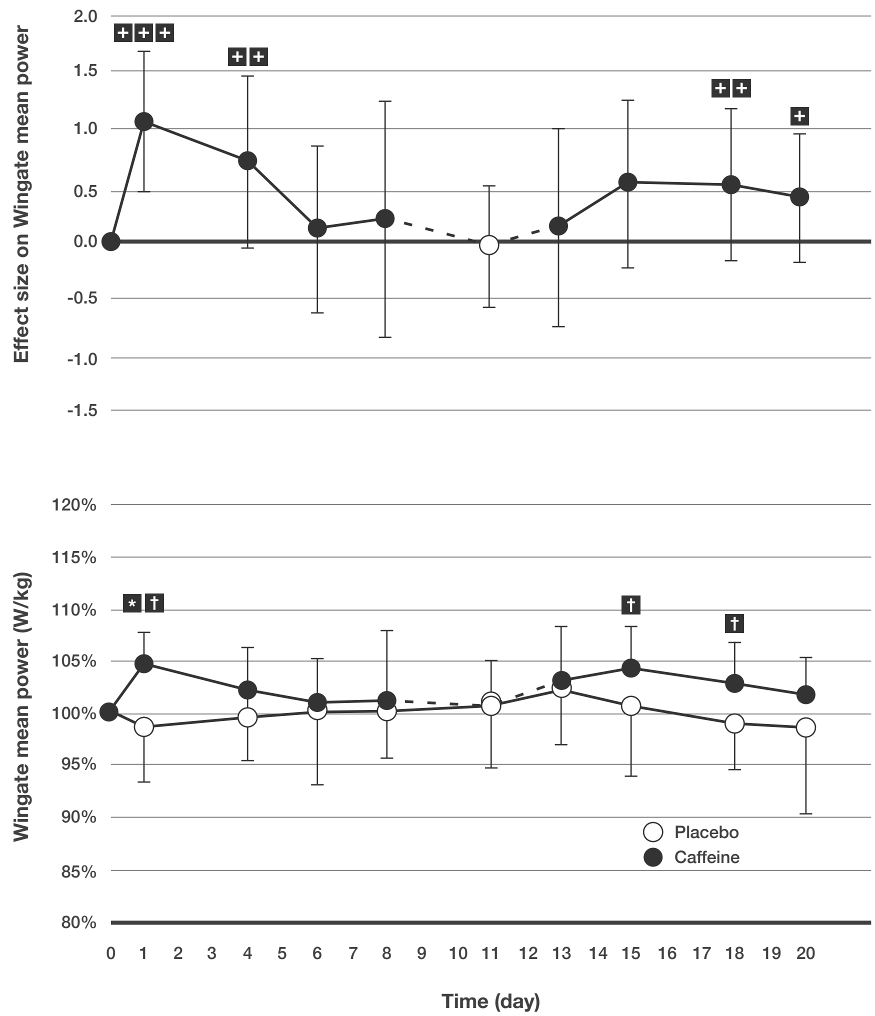
the ergogenicity progressively decreased over time. This was especially true for VO2max and, to a lesser extent, Wingate mean power. Wingate peak power and wattage at VO2max were still elevated after 20 days of consecutive supplementation. During session 11 (when VO2max and Wingate testing took place prior to supplementation), VO2max dropped off pretty substantially, whereas the decrease was smaller for the other three measures, especially Wingate peak power and wattage at VO2max.

Interpretation

To start, I feel like I should explain why I chose this study for MASS. After all, this is a strength and physique research review, not a cycling research review. However, Wingate tests (and especially half-Wingate tests) are similar enough to resistance training to serve as a somewhat decent proxy. It's resisted exercise (it's *not* easy to crank the pedals during a Wingate test), the duration is short, and peak power is probably at least decently related to maximal strength. I don't care too much about the VO2max findings, but the half-Wingate findings are interesting.

What I like about this study is that they used an experimental model that can actually be used to directly assess and monitor habituation and tolerance. If you'll remember, Eric reviewed an article looking at caffeine tolerance a few months ago (2). In that study, habitual caffeine users and nonusers simply completed two exercise bouts – one after tak-

Figure 2 Mean cycling power obtained during adapted version of the Wingate test



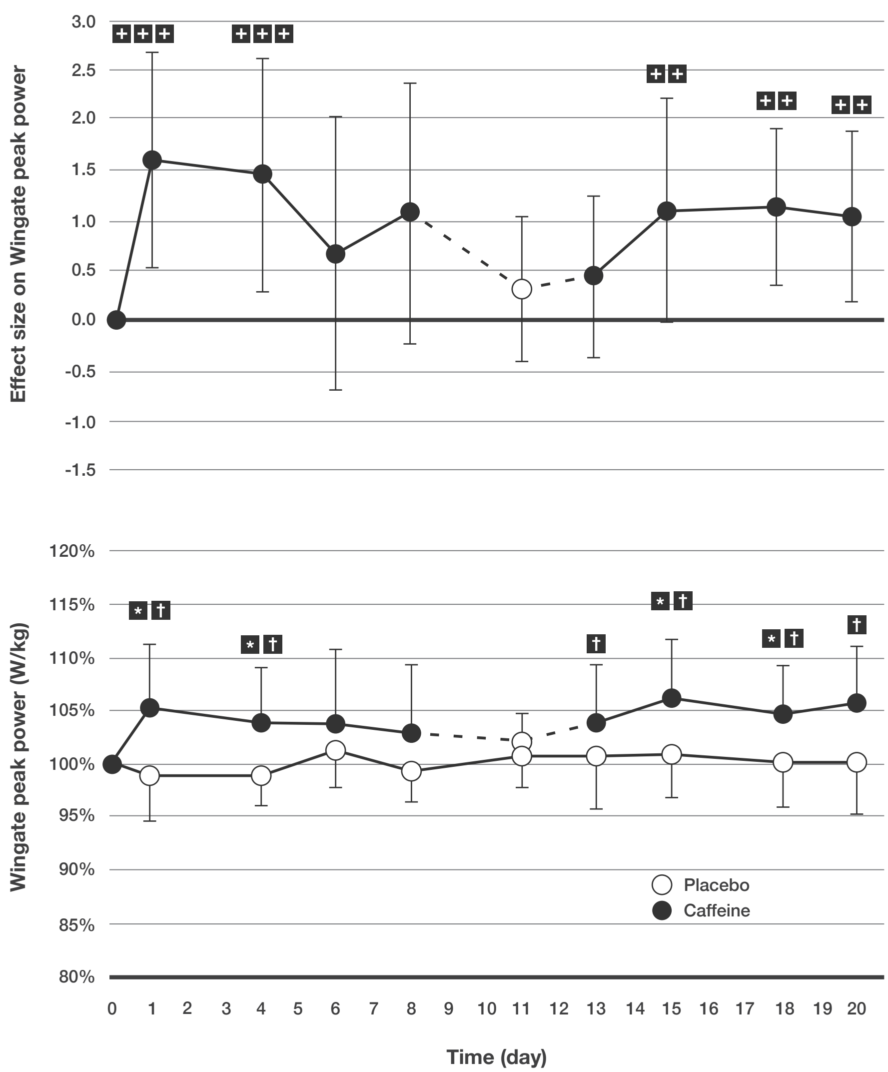
The upper panel depicts the effect size (±90% confidence intervals) for all pairwise comparisons. Only effect sizes with a possible likelihood of difference (>25%) are categorized.
++++ = most likely, +++ = very likely, ++ = likely, + = possibly.

The lower panel depicts data presented as a mean ± standard deviation. The data have been normalized with respect to the values obtained on day 0 of each treatment to provide a better comparison of the caffeine ergogenic effect in the studied variables.
** = caffeine different from placebo for same day, P < 0.05; † = different from day 0 within the same treatment, P < 0.05*

ing caffeine, and one after taking a placebo. However, that sort of a design can't actually be used to determine if the ergogenic effects of caffeine decrease over time in habitual users; caffeine could have been truly ergogenic in the subjects without tolerance, but simply preventing poor performance due to withdrawal in the caffeine users. The design of this study is better for drawing causal inferences.

However, I did have one little quibble with this study: I wish it was a bit longer. That's a cheap criticism, of course (most studies could stand to be longer, and I wouldn't have been the person manning

Figure 3 Peak cycling power obtained during adapted version of the Wingate test



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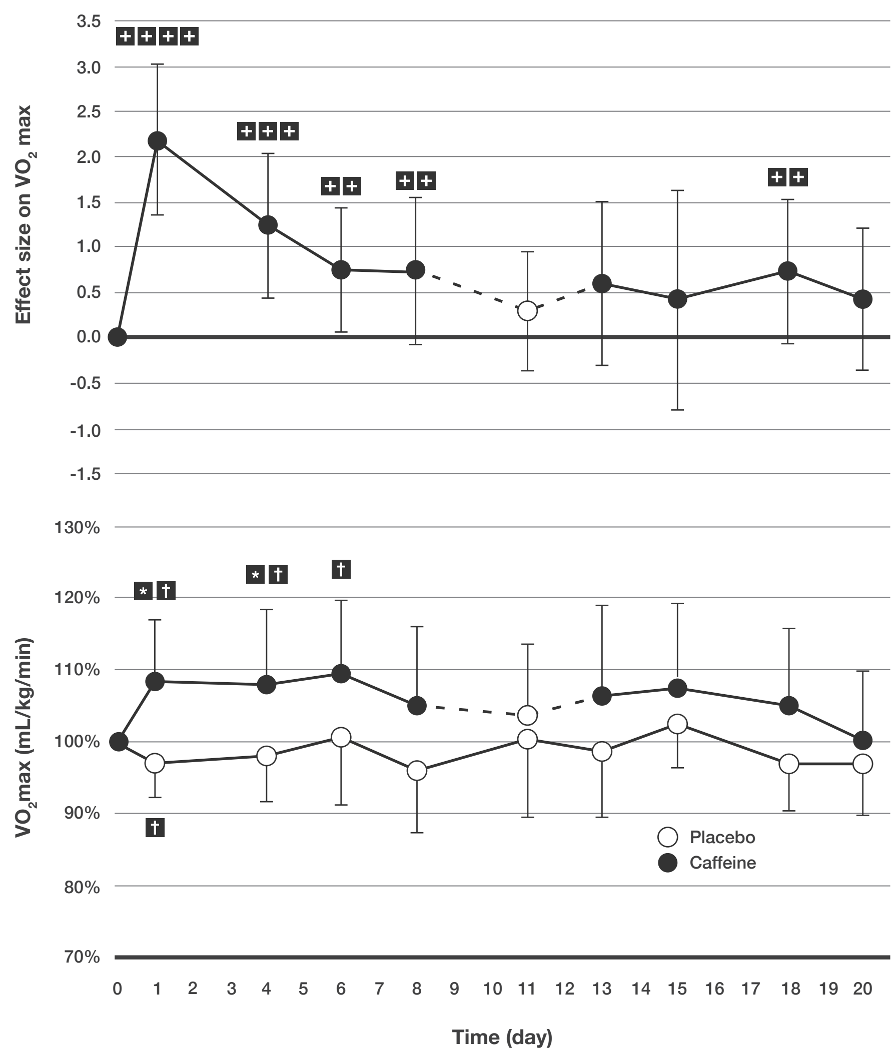
all of the extra visits), but I think it's important for being able to confidently interpret this particular study. When looking at Wingate peak power (which is what probably matters to most MASS readers), it's hard to tell whether you're seeing progressive tolerance, or whether you're seeing the subjects develop a fixed level of tolerance by day 6 that doesn't increase thereafter.

If it's progressive tolerance, that would mean you'd probably need to cycle caffeine usage if you wanted to consistently experience ergogenic effects. If the level

Figure 4 Maximal oxygen uptake (VO_2 max) obtained during a graded exercise test



The upper panel depicts the effect size (±90% confidence intervals) for all pairwise comparisons. Only effect sizes with a possible likelihood of difference (>25%) are categorized.
++++ = most likely, +++ = very likely, ++ = likely, + = possibly.

The lower panel depicts data presented as a mean ± standard deviation. The data have been normalized with respect to the values obtained on day 0 of each treatment to provide a better comparison of the caffeine ergogenic effect in the studied variables.
** = caffeine different from placebo for same day, $P < 0.05$; † = different from day 0 within the same treatment, $P < 0.05$*

of tolerance and ergogenicity plateaus, then there wouldn't be much reason to cycle caffeine during your training, because you'd always be getting a boost.

However, it does seem clear that the ergogenic effects of caffeine are largest if you're completely naive to caffeine usage. One somewhat common strategy among power athletes is to stop using caffeine about a month out from a competition in order to resensitize yourself to its effects. Whether that's prudent in the grand scheme of things is up for discussion – is it a good idea to do your

APPLICATION AND TAKEAWAYS

For the time being, I'd think the better-safe-than-sorry approach is just to recommend that you only use caffeine for your most important workouts, and to otherwise avoid it if possible. Daily use does seem to cause at least some degree of tolerance.

heaviest, most important peaking work while you're going through caffeine withdrawals? – but if your goal is solely to boost your performance on one day, all else being equal, taking some time to resensitize yourself to the effects of caffeine does seem to be worthwhile.

As one final note, I'd be wary of generalizing beyond the dose and type of protocol used in this study. They used 3mg/kg in this study, but some research suggests (3, 4) that the ergogenic effects of caffeine increase up to around 5-6+ mg/kg. At a dose that high, it's possible that people may develop a greater tolerance and develop it faster. Similarly, the subjects in this study just consumed caffeine once per day, and they did so in the morning (so that it was unlikely to negatively impact sleep). So, we can't know if the effects would be the same if you consumed caffeine throughout the day or if you took a large dose in the afternoon or evening. My hunch is that the single daily dose (rather than gradually consuming caffeine throughout the day) is important for not developing a complete tolerance (typically, all else being equal, the more time a drug is in your system, the greater the tolerance you develop), but I could be wrong about that.

Next Steps

I'd obviously love to see a similar study using resistance exercise for the performance assessments (possibly velocity with submaximal loads). There's cross-sectional research on resistance training (5), but no longitudinal research. I'd also like to see a longer study assessing whether tolerance does progressively increase or whether it plateaus.

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Study Reviewed: Damage Protective Effects Conferred by Low-Intensity Eccentric Contractions, on Arm, Leg, and Trunk Muscles. Huang et al. (2019)

Training Light Makes Sure Your Heavy Training Doesn't Crush You

BY MICHAEL C. ZOURDOS

Have you ever written out Week 1 of your new training block feeling ready to crush it, only to get crushed? Perhaps you should have run an introductory cycle. Let's talk about the repeated bout effect and how it applies to you.

KEY POINTS

1. The repeated bout effect is the attenuation of muscle damage when a muscle group is trained again relatively soon after a prior training session.
2. This study shows that the repeated bout effect can occur when an initial training session is performed with only a very light load (i.e. 10% of maximal voluntary contraction force).
3. In other words, this study shows that you can "protect" against muscle damage by performing a light training session. This concept suggests that using introductory weeks before high-volume or high-intensity training blocks is a good idea to avoid the excessive fatigue that often accompanies the first week of a training block.

Even if you are not familiar with the term "the repeated bout effect," you know exactly what it is. If you've taken time off from the gym, you are pretty sore after your first day back. Or, if you haven't done high reps or high volume in a while, you are pretty sore for a few days after you do it again. However, in your second week back in either scenario, you don't feel as terrible. That is the repeated bout effect. For a textbook definition, the repeated bout effect is the attenuation (lessening) of muscle damage and consequences of muscle damage (i.e. soreness, range of motion, etc.) when the same muscle group is trained again (2) or when you expose your muscles to a similar stimulus again (i.e. high volume) (3). The repeated bout effect also refers to the "protection" against muscle damage; in other words, by performing a light training session a few days before a heavy one, you can "protect" against the amount of damage that will occur after the heavy session, which means a shorter recovery time. Training with as little as 10% of one-repetition maximum (1RM) in the initial training session has been shown to elicit this protective effect; however, using loads that low has only been shown to be effective so far in the biceps, quads, and hamstrings (4). This study (1) had untrained men perform eccentric contractions with 10% of maximal voluntary contraction force on exercises for the following muscle groups: biceps, triceps, pecs, quads, hamstrings, calves, latissimus, abs, and erectors, then had the men perform these exercises with 80% of maximal voluntary contraction force two days later. Another group of men only performed the 80% contractions. Indirect markers of muscle damage were measured to assess recovery for the next five days following the 80% session in each group. The group that did the 10% contractions had less damage and recovered faster for every muscle group compared to the 80% group. Further, the

Table 1 Subject characteristics

Subjects	Age (years)	Body mass (kg)	Height (cm)	Training experience
24 men	21.6 ± 1.8	68.8 ± 11.8	172.4 ± 5.9	Untrained

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

authors suggested that the 10% 1RM training protected against damage better in the upper body than in the lower body. So, you can elicit the repeated bout effect with really light training. This article will cover how to apply these data to implement introductory cycles in experienced lifters, and how to introduce training to novices who are particularly susceptible to muscle damage.

Purpose and Research Questions

Purpose

The purpose was to investigate if performing a light eccentric training session with only 10% of maximal voluntary contraction force two days before training with 80% maximal voluntary contraction force could lessen muscle damage compared to only doing the 80% training.

Research Questions

1. Is training with only 10% of maximal voluntary contraction force enough of a stimulus to protect against muscle damage from a session performed two days later with 80% of maximal voluntary contraction force?
2. Does the protection against subsequent muscle damage afforded by low-load training differ between muscle groups?

Hypotheses

The authors hypothesized that training with 10% of maximal voluntary contraction force would protect against damage and that the magnitude of protection would be greater in arm muscles than in the leg muscles.

Subjects and Methods

Subjects

Twenty-four untrained and healthy male Taiwanese college students participated. As a clerical note, using untrained subjects is necessary for a study like this to ensure enough muscle damage can occur. However, the results will still allow us to discuss how this information can be used by trained lifters. Full subject details are in Table 1.

Table 2 Indirect muscle damage and recovery outcome measures

Plasma creatine kinase and myoglobin	An enzyme and a protein which are analyzed in the blood as common markers of muscle damage
Maximal voluntary contraction force	The same isometric measure of strength as discussed in the text above
Muscle soreness	Measured via a visual analog scale. This scale is a continuous horizontal line with “0” and “100” at the left and right of the line respectively. Subjects mark their level of pain with a pencil/pen and a ruler is used to determine the level of soreness.
Index of protection (only in 10% group)	A percentage showing the magnitude to which the 10% training attenuated indices of muscle damage compared to the 80% only group.

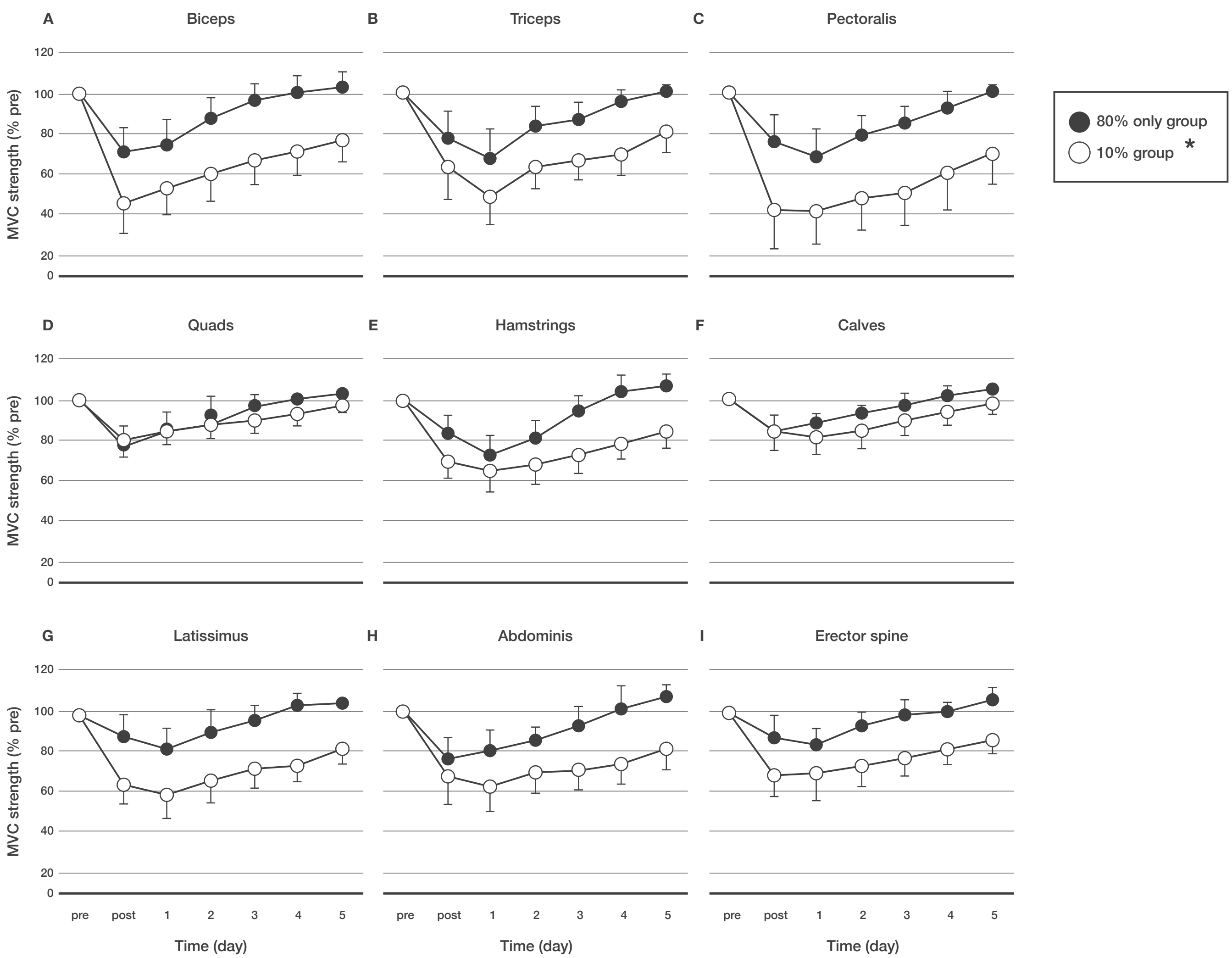
Protocol

All 24 subjects had preliminary maximal voluntary contraction force (i.e. isometric force production) tested on the following machine-based exercises (muscle group): biceps curl (biceps), triceps extension (triceps), chest press (pectoralis), leg extension (quadriceps), leg curl (hamstrings), standing calf raise (calves or plantar flexors), lat pull-down (latissimus), abdominal crunch (abs), back extension (erectors). This was the machine used, and a load cell was attached to the machine to obtain isometric strength.

Following this testing, one group of 12 subjects then performed 5 sets of 10 eccentric contractions on each exercise with a load corresponding to 10% of the maximal voluntary contraction force. Each eccentric contraction lasted 15 seconds. Two days later, those 12 subjects then performed 5 sets of 10 eccentric contractions with a weight corresponding to 80% of maximal voluntary contraction force. A second group of 12 subjects did the preliminary testing and then *did not perform the 10% training session*, took two days off, and then performed 5 sets of 10 eccentric contractions with a load corresponding to 80% of maximal voluntary contraction force.

Indirect measures of muscle damage were taken immediately pre- and post-exercise and two days after the 10% training. These measures were also taken immediately pre- and post-exercise and for the next five days following the 80%

Figure 1 Strength changes following the 80% training in each muscle group

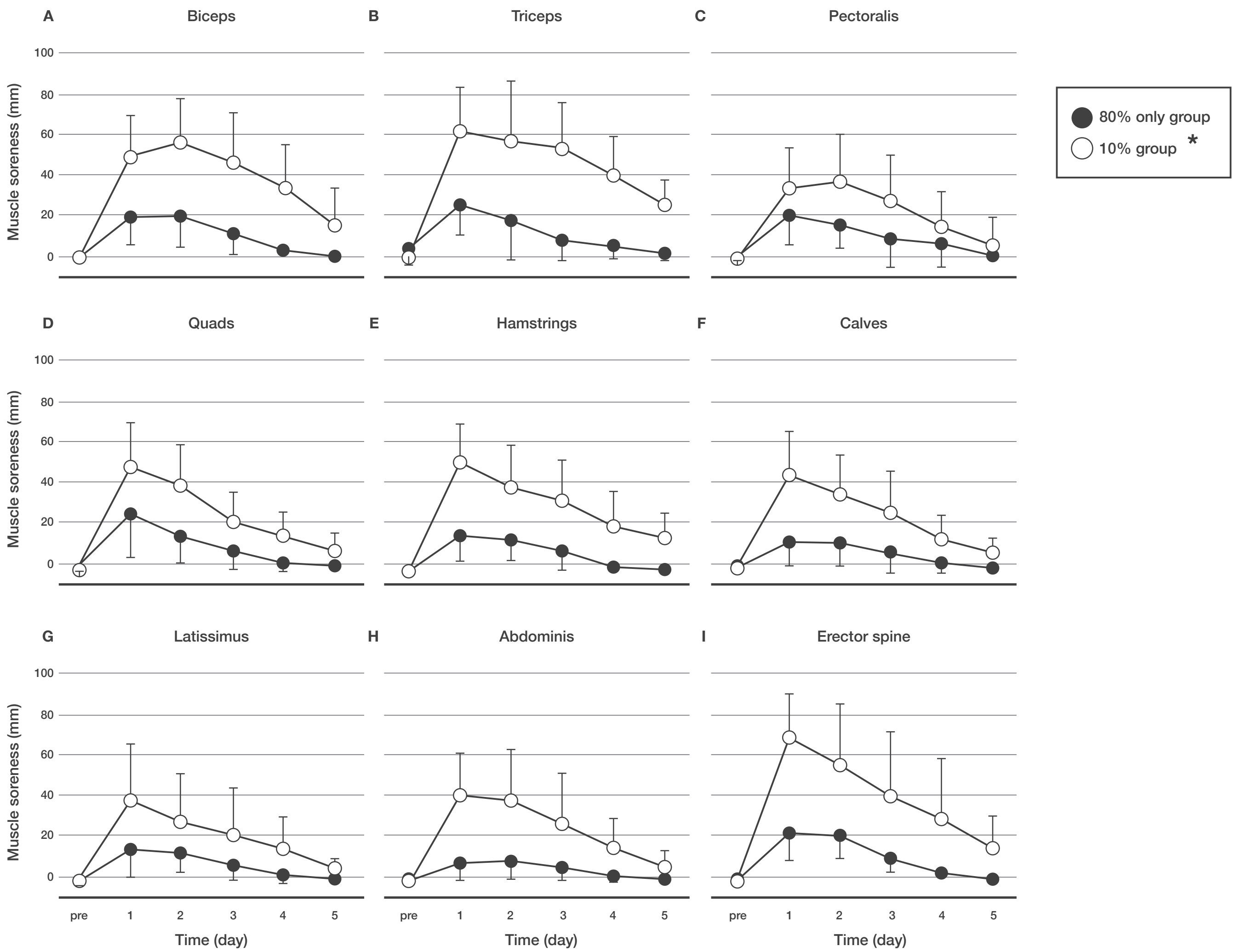


**Significantly less damage and greater recovery in 10% group; MVC = Maximal Voluntary contraction*
Each figure represents the percentage change in maximal voluntary contraction strength from baseline to five days after when the 80% training was performed in each group.
Data are mean ± SD.

training in both groups. This allowed the researchers to examine if fatigue occurred following the 10% session, to assess the magnitude of muscle damage after the 80% training sessions, and to compare the difference in the damage after the 80% session in both groups. The muscle damage measures taken are in Table 2.

The "index of protection" calculated a percentage for all outcome measures for the 10% group. This was designed to show the degree to which muscle damage was protected against compared to the group only doing a session at 80%. The equation was: (Recovery for the 10% group – recovery in 80% only group) / recovery for 10% group X 100. For the

Figure 2 Muscle soreness changes following the 80% training in each muscle group



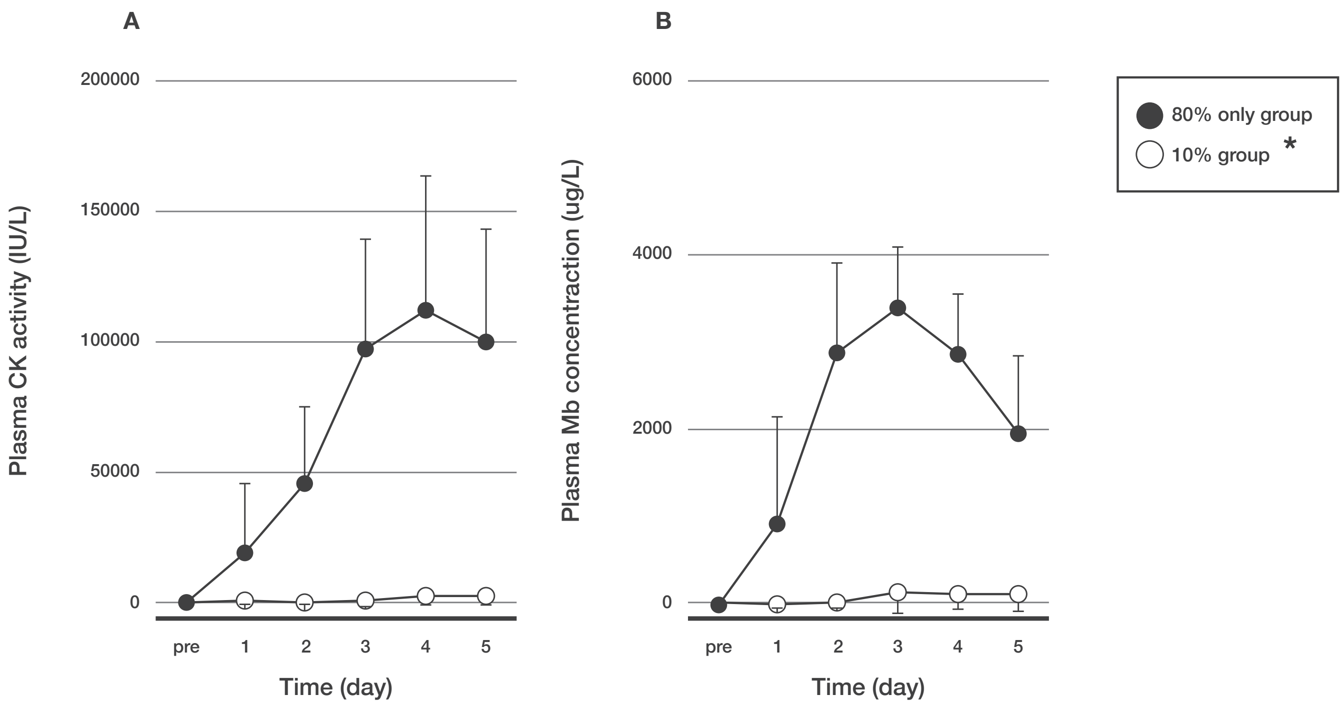
**= Significantly less damage and greater recovery in 10% group. Each figure represents the change in muscle soreness from baseline to five days after when the 80% training was performed in each group.*
Data are mean ± SD.

equation, maximal voluntary contraction values at two days post-training were used and peak values for all other variables were used. Here's an example: if soreness was 6mm in the 80% only group and 3mm in the 10% group, then the equation would be (2 – 8) / 2 X 100 = -0.03 or 30%. This example indicates that for muscle soreness, the 10% eccentric training attenuated soreness by 30% compared to the group not doing a prior session at 10%.

Findings

First, the 10% session did not induce any significant change in any indirect marker of muscle damage.

Figure 3 The creatine kinase and myoglobin response to 80% training in each group



** = Significantly lower CK and myoglobin in the 10% group. Each figure represents the change in creatine kinase (panel A) or myoglobin (panel B) from baseline to five days after when the 80% training was performed in each group.*
Data are mean ± SD.

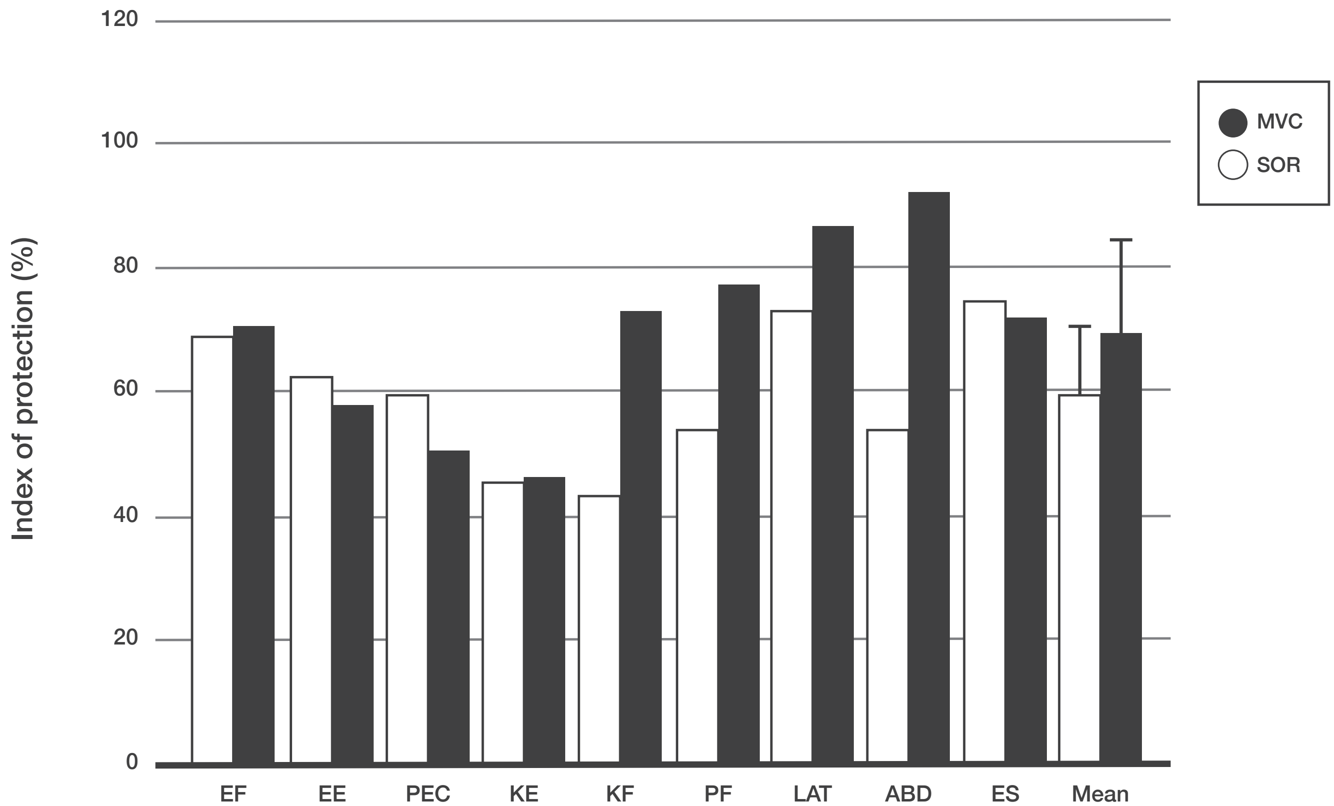
Comparison Between Groups

Here is the most important finding: *The 10% training was effective at protecting against muscle damage in all muscle groups and across all outcome measures. Specifically, damage was lower and recovery was faster in the 10% group versus the 80%-only group.* Figures 1, 2, and 3 show the results for every indirect damage measure. In Figures 1 and 2, you can clearly see that the 10% group (solid circle) has a smaller drop and faster recovery for every muscle group for strength (Figure 1) and soreness (Figure 2) than the 80% only group (open circle). In Figure 3, it is clear that there is a large increase in creatine kinase and myoglobin in the 80%-only group and no increase in the 10% group. There was a significant difference between groups ($p<0.05$) for every measure in these figures.

Index of Protection

The index of protection calculated degree to which training at 10% was able to protect against damage. In Figure 4, you can see the index of protection values for maximal voluntary contraction and for every muscle group. These values show that although the 10% training protected against damage for all muscle groups, protection tended to be greater in the upper body versus the lower body.

Figure 4 Index of protection values in the 10% group



These data show the magnitude (in terms of percentage) for how much damage was protected against when the 10% exercise was done 2 days prior to the 80% exercise.
EF = Elbow Flexors (biceps); EE = Elbow Extensors (triceps); PEC = Pectoralis (chest); KE = Knee Extensors (quads); KF = Knee Flexors (hamstrings); PF = Plantar Flexors (calves); LAT = Latissimus (back); ABD = Abdominis (abs); ES = Erector Spinae (back); mean = average of all muscle groups.

Interpretation

Within the concept of the repeated bout effect, this study adds that you can elicit the repeated bout effect with very light training and that it works across all muscle groups (at least all muscle groups tested in this study). So, how should we apply the concept of the repeated bout effect to our training? The main application is understanding the importance of introductory weeks, which can be used in both trained and untrained lifters. In this interpretation, we will discuss the importance of intro cycles and include actionable strategies, but first let's talk about everything we know to date about how to elicit a protective effect against muscle damage.

What We Know About the Repeated Bout Effect

Although training with just 10% does elicit the repeated bout effect as it did here (1), it doesn't actually last that long.

A previous study showed that performing eccentric training with 10% of maximal voluntary contraction force protected against damage for two weeks for the biceps and only for one week for the lower body (4). However, when much higher volume training is performed, the repeated bout effect can actually last up to six months (3). That's not to say that if you train now and then you don't train again for six months, you'll get the full magnitude of the repeated bout effect; rather it's just to say that muscle damage is still lessened a bit if you take six months between sessions (not that you'd do that). And of course, the repeated bout effect magnitude would be greater at one week following the initial session than it would be at one month, and it would be greater at one month than two months, and so forth. Thus, the magnitude of the repeated bout effect is dependent upon the proximity of the initial session to the next session, in that the closer sessions are to each other, the more muscle damage will be attenuated in the second session.

RUNNING AN INTRO WEEK(S) ALLOWS YOU TO PERFORM LIGHTER TRAINING TO PROTECT AGAINST MUSCLE DAMAGE, SO THAT WEEK 1 OF YOUR BLOCK DOESN'T HAVE YOU STRUGGLING.

The magnitude of the repeated bout effect is also dependent upon the volume and intensity performed in the initial training bout. So, even though really light training (10%) or low volume exercise can elicit the repeated bout effect, increasing the intensity or volume in the initial session increases the magnitude of the repeated bout effect. For example, a classic study from Nosaka et al in 2001 (5) showed that performing 2, 6, or 24 eccentric contractions of the elbow flexors on a dynamometer all induced the repeated bout effect, evidenced by attenuated damage following a session of 24 eccentric contractions two weeks later. However, in Nosaka's study, the magnitude of the repeated bout effect was volume-dependent: the repeated bout effect occurred to the greatest degree when 24 contractions were performed in the initial session. A few points about this classic study: first, that study and most studies in this area use eccentric exercise because it causes the majority of muscle damage. Although 24 contractions provided more damage protection than 2 or 6, you wouldn't want to perform the same exact volume in the intro week as you would in week one of a training block like Nosaka et al did –

Table 3a Theoretical introductory week for block-to-block transition

Exercise	Monday	Wednesday	Friday
Intro week			
Squat	2x8 @ 60%	3x6 @ 65%	4x4 @ 70%
Actual training block week 1			
Squat	4x7 @ 70%	4x6 @ 75%	5x4 @ 80%

that, by definition, is not an intro cycle. The point of the study is that Nosaka and friends were simply demonstrating the concept that the repeated bout effect is volume-dependent, not designing a real-world training plan.

The Repeated Bout Effect and Intro Cycles

On a few occasions (one, two), MASS has touched on introductory cycles and the repeated bout effect. In short, intro cycles can be performed with reduced volume, intensity, and/or frequency for a week or even a few weeks prior to the first full week of a training block. The purpose of these intro cycles is to precondition yourself for the training block to ensure that you don't get crushed by entering a new block unprepared. Think logically: If you are moving from an intensity block to a volume block, does it make sense to jump right into it? Absolutely not. Does it make sense to jump right back into a training block if you've been off for a few weeks? No way. Let's say you have tapered for a week, then competed in a powerlifting meet; does it make sense to begin a full training block a few days after the meet. Again, no. All of these examples place an individual in a situation where they are susceptible to muscle damage, and running an intro week(s) allows you to perform lighter training to protect against muscle damage, so that Week 1 of your block doesn't have you struggling to walk for a few days. If you are transitioning from intensity to volume, Tables 3A and 3B provide some examples of intro cycles.

Again, Table 3AB is just a hypothetical, but it should show the general concept. Of course, Table 3AB only shows one exercise, but as you understand the concept, you would simply do something like this for all exercises. If just transitioning from one block to the next, a decent general rule is to take off about 10% and one or two sets per day for the intro week. If the intro examples look really easy to you, good, that's how it should look. Table 3B is a more gradual

Table 3b Theoretical introductory week after a layoff from volume

Exercise	Monday	Wednesday	Friday
Intro cycle			
Squat	3x7 @ 55%	Off	3x4 @ 65%
Squat	3x8 @ 60%	2x6 @ 65%	3x4 @ 70%
Squat	3x8 @ 65%	3x6 @ 70%	3x4 @ 75%
Actual training block week 1			
Squat	4x8 @ 70%	4x6 @ 75%	5x4 @ 80%

progression and would be a better option than Table 3A after a few weeks off from training, after a powerlifting meet, or if you are building volume again after time doing intensity. While intro weeks are easy physically, they can be tough mentally; but I would ask, what's the downside of an intro cycle? Trust me, you're not going to get weaker from taking it easy for one week in a time where you may be susceptible to muscle damage. This doesn't mean that you have to run intro cycles constantly, but in the scenarios above, what could possibly be the downside? The upside is you avoid the scenario in which you can't complete Week 1 of your aggressive training block due to too much fatigue. Training hard is the easy part; it's programming an intro cycle or taking it easy for a week that's the hard part.

In the presently reviewed study (1), the 10% load seemed to confer a little bit better muscle damage protection in the upper body than in the lower body. However, I don't think that finding matters too much. In our context, we are going to run intro cycles with considerably more than 10% of 1RM, so the magnitude of protection will be greater, and most people reading this will not be as susceptible to muscle damage as the untrained individuals in this study were. So, I don't think the percentages or difficulty (maybe you use RPE or velocity to prescribe load) need to be much different between upper and lower body exercises in an intro week. The 10% number is important for beginners, though. When someone is just getting started, they are uniquely susceptible to muscle damage and fatigue, and novices don't really like the feeling of extreme soreness. So, starting novices with really light training can avoid significant soreness and possibly increase enjoyment and adherence to training. This could possibly be the difference between a novice sticking with

APPLICATION AND TAKEAWAYS

1. These results demonstrate that training with very light loads can protect against muscle damage when much heavier loads are used just a few days later.
2. This "protection against muscle damage," or the repeated bout effect, is a good thing, as it allows lifters to avoid significant fatigue and soreness. Therefore, this provides a rationale for using introductory weeks to prepare a lifter for a training block.
3. By using an introductory week, a lifter decreases the risk of not being able to complete their prescribed training. Intro weeks are quite useful when beginning a new training block, coming back after a layoff, switching from intensity- to volume-type training or vice versa, or returning to higher volume after a competition. In all of those situations, a lifter is more susceptible to muscle damage, so it makes sense to be proactive and avoid doing too much too soon. Understanding the concept of the repeated bout effect and how to apply it in intro cycles allows the lifter and coach to be proactive.

training or giving it up quickly. Besides, a beginner can make rapid progress with very little stimulus, so there's little benefit to doing anything too difficult in the initial training stage. The protection index (Figure 3) generally shows between a 40-80% attenuation of muscle damage from just a 10% initial session in beginners. To me, that's a pretty convincing finding to start beginners off with a light intro cycle.

Next Steps

Most repeated bout effect studies are carried out with untrained subjects lifting on machines, a dynamometer, or performing dumbbell curls. As we stated earlier, these are the ideal conditions to induce damage and easily examine the recovery period. However, it would be great to have trained individuals train only with high intensity (≥85%) and low reps (≤5) for low volume for a few training blocks on the squat, bench, and deadlift and then throw them back into high-volume training. Then, examine the magnitude of damage response with and without an intro cycle when going back to the high-volume training. That could truly validate what we are advocating for in this interpretation.

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Study Reviewed: Supplementation of Probiotics and Its Effects on Physically Active Individuals and Athletes: Systematic Review. Möller et al. (2019)

Probiotics: Is the Hype Real?

BY ERIC HELMS

New science quickly becomes all the rage because the mystery of what we don't know creates a void that sexy marketing can fill. Right now, gut health is hot, and supplements are flying off the shelves. The most common type are probiotics, but does the science support the hype?

KEY POINTS

1. Probiotics are microorganisms that are purported to provide health benefits when consumed by colonizing the gut with beneficial bacteria. Probiotics come in many strains, but are usually lactic acid bacteria from fermented dairy products (Greek yogurt, kefir, etc.) and vegetables (kimchi, pickled vegetables, etc.). They differ from prebiotics, which are generally non-digestible fibers that ferment in the large intestine, providing fuel to support your existing gut microbiota.
2. In this systematic review, the authors explored the effects of probiotic supplementation among physically active individuals, including athletes. Specifically, they explored the impact of probiotics on upper respiratory tract infections, global immune function, inflammatory markers, gastrointestinal health, metabolic function, and athletic performance.
3. Although there was a large degree of heterogeneity between studies, effects were largely neutral or beneficial, with positive effects on markers for disease, including respiratory tract infection and global immune function, and unclear effects on performance.

Gut health is an emerging research topic worldwide. In the nutrition and fitness industry, a common theme is that the newest – and therefore shakiest and least conclusive – research becomes the next hottest thing marketed and sold. Why? Because on the fringes of what we know, marketing can fill in the gaps of uncertainty with hope and hype. Something like creatine, for example, has a known beneficial effect which, while substantial as far as supplements are concerned, just doesn't match the standard level of hype used in the supplement industry. On the other hand, an unknown, minimally investigated question mark with a potential to do something is ripe for hyperbolic marketing. However, despite the hyperbolic marketing that has surrounded probiotics and other gut health products (like prebiotics) for years, only now is there enough research to start making confident scientific claims. This article reviews a just-published systematic review (1) that shows that while probiotics aren't *all* hype, they might not live up to the extreme marketing claims. The authors concluded that, when looking at the broad spectrum of effects of probiotic supplementation on physically active individuals and athletes, there were some positive results but also some null findings for probiotic supplementation. These findings should be interpreted with caution, as there was a great deal of

Table 1 Probiotics vs. placebo in trained and untrained individuals

Certainty assessment						
Number of participants (studies) follow-up	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	General quality of evidence
Respiratory tract infection (follow-up: mean of 2 months)						
1324 (10 RCTs)	Serious	Not serious	Serious	Not Serious	All potential confounding factors reduced the effect demonstrated	Moderate
Immunity / mucosa (follow-up: mean of 2 months)						
318 (5 RCTs)	Not serious	Not serious	Not serious	Not serious	All potential confounding factors reduced the effect demonstrated	High
Gastrointestinal tract (follow-up: mean of 2 months)						
146 (3 RCTs)	Not serious	Not serious	Not serious	Not serious	All potential confounding factors reduced the effect demonstrated	High
Parameters related to physical exercise (follow-up: mean of 2 months)						
328 (5 RCTs)	Not serious	Serious	Not serious	Not serious	Strong association	High

RCTs = randomized clinical trials; GRADE = classification of the quality of the body of evidence
High quality = further research is very unlikely to change our confidence in the estimate of effect
Moderate quality = Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate
Low quality = Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate
Very low quality = We are very uncertain about the estimate

heterogeneity in the populations investigated, the supplementation protocols used, the types of probiotics supplemented, and the outcomes that were tested across studies. So, while this review found some positive effects for global immune and respiratory tract function overall, we cannot yet make definitive recommendations. If you run into hyperbolic claims or recommendations for probiotics or specific suggestions on what to buy, how much to take, or what they will do for you, be skeptical.

Purpose and Research Questions

Purpose

The purpose of this systematic review was to assess clinical trials investigating the effects of probiotic supplementation in physically active populations across a spectrum of health and performance outcomes.

Subjects and Methods

As a systematic review, the authors followed a step-by-step protocol to find studies, determine which studies to review, categorize the outcomes, and qualitatively assess the aggregate findings. The authors assessed the quality of evidence for each outcome investigated among the studies included. In Table 1, the authors' assessment of the evidence quality and the likelihood that future published research would alter their findings is shown. As a side note, the authors found a high risk of publication bias specifically among the studies on physical exercise performance (as a reader, this just means to take these findings specifically with a relatively large grain of salt).

Findings and Interpretation

Because this is a systematic review on the broad spectrum effects of probiotics in physically active individuals and athletes, I've combined the findings and interpretation to cover the broad outcomes reviewed.

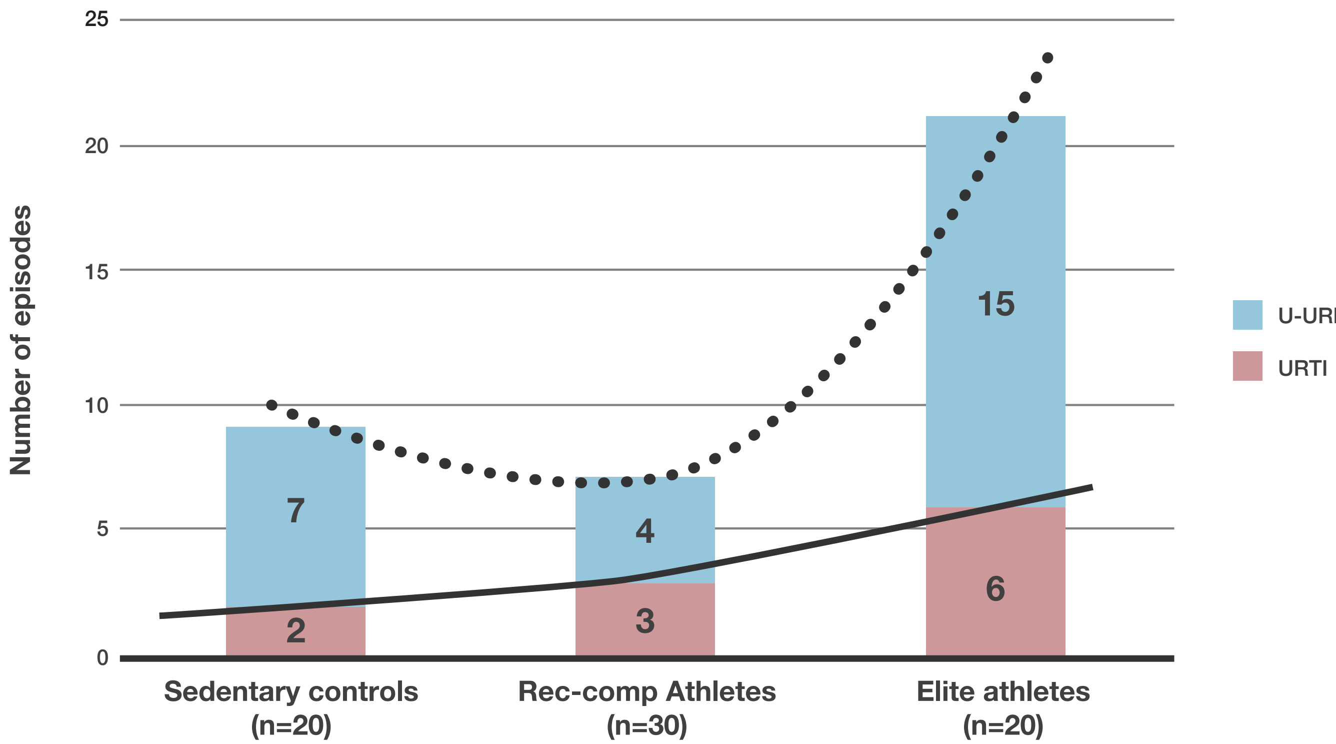
Effects on Performance

We'll start with the findings that MASS readers care the most about; however, these were the least impressive findings. Of the 24 studies included in this review, only five measured athletic performance, and only three assessed performance relevant to MASS readers. Specifically, Jager and colleagues investigated probiotic effects on muscle function and recovery following damaging bouts of training (unaccustomed eccentric training) in a crossover trial (2) and a parallel groups investigation (3). In the former study, resistance trained males supplementing with the probiotic Bifidobacterium breve BR03 and Streptococcus thermophilus FP4 for 21 days experienced a smaller decrease in range of motion and had lower resting interleukin-6 (a marker for inflammation) concentrations compared to placebo, following damaging bouts of exercise. In the latter study, recreationally trained

ON THE FRINGES OF WHAT WE KNOW, MARKETING CAN FILL IN THE GAPS OF UNCERTAINTY WITH HOPE AND HYPE.

males supplementing with casein with added Bacillus coagulans GBI-30 6086 at breakfast reported a significantly higher perceived recovery status, lower perceived muscle soreness, lower creatine kinase levels, and higher Wingate power outputs that weren't quite significant (p = 0.07 to 0.08) compared to a group supplementing casein without added probiotics. However, a study (4) on males performing circuit resistance training with or without probiotics taken prior to exercise (Lactobacillus acidophilus, L. lactis, L. casei, Bifidobacterium longum, B. bifidum and B. infantis) observed no significant differences between groups in isokinetic muscular strength or power and unclear effects on both inflammatory and anti-inflammatory cytokines (interleukin-6 and 10). Overall, no direct effect on muscular performance was observed among any studies, with a possible indirect effect on recovery, which may or may not be relegated to unrealistic, muscle damage-heavy lab protocols. Further research is needed to assess

Figure 1 J-shaped relationship of upper respiratory infections and illness (5)



From Spence et al. 2007
Five month period of observation among sedentary controls, recreational competitive (rec-comp), and elite athletes (5).
U-URI: unidentified upper respiratory illness, URI: upper respiratory tract infection.

if probiotics can aid in bodybuilding or strength training.

Inflammation, Immunity and Health

You may remember my recent review on nutrition and immune function from Volume 3, Issue 2. Specifically, I explained that active individuals and recreational athletes get sick less often than sedentary individuals (which makes sense), but that – on average – hard-training athletes get sick *more* than both recreational athletes/physically active individuals *and* sedentary controls, presumably because of transient immune suppression. This "J-shaped" relationship, illustrated by Spence and colleagues (5) in Figure 1, *may* be somewhat modifiable with probiotic supplementation based on their mechanisms and the present findings.

Indeed, the strongest findings in the present review were that *overall*, positive effects on upper respiratory tract infections were observed (with some exceptions), both in terms of frequency

> **OVERALL, POSITIVE EFFECTS ON UPPER RESPIRATORY TRACT INFECTIONS WERE OBSERVED (WITH SOME EXCEPTIONS), BOTH IN TERMS OF FREQUENCY OF OCCURRENCE, SYMPTOMATOLOGY, AND DURATION OF ILLNESS.**

of occurrence, symptomatology, and duration of illness. Probiotics can produce anti-pathogenic compounds, stimulating the immune system and competing for pathogen receptor and binding sites. Also, the metabolic byproducts of a robust microbiota are short chain fatty acids, and probiotics are also involved in the production of immunomodulators and neuroactive compounds, all of which are known to bolster immune function (6). Likewise, high-intensity exercise transiently lowers immune function; some of this lowering effect may be related to intense exercise decreasing splanchnic blood flow and increasing gut permeability, temporarily adding to the increased risk of infection in hard-training athletes (7). Therefore, some of the negative effects of hard training on immune function may be a function of intense exercise's effect on the gut, which plausibly could be reduced with probiotic supplementation.

With that said, the results were much less clear for metabolic health, markers for inflammation, and gastrointestinal symptomatology among athletes overall. In fact, while it was the only negative finding, it is worth mentioning that one study reported a possible increase in gastrointestinal distress among female cyclists (8). So, while the results are positive overall, it's important to remember we are looking at a broad range of probiotic supplement strains, dosages, protocols, populations, and outcomes. Caution is warranted before concluding much at this stage.

Next Steps

Understandably, most of the research reviewed was on endurance athletes. Given the necessity of onboarding nutrients during training and competition among endurance athletes to optimize performance and the considerable strain on the gut this can impose (which is sometimes the bottleneck to a personal best), it makes sense that most research surrounding gut health in athletes occurs in the endurance sector. However, dieting itself is a stress to the gut, and I wonder if bodybuilders during prep or

APPLICATION AND TAKEAWAYS

1. Probiotic research is promising at this stage, but by no means does it live up to the hype you might see on social media. At best, this review should serve as an indicator to "watch this space," rather than an endorsement for supplementation.
2. The most promising pathways by which probiotic supplementation might improve your "gains" are indirect. Meaning, they likely won't directly contribute to fat loss, muscle gain, or strength. Rather, it is possible that once we do more research, we could find probiotic supplementation regimes that could aid training recovery or immune function, allowing you to train harder, longer, and with a lower risk of illness. But again, at this stage, it's speculatory at best.

weight-class strength athletes cutting to make weight could possibly benefit from probiotic supplementation. We are a long way from knowing the specific strains and dosage protocols we should even study to assess if this is true, but I do hope that some researchers take up the call.

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Study Reviewed: Heel-Raised Foot Posture Does Not Affect Trunk and Lower Extremity Biomechanics During a Barbell Back Squat in Recreational Weight Lifters. Lee et al. (2019)

Flat-Soled Shoes are Probably Fine for More Lifters

BY GREG NUCKOLS

Ten years ago, it seemed like almost all lifters squatted in Chuck Taylors. Now, weightlifting-style shoes with a raised heel dominate the platform. It seems the shift may have more to do with fashion and tastes than performance.

KEY POINTS

1. Fourteen subjects performed squats with 80% of 1RM under three different conditions: barefoot on flat ground, barefoot with heels raised, and wearing shoes with a raised heel.
2. There were no kinematic or electromyographical (EMG) differences between the three styles.
3. Most people can likely squat with whatever footwear they're the most comfortable with. A raised heel is primarily going to benefit people with very limited ankle dorsiflexion, or people who are trying to squat as upright as possible.

I remember the good old days when the only footwear decision a powerlifter had to make was "what color Chuck Taylors should I get?" Now there are a plethora of different options to choose from, and most lifters squat with a weightlifting-style shoe with a raised heel. Does squatting in a raised heel actually affect technique and muscle activation, though?

In the present study (1), 14 subjects performed squats with 80% of 1RM under three different conditions: barefoot on flat ground, barefoot with heels raised, and wearing shoes with a raised heel. Researchers assessed knee and spine kinematics, and quad and spinal erector EMG. They found that, contrary to popular belief, squatting with a raised heel didn't lead to a more upright squat or increased quad activation.

Purpose and Research Questions

Purpose

The purpose of this study was to investigate the neuromuscular and biomechanical effects of foot posture and footwear during barbell back squats.

Research Questions

1. Would foot posture (flat versus raised heel) or footwear (barefoot versus weightlifting shoes) affect knee or spine kinematics when squatting with 80% 1RM loads?
2. Would foot posture or footwear affect vastus lateralis or spinal erector EMG amplitudes?

Hypotheses

The authors directly hypothesized that squatting with a raised heel would allow the lifters to squat with a more upright trunk posture, leading to less thoracic and lumbar flexion and lower spinal erector activation. The wording of the introduction also suggests that the authors expected squatting with a raised heel to increase quad activation.

Subjects and Methods

Subjects

The researchers recruited seven men and seven women to participate in this study. To be included in the study, subjects needed to have at least two years of squatting experience. However, these subjects weren't incredibly well-trained, as the average squat 1RM was only about 1.22 times body mass. You can see more information about the subjects in Table 1.

Study Overview

This study took place over two visits. In the first visit, the subjects tested their 1RM barefoot squat. All squats were performed to parallel with a shoulder width stance, neutral foot position (i.e. toes pointed forward), and a high bar position. Note that "parallel" in this study would probably be a couple of inches high by powerlifting standards – they ensured that the hip joint dropped to the level of the knee joint, which is a bit higher than ensuring the crease of the hip drops below the top of the knee.

In the second visit, the subjects were outfitted with EMG electrodes on their vastus lateralis and spinal erectors (at the level of L3 and T12-L1). They started the visit by performing maximal voluntary isometric knee extensions and back extensions. The EMG amplitudes during these isometric contractions were used to normalize the EMG readings during the squat. After this, the subjects were also outfitted with reflective markers, and then warmed up to squat. In a randomized, counterbalanced order, each subject performed three sets of one rep with 80% of 1RM with three different foot postures or footwear conditions. The three conditions were: 1) barefoot on flat ground, b) barefoot on an inclined surface, and c) wearing weightlifting shoes with a raised heel (3.3cm). The inclined surface was "lined with high friction material" so it wouldn't be slippery, and the angle of the surface was fixed at 4.3 degrees to mimic the foot posture of weightlifting shoes. EMG amplitudes were recorded for each rep, and a camera system captured the lifters' movements during each rep.

Measurements

The researchers reported five kinematic and nine EMG measures: peak knee

Table 1 Subject characteristics

Number of subjects	Age (years)	Height (m)	Mass (kg)	Mean 1-RM (kg)	Years strength training	Workouts per week	Workout duration (min)
14 (7 male, 7 female)	26.0 ± 2.5	1.68 ± 0.11	72.7 ± 12.9	89.0 ± 31.3	4.0 ± 1.5	3.4 ± 0.9	59.6 ± 12.8

Values presented as mean ± SD.

Table 2 Joint kinematics of the three foot posture conditions (unit: degrees; mean ± SD)

Variable	Barefoot	Platform	WL shoe	*p*	Cohen's *d* (between barefoot and WL shoe)
Peak knee flexion	125.65 ± 11.75	128.17 ± 10.29	127.89 ± 10.16	0.056	-0.204
Thoracic flexion at peak knee flexion	38.47 ± 8.66	37.08 ± 6.55	37.16 ± 6.63	0.348	0.170
Peak thoracic flexion	44.03 ± 7.42	42.67 ± 5.35	42.89 ± 6.82	0.397	0.160
Lumbar flexion at peak knee flexion	25.55 ± 15.07	26.65 ± 14.58	26.05 ± 15.29	0.283	-0.033
Peak lumbar flexion	26.88 ± 15.52	27.82 ± 15.10	27.31 ± 15.69	0.290	-0.028

flexion, peak thoracic flexion, peak lumbar flexion, peak thoracic and lumbar flexion at the moment of peak knee flexion, and mean EMG of the thoracic spinal erectors, lumbar spinal erectors, and vastus lateralis during the eccentric, concentric, and "terminal depth" portion of each rep. "Terminal depth" was defined as the one-second time window around the moment of peak knee flexion (from half a second before until half a second after the moment of peak knee flexion).

Findings

There were no significant differences for any of the measures. Peak knee flexion was almost significantly greater when squatting barefoot on an inclined surface than when squatting barefoot on a flat surface (p = 0.056), but the difference was pretty tiny (~2.5 degrees).

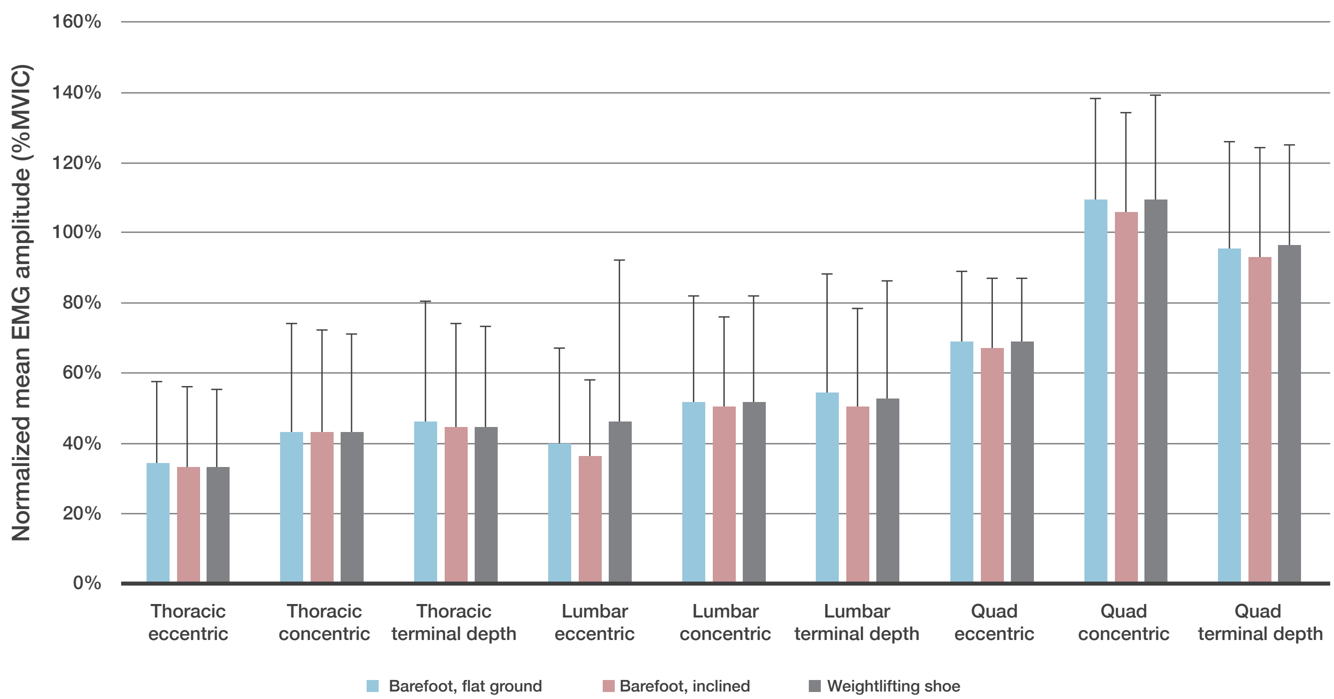
Interpretation

I wanted to review this article because a) the findings are probably counterintuitive for a lot of people, and b) the findings *shouldn't* be surprising, if you think about what a raised heel actually accomplishes.

Most of the time, when people think about squatting with a raised heel, they immediately assume that a raised heel means a more knee-dominant squat. I think people make that connection due to the immediate association between raised heels and weightlifting-style, "knee-dominant" squats. However, a raised heel doesn't *cause* you to squat like that. Rather, especially if you have tight ankles, raised heels *allow* you to squat like that.

With a raised heel, you initiate the lift with some degree of ankle plantar flexion. If your ankle has 30 degrees of dorsiflexion ROM, but you're in 10 degrees of plantar flexion before you start descending in the squat due to a raised heel, you're effectively working with 40 degrees of dorsiflexion ROM. With a flat sole, you'd be restricted to just 30 degrees of dorsiflexion, which means your knees can't travel quite as far forward, necessitating increased forward lean.

Figure 1 Effects of footwear and foot position on EMG in the back squat



However, that's assuming that you prefer to squat with maximum dorsiflexion (i.e. maximum forward knee travel). If, on the other hand, you have 30 degrees of dorsiflexion ROM, but you feel the strongest and most comfortable with less-than-maximum forward knee travel – just 20 degrees of dorsiflexion ROM – squatting with a raised heel won't magically force you to squat with greater forward knee travel. You'd just be staying 20 degrees from end-ROM instead of 10. And, as we've covered in MASS before, most people *don't* squat with maximum forward knee travel (2). Rather, ankle dorsiflexion during the squat is ~11 degrees shy of maximal dorsiflexion, on average.

However, if you have tight ankles, and your squat feels awkward because your knees can't travel forward far enough, shoes with a raised heel will probably help you out. Furthermore, if you're purposefully trying to either maximize forward knee travel or to keep your torso as upright as possible (possibly for front squatting), shoes with a raised heel can certainly be helpful. Finally, some people just report feeling stronger and more comfortable squatting with a raised heel, even if doing so doesn't necessarily change their technique, so I think it's certainly something worth experimenting with. But, unless you squat with maximum dorsiflexion and forward knee travel, you probably shouldn't expect the raised heel to change your technique

APPLICATION AND TAKEAWAYS

For most people, you should just squat in whatever non-squishy shoes you prefer. However, if you have very tight ankles, or if you're simply trying to squat as upright as possible, you should look into squatting with shoes that offer a raised heel.

much, if any.

Finally, it's worth noting that the results of this study fit comfortably with other research on this topic. Sato and colleagues compared squatting in weightlifting shoes and running shoes (3), and found that lifters tend to have a bit less forward lean with weightlifting shoes, but the overall difference was pretty trivial (~2cm). More recently, Whitting and colleagues also compared weightlifting shoes and running shoes (4), finding that the subjects actually had a bit more ankle dorsiflexion with the running shoes (~5 degrees), but no other significant kinematic differences. So, the only statistically significant effects seen in the literature to this point have been quite small, and most of the comparisons in the prior two studies were null as well, so the full slate of null findings in this study fits right in.

Next Steps

One drawback of this study was that the subjects weren't super well-trained. The results may be different if the subjects were all strength athletes, some of whom prefer to squat with a raised heel, and some of whom prefer flat-soled shoes. Furthermore, this study didn't touch kinetics, and it overlooked hip kinematics or EMG of the hip extensors. Future studies should aim to get a more well-trained cohort and to collect data about hip kinematics and EMG of the hip extensors.

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VIDEO: Improving 1RM Strength for Hypertrophy

BY MICHAEL C. ZOURDOS

Welcome to our very first question and answer video. One of our subscribers has asked if increasing 1RM with low rep work is beneficial for hypertrophy or if you are better off just training in the moderate to high rep ranges. This video tackles that question and lays out practical strategies for how strength and hypertrophy training don't have to be mutually exclusive.

Click to watch Michael's presentation.

MASS VIDEO SERIES | VOLUME 3, ISSUE 4 | APRIL 2019

Relevant MASS Videos

1. Mesocycle Construction for Bodybuilding (Volume 1 Issue 9)
2. Strategies to Improve Neuromuscular Efficiency (Volume 2 Issue 10)

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VIDEO: Implementing Deloads, Part 2

BY ERIC HELMS

Deloads – often referred to as light weeks, recovery weeks, or unloads – are a fundamental part of training periodization and programming. In part 2 of this series, Eric builds on the rationale, tenets, and periodization concepts of part 1, by giving specific examples you can use as templates to build on.

Click to watch Eric's presentation.

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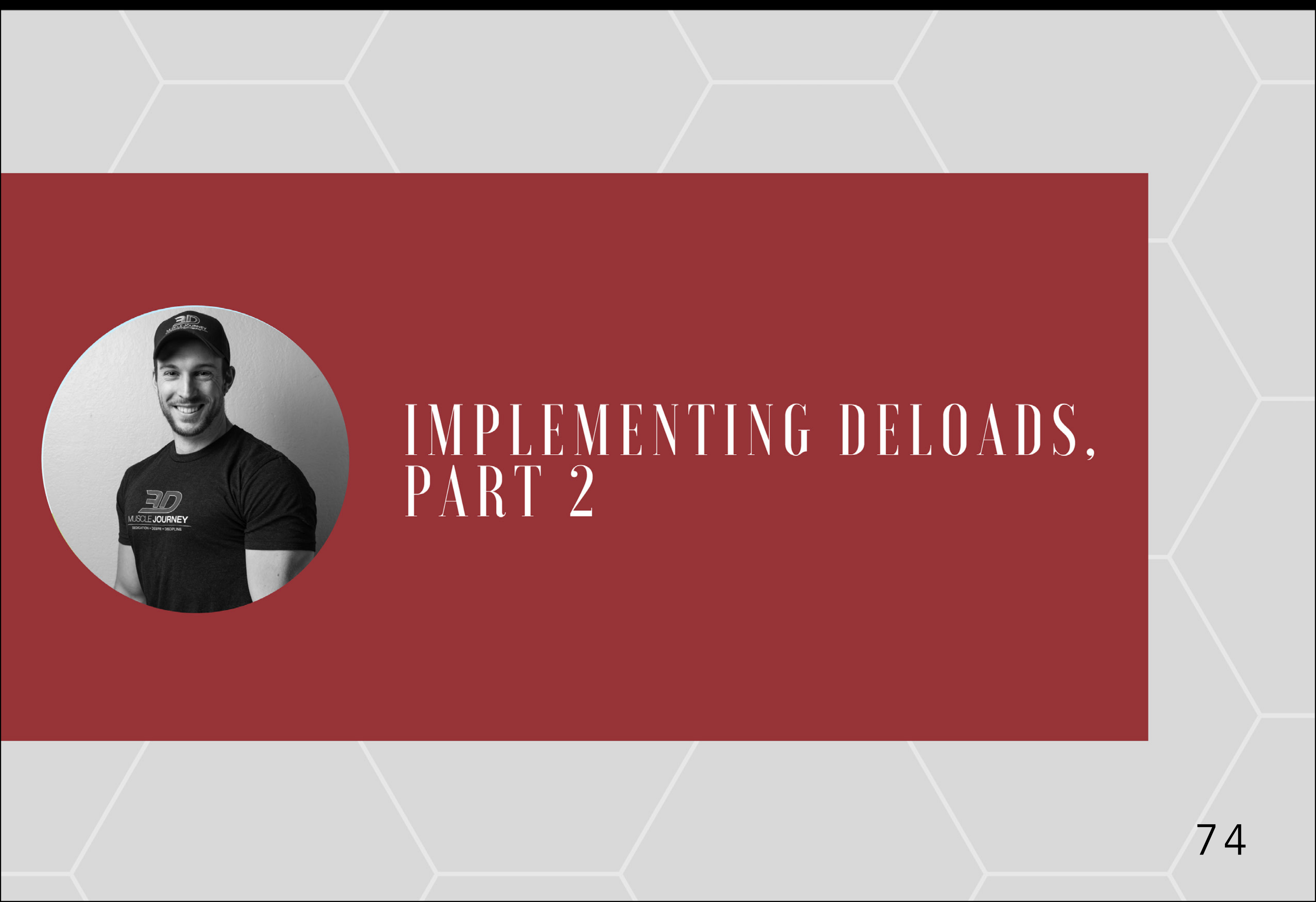

Relevant MASS Videos

1. Comprehensive Program Design Part 1

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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.

- Viana et al. Is interval training the magic bullet for fat loss? A systematic review and meta-analysis comparing moderate-intensity continuous training with high-intensity interval training (HIIT)
- Bauer et al. Combining higher-load and lower-load resistance training exercises: A systematic review and meta-analysis of findings from complex training studies
- Oranchuk et al. Isometric training and long-term adaptations: Effects of muscle length, intensity, and intent: A systematic review
- Salinero et al. Effects of acute ingestion of caffeine on team sports performance: a systematic review and meta-analysis
- Balderree and DeBeliso. The Effects of Back and Front Squat Exercises on Sprint Speed and Vertical Jump: A Pilot Study
- Carbone et al. Recent Advances in the Characterization of Skeletal Muscle and Whole-Body Protein Responses to Dietary Protein and Exercise during Negative Energy Balance
- Bowtell and Kelly. Fruit-Derived Polyphenol Supplementation for Athlete Recovery and Performance
- Close et al. From Paper to Podium: Quantifying the Translational Potential of Performance Nutrition Research
- Stutz et al. Effects of Evening Exercise on Sleep in Healthy Participants: A Systematic Review and Meta-Analysis
- Nimphius et al. Comparison of Quadriceps and Hamstring Muscle Activity during an Isometric Squat between Strength-Matched Men and Women
- Vargas et al. Comparison of changes in lean body mass with a strength- versus muscle endurance-based resistance training program
- Belcher et al. Time Course of Recovery is Similar for the Back Squat, Bench Press, and Deadlift in Well-Trained Males
- Lundberg et al. Regional and muscle-specific adaptations in knee extensor hypertrophy using flywheel vs. conventional weight-stack resistance exercise

Thanks for reading MASS.

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

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