SAMPLE ISSUE 2017

MASS

MONTHLY APPLICATIONS IN
STRENGTH SPORT

ERIC HELMS | GREG NUCKOLS | MICHAEL ZOURDOS

Letter from the Reviewers

WELCOME to the sample issue of Monthly Applications in Strength Sport (MASS)!

If you (or your clients) want to build muscle, get stronger, and/or drop fat as efficiently and effectively as possible, MASS is for you. Our focus is narrower than other research reviews, focusing solely on strength and physique athletes and coaches. This means that every month, we'll review only the research that's the most relevant for you and your results.

It's important for athletes and coaches to be on top of the research, but we know that doing so is quite inefficient when flying solo. It takes a long time to sift through journals and find the studies that are relevant to you. It takes even longer to read and digest those studies, and it takes even longer yet to contextualize new research in the broader body of literature. That's what MASS is for. We do all the heavy lifting for you and distill the most important findings into an easy-to-read monthly digest.

This sample issue should give you an idea of what you can expect from MASS. We cover the relationship between muscle damage and muscle growth, whether the intensity of aerobic training affects the degree to which cardio interferes with strength and muscle gains, whether flexible training plans produce better results than rigid training plans, and much more. Each issue will tackle new questions, keeping you up to date with the current research, and giving you a thorough understanding of the best science-based practices. We hope you enjoy it, and we hope you'll subscribe so you can stay on the cutting edge of our field to get the best results possible for yourself or your clients.

Thanks so much for reading.

The MASS Team

Michael, Eric, and Greg

The Reviewers

Eric Helms

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

Greg Nuckols

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

Michael C. Zourdos

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

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Is It Better to Combine Lifting With High Intensity or Traditional Cardio?

Study Reviewed: Endurance training intensity does not mediate interference to maximal lower-body strength gain during short-term concurrent training. Fyfe et al. (2016)

BY GREG NUCKOLS

Concurrent training is the simultaneous inclusion of both resistance and endurance training within the same training program. Previous research (1) suggests that concurrent training leads to somewhat smaller gains in strength and muscle mass than resistance training alone. However, to this point, no studies had compared concurrent training utilizing high intensity endurance training (intervals) versus

KEY POINTS

1. The interference effect describes the relatively smaller gains in strength and hypertrophy seen when combining strength and endurance training versus performing strength training in isolation.
2. This study set out to see whether high intensity intervals or moderate intensity steady state cardio interfered more with hypertrophy and strength gains when combined with strength training.
3. High and moderate intensity cardio interfered with strength gains and hypertrophy to a similar degree – the subjects made gains, but smaller gains than the folks only doing strength training.
4. When looking at both results and effort invested, moderate intensity cardio came out on top. The participants consistently rated high intensity interval training as consistently more challenging than moderate intensity cardio, even though time and workload were equated.

moderate intensity endurance training.

In this study, both concurrent training groups gained a similar amount of strength in the bench press and leg press, but less strength in the leg press than the group only performing strength training. Measures of explosive strength (peak force and peak power in the counter-movement jump) favored the group only performing resistance training, and unsurprisingly, measures of endurance (VO_2 peak, and peak aerobic power) favored the concurrent training groups. The concurrent training group doing moderate intensity endurance training gained roughly the same amount of lower body lean mass compared to the group only performing resistance training, while the concurrent training group doing high intensity endurance training gained slightly less lower body lean mass.

Purpose and Research Questions

Numerous studies have compared concurrent training with resistance training. However, the endurance training aspect of concurrent training can take many forms, running the gamut from very low intensity cardio to very high intensity intervals. To this point, no studies had directly compared concurrent training programs utilizing two different approaches to endurance training.

The authors hypothesized that high intensity endurance training (HIT) would compromise gains in strength more so than moderate intensity endurance training (MOD), since HIT tends to be more fatiguing and lead to larger acute decreases in strength when compared to MOD with similar volumes. Alternately, various prominent writers and coaches have proposed

PROGRESSION OF RESISTANCE TRAINING PRESCRIPTION

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
MON./FRI. PROGRAM: leg press, bench press, seated row, leg extension, and leg curl								
Sets × repetitions	3×12	3×10	3×8	3×6	4×6	4×6	4×4	5×4
RM load	14	12	9	7	7	7	4	4
Rest period (min)	2	2	2	3	3	3	3	3
% 1RM load	65	70	77.5	82.5	82.5	87.5	90	90
WED. PROGRAM: leg press, DB bench press, lat pulldown, DB lunges, and leg curl								
Sets × repetitions	3×12	3×12	3×10	3×10	3×8	3×8	4×6	3×6
RM load	14	14	12	12	9	9	7	7
Rest period (min)	2	2	2	2	2	2	2	2
% 1RM load	65	65	70	70	77.5	77.5	87.5	87.5

RM = repetition maximum | 1RM=one-repetition maximum

that MOD will cause muscle atrophy and strength losses, while HIT will help one build muscle and strength.

Subjects and Methods

The subjects were males, mostly 25-35 years old, who participated in some form of resistance or aerobic exercise at least twice per week.

At the outset of the study, they were DXA scanned, tested their 1RM bench presses and leg presses, took a graded exercise test on a cycle ergometer, and performed a counter-movement jump test. All of these tests were repeated at the end of the study, and the exercise tests were also performed again at the midpoint of the training intervention.

The participants were assigned to one of three training programs: resistance training only, resistance training plus HIT, and resistance training plus MOD. All groups carried out the same resistance training program three days per week, which utilized a basic linear periodization design, starting with 3 sets of 12 with 65% of 1RM, and progressing to 5 sets of 4 with 90% of 1RM over 8 weeks.

The endurance training was performed directly before the strength training (lifting started 10 minutes after the endurance training session finished). HIT and MOD were matched for both time and total training volume. HIT consisted of cycling intervals consisting of 2 minutes of high exertion and 1 minute of rest. Volume and intensity increased over the course of the study, from 5 intervals at 120% of lactate threshold (roughly 70-75% of VO_2 peak) to a max of 11 intervals at 150% of lactate threshold (roughly 90% of VO_2 peak). MOD consisted of steady-state cycling, starting with 15 minutes at 80% of lactate threshold (roughly 50% of VO_2 peak) and peaking at 33 minutes at lactate threshold (roughly 60% of VO_2 peak).

The researchers also monitored diet and per-session rating of perceived exertion.

		HIT		MOD	
		No. of 2-min intervals	Training intensity (% LT)	Duration of continuous training (min)	Training intensity (% LT)
WEEK 1	SESSION 1	5	120	15	80
	2	6	120	18	80
	3	7	120	21	80
2	1	6	120	18	80
	2	8	120	24	80
	3	7	120	21	80
3	1	8	130	24	86.7
	2	9	130	27	86.7
	3	8	130	24	86.7
4	1	7	130	21	86.7
	2	6	130	18	86.7
	3	5	130	15	86.7
5	1	7	140	21	93.3
	2	8	140	24	93.3
	3	9	140	27	93.3
6	1	8	140	24	93.3
	2	9	140	27	93.3
	3	10	140	30	93.3
7	1	9	150	27	100
	2	11	150	33	100
	3	10	150	30	100
8	1	9	150	27	100
	2	7	150	21	100

Findings

Perceived difficulty

The participants gave HIT a higher rating of perceived exertion, indicating that they found it more challenging than MOD. Both concurrent training conditions were rated as substantially more challenging than resistance training alone, unsurprisingly.

Nutrition

All three groups had similar caloric intake and macronutrient profiles. Most important for our purposes here, protein intake was similar, at 1.1-1.3g/kg, which is below or at the very bottom end of the 1.3-1.8g/kg range (2) proposed to maximize muscular adaptations to resistance training.

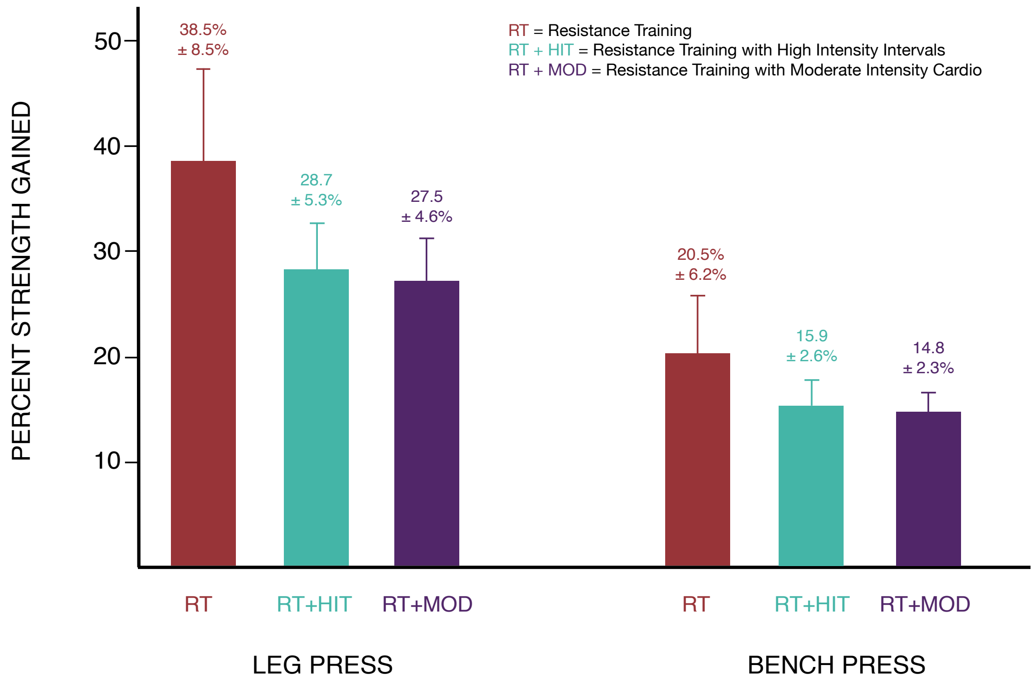
Strength

The resistance training group gained more strength in both the leg press and the bench press than either of the concurrent training groups. However, there were only meaningful effect size differences for the leg press. The resistance training group gained 38.5 ± 8.5% on the leg press, versus 28.7 ± 5.3% for the HIT concurrent training group, and 27.5 ± 4.6% for the MOD concurrent training group. For the bench press, the resistance training group gained 20.5 ± 6.2%, vs. 15.9 ± 2.6% for the HIT concurrent training group and 14.8 ± 2.3% for the MOD concurrent training group.

Counter-movement jump

The improvements in all measures (peak force, peak power, peak velocity, and peak displacement) tended to favor the resistance training group over either concurrent training group, but there were no statistically significant differences between groups.

STRENGTH GAINS



Hypertrophy and body composition

Lower body lean mass increased slightly more in the resistance training group (4.1 ± 2.0%) and MOD concurrent group (3.6 ± 2.4%) versus the HIT concurrent group (1.8 ± 1.6%), but the difference wasn't significant.

Upper body lean mass and total lean mass didn't increase to a meaningful degree in any of the groups (only 0.4-1.8% and 1.6-2.4%, respectively). None of the groups had a significant change in body fat percentages, with decreases ranging from 0.2-0.9%.

Aerobic fitness

Both concurrent training groups experienced similar increases in VO_2 peak (5.3 ± 2.7% for HIT, and 6.1 ± 5.0% for MOD). The MOD concurrent training group had the largest increase in lactate threshold (12.6 ± 8.0%), with similar gains seen in the resistance training (7.4 ± 9.4%) and HIT concurrent training (8.3 ± 6.5%) groups. There were no significant between-group differences.

The HIT concurrent training group was the only one that experienced an increase in peak aerobic power (8.8 ± 4.1%). The gains seen in the MOD concurrent training group (4.9 ± 4.8%) weren't significant. There was a small, non-significant decrease in the resistance training group (−2.2 ± 6.5%).

Interpretation

If you want to maximize rates of strength gains, your best bet is to limit cardio. The magnitude of interference effects seems to depend on the frequency (3), volume, and mode of the cardio you do (1), with lower frequencies, lower volumes, and lower impact forms of cardio (i.e. cycling instead of jogging or running) leading to a smaller interference effect. However, these measures do not negate the effect entirely.

The main finding of this study was that intensity of endurance training doesn't seem to influence the interference effect if volume is matched; both moderate and high intensity cardio led to similar decrements in strength gains. Since the changes in body composition in this study were small, and between-group differences were small and non-significant, it's hard to say whether cardio intensity would have a meaningful impact on hypertrophy, muscle maintenance in a calorie deficit, or overall body composition in a longer-term concurrent training program.

One could contend that moderate intensity cardio came out ahead in this study for hypertrophy since the MOD concurrent training group gained twice as much lower body lean mass as the HIT concurrent training group, but the changes were small in both groups (which makes it easier to see larger percent differences), and the difference between groups wasn't particularly close to statistical significance (the p-value for this particular relationship wasn't reported, but it can be inferred to be substantially higher than 0.05 based on what was reported). Before reaching that conclusion, I'd need to see a longer study with a larger sample size.

One other important takeaway from this study was that moderate intensity cardio seemed to be more effective per unit of effort invested. Training volume (total time and workload) of endurance training was matched between the two concurrent training groups, but the per-session RPE was higher for the group doing HIT. However, both groups experienced very similar adaptations.

Finally, it's important to keep timing in mind. In this study, the strength training took place directly after the endurance training. The effects may have been different if the participants did the strength training first, if they separated their strength training and endurance training sessions by several hours, or if they performed strength training and endurance training on different days. Doing so would likely help mitigate the interference effect on a molecular level (4), and also, on a more practical level, allow for resistance training to take place with less acute fatigue from cardiovascular training (which would be a bigger issue with HIT than MOD).

The major takeaway of this study is that if you want to maximize your rate of strength gains, you should try to avoid cardio or limit the amount you do. If you undertake concurrent training, the intensity of the endurance training you do doesn't seem to meaningfully affect the magnitude of the interference effect. However, moderate intensity endurance training is less difficult per unit of training volume.

APPLICATION AND TAKEAWAYS

1. If your goal is to maximize gains in strength and muscle mass, your best bet is to limit any sort of endurance training to a bare minimum (or exclude it entirely).
2. If you need to perform endurance training, both high intensity intervals and moderate intensity aerobic exercise seem to elicit the interference effect to roughly the same degree.
3. As moderate intensity cardio was rated to be easier than high intensity intervals per unit of workload, it may be the better choice. However, feel free to use whichever mode of cardio you find to be the most enjoyable and easiest to stick with, assuming you need to do it in the first place.

Next Steps

To further elucidate the impact of endurance training intensity on the interference effect, future studies should include a low intensity group, test different populations (such as athletes with more strength training experience), and experiment with the impact of timing of the endurance exercise training.

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Does the Configuration of Weekly Training Session Order Matter for Strength?

Study Reviewed: Comparison of powerlifting performance in trained males using traditional and flexible Daily Undulating Periodization. Colquhoun et al. (2017)

BY MICHAEL C. ZOURDOS

KEY POINTS

1. This study compared a fixed weekly order of daily undulating periodization training versus a program in which weekly training order was flexible based upon a lifter's readiness.
2. Both groups had significant increases in squat, bench press, and deadlift strength over 9 weeks of training, with no significant differences between groups.
3. Despite no strength differences, a flexible weekly order may increase adherence.
4. Lifters in the present study were fairly well-trained, which makes these findings particularly applicable to the readers of MASS.

Daily undulating periodization (DUP), the practice of altering repetitions or training focus (hypertrophy, strength, or power) each session, has increased in popularity in recent years. However, when the prescribed repetition schemes are performed in a fixed order throughout the week, the resulting rigidity may not accommodate fluctuations in the athlete's readiness, so it may be beneficial to incorporate some form of autoregulation within a DUP model. This study compared a flexible DUP (FDUP, n=14) strategy against a fixed DUP (n=11) weekly strategy to test this hypothesis with trained males. The FDUP lifters could choose which daily training session they wanted to do (hypertrophy, strength, or power) based upon their daily readiness, with the stipulation that each of the three sessions must be performed within each week. The DUP group performed training in the fixed weekly order of hypertrophy (Monday), power (Wednesday), and strength (Friday). The training programs lasted 9 weeks, and squat, bench press, and deadlift 1RMs, along with Wilks Score (relative strength) were tested before and after the 9 weeks. Further, total volume and repetitions performed were compared between groups.

Both groups had significant increases ($p<0.05$) in both absolute and relative strength for all individual lifts and powerlifting total (FDUP: +9.3% and DUP: +9.2%) over the 9 weeks, but there were no differences between groups for any strength measure ($p>0.05$). Additionally, there were no group differences in training volume or repetitions ($p>0.05$). Interestingly, there was possibly slightly greater adherence to training in favor of FDUP. Importantly, FDUP produced similar adaptations in trained males to a fixed weekly order DUP configuration of hypertrophy, strength, and then power over 9 weeks.

Purpose and Research Questions

The purpose of this study was to compare the effects of 9 weeks of DUP versus FDUP (i.e. flexible order of weekly training sessions) training on training volume and absolute and relative strength in the powerlifts and powerlifting total. A secondary aim was to assess if there were any differences between satisfaction of training sessions, rating of perceived exertion (RPE) per session, or motivation to train when using a flexible versus a fixed weekly training order.

Research question 1: Does a flexible weekly training order (FDUP) result in greater strength and total volume performed than a fixed weekly training order (DUP)?

Research question 2: Does FDUP result in greater motivation to train and training satisfaction than DUP due to allowing individuals to choose workouts based upon daily readiness and desire?

The authors hypothesized: 1.) That FDUP would result in greater strength adaptations (absolute and relative) compared to DUP due to greater readiness allowing for more repetitions performed, thus more total volume; and 2.) Subjects would have higher motivation to train and greater satisfaction with a training session with FDUP compared to DUP.

Clarity note

These hypotheses are based on the concept that autoregulating training sessions based upon daily readiness would improve performance.

Subjects and Methods

Subjects

Subjects were 34 males with at least 6 months of training three times per week and 1RMs of at least the following:

- Back squat: 1.25 times body mass (BM).
- Bench press: 1 times BM.
- Deadlift: 1.5 times BM.

However, only 25 subjects completed the study (FDUP: n=14, DUP, n=11).

This is about a 16% dropout rate, for various reasons, which is not uncommon in a training study. 25 finishing subjects is a pretty good sample size in comparison to similar research (2).

For 9 weeks, each group trained on three non-consecutive days per week. DUP trained in the weekly order of hypertrophy, power, and then strength. FDUP could choose which session they wanted to perform upon entering the laboratory with the stipulation that all session types must be performed each week; therefore, each group would be performing one hypertrophy, one power, and one strength session per week, albeit in a potentially different configuration. At pre- and post-testing, there were 1RM tests for the powerlifts along with body composition assessment via ultrasound.

Further, session RPE was assessed following each training session to gauge a measure of overall post-training fatigue, while motivation to train and training satisfaction were gathered before and after each session, respectively.

Training program

The specifics of the training program can be seen in Table 1.

The only difference between groups was the ability of the FDUP group to choose the weekly training order. Squat and bench press were performed every session, while deadlift was only performed during power sessions.

TABLE 1: TRAINING PROGRAM

HYPERTROPHY DAY					
	Week 1	Weeks 2-3	Weeks 4-6	Weeks 7-8	Week 9
Squat	4×8+ @70%	4×8+ *	4×6+ *	4×5+ *	2×5+ *
Bench press	4×8+ @70%	4×8+ *	4×6+ *	4×5+ *	2×5+ *

POWER DAY					
	Week 1	Weeks 2 and 3	Weeks 4-6	Weeks 7-8	Week 9
Squat	6×1 @80%	6×1 @80% P1RM	6×1 @85% P1RM	4×1 90% P1RM	2×1 @90% P1RM
Bench press	6×1 @80%	6×1 @80% P1RM	6×1 @85% P1RM	4×1 @90% P1RM	2×1 @90% P1RM
Deadlift	6×1 @80%	6×1 @80% P1RM	6×1 @85% P1RM	4×1 @90% P1RM	2×1 @90% P1RM

STRENGTH DAY					
	Week 1	Weeks 2 and 3	Weeks 4-6	Weeks 7-8	Week 9
Squat	4×3+ @85%	4×3+ **	4×2+ **	4×1+ **	2×1+ **
Bench press	4×3+ @85%	4×3+ **	4×2+ **	4×1+ **	2×1+ **
Deadlift	4×3+ @85%	4×3+ **	4×2+ **	4×1+ **	2×1+ **

This table displays the training program for the main lifts for the entire study. All notations are “Sets×Reps”. For the power day, percentages of one-repetition maximum (1RM) after week 1 were based upon a predicted 1RM, which was calculated via the Epley Formula using the previous week’s plus set performance on the strength day. Pre-testing was completed 48-72 hours prior to the first training session, and post-testing occurred 48-72 hours following the last session in week 9. Additionally, assistance exercises: (DB lateral raise, DB triceps extension, DB curl for hypertrophy day; pullups and abs for power day; and barbell row and abs for strength day) were performed with either 3×12 or 3×15 in week 1 and decreased to either 2×6 or 2×8 in week 9.

+Plus set= As many repetitions as possible were completed on the last set of this exercise.

*Hypertrophy day progressed based upon plus set repetitions in accordance with Table 2.

** Strength day progressed based upon plus set repetitions in accordance with Table 2.

TABLE 2: WEEKLY LOAD PROGRESSION CHART

PLUS SET REPETITIONS	WEEKLY LOAD ADJUSTMENT
5 reps or fewer under goal	Decrease 7.5kg for next week session-type
3-4 reps under goal	Decrease 5kg for next week session-type
1-2 reps under goal	Decrease 2.5kg for next week session-type
0-1 reps under goal	Same load for next week session-type
2-3 reps above goal	Increase 2.5kg for next week session-type
4-5 reps above goal	Increase 5kg for next week session-type
6 reps or more above goal	Increase 7.5kg for next week session-type

Adjustments are referring to the same session type for the following week. For example, if 5 more repetitions than required were completed on the strength session in week 2, then 7.5kg would be added for the strength session in week 3. Adapted from Colquhoun et al. (1)

Load progression

For progression, a plus set (as many repetitions as possible) was implemented on hypertrophy and strength sessions, and loads were autoregulated for the following week on that session based upon plus set performance (Table 2). Additionally, 2-3 assistance exercises were performed each session in the exact same manner for each group to avoid subjects doing additional training outside of the laboratory.

Findings

All strength measures increased; however, there were no statistically significant differences between groups for any measure.

Training volume, repetitions completed, and average training intensity

Both groups did roughly the same number of reps on their plus sets, and volume through the rest of the training week was equated. Therefore, there were no significant group differences ($p>0.05$) in training volume or total reps performed.

Further, since progression was autoregulated, average intensity could be calculated. There was no difference (p>0.05) between groups for average intensity, suggesting that rate of progression was similar between groups. In fact, average intensity throughout the 9 weeks was very similar for squat (DUP: 87% and FDUP: 86% of 1RM), bench press (DUP: 86% and FDUP: 87% of 1RM), and deadlift (DUP: 87% and FDUP: 83% of 1RM).

Strength

As previously stated, all strength measures increased from pre- to post-testing, but no differences existed between groups (Table 3). Furthermore, an effect size was calculated for each group from pre- to post-testing to examine the magnitude of change. No effect sizes were drastically different between groups, indicating that the meaningful magnitude of change was also similar.

Research understanding note: The calculated pre-to-post effect size for both groups is not a direct comparison; rather, it is a magnitude inference for each individual group. However, effect sizes can also be calculated in a manner which allows you to compare the groups directly, which may be more helpful than simply calculating pre-to-post effect sizes for each group (3).

Research applicability note: The absolute values for squat, bench press, and deadlift 1RM are presented in Table 3 to show the training status of the individuals. While an average ending deadlift of >180kg in each group (about 400lbs) and squat of 165kg (363lbs) in DUP is not overly impressive to most readers of MASS, this is actually quite good for resistance training research, which makes these findings more applicable than most for a competitive strength sport population.

Perceptual measures

All perceptual measures (motivation to train, training session satisfaction, and session RPE) were similar between groups. FDUP did not provide an additional psychological benefit compared to the DUP weekly training order of hypertrophy, power, and strength.

Body composition

There were no changes from pre- to post-testing, nor were there any differences between groups for any of the body composition measures (fat-free mass, fat mass, or body fat percentage). No change here should have been expected, as this was not the point of the study, nor was dietary intake tracked. As a side note, just to give greater insight into the population, body fat percentage was about 11% in FDUP and 13% in DUP for males who weighed 80kg on average.

Interpretation

This study reported no significant differences in strength gains between groups; therefore, allowing flexibility in weekly session configuration using DUP did not enhance adaptations compared to a fixed session order. Correspondingly, the average number of repetition across all plus-set days was almost identical (FDUP: 9 versus DUP: 8), meaning there were no group differences in training volume.

Previously McNamara and Stearne (2010) reported that a flexible non-linear periodiza-

TABLE 3: PRE-TO-POST STRENGTH CHANGES IN EACH GROUP

MEASURE	FDUP			DUP		
	PRE	POST	% CHANGE	PRE	POST	% CHANGE
Squat 1RM (kg)	132.4 ± 34.2	148.0 ± 32.8	+11.8%	137.2 ± 30.7	165.2 ± 25.4	+12.2%
Bench 1RM (kg)	95.8 ± 20.1	102.3 ± 18.8	+6.8%	118.0 ± 20.8	126.8 ± 21.2	+7.5%
Deadlift 1RM (kg)	166.2 ± 40.6	181 ± 37.1	+8.9%	174.3 ± 25.4	187.9 ± 29.2	+7.8%

Powerlifting Total= Sum of squat, bench press, and deadlift. All pre- to post-testing changes are statistically significant; however, no group differences existed for any measure. Adapted from Colquhoun et al. (1)

tion model produced greater strength gains than an inflexible non-linear approach (4) in a 12-week program that allowed subjects to choose between a 20-, 15-, or 10-repetition day over two weekly training sessions. However, subjects in that study only had the stipulation that they had to complete each training type eight times (1/3 of the 24 total sessions) over the 12 weeks, whereas the presently reviewed study from Colquhoun and colleagues restrained subjects to only allowing within-week flexibility (i.e. hypertrophy, strength, and power all had to be performed within the same week). Because there was less flexibility in Colquhoun's study, there was an increased chance of an individual training with low readiness, possibly resulting in the conflicting results.

As a side note, these two studies used different terminology: flexible daily undulating periodization versus flexible non-linear periodization. While both are correct, non-linear can refer to weekly or daily undulating; thus, daily undulating is more specific and is an easier term to visualize for the reader (I prefer Colquhoun's terminology).

This study was also modeled after Zourdos et al. (2016), and the present results also differed slightly in this comparison. Zourdos and colleagues (2) compared two fixed weekly session configurations of DUP in powerlifters: 1.) Hypertrophy, power, and then strength (HPS – the same order as Colquhoun's fixed group) versus 2.) Hypertrophy, strength, and then power (HSP). HPS was designed to manage fatigue (separating the strength session from the hypertrophy session, which was likely to cause the most muscle damage), and it led to larger strength gains than HSP, as hypothesized (2). Colquhoun then adapted the already-successful HPS configuration and compared it to FDUP. Ultimately, FDUP may have not been more favorable in the presently reviewed study because the comparison model (HPS) already has fatigue and readiness management built into the configuration (i.e. separating strength 96 hours from the most damaging weekly session: hypertrophy). However, none of the above is to say that an FDUP strategy is not useful or never has its place. As with any finding, we cannot look at results in a vacuum; we must learn to think conceptually. Below, I want to present two ways of how understanding conceptually can allow you to utilize a flexible template:

1). When looking further into these results, we see that overall adherence to training may have been slightly better in FDUP. Specifically, both groups started with 16 subjects, for a total of 32 subjects (34 total were screened, but 2 did not meet the inclusion criteria). All 16 finished the FDUP protocol, while only 11 finished the DUP protocol. At the end, data from only 14 subjects were used for FDUP (as 2 were excluded for engaging in exercise outside of the study). Furthermore, 79% of the subjects in the FDUP group completed every training session, while 73% of the subjects in the DUP group completed every training session. It may be that allowing within-week flexibility increased adherence, despite not producing differences in the motivation to train on the Likert scale. Adherence is obviously one of the most important factors when designing a training program. If an individual does not adhere to the training prescription, everything else is of trivial importance. Thus, some flexibility may be beneficial in the long-term.

2). Second, utilizing a "somewhat flexible" weekly configuration may be beneficial. This recommendation takes into account that the already-established weekly order of HPS is beneficial, but fluctuations in daily readiness do happen, and long-term increased adherence should still play a role in program design. Therefore, it seems logical that you could train with a pre-determined order of HPS while reserving the right to still implement a flexible strategy in extreme situations (i.e. < 4 hours sleep or less than 30 minutes of availability to train). To accomplish this, we must think outside of the box.

Even though one hypertrophy, one power, and one strength day were performed within each study by both Colquhoun and Zourdos, if a "somewhat" flexible model (Table 4) is used, the HPS order could be implemented with the freedom to add a power day (since power-type sessions are the least taxing and consume the least amount of time) in the situations mentioned above, then continue on with the next day that had already been scheduled before the power day was "flexed" in. In essence, this would not control for number of session types within each week; it would simply allow a power-type session to be substituted when readiness or time stipulations occur. If preferred, session-type

TABLE 4: PROPOSAL OF SOMEWHAT FLEXIBLE TRAINING MODELS

WEEK	WEEK 1			WEEK 2		
DAY	MON.	WED.	FRI.	MON.	WED.	FRI.
FIXED: HPS (Zourdos / Colquhoun)	H	P	S	H	P	S
Somewhat flexible, example 1	H	P	P	S	H	P
Somewhat flexible, example 2	H	P	S	P	H	P

In the proposed model, the last two rows present a "somewhat flexible" weekly configuration. In example 1, the lifter sets out with a normal HPS (hypertrophy, power, and strength) weekly training order; however, the individual can "flex" in a power day when necessary without altering the overall pattern. Thus, after the extra power day is inserted in week 1 due to poor readiness (fatigue, sleep disruption, etc.), the individual simply keeps the planned order and picks up with strength in the following session. In example 2, the individual "flexes" in a power day as needed on Monday of week 2 and then simply picks up with hypertrophy-type training in the next session, which would otherwise have been performed on Monday.

stipulations could be given in the long-term (i.e. over months). Two examples of "somewhat" flexible strategies can be seen in Table 4 compared to the fixed HPS.

It should also be noted that this study provides an example of an integrated periodization strategy (this can be seen in the methods). Specifically, although DUP was used within each week, the methods describe how repetitions on the hypertrophy- and strength-type days decreased every few weeks, thus causing an increase in intensity in an effort to peak. This design shows a within-week DUP strategy encompassed with overall linear changes. I am sure MASS will cover this concept in more detail at some point, but this is an excellent example of how to look beyond the presented data to see the intricate details of a study design. The design demonstrates that these authors possess a solid understanding of scientific and practical program design.

APPLICATION AND TAKEAWAYS

1. Within-week flexibility of session order when using hypertrophy-, power- and strength-type sessions did not allow for higher training volumes or produce larger strength gains than a fixed weekly order of HPS.
2. The flexible DUP model did perhaps provide a slight increase in adherence to training.
3. If using DUP, it may be beneficial to utilize a weekly order of HPS but allow for some flexibility to increase adherence and maximize daily readiness on high intensity days.
4. An integrated periodized approach – which fluctuates number of repetitions within the week, yet still decreases volume and increases intensity over time – is a beneficial and practical approach to programming.

Next Steps

Ultimately, the flexible strategy implemented was not more effective than the fixed HPS order; however, this is not to say that flexible templates have no benefit (as discussed above). It is important to implement a flexible strategy over the long term in future studies to examine if adherence is truly increased. If adherence is indeed increased in the long term, this would be solid evidence for allowing a "somewhat" flexible strategy within your program design to avoid having a high intensity session when readiness to train is poor.

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Is Muscle Damage Related to Hypertrophy?

Study Reviewed: Resistance training-induced changes in integrated myofibrillar protein synthesis are related to hypertrophy only after attenuation of muscle damage. Damas et al. (2016)

BY ERIC HELMS

To better understand how muscle growth occurs in response to weight training, 10 young males performed the leg press and leg extension twice per week for 10 weeks. Very small portions (100 mg) of thigh muscle were surgically removed

KEY POINTS

1. Initial muscle protein synthesis response to resistance training (within ~48 hours) is not predictive of long-term hypertrophy when muscle damage is high (due to unfamiliar movements, untrained participants, or eccentric training). Rather than muscle protein synthesis being driven toward hypertrophy, the initial elevation is driven by muscle damage repair.
2. Conclusions about the muscle growth potential of nutrition or training protocols cannot be made based on muscle protein synthesis data when substantial muscle damage is present.
3. Muscle protein synthesis after multiple weeks of training, after the repeated bout effect has dampened muscle damage, is highly predictive of hypertrophy.
4. Muscle damage was not correlated with hypertrophy in this study. Additionally, high levels of muscle damage (such as when training for the first time, or after an extended lay off, or when training a muscle group for the first time) reduces strength by more than 20% for at least 48 hours. Thus, muscle damage likely should not be purposefully sought out in training. Additionally, a gradual increase in volume and intensity is advised to reduce the damage response in order to manage fatigue and promote faster strength gains.

(a biopsy) immediately before, 1 day and 2 days after the first training session, during a session in week 3, and at the last training session in week 10. Individual muscle fiber cross-sectional area, the rate that new proteins were added to the muscle (muscle protein synthesis - MPS), and the damage to the muscle from training were determined from these biopsies.

Muscle fiber growth was measurable by week 10. Muscle damage was the highest after the initial training session, lower by week 3, and the lowest at week 10. MPS was highest after the initial session, and lower by week 3, which remained the same at week 10. Fiber growth had a very strong relationship with MPS at week 3 and 10 but had no relationship with MPS after the first training session. Thus, MPS in the earliest stage of resistance training is not primarily directed toward muscle growth. Muscle growth and MPS are only strongly related once muscle damage decreases.

Purpose and Research Questions

The researchers wanted to know at what time point MPS becomes predictive of hypertrophy. They hypothesized that the initial rise in MPS in response to resistance training would be higher than at later time points and that this would be due to muscle damage. Additionally, they hypothesized that muscle damage would be the highest after the initial training bout and would decrease over time. Finally, they speculated that MPS would not be related to hypertrophy initially [as was shown by a previous study from this lab (1)], but would by week 3 and 10, after muscle damage decreased.

Subjects and Methods

10 more-or-less untrained young men participated in this study; they hadn't performed lower body training for 6 months, but had previous experience with it (this indicates the participants had participated in this lab's research before but did not regularly lift weights).

The methods used in this study are a big reason why the findings are important. This was a long-term study measuring MPS at multiple time points over 10 weeks.

The majority of prior research in this area consists of short-term studies done post-exercise and lasting ~6-12 hours, in which chemically labeled amino-acids are infused via catheters and traced to determine the rate at which they are incorporated into muscle.

Unlike prior research, in this study, the investigators had the participants drink deuterium oxide (heavy water; ^2H_2O) and measured the "deuterated" amino acids that had been incorporated into the muscle samples. Additionally, they took indirect measurements of muscle damage: subjective ratings of soreness on a 1-100 scale, creatine kinase (a blood marker of muscle damage), and maximum isometric voluntary contractile strength (this tends to decline when damage is high). They also directly assessed muscle damage by microscopically viewing z-band streaming (the mechanical disruption of the actin-myosin cross bridges) in the biopsies.

Findings

The highest MPS occurred 24 hours after the initial training session, and this dropped slightly at the 48-hour mark. Integrated (0-48 hours post-exercise combined) MPS was higher after the initial exercise session than after sessions in week 3 or 10, which were similar to one another. At all time points (initial and weeks 3 and 10), MPS was higher 24 hours post-exercise than 48 hours post-exercise. Interestingly, when the MPS specifically related to damage was corrected for (using the formulae: MPS × (100 – fiber area where Z-band streaming was present)/100), MPS was not different between weeks 1, 3, and 10.

Soreness peaked 48 hours after the initial exercise bout (61/100), and the second highest soreness rating was 24 hours after the initial bout (40/100). In weeks 3 and 10, soreness remained very low at all time points (0-10/100). Creatine kinase levels in week 1 were the highest, and they dropped by ~50% by week 3, and then dropped again by 50%

HYPERTROPHY HAD NO RELATIONSHIP WITH ANY MARKER OF MUSCLE DAMAGE, DIRECT OR INDIRECT, AT ANY TIME POINT.

in week 10, relative to week 3. Maximum voluntary contractile strength decreased ~22% 24-48 hours after the initial training session, and then only by 2-6% 24-48 hours after sessions in weeks 3 and 10. Direct measurement of z-band streaming showed the highest muscle damage after the first training session, decreasing dramatically by weeks 3 and 10.

Fiber hypertrophy of ~14% was measurably different relative to baseline by week 10. Hypertrophy had no relationship with any marker of muscle damage, direct or indirect, at any time point. Furthermore, hypertrophy had no relationship with MPS after the initial training bout. However, fiber hypertrophy had a strong relationship ($r = 0.91$) with integrated MPS at week 10. Whole muscle cross sectional area shown in a different study using the same participants (3) also had no relationship after the initial exercise bout and a strong relationship with integrated MPS at weeks 3 ($r = 0.86$) and 10 ($r = 0.95$); this means that MPS can explain 74-90% of the variation in muscle growth if it's measured once muscle damage has subsided. Interestingly, initial post-exercise MPS had a moderate and nearly significant relationship with the direct measure of muscle damage 48 hours after the first training bout ($r = 0.56$, $p = 0.09$).

STRENGTH IS ACUTELY DECREASED BY MUSCLE DAMAGE, WHICH DECREASES YOUR ABILITY TO PRODUCE PROGRESSIVE OVERLOAD.

Interpretation

This study is groundbreaking for several reasons. First, it had long been assumed that MPS was a surrogate measurement for hypertrophy. This was not questioned until the now-famous Schoenfeld, Aragon, and Krieger meta-analysis of post workout protein consumption found, at best, a weak relationship between post-workout protein consumption and hypertrophy, which contrasted starkly with MPS data (4). The second blow to the value of MPS data came in the form of a 16-week training study that found no relationship between MPS after the first session and hypertrophy (1). This study came directly from Stu Phillips' lab, where the most well-known research in this area is conducted. At the time, it was not known why there was no relationship, but this study explains why. Now, we know that initial MPS is likely driven by damage repair, not muscle growth. This discovery was only possible because of the new methods used to measure MPS employed in this study, which allow collections to occur over weeks versus hours.

However, an interesting side effect of this study is that it draws into question the assumptions made about hypertrophic-potential in prior research using short-term MPS methods. It is possible that many of the previous short-term MPS studies that utilized untrained participants, or unfamiliar movements, were in large part capturing the damage response rather than MPS directed at muscle growth. Based on the data presented in this study, MPS can only be assumed to relate to hypertrophy in short-term studies if participants with prior resistance training experience performed movements with which they were familiar that were not eccentrically biased [eccentric contractions cause the most muscle damage (5)]

Additionally, this study serves as an instructive tool for the repeated bout effect. The repeated bout effect is a phenomenon in which the muscle is protected against damage from future muscular work when it performs repeated bouts of a similar task (6). As demonstrated in this study, both direct and indirect markers of muscle damage decreased by weeks 3 and 10 of training. Interestingly, there has been considerable debate as to the role of muscle damage in hypertrophy, with some stating it is a mechanism influencing muscle growth (7), while others claim that it occurs during muscular work but is not causative (8). Thus, there is understandable confusion as to whether the repeated bout effect is a "good or bad" thing. Indeed, if muscle damage is a critical component to hypertrophy, then efforts should be employed to ensure muscle damage continues and the repeated bout effect is avoided (i.e. changing exercises, purposeful detraining, etc). However, if muscle damage is not a critical component to hypertrophy, efforts should be employed to elicit the repeated bout effect. As shown in this study, strength is acutely decreased by muscle damage, which decreases your ability to produce progressive overload.

While this study doesn't definitively answer whether muscle damage is "good or bad," it does show that muscle damage is not related to hypertrophy. However, we can't conclude from this study that muscle damage has a *directly* negative effect on hypertrophy, as it appears that MPS, when it was corrected for damage, was very similar at all three points. If damage was actually having a *directly* negative effect on muscle growth (i.e. the drive to repair muscle was taking away from the drive to build it), you would expect to see damage-corrected MPS at its lowest after the first session when damage was highest. At worst, you could conclude from this study that damage could have an indirectly negative effect on muscular adaptation. Strength was decreased by ~22% for 48 hours (and perhaps longer) after the initial bout. However, after the repeated bout effect was in place, strength was only decreased by 2-6% in the 48 hours after the bouts in weeks 3 and 10.

As a strength athlete, a large part of performance improvement comes down to managing the fatigue generated by training. Thus, efforts should be made to acclimate your body to the workload you are attempting to achieve in training. Introductory mesocycles where load, stress per set (RPE), and volume are purposely low are an excellent method of starting a training block. Additionally, increasing volume in a gradual, incremental manner over a career also serves to acclimate you to higher workloads in a macroscopic sense.

Next Steps

While this study suggests a lack of relationship between hypertrophy and muscle

APPLICATION AND TAKEAWAYS

1. Short-term studies examining MPS using untrained subjects, unfamiliar movements, or assessing subjects after a detraining period may not be predictive of long-term hypertrophy due to the elevations in MPS being driven by damage rather than hypertrophy.
2. The "hypertrophic potential" of a study protocol can only be accurately assessed after damage has subsided due to the repeated bout effect.
3. The repeated bout effect protects against the suppression of strength caused by muscle damage. Jumping into a high-volume or high-intensity training approach, relative to what you were previously doing, can circumvent progress due to degradation of strength from excessive muscle damage. Combine this with the lack of a relationship between hypertrophy and damage, and we can conclude that we should not purposefully seek out muscle damage in training.
4. To avoid the detrimental effects of excessive muscle damage, gradually acclimate yourself to higher levels of volume and intensity as needed to progress, in an incremental fashion.

damage, it is important to point out that this is a single group, correlational analysis of two variables within this group. To truly answer the riddle of whether muscle damage has an additive, causative, or negative role in hypertrophy, future research needs to compare two groups in which volume and intensity are matched, yet greater damage is elicited in one group. This is certainly not an easy task and would likely require eccentrically biasing the training of one group while maintaining matched volume and intensity. However, despite the difficult design, it would be necessary to finally answer this question.

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When the Whole is Less Than the Sum of its Parts

Study Reviewed: Bilateral deficit in maximal force production. Škarabot et al. (2016)

BY GREG NUCKOLS

The bilateral deficit is a simple concept: If you do a one-rep max for both limbs using a unilateral exercise, then add up those two lifts, the result will generally be greater than your one-rep max for a bilateral version of the same exercise. For example, if you do a one-rep max unilateral knee extension (which is used in much of the research), and you can move 65kg with your dominant leg and 60kg with your non-dominant leg, your one-rep max knee extension when using both legs will probably be a bit less than

KEY POINTS

1. Generally, people are capable of producing a bit less than twice as much force bilaterally as unilaterally. For example, if you added up your 1RM dumbbell preacher curls with both arms, the resultant weight would likely be a bit more than you could preacher curl with a barbell using both arms at the same time. This is known as the bilateral deficit.
2. For measures of maximal force, the bilateral deficit tends to be around 10%.
3. For measures of explosive force, the bilateral deficit tends to be considerably larger.
4. Many mechanisms have been proposed to explain the bilateral deficit. Several of the more likely mechanisms are discussed in this article.
5. The bilateral deficit is affected by training. When people train unilaterally, the bilateral deficit tends to get larger, and when people train bilaterally, the bilateral deficit tends to get smaller. In fact, a few studies actually show bilateral facilitation can occur, where the sum of maximal unilateral forces is lower than maximal bilateral force.

125kg.

The bilateral deficit has been observed in many contexts, including exercises ranging from knee extensions to gripping to finger adduction, and including concentric, eccentric, isometric, and even explosive movements. This review set out to identify the magnitude of the bilateral deficit and to evaluate several hypotheses that have been used in an attempt to explain why it occurs.

Purpose and Research Questions

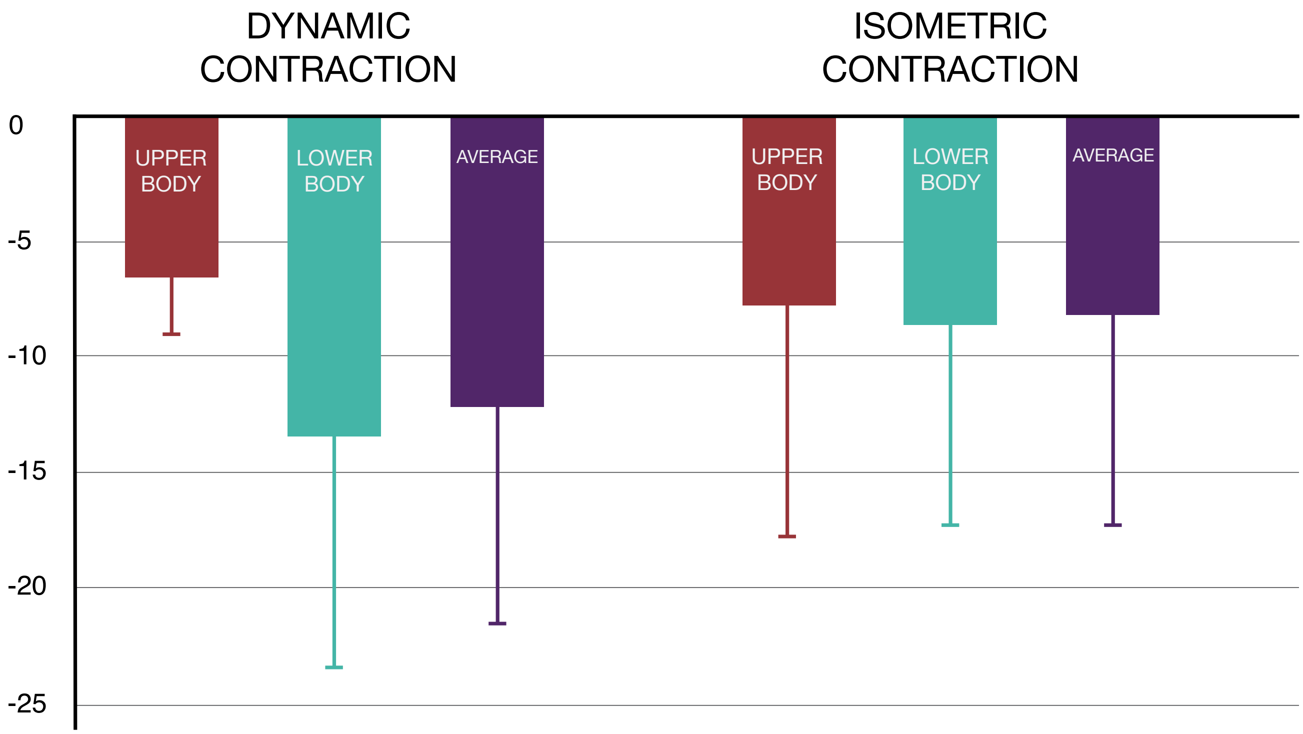
The bilateral deficit was first noted by the researchers Henry and Smith in 1961. Since then, dozens of studies have investigated the effect, employing a wide array of research designs. The last thorough review (1) of the phenomenon was from 2001, so the authors of this review sought to give an updated picture of the state of the research.

The authors set out to determine if the bilateral deficit depended on the type of contraction or type of movement and to tease out the underlying mechanisms explaining the bilateral deficit. Finally, they wanted to see if the bilateral deficit was related to athletic performance or injury risk.

Subjects and Methods

As this was a review paper, subjects involved in the studies that were reviewed run the gamut of age, sex, and experience level. The studies reviewed used a wide variety of protocols to measure the bilateral deficit, including maximal isometric and dynamic contractions, and explosive movements such as counter-movement jumps. Importantly, all of the studies employed maximal contractions of some sort.

MAGNITUDE OF THE BILATERAL DEFICIT



Findings

Magnitude of the bilateral deficit

For dynamic (not explosive) contractions, the bilateral deficit averaged 5.8±3.5% for the upper body and 13.2±10.3% for the lower body. For isometric contractions, the bilateral deficit averaged 9.0±8.0% for the upper body and 8.1±9.2% for the lower body. The average bilateral deficit tended to be somewhat larger for explosive movements, but the measurements were too heterogeneous (rate of force development, power, jump height, etc.) to make a simple average meaningful.

Likely mechanisms for the bilateral deficit

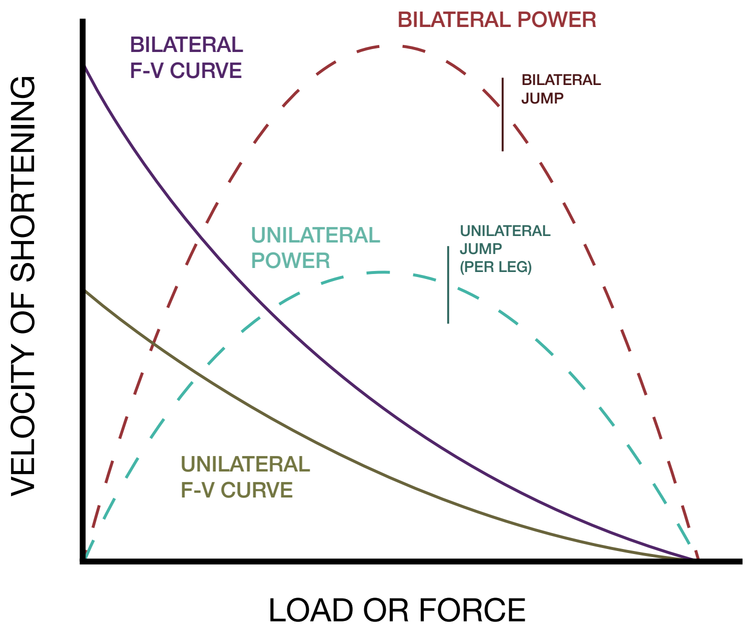
The researchers identified 13 potential mechanisms for the bilateral deficit that have been proposed in previous studies. Many were deemed to be unlikely (or incredibly minor) contributors, but they identified several factors that *do* likely contribute to the bilateral deficit.

1.) *Task familiarity*: Most of your movements in day-to-day life are reciprocal (each side of the body doing different things independently). The simplest example is walking – one leg is planted on the ground while the other swings forward. You don't hop on both legs like a kangaroo for locomotion. With that in mind, it would make sense that when exposed to a new movement, people would naturally be better at using one limb at a time instead of using both simultaneously. In fact, research has shown (2) that the magnitude of the bilateral deficit decreases as familiarity with a task increases, lending support to this idea. It may be that you're not inherently stronger using one side of your body at a time, but rather that using one side of your body at a time is just what comes the most naturally before you learn the bilateral version of a movement.

2.) *Postural stability and the use of counterbalances*: If you've ever done unilateral knee extensions, I'm sure you know what position your body winds up in when you're trying to eek out the last couple of reps. You lean away from the leg you're using, and squeeze down on the handle of the machine with your opposite hand; you may not be entirely sure why you do it, but you know it lets you grind out another rep or two. The same thing can happen in the lab. When people are tested on a dynamometer that allows for leaning and twisting of the trunk, the bilateral deficit shows up. When you take measures to ensure a neutral posture, the bilateral deficit decreases or disappears. This distinction was only made in the literature (3) 13 months ago, so future studies may discover the bilateral deficit is either smaller or nonexistent as methodology gets more rigorous. On the other hand, in a "real world" scenario (i.e. if you're worried about applicability of this concept outside of a lab setting), you can contort your body and brace in ways to gain an advantage with unilateral tasks that aren't available with bilateral tasks. In other words, even if the actual maximal force of muscle contraction isn't different with unilateral versus bilateral tasks, that doesn't necessarily mean performance in unilateral exercises won't be more than half the performance of bilateral exercises in less controlled conditions.

POWER OUTPUT IS MAXIMIZED WHEN ATTEMPTING TO APPLY MAXIMAL FORCE TO INTERMEDIATE "LOADS."

3.) *Force-velocity relationship:* This factor applies to the bilateral deficit observed in explosive movements. Power is calculated by multiplying force × velocity. If the required force output is too high so that velocity is very low (i.e. like a one-rep max deadlift), you can't maximize power output. Similarly, if velocity is too high (i.e. trying to throw a Wiffle ball), then force output will be too low to maximize power output. Power output is maximized when attempting to apply maximal force to intermediate "loads." In this case, for something like a counter-movement jump, your bodyweight is a very light load when jumping off of two legs, but a more intermediate load when jumping off one leg; thus, you can achieve higher power output (per leg) with unilat-



eral jumps versus bilateral jumps. This same concept applies to measures of explosive strength using other experimental models as well. For example, one study (4) examining combined knee and hip extension on a dynamometer found that the bilateral deficit increased linearly from 9% with isometric contractions, up to 49% with very fast contractions (424°/s).

4.) Neural factors: I won't belabor the details here because, quite frankly, they're interesting if you're a neurophysiology geek, but they aren't overly relevant for athletes or coaches. In short, there *may* be differences in how well you can activate your muscles due to feedback at the level of the spinal cord, and potentially interference at the level of the brain. We know that spinal reflexes can modulate force output, and they seem to be "tuned" in favor of reciprocal movements (like walking or running). Additionally, the signals for muscle contractions in the brain have to cross between the hemispheres of the brain before making their way to your spine and eventually your muscles, so it's possible that when you send those signals from both sides of your brain simultaneously, they interfere with each other to some degree. Thus far, the experimental evidence hints that these factors may contribute, but the results are still pretty murky.

Injury risk and performance

It has been proposed (5) that since most athletic movements are unilateral or reciprocal, the bulk of the strength training that athletes do should be unilateral (which would increase the bilateral deficit). However, the only study (6) examining the impact of the bilateral deficit on markers of performance found that sprinters with a smaller bilateral deficit were able to impart a larger total impulse of force on the blocks.

To date, there have been no studies examining the impact of bilateral deficit magnitude on relative injury risk.

Other important findings

There are two more important things to note about the bilateral deficit from this review:

1.) The bilateral deficit isn't a unanimous finding. Across all contraction types, roughly 20-30% of studies don't report a bilateral deficit. There's a lot of variability between studies, with some reporting bilateral deficits close to 50%, and a few (7, 8, 9) actually reporting bilateral *facilitation* (bilateral strength greater than the sum of unilateral strength of both limbs).

2.) Within the individual studies themselves, most reported a lot of variation between individuals.

Interpretation

For an athlete or coach, there are a few things you should take away from this review.

For untrained athletes, a bilateral deficit seems to be the norm, especially for explosive movements. Most of our movements in day-to-day life are reciprocal, so unilateral movements may simply come more naturally. Moreover, our nervous systems may simply be wired to perform slightly better with unilateral movements.

However, as mentioned above, the bilateral deficit tends to decrease as people get more experience with bilateral exercises, and some studies actually show bilateral facilitation. It's worth noting that two of the studies showing bilateral facilitation were both performed on well-trained athletes [weightlifters (9), in one case]. Similarly, other studies show that exclusively training unilateral movements increases the size of the bilateral deficit. This may not be a sexy conclusion, but if there's one major takeaway for athletes and coaches, it's that specificity is king (10, 11, 12, 13, 14, 15, 16).

THIS MAY NOT BE A SEXY CONCLUSION, BUT IF THERE'S ONE MAJOR TAKEAWAY FOR ATHLETES AND COACHES, IT'S THAT SPECIFICITY IS KING.

If it is true that muscle activation and maximal force output are actually higher in unilateral exercises (and not simply an artifact of dynamometers that allow for inflated unilateral numbers via counterbalancing), it may be worth including unilateral exercises (like split squats, alternating dumbbell curls, one-arm delt raises, etc.) in your training to more effectively overload and stimulate your muscles.

However, if you're primarily training to build strength in bilateral exercises (i.e. the squat, bench press, and deadlift), they should comprise the largest chunk of your training,

APPLICATION AND TAKEAWAYS

1. The bilateral deficit seems to be perfectly normal, especially for untrained people, though its exact mechanisms, at least for maximal force contractions, aren't entirely clear.
2. If it is true that the nervous system is naturally better tuned for unilateral movements, it may be advisable for strength and physique athletes to include unilateral exercises for accessory work, as they may be able to stimulate the targeted muscles slightly better than their bilateral counterparts.
3. The bilateral deficit tends to decrease with bilateral training, so you don't need to worry about it negatively impacting squat, bench, or deadlift strength. Amelioration of the bilateral deficit – training the nervous system to use both sides of the body together as effectively as it can use each side of the body in isolation – may help partially explain the rapid increases in strength that occur with the onset of bilateral training.

as this review shows that the bilateral deficit can be decreased, or even reversed, with bilateral training. Strength is highly specific to the movement patterns you train consistently. Split squats may improve your squat, but not to the same degree as more good, old-fashioned squatting will.

Next Steps

At this point, it's clear that the bilateral deficit exists for explosive contractions, and there's a simple mechanism to explain the bilateral deficit in that context (force-velocity relationship). However, more studies are needed utilizing dynamometers that don't allow for the counterbalancing and changes in posture, which may artificially inflate unilateral strength. Additionally, more studies are needed to examine the relationships between bilateral deficit magnitude and athletic performance or injury risk.

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More Volume is Not Always Better

Study Reviewed: Effects of a modified German Volume Training program on muscular hypertrophy and strength. Amirthalingam et al. (2016)

BY MICHAEL C. ZOURDOS

A popular training program among individuals looking to increase size and strength is German Volume Training (GVT), which involves performing 10 sets of a specific exercise (often 10 sets of 10 repetitions), thus resulting in high volume training. This study compared a modified GVT program (10-set) with 10 sets

KEY POINTS

1. This study compared 10 sets of 10 versus 5 sets of 10 for 6 weeks.
2. Muscle thickness changes were not different between groups.
3. The 5-set group had greater increases in strength than the 10-set group.
4. Some changes in body composition seemed to favor the 5-set group.
5. In moderately trained lifters, moderate volume may be better than high volume for strength progress.

of 10 repetitions for the main exercises, to a more traditional program with 5 sets of 10 repetitions for the main exercises (5-set). Each group trained three times per week for 6 weeks, and measurements of hypertrophy, strength, and body composition were assessed and compared between groups before and after training.

Neither group experienced significant hypertrophy, in terms of either increases in muscle thickness or gains in leg lean body mass. However, the 5-set group had larger increases in trunk and arm lean body mass than the 10-set group. Furthermore, both groups increased all strength measures, but again, the 5-set group had greater increases in bench press and lat pull-down strength than the GVT group.

Despite the popularity in the practical realm, GVT did not yield better results than 5 sets of 10 repetitions. Actually, 5 sets of 10 repetitions produced larger gains in strength and lean body mass in some cases than a modified GVT program over a short-term, 6-week training cycle.

Purpose and Research Questions

The purpose of this study was to compare the effects of 10 sets of 10 repetitions (10-set) versus 5 sets of 10 repetitions (5-set) for hypertrophy, strength, and lean body mass outcomes over 6 weeks in males with at least one year of previous resistance training experience.

Research question 1: Does the added volume of 10-set (10×10) produce greater hypertrophy compared to 5-set (5×10) in a 6-week training cycle in previously trained males?

Research question 2: Does the added volume of 10-set produce greater strength gains compared to 5-set in a short-term, 6-week training cycle in previously trained males?

The authors hypothesized: 1.) That 10-set (i.e. modified GVT) would produce greater hypertrophy than 5-set due to the increased volume; however, they also hypothesized 2.) There would be no difference in strength because relative training intensities were designed to be similar.

Subjects and Methods

Subjects

Subjects were 19 drug-free males with at least 1 year of previous resistance training experience and 3 months of at least 3 sessions per week training frequency.

There were 10 subjects in the 10-set group, and 9 subjects in the 5-set group.

Both groups trained for 6 weeks. Muscle size (via muscle thicknesses), body composition (via DXA), and strength (via 1RM tests) were assessed before and after the 6 weeks of training. The lifts that were 1RM tested at the beginning and end of the study were bench press, lat-pulldown, and leg press. Each group trained three days per week on non-consecutive days (i.e. Monday, Wednesday, and Friday).

The training program for both groups can be seen below in Table 1. Only the first two exercises of each training session differed between groups, meaning the 10-set program and 5-set program only differed in volume for the first two exercises of each day, while all other exercises were done for the same sets and repetitions for both groups (i.e. 4×10 for exercises 3 and 4 each day; and 3×20 for the last exercise of each day). Thus, a total of 31 sets were performed per session for the 10-set program, and a

TABLE 1: TRAINING PROGRAM

SESSION 1 (Monday)			SESSION 2 (Wednesday)			SESSION 3 (Friday)		
Exercise	Load	Sets x Reps	Exercise	Load	Sets x Reps	Exercise	Load	Sets x Reps
Bench Press*	60%	10 or 5 X 10	**Leg Press***	80%	10 or 5 X 10	**Shoulder Press***	60%	10 or 5 X 10
Lat Pulldown*	60%	10 or 5 X 10	**Dumbbell Lunges***	70%	10 or 5 X 10	**Upright Row***	60%	10 or 5 X 10
Incline Bench Press	70%	4 X 10	**Leg Extensions**	70%	4 X 10	**Triceps Pushdown**	70%	4 X 10
Seated Row	70%	4 X 10	**Leg Curls**	70%	4 X 10	**Bicep Curls**	70%	4 X 10
Crunches	Close to max	3 X 20	**Calf Raises**	Close to 1RM	3 X 20	**Sit-ups with twists**	Close to max	3 X 20

RM = Repetition Maximum. Percentages (%) are % of one-repetition maximum (1RM).

*10 or 5 sets of 5 depending on if the subject was in the 10-set (10×10) or 5-set (10×5) group. Adapted from Amirthalingam et al. Epub Ahead of Print (1).

total of 21 sets were performed per session for the 5-set program (we will return to this point later).

On the last set of each of the first two exercises on each day, subjects performed as many reps as possible up to 10 repetitions (they stopped at 10, even if they could do more). This set was used to dictate weekly load progression.

Additionally, as you can see in Table 1, squats and deadlifts were not performed in this study. The authors noted the reason for their exclusion was that many of the subjects did not regularly perform those exercises. This is a valid reason for exclusion of those exercises, but this also gives further insight into the training status of the participants and decreases the ability to extrapolate these findings to those lifts.

Load progression

A 5-10% load increase occurred from one session to the next (not week-to-week, but session-to-session) when 10 repetitions were completed on the as-many-reps-as-possible set. However, it was also noted that "load was not reduced to enable the targeted number of repetitions to be performed." Further, there was no description of how "assistance work" load was altered, so it seems the starting percentages were used throughout, but we cannot be sure. Further, since no 1RM was performed on the assistance exercises, it is not clear exactly how the load was established based upon percentages for those exercises.

Note: The lack of clarity in load progression and assignment is a common flaw in resistance training literature. When reading a methods section, a researcher should be able to replicate a study exactly without contacting the authors. I do not feel that I could do that here. Methods in a training study should be reproducible and clearly state every circumstance of progression, such as in this citation (2).

Rest intervals

60 seconds were allotted for rest; however, the authors noted that 90 seconds were given over the last few sets (this is vague as well). 60 seconds were allotted between exercises.

Pre- and post-testing measurements

- Body composition (i.e., lean mass) was assessed via Dual X-ray Energy Absorptiometry (DXA).
- Hypertrophy was assessed by taking muscle thickness with ultrasonography.
- Strength was assessed by a 1RM test for bench press, lat-pulldown, and leg press.

Dietary control

- 3 day food logs were obtained before and after the training period, and subjects were instructed to increase caloric intake throughout the study.
- 30g of whey protein was fed to all subjects immediately following each training session.

Findings

Muscle thickness (MT)

There were no significant increases in muscle thickness for either group, nor were there any significant differences between groups. However, there were small effects (according to effect size, which can detect "meaningful" change) in favor of the 10-set program for triceps muscle thickness (10-set: +10.7% vs. 5-set: +5.6%), and in favor of the 5-set program for biceps muscle thickness (5-set: +7.3% vs. 10-set: +0.9%). There may have been small but meaningful changes in muscle thickness. It should also be noted that the small effect sizes alluded to were 0.35 and -0.40 respectively (the second one is negative because it favored the 5-set program, which was contradictory to the hypothesis). In other words, the small changes in muscle thickness mean these guys are not ready for spring break.

Strength

All 1RM measures (bench press, lat-pulldown, and leg press) increased over the 6 weeks for both groups. Importantly, there was a significantly greater increase in bench press ($p=0.014$) and lat-pulldown ($p=0.003$) 1RM in the 5-set group (bench press: +14.9% and lat-pulldown: +15.1%) versus the 10-set group (bench press: +6.2%, lat-pulldown: +4.5%). However, there was no significant difference ($p=0.27$) between groups for increases in leg press 1RM, but a small effect size (-0.36) did favor the 5-set group; thus, there may have been a meaningful difference in strength gains in favor of the 5-set group for leg press. Overall, where differences or effects occurred for strength gains, they were all in favor of the 5-set group.

Body composition

As assessed by DXA, several measures of lean body mass increased (total lean body mass, trunk lean body mass, and arm lean body mass) over the 6 weeks in both groups.

OVERALL, WHERE DIFFERENCES OR EFFECTS OCCURRED FOR STRENGTH, THEY WERE ALL IN FAVOR OF THE 5-SET GROUP.

Lean leg mass did not increase. The only body composition change in which there was a significant difference between groups was trunk lean mass in favor of the 5-set group ($p=0.043$). There were no significant differences for any other body composition measure between groups. However, the p-value for the interaction regarding arm lean mass approached significance in favor of the 5-set group. This p-value was $p=0.083$ and is said to be approaching significance because it was greater than the significance threshold of 0.05, but less than 0.10. Similarly to the findings for strength, all significant or meaningful differences between groups for body composition favored the 5-set program.

Interpretation

Overall, there were no significant differences between groups for hypertrophy, with one small effect in favor of the 10-set program (triceps) and one small effect in favor of the 5-set program (biceps). For strength, it seems clear that the 5-set program produced superior results to the 10-set program, as there were significant differences for bench press and lat-pulldown, and the effect that existed for leg press favored the 5-set program. In terms of body composition, there was one significant group difference (trunk lean tissue) and a possible meaningful group difference (arm lean mass) – both favoring the 5-set program.

By design, total volume load (load × repetitions) was significantly greater for the 10-set program versus the 5-set program, and total volume was fairly substantial in each group. At first glance, the fact that only small changes in MT exist might seem surprising since it is well-known that volume is a primary driver of hypertrophy. However, when we look at the distribution of training frequency (Table 1), some muscle groups were only trained directly 1x/week in the present investigation, even though current data suggests that 2-3x/week may be most appropriate for muscle growth (3). It is true that some muscle groups were trained indirectly more than 1x/week in the present study (i.e. triceps were trained with triceps pushdowns and bench press); however, the main lifts were only performed once during the week, and some large muscle groups (i.e. legs and chest) were only trained at all once per week. Ultimately, muscle growth is indeed related to training volume (4); however, it is difficult to detect this finding in a short-term (6-week) training cycle in already-trained individuals with only a 1x/week frequency per muscle group. Therefore, it seems that in a real-world setting, volume should be split up into multiple sessions across a week to comply with both frequency and volume recommendations. In order to understand how these findings fit into the bigger picture of everyday training, it's necessary to examine a training program's details in this way.

THERE IS STRONG EVIDENCE THAT IN THE SHORT-TERM, A MODERATE AMOUNT OF VOLUME ACTUALLY YIELDS BETTER STRENGTH THAN A HIGH AMOUNT OF VOLUME.

The 5-set program produced larger strength gains than the 10-set modified GVT program. Similar to hypertrophy, this seems to be surprising at first since greater volume is positively correlated with strength (5). However, two clear explanations exist to explain the current findings in favor of 5-set despite less volume: 1.) The 5-set group actually ended up training at a higher relative percentage of 1RM in the final week of the study, even though the study design intended intensities to be similar in both groups (about 4% higher for bench press and lat-pulldown and 2% higher for leg press); and 2.) There is strong evidence that in the short-term, a moderate amount of volume actually yields larger strength gains than a high amount of volume (6).

It takes time to adapt to an increase in volume. Thus, while more volume is likely better for strength gains over time, if an individual is not of a high enough training status and is not yet ready for a given level of volume, recovery might be disrupted, and somewhat lower volume might therefore be superior. To illustrate, the individuals in this study had some training experience, but were not especially well-trained: Starting bench press 1RMs were 79.7kg in the 10-set group and 70.7kg in the 5-set group.

This brings us to a third and less clear explanation of the strength results. When comparing the starting 1RMs, the 10-set group had a 9kg greater 1RM than the 5-set group (the 5-set group also had a 11kg lower lat-pulldown and 10kg lower leg press at pre-testing). These differences are non-significant; however, it is worth noting that the 5-set group simply had a lower starting point, thus the 5-set group may have simply had more strength to gain. Ultimately, volume is important for strength, but too much volume too soon in a training career may overwhelm one's ability to recover. Volume should be progressed methodically over time.

Both groups did demonstrate positive changes in body composition, and the significant or meaningful group differences all favored the 5-set group. Consequently, moderate volume may be superior for gaining lean body mass in the short term (6 weeks) versus high volume in moderately trained individuals. It is possible that, similar to strength, the 10-set program caused short-term overreaching, which would have had a negative effect on these body composition measures, even though high volume may be better at a much higher training age.

In summary, the moderate volume 5 sets of 10 training program produced similar hypertrophy and greater strength improvements compared to a modified German Volume Training (i.e. 10×10) program in a short-term, 6-week mesocycle. However, this is not to say that GVT doesn't "work." Remember, the GVT group did get stronger over the 6 weeks because the basic principle of progressive overload was adhered to. However, even though volume is important for hypertrophy and strength, too much volume too soon is not a good idea. Judging by the starting bench press 1RMs (<80kg), these individuals had a very young training age despite lifting for 1 year.

Knowing all of this, there are a few things to keep in mind:

1.) Excessive training volumes that you aren't ready for may decrease rate of progression in the short-term.

2.) A higher training frequency may have made the 10-set program more effective, as volume could have been dispersed more efficiently throughout the training week.

3) Do not look at things in a vacuum (i.e., seeing GVT as good or bad). Extreme volumes within one training session (i.e. 10×10) might impede recovery and limit muscle adaptations in the short term; however, as training age increases, the amount of volume one can handle will increase. Therefore, a high volume phase can still fit within a periodized training plan (such as early on in a macrocycle when volume is high or as a short-term overreaching strategy). The goal is to understand data and training conceptually, and when you do that, you'll realize why modified German Volume Training was not superior here, but also why high volume may have a place at some point.

APPLICATION AND TAKEAWAYS

1. In moderately trained lifters, moderate training volume might produce larger strength gains than high volume in the short term.
2. This provides evidence that volume should not be increased too quickly for lifters with a relatively low training age.
3. Rather than looking for high volume in one session, it is likely better to disperse volume for an exercise or muscle group over a frequency of 2-3 sessions/wk.
4. This strategy allows for a quicker recovery from one session without diminishing total weekly volume.

Next Steps

The concept of GVT – or in more general terms, high volume training within a single session – should be investigated in a more well-trained population who may have a better ability to recover from higher training volumes. Easy-to-collect indirect markers of muscle damage (such as soreness, range of motion changes, limb girth, isometric force, etc.) can be taken in the days following the high session volume to assess temporal recovery. Further, high session volume should be incorporated into modern periodization designs in future studies to understand the placing of this strategy within a macrocycle.

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Pushing It to the Limit: Gauging How Far We Are From Failure

Study Reviewed: Accuracy in estimating repetitions to failure during resistance exercise. Hackett et al. (2016)

BY ERIC HELMS

The researchers set out to measure the accuracy of estimating how many repetitions in reserve (RIR) can be performed before reaching failure. They also set out to determine if accuracy of estimating RIR was influenced by training experience, exercise performed, or sex. Participants performed multiple sets (up to 10) with 70%

KEY POINTS

1. Both trained and untrained men and women can accurately (within 1 repetition) gauge how many more repetitions they can perform when they are 0-5 repetitions from failure when performing machine chest press.
2. Trained and untrained men can also gauge repetitions remaining, with the same degree of accuracy, when 0-5 repetitions from failure on the leg press. However, trained and untrained women become inaccurate when they have more than 3 repetitions remaining before failure.
3. Based on prior research and the low (yet non-significant) p-value associated with training age, lifters with greater training experience may be able to more accurately gauge repetitions remaining before reaching failure.
4. When greater than 5 repetitions (for men on the leg press or men and women on the chest press) or 3 repetitions (for women on the leg press) remain, lifters systematically under-predict how many more repetitions they can perform before reaching failure.

1RM on chest press and 80% 1RM on leg press. After completing 10 repetitions, participants verbally stated RIR, then immediately continued performing repetitions until failure to compare estimated versus actual RIR. When combining outcomes of both lifts, mean estimated RIR was off by about 1 from actual RIR, when there were 0 to 5 actual RIR remaining. However, when actual RIR was 7 to 10, estimated RIR were off by more than 2. Comparing chest press to leg press, the average error in estimated RIR was less than 1 repetition for chest press when actual RIR was 0 to 5. However, for the leg press, this was only true when actual RIR was 0 to 3. Males were more accurate at assessing RIR than females during leg press only. Training experience did not impact accuracy. Since lifters can accurately estimate RIR, it can be used for prescribing and tracking intensity.

Purpose and Research Questions

These researchers previously conducted a similar experiment on a smaller group of male bodybuilders performing the back squat and bench press (1). However, in the present study, they set out to determine the accuracy in a larger, mixed-sex group with varied levels of training experience performing machine leg and chest press. They hypothesized RIR accuracy would be greater when closer to failure. Additionally, they hypothesized accuracy would be greater among more experienced lifters, and would not be influenced by sex or exercise type.

WHEN PARTICIPANTS WERE NEAR FAILURE (0-3 ACTUAL RIR FOR LEG PRESS AND 0-5 FOR CHEST PRESS), THEY EITHER ACCURATELY ESTIMATED RIR OR JUST SLIGHTLY OVERESTIMATED. WHEN THEY WERE AT MORE THAN 5 ACTUAL RIR FOR CHEST PRESS AND MORE THAN 3 FOR LEG PRESS, PARTICIPANTS SYSTEMATICALLY UNDERESTIMATED RIR.

Subjects and Methods

53 males and 28 females with varying resistance training experience participated. 16 had ≤ 6 months of training experience, 14 had 1 to 2 years, and 51 had ≥ 3 years.

The participants performed 1RM tests, and 48 hours later performed multiple sets of 10 repetitions with 70% and 80% of 1RM on the chest press and leg press, respectively. These 1RM percentages were chosen as they resulted in performance of ≤ 20 repetitions in pilot testing.

After completion of each set, participants stated how many more RIR they believed they could perform. Participants continued performing sets (to a maximum of 10) until they couldn't complete at least 10 repetitions in a set.

Findings

Actual RIR after completing the prescribed 10 repetitions on both chest and leg press – for men and women – ranged from 0 to 10. Combined leg and chest press analysis revealed there was greater accuracy estimating RIR the closer to failure one was. Additionally, participants more accurately assessed RIR with chest press compared to leg press, and males were more accurate than females. Finally, resistance training experience did not impact accuracy (the p-value was low, but not quite down to 0.05).

For chest press specifically, estimated RIR accuracy was on average ≤ 1 repetition from actual RIR. However, this level of accuracy was only obtained when actual RIR was 0 to 5. As actual RIR increased, estimation accuracy decreased. The same trend was found for leg press. However, accuracy fell off earlier for leg press, with an error of ≤ 1 repetition only when actual RIR was 0 to 3.

Both lifts followed the same pattern in that when participants were near failure (0-3 actual RIR for leg press and 0-5 for chest press), they either accurately estimated RIR or just slightly overestimated (on average by ~1 repetition). However, when they were at more than 5 actual RIR for chest press and more than 3 for leg press, participants systematically underestimated RIR. Furthermore, the degree of underestimation increased when further from failure. For example, when there were 6 actual RIR, participants on average estimated 4 or 5 RIR, underestimating by 1-2. However, when there were 10 actual RIR, participants

RPE SCALE BASED ON REPETITIONS IN RESERVE	
10	Could not do more reps or load
9.5	Could not do more reps, could do slightly more load
9	Could do 1 more repetition
8.5	Could definitely do 1 more repetition, chance at 2
8	Could do 2 more repetitions
7.5	Could definitely do more 2 more repetitions, chance at 3
7	Could do 3 more repetitions
5-6	Could do 4 to 6 more repetitions
1-4	Very light to light effort

Adapted from Zourdos et al. (2)

on average estimated 5 to 7 RIR, underestimating by 3-5.

The difference in accuracy between sexes was relegated to leg press, and furthermore, only existed when estimating RIR if there were 4 or more actual RIR. Meaning, when there were 0 to 3 actual RIR on the leg press, males and females estimated RIR with the same accuracy.

Interpretation

This study is the most direct measurement of RIR accuracy to date. While Dr. Zourdos and I validated an RIR-based RPE scale with velocity (see figure above), showing higher RPE scores (indicated by fewer RIR) correspond to decreases in bar velocity (2, 3), we did not directly measure actual versus estimated RIR. Hackett and colleagues were the first to do so in 2012 (1). However, their 2012 study primarily presented accuracy with correlations between actual and estimated RIR. This 2016 study presents data in a clearer way, showing where breakpoints in accuracy occur and the degrees of under- and overestimation.

In contrast to the recent study by Zourdos and colleagues, which reported novice lifters as less accurate than experienced (2), Hackett found RIR accuracy was not influenced by training experience. However, the p-value of the difference between novices and experienced lifters was 0.134.

P-values are statistics that estimate the likelihood findings are due to chance. Meaning, the difference in accuracy between inexperienced and experienced lifters only had a 13.4% chance of being random statistical variation.

Thus, while Hackett – in a strict sense – found no significant difference between novice and experienced lifters, there may have been one. Furthermore, the least experienced participants in the present study had ≤ 6 months of experience, while the most experienced had ≥ 3 years of experience. In Zourdos' investigation, there was a greater gap with a mean of 0.4 years of experience in the novice group, and an average of 5.2 years among the experienced group, which may have been a large enough gap to show a difference. Finally, this discrepancy may have been due to using different exercises. Zourdos' participants performed the back squat, while Hackett's performed machine leg press, which arguably takes less experience to master.

In contrast to another recent study on RIR-based RPE differences in powerlifters that Dr. Zourdos and I published, Hackett and colleagues found greater accuracy in the chest press compared to the leg press. However, we found no differences in RPE among the squat, bench press, or deadlift (3).

Hackett et al. proposed that greater accuracy in the chest press may be due to a higher sensory organ density in the upper versus the lower limbs (4). They also point out that this may be the reason women were less accurate only in the leg press, as males have a higher sensory organ density in the lower body (4). While plausible, it is also possible that the greater perceived effort of going to failure during lower body versus upper body exercises (5) resulted in participants having less prior experience going to failure on leg press than chest press. To explain the sex difference, perhaps societal differences in male versus female lifting culture (the "go hard or go home" mentality) encourage men to push themselves to failure more regularly on leg press, thus better developing their awareness of RIR. This may be why we found no difference in RIR-based RPE among powerlifters performing upper and lower body exercises, while Hackett did.

Interestingly, the authors address the utility of the RIR-based RPE scale that Dr. Zourdos and I study (see figure on previous page), which was originally developed by powerlifter and coach Mike Tuchscherer in 2008 (6). They state this scale is not intuitive, as RPE and RIR are inversely related, adding an unnecessary layer of complexity by forcing the user to translate RIR into an RPE. I don't completely disagree with this notion. However, this is easily alleviated by allowing participants to report whichever they are most comfortable with, either RPE

IT SEEMS EXPERIENCED LIFTERS CAN TELL WITH MORE ACCURACY THAN NOVICES WHEN THEY ARE LESS THAN 1 RIR FROM FAILURE.

or RIR. Then, the investigator confirms the opposite to ensure understanding. For example, when a participant completes a set, we show them the scale and they are free to state "I had 2 repetitions remaining." At that point we confirm "so an 8 RPE?," or vice versa.

Additionally, the RIR-based RPE scale has some advantages over reporting raw RIR. In the initial study introducing the scale, novice and experienced lifters worked up to a 1RM, using the scale to determine when it was achieved. Specifically, if an RPE less than 10 was called, an increase in load was made on the subsequent set. If the attempt was missed, the participant was "stuck" with an RPE less than 10. Novice lifters were "stuck" with an average RPE of 8.96, while experienced lifters achieved a 9.8 (2). An average RPE of 9.8 was due to a large proportion of lifters achieving 9.5 RPE scores in attempts leading up to their final, then making small jumps to try to reach a 10 RPE. Thus, it seems experienced lifters can tell with more accuracy than novices when they are less than 1 RIR from failure. This shows the value in having a scale which allows 9.5, 8.5, and 7.5 values, especially considering that the data from

APPLICATION AND TAKEAWAYS

1. Stress per set can be accurately gauged by most lifters using RIR or RPE-based RIR when 0-3 repetitions from failure. When using pure RIR, the accuracy of values greater than 5 should be viewed with caution. Values greater than 3 should be viewed with caution when used by women performing lower body movements. However, this may not be the case in well-trained female athletes.
2. Compared to pure RIR, the RPE scale based on RIR has the advantage of using broader repetition ranges and more subjective language after 3 RIR to account for decreasing accuracy further from failure. However, it also has an extra layer of interpretation as RIR must be translated to RPE. Thus, RIR can be recorded and then converted to RPE later if so desired.
3. Given prior research on the accuracy of RPE when used by novices compared to experienced lifters and the low p-value associated with training age reported in this study, lifters new to gauging RIR or RPE should go through a familiarization period. Thus, a mesocycle in which load is programmed with percentage of 1RM and RIR or RPE is simply recorded, should occur before a mesocycle where load is prescribed with RIR or RPE values.

the current study by Hackett show similar accuracy when 0-3 RIR remain.

In fact, the structure of the RIR-based RPE scale is supported by Hackett's findings. Half-point RPE scores are not used below an RPE 7 (RIR 3). Rather, RPE 5-6 represents 4-6 RIR, while RPE values below 5 are given subjective terminology indicating effort. This aligns well with the present findings, considering accurate estimations are difficult when greater than 3 RIR remain. With that said, RPE scores below 7 still have utility. As we proposed in a recent review article, when explosive lifting far from failure is the goal (i.e. velocity dominant power training), if the lifter feels they can accurately gauge RIR, the load is too high or too many repetitions are being performed with that load. Thus, an "RPE cap" can be used for power training whereby 1-6 RPE values can be used depending on whether force (5-7 RPE) or velocity (1-4 RPE) dominant power training is the goal (7).

With all that said, lifters should feel free to use either the RIR-based RPE scale above or raw RIR, based on whichever is more intuitive. You can avoid the downside of raw RIR not having half-point values by simply recording <1 RIR to be equivalent to a 9.5 RPE, and 1-2 and 2-3 RIR to be equivalent to an 8.5 and 7.5 RPE, respectively.

Next Steps

At this point, thanks to Hackett and colleagues, the accuracy of RIR as a measure of resistance training effort has been well established. The next step is to conduct training studies in which resistance training intensity is prescribed with an RIR or RIR-based RPE value and compare that to a traditional model of training using percentage 1RM to see if there is any advantage or disadvantage to doing so. Furthermore, based on my anecdotal coaching experiences, certain personalities are better suited to gauging RIR than others. Thus, future research should strive to determine how to identify which individuals are suited to using this method of gauging effort in training and which individuals are not.

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Can You Improve Your Lifting Technique By Intentionally Screwing Up?

Study Reviewed: The effects of two different correction strategies on the snatch technique in weightlifting. Milanese et al. (2017)

BY GREG NUCKOLS

The standard means of correcting technique errors involves pointing out a technical error to the athlete and offering advice concerning how to fix the error in subsequent sets. The athlete then tries to implement the advice he or she was given

KEY POINTS

1. The typical method of correcting technique errors involves identifying the error and telling the athlete what he or she needs to do to avoid the error.
2. A relatively novel method of correcting technique errors, known as the "method of amplification of error" (MAE), involves instructing the athlete to take actions that will magnify the error. MAE rests on the assumption that by feeling the consequences of the amplified mistake, the athlete will gain a better implicit and explicit understanding of the movement and learn how to address the mistake himself/herself.
3. This study tested traditional instruction against MAE instruction for improving snatch technique. Of the kinematic variables analyzed that most directly relate to efficient snatch technique, MAE instruction produced larger improvements, and most of those improvements were retained for a post-test a week later.
4. Since this study only involved a single session of instruction, it should be viewed with some caution, but it suggests that MAE instruction may be superior to traditional technique correction strategies, at least in well-trained lifters. At the very least, it should be a weapon in the coach's arsenal.

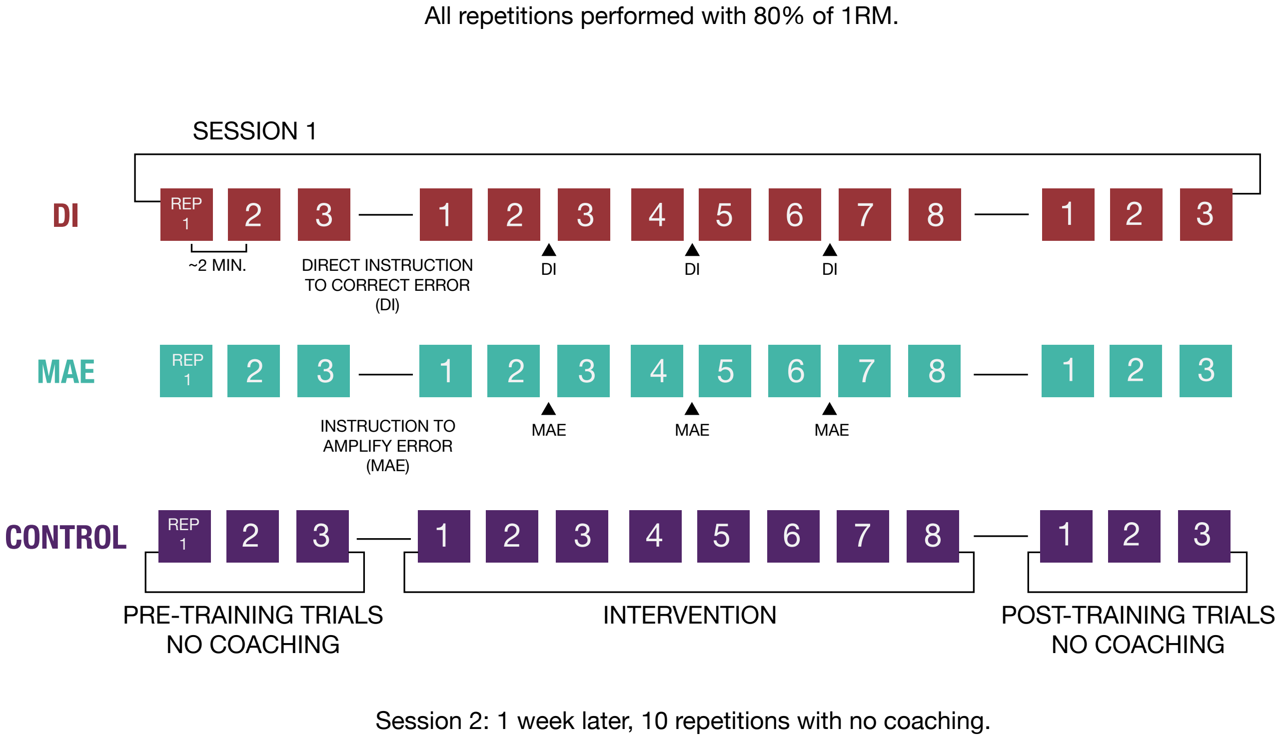
to minimize or correct the error. This study compared the standard coaching practice to the "method of amplification of error" (MAE). With MAE, instead of pointing out the error and asking the athlete to correct it, you'd cue the athlete to make the error even worse. For example, if someone's hips shoot up too fast coming out of the bottom of a squat, you'd tell them to purposefully shoot their hips up even faster on the next set.

This study tested both models of instruction on performance of the snatch in a cohort of well-trained weightlifters. In these subjects, it wouldn't be feasible to expect new one-rep maxes (1RM) right away, so the researchers used an array of kinematic variables to assess changes and improvements in technique. MAE produced better results than traditional instruction in this group of athletes in a single session, and those improvements were still evident a week after the coaching session.

Purpose and Research Questions

Most people would expect that the best way to master a skill is to perform it perfectly, over and over again, with the repetition of perfect technique ingraining and refining the motor pattern. Paradoxically, the opposite tends to be true (1): The more you screw up when learning a new skill, the faster the skill is learned and the better it is retained. This leads to the general theory that mastering a motor skill *does* require repetition, but mastery is accelerated by error identification

CORRECTION STRATEGIES



and correction.

All coaching and cuing paradigms incorporate this knowledge either implicitly or explicitly; you identify errors in your athletes' technique (or your own technique), and tell the athlete what to do to correct those errors. This feedback leads to faster skill acquisition than simply having someone practice a movement over and over without any feedback about what to improve.

MAE rests on the assumption that feedback on an implicit level will be more effective than explicit feedback. Instead of simply telling an athlete what he or she did wrong, you'd be better off putting the athlete in a position that magnifies the error. This kinesthetic feedback teaches the athlete (both consciously and subconsciously) what "wrong" feels like, so he or she can make technique corrections to avoid the error.

Previous research (2,3) has shown that rate of motor learning is proportional to the amount of errors experienced: The more you screw up (as long as you're aware you're screwing up), the faster you learn. Furthermore, the primary author of this study had previously demonstrated that MAE could be used to improve golf swing technique. The aim of this study was to see if MAE would prove to be equally effective at improving technique in the snatch.

Subjects and Methods

The participants were 30 well-trained male weightlifters (age 23.9±10.5 years) who competed at the regional or national level. They were randomized into one of three conditions: Direct Instruction (DI), Method of Error Amplification (MAE), or control.

When they showed up to the lab, they warmed up, worked up to 80% of their 1RM snatch, and performed 3 repetitions without any instruction at a pre-training trial to compare subsequent performance against.

The control group performed 8 more repetitions without any coaching.

The DI group performed 8 repetitions with feedback directly addressing technical errors on every second repetition. For example, if a lifter started with his chest too far behind the bar, he'd be told, "your chest was too far behind the bar, keep your chest over the bar as far as possible at the start position" before his first rep, and for his second rep, he'd simply be told to "do his best." Before his third rep, he'd be given further feedback, and before his fourth rep, he'd simply be told to do his best.

The MAE group's instruction followed the same pattern, except that their instruction was aimed at amplifying any errors that were identified. For example, if the bar didn't move toward the lifter or stay close enough to the lifter's shins during the first pull, he'd be told, "Move the bar forward as far as possible while performing the first pull." For his second rep, he'd simply be told to "do his best" (i.e. lift with proper technique, and not with amplified errors).

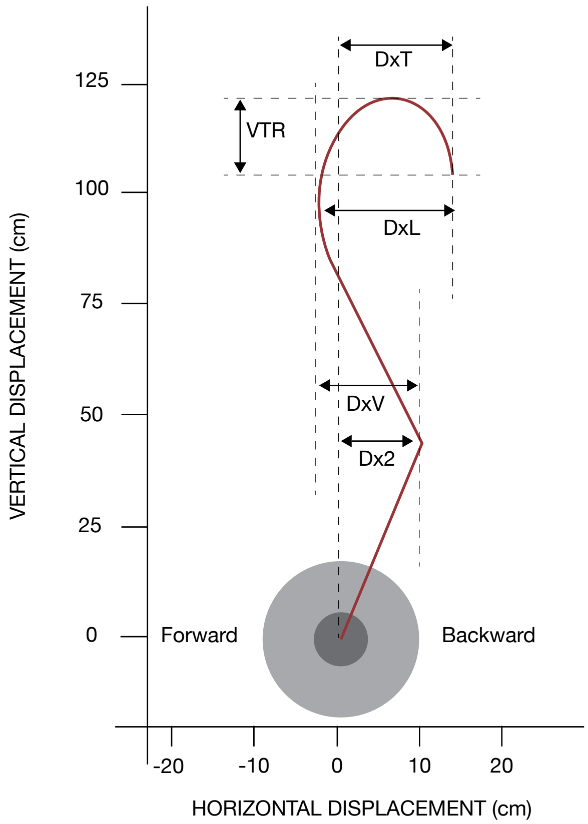
After 8 coached reps (4 with instruction, and 4 without), they performed three more attempts as a post-training trial.

A week later, all the lifters performed 10 more snatches with the same loads as a retention test to see if the technique changes from the initial training session had remained. On both days, lifters took approximately 2 minutes of rest between reps.

The researchers analyzed 8 variables:

1. Dx2: Horizontal displacement of the bar during the first pull (from the floor to knee height).
2. DxV: Horizontal displacement of the bar during the second pull (from knee height to the point of farthest forward travel).
3. DxL: Horizontal displacement of the bar during the catch (the farthest point forward during the second pull to the "catch" position).
4. DxT: Total horizontal displacement of the bar during the entire lift.
5. VTR: Vertical displacement between the barbell's highest point and the "catch position" (to see how much the bar was "crashing" on the subjects).
6. Vvel_FP: Maximum bar velocity during the first pull (from the floor to knee height).
7. Max_Vvel: Maximum bar velocity during the second pull (above knee height).
8. Diff_Max_Vvel: Difference in maximum bar velocity between both sides of the barbell (as a means of seeing how symmetrical the lift was).

KINEMATIC PARAMETERS OF THE SNATCH



Adapted from Milanese et at. (2017)

Findings

Significant differences between groups were noted for Dx2, DxL, VTR, and Diff_Max_Vvel, all favoring the MAE group over the DI group and the control group.

Dx2, DxT, DxL, Diff_Max_Vvel, and VTR decreased by 23.54%, 12.71%, 14.92%, 23.05%, and 4.96% (respectively) from pre-training to post-training in the MAE group, all of which were significant changes. All of these changes, with the exception of VTR, persisted, didn't meaningfully change, and remained significant at the retention test a week later. VTR was not significantly different between post-training and retention test, though by the retention test, it was no longer significantly different from pre-training.

Dx2 decreased by 10.32% from pre-training to retention test, and Diff_Max_Vvel increased by 18.18% from pre-training to retention test in the DI group. No other significant changes were noted.

In the control group, VTR increased pre-training to post-training (7.44%), and pre-training to retention test (7.15%). DxL also increased pre-training to retention test (9.65%). No other significant changes were noted.

Interpretation

In layman's terms, MAE coaching helped lifters adopt a more linear bar path throughout the movement, helped the lift become more symmetrical (both sides of the bar attained more similar peak velocities), and helped the lifters keep the bar from crashing on them.

The DI group gained a more linear bar path from the floor to knee height, without significant changes in bar path for the rest of the lift, while the lift actually became slightly less symmetrical.

The control group's overall bar path (from the start of the lift to the catch position) became slightly less linear, and the bar crashed on them a bit more.

If you assume that a more linear bar path (less horizontal displacement) necessarily means better weightlifting technique, this study would support MAE as a better coaching style than DI. However, that's not unambiguously true. On one hand, in a study by Winchester (4), Dx2 and DxT actually increased along with an increase in peak force and peak power in the power snatch. On the other hand, data from Hadi (5) show that elite weightlifters adopt an increasingly linear bar path as loads increase. Assuming that more efficient bar paths are required to lift increasingly heavy loads, that would indicate that a more linear bar path is a more efficient one.

IF YOU ASSUME THAT A MORE LINEAR BAR PATH NECESSARILY MEANS BETTER WEIGHTLIFTING TECHNIQUE, THIS STUDY WOULD SUPPORT MAE AS A BETTER COACHING STYLE THAN DI.

The three factors analyzed in this study that are unambiguously positive for weightlifting performance are a small DxL (the amount of "looping" of the bar from the second pull to the catch position), a small VTR (how much the bar "crashes" on the lifter), and a high Max_Vvel (peak bar velocity).

A large DxL is detrimental because it requires greater horizontal deceleration to stabilize the bar in the catch position. If a very heavy load "loops" too much, the horizontal momentum of the bar will cause the lifter to miss the lift behind them. A large VTR also makes the catch more challenging as the bar's downward momentum makes it more difficult to keep the elbows extended during the catch. Finally, a higher maximum velocity (obviously) helps the lifter propel the bar high enough to catch.

Of these three factors, two (DxL and VTR) improved pre-training to post-training in the MAE group. Furthermore, DxL was still decreased at the time of the retention test in the MAE group. None of these factors improved in the DI group. Hence, it does seem that MAE was more effective than DI at improving snatch technique in well-trained weightlifters, at least in the short term.

There are a few shortcomings in this study. First, each group was small, with only 10 participants. Second, the technique errors that were addressed in this study were chosen for each lifter by a single coach; he chose the errors before becoming aware of which group they would be assigned to, which reduces the risk of bias, but there's a chance that another coach would have done a better job of identifying the primary technical error to address with each lifter. Third, this was a short-term study, analyzing the effects of only a single coaching session with each method of instruction; different effects may have been noted with a long-term study. Finally, the participants in this study were

APPLICATION AND TAKEAWAYS

1. MAE instruction – magnifying a technical error to help an athlete better feel and understand the consequences of the error in order to fix it – may be a useful way to quickly increase technical proficiency, at least in lifters who are already well-trained.

regionally or nationally competitive lifters; MAE may be more effective for this population, which already possessed a lot of technical skill and intrinsic understanding of the lifts, but DI may be more effective for a less well-trained population that would benefit from explicit instructions while learning the movements.

If you train lifters who are experienced with a particular lift, MAE may be an effective means of fixing technical errors, especially if they consistently make a technical mistake that isn't readily resolving itself with more conventional cuing. By amplifying the error in their technique, they'll be able to more readily notice the ways in which it is detrimental to performance and make the necessary corrections.

For example, if you have a lifter whose hips shoot up too quickly in the squat, have her perform squats where she intentionally aim to drive her hips up dramatically faster than her chest rises. Or, if a lifter consistently struggles to lock out deadlifts because his center of balance has shifted too far toward their toes, have him do some deadlifts with his weight intentionally shifted forward (obviously in both of these scenarios, submaximal weights should be used for safety). This should give your lifters a better implicit and explicit understanding of the movement consequences of such errors so that they can alter their technique. The method used in this study (alternating one set with amplified errors with one set attempting to display good technique) would likely be an effective way of implementing MAE, as it gives the lifter an opportunity to implement the technique correction directly after experiencing an amplified version of what "wrong" feels like.

This style of instruction provides an additional layer of feedback to athletes. It goes beyond simply telling lifters that they're making an error and telling them how to correct it; it also ensures lifters "feel" the error, so that they can better understand it and alter their technique to avoid it.

Next Steps

Future studies should test MAE against DI in a longitudinal fashion to see if the relative benefits of MAE manifest quickly and plateau, or whether they accrue over time. Furthermore, MAE should be tested on less well-trained populations to see if it's a tool that can help anyone, or if it's only beneficial for people with a well-developed implicit and explicit understanding of the movements they're trying to improve. MAE also simply needs more studies supporting its efficacy; the theory it rests upon seems to be sound, but this is only the second study using this method of instruction. Finally, MAE should be tested against DI for other motor tasks where error identification is more objective; the subjectivity of having a single coach identify the error to be addressed in each athlete may have influenced the outcomes.

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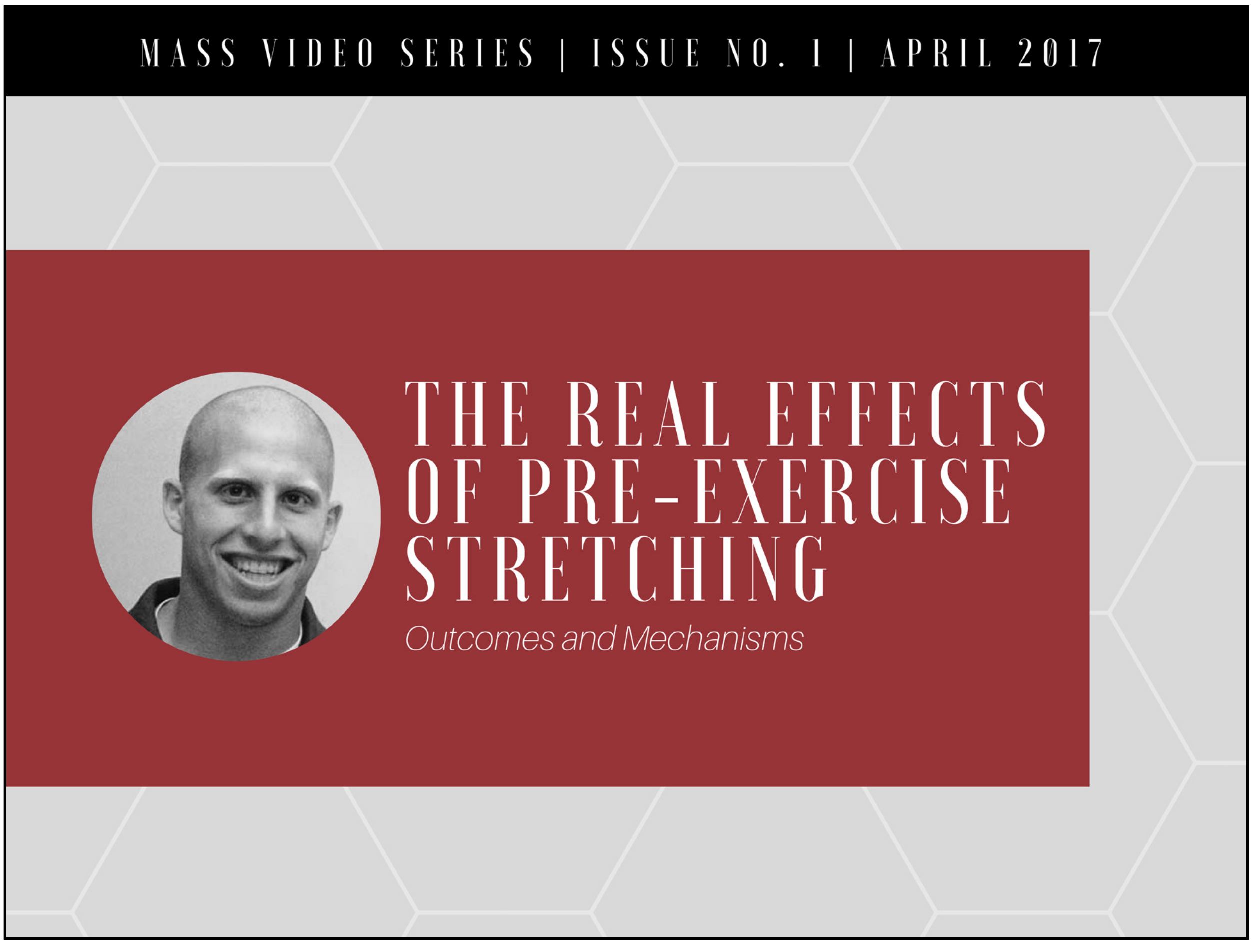

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