Training Clients to Failure? Resolving a Long-Standing Debate with Fitness Professionals

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Introduction: Failure versus Non-Failure in Resistance Training

It is well-established that resistance training (RT) stimulates several neuromuscular adaptations that include local muscular endurance, skeletal muscle hypertrophy and strength (1). Fitness professionals manipulate several fundamental training variables when writing RT programs such as volume, intensity, frequency, and rest intervals (1). Although it may be considered an ancillary training variable, proximity to muscular failure is also considered when prescribing RT. In fact, there is a polarizing debate in the RT literature regarding if sets should be performed to failure -- the moment in which a client is physically unable to perform another complete repetition -- to optimize increases in muscular strength and size (2). Recently, a meta-analysis concluded that failure and non-failure RT are equally effective for hypertrophy and strength, but there are several nuances to consider for practical application (2). For example, training status, intensity, tempo, fitness goals, and the definition of "failure" should all be considered when prescribing failure or non-failure RT. Hence, the aim of this article is to discuss the outcomes from recent studies that have compared failure to non-failure RT, and to describe how fitness professionals can apply the results to suit their client's goals.

Understanding Motor Unit Recruitment during Failure Sets

It is possible that training to momentary muscular failure (MMF) elicits greater gains in strength and hypertrophy due to maximal motor unit (MU) recruitment (3, 4). This theory stems from Henneman's size principle, which proposes that smaller MUs (i.e., low threshold, type I muscle fibers) are recruited before larger MUs (i.e., high threshold, type II muscle fibers) as the intensity of a task increases (3, 4). It is well established that smaller MUs are recruited to perform submaximal, non-fatiguing skeletal muscle contractions while larger MUs are recruited to preserve force production as fatigue ensues during a set (3, 4). Generally, it is accepted that recruiting larger MUs is important because they innervate type II muscle fibers, which are essential for developing hypertrophy and strength (1, 2, 3, 4). Some acute studies have investigated the effect of training to MMF on MU recruitment. For example, Sunstrop et al. (3) found significantly higher muscle activation when training with loads that corresponded to 3 repetition-maximum (i.e., 3RM) and 15RM. Interestingly, when using the 15RM, muscle

activation (e.g., measured by electromyography) plateaued 3 to 5 repetitions short of MMF, which suggested that performing low-intensity RT short of MMF induced similar MU recruitment as high-intensity RT. More recently, Morton and colleagues (4) examined the effect of load (30% vs. 80% of 1RM) and tempo (3 vs. 7 seconds) on MU recruitment as measured by glycogen depletion in type I and II muscle fibers. Their data revealed that maximal MU recruitment occurred regardless of intensity or tempo, as long as MMF was achieved.

Theory to Practice Application

Maximal MU recruitment occurs regardless of intensity (3) or tempo (4) when sets of RT are performed near MMF. In addition to maximal MU recruitment, anaerobic fuel utilization and metabolic stress (i.e., blood lactate) are greater during failure sets compared to non-failure sets (5). This suggests that compared to non-failure sets, training near MMF may lead to superior RT adaptations in muscular endurance, hypertrophy and strength. The following sections will discuss the long-term effects of failure vs. non-failure RT.

Does Intensity Really Matter?

Because the repetition range for hypertrophy and strength is wide (e.g., 3-35 reps) (1), fitness professionals may wonder if the effectiveness of training to MMF depends on intensity. Considering the direct relationship between RT intensity and MU recruitment, it has been hypothesized that training to MMF is more important when performing low-intensity RT (6, 7). To test this theory, Nobrega and colleagues (6) had untrained males perform unilateral leg extension with one of four protocols for eight weeks: 80% 1RM to failure, 80% 1RM to non-failure, 30% 1RM to failure, and 30% 1RM to non-failure. All four conditions produced significant improvements in strength and hypertrophy with no differences between them. A nearly identical study was completed by Lasevicius et al. (7), but they prescribed significantly different repetition numbers between failure and non-failure sets. For each training session, subjects performed three sets of unilateral leg press to failure before performing five non-failure sets of unilateral leg press on their opposite leg. Each non-failure set was performed with 60% of the repetition volume (i.e., total number of repetitions) achieved during the preceding failure sets. The results indicated that when intensity is low (30% 1RM), it is important to perform sets of RT closer to failure. Conversely, when intensity is high (80% 1RM), training to failure provided no additional benefit for strength or hypertrophy.

Theory to Practice Application

Fitness professionals should teach their clients to lift close to failure (i.e., one to two repetitions from MMF), but not go to complete failure, when using low and high-intensity RT. For example, an elderly client training with a 20RM load can stimulate hypertrophy and strength by finishing sets at 17-18 repetitions. Similarly, a younger client training with a 5RM can elicit positive adaptations by ending the set at 3-4 repetitions.

Let's Explore Deeper: How is "Failure" Defined?

It is also important to consider how "failure" is defined during RT. Specifically, MMF is typically described as physical exhaustion where the lifter is incapable of completing the concentric phase of a repetition (7). By contrast, volitional interruption (VI) occurs when a lifter voluntarily terminates their set before MMF because they sense that they are beginning to fatigue (6). Sets performed to MMF elicit greater fatigue and require higher amounts of effort compared to VI training. A recent study by Santanielo et al. (8) concluded that after ten weeks of training, MMF and VI stimulated similar increases in muscular hypertrophy and strength. These outcomes are intriguing because the MMF group performed more repetitions per set than the VI group (12.0 vs. 10.4 reps), meaning that VI sets were terminated ~1.5 repetitions short of failure. In other words, training to VI led to similar adaptations despite requiring less work.

Another way to describe VI is to say that each set of RT is terminated with 1-2 repetitions in reserve (RIR), which means that the exerciser estimated that they were 1-2 reps away from achieving MMF (Sidebar #1). The concept of terminating a set with an RIR of 2 was studied by Sampson and Groeller (9) as they compared training to failure (6 reps) vs. non-failure (4 reps) with intensity matched (85% 1RM). After 12 weeks, data revealed that both programs led to significant hypertrophy and strength with no differences between groups. Despite similar outcomes for fitness, the failure group performed significantly more volume, longer time under tension, and reported higher ratings of RPE compared to the non-failure group.

Theory to Practice Application

Together, these studies confirm that MMF and VI are equally effective for hypertrophy and strength when intensity is high (75%-85% 1-RM) and both training styles can be used within the same training session. For example, if you have planned four sets of an exercise, the first three can be performed to VI while the final set can be performed to MMF.

V. Back to Basics Planning: What is the Goal of the Training Program?

Training goals (e.g., hypertrophy, strength, or power) will change based on the specific phase of a client's training plan, and it behooves fitness professionals to consider if failure and non-failure training have different effects on these adaptations. For example, with intensity matched at 75% 1-RM, Karsten et al. (10) compared the effect of different set configurations during total-body lifting: 8 sets, 5 reps, 60 second rest intervals (i.e., non-failure) versus 4 sets, 10 reps, 120 second rest intervals (i.e., failure). The 4 x 10 program involved training to MMF while the 8 x 5 program involved training to an RPE of 4-6 (e.g., 10 point scale, moderate effort). After six weeks, subjects significantly increased their bench press and back squat 1RM with no differences between groups. In addition, both programs elicited significant hypertrophy, but better outcomes were achieved by the failure group. In contrast, upper-body power increased only for the non-failure group. In other words, failure and non-failure RT were equally effective for strength, but the 4 x 10 program was a better option for hypertrophy while the 8 x 5 program was more effective for power.

Theory to Practice Application

These results can be applied to a basic periodization model to help a client achieve several fitness goals. For example, when skeletal muscle size is the primary goal, the Karsten et al. 4 x 10 rep program can be used (10). As the program advances, strength and power may become the primary goals, and your client may wish to accrue less fatigue during RT sessions. The Karsten et al. (10) non-failure program (8 x 5 rep) may be a more viable option during this phase in a program.

Conclusion: Six Theory to Practice Takeaways for Fitness Professionals

Clearly, there are several nuances for fitness professionals to consider when deciding to incorporate failure or non-failure RT. In the context of different intensities, research suggests that training to MMF or VI are both effective for hypertrophy and strength regardless of the external load used (30% vs. 80% 1-RM) (6, 7). Together, these studies also highlight the importance of how personal trainers define "failure" because training to MMF requires physical exhaustion while training to VI does not. Compared to MMF, training to VI has led to similar adaptations with fewer repetitions per set (8), less training volume (8), lower RPE (9), and shorter training sessions (9). Based on these data, we submit that using the VI approach is a suitable medium between failure and non-failure training, and fitness professionals should teach their clients how to lift to RPEs of 8-9 (on a 10 point scale), which correspond with RIRs of 1-2

(See Sidebar #1). Fitness professionals should also consider their client's primary training goal when prescribing failure and non-failure RT. For example, research has shown that failure-RT stimulates more hypertrophy while non-failure-RT is more effective for power (10). Above all, the choice between failure and non-failure RT does not need to be a binary decision, and we encourage fitness professionals to consider the following theory to practice applications:

1. Both training styles can be incorporated in a periodized manner. For example, one could prescribe failure weeks and non-failure weeks and/or failure days and non-failure days within the same training program. Moreover, failure RT can be reserved for phases of overreaching when a client can provide high levels of effort while non-failure RT can be used for phases of tapering/de-loading when recovery is the primary goal.
2. Incorporate failure vs. non-failure training with a flexible periodization approach (11). This personalized program allows the fitness professional to adjust workload/effort according to their client's baseline fatigue levels (11). For example, a workout plan can be modified to include more failure sets if your client feels rested and energized. In contrast, more non-failure sets can be used on days when your client comes to the gym feeling sore and/or fatigued.
3. Failure and non-failure sets can be included for the same exercise during one training session. For example, if a client is performing four sets of lat pull down, the first three sets can be performed to VI while the fourth set can be performed to MMF.
4. Consider the demands of free-weight and machine-based exercises. It may be safer and more comfortable for a client to perform failure sets during a machine-based exercise (e.g., seated chest press) compared to a free-weight exercise for the same muscle group (e.g., barbell bench press).
5. Save failure sets for single-joint exercises. For example, during a session of lower-body RT, have your client perform sets of multiple-joint exercises (e.g., goblet squats and Romanian dead lift) to non-failure and sets of single-joint exercises (e.g., prone hamstring curls and calf raises) to failure.
6. Prescribe failure and non-failure RT based on your client's training experience. For example, failure RT may be more suitable for a 25 year old client with five years of training experience compared to a 55 year-old post-cardiac-rehabilitation client who is just starting a RT program.

Sidebar #1: Practical Applications for Monitoring Proximity to Failure

Ratings of perceived exertion (RPE) and repetitions in reserve (RIR) are inversely related scales that can help an exercise enthusiast quantify their proximity to muscular failure during sets of RT (11). For example, when a set is terminated with an RPE of 8 (on a 10 point scale), this would correspond with an RIR of 2, meaning that the client approximated that they would have achieved muscular failure if they performed two additional repetitions. By contrast, if a set is terminated with an RPE of 10, this would correspond with an RIR of 0, meaning that the exerciser maximized her/his effort and achieved muscular failure. Applying these scales to commonly used definitions for failure, the RPE = 8, RIR = 2 example may be considered "volitional interruption" (6, 8) while the RPE = 10, RIR = 0 example represents "momentary muscular failure" (7). It is important to consider a client's ability to approximate failure when using the RPE and RIR scales (12). Specifically, Hackett et al. (12) concluded that trained and untrained participants can accurately predict their proximity to failure and their accuracy improved as they lifted closer to failure. However, to eliminate any guess work, a fitness professionals could simply measure a client's repetition maximums (e.g., 10RM) and prescribe sets that correspond with RIR of 1-2 (e.g., 8-9 repetitions with their 10RM).

Sidebar #2: Theory to Practice Case Studies

Case Study 1- Jane (45-year-old female general population client with no RT experience)

Primary goals: Jane is exercising for general health benefits and wants to use RT as a means to increase her muscle mass and strength.

Evidenced-based programming: In clients with no previous RT experience, a wide spectrum of intensities can be utilized to improve strength and muscle mass (1). At high and low intensities, research has shown that increases in strength and hypertrophy are maximized when RT is performed to sufficient fatigue, but short of complete muscular failure (6,7). Therefore, we recommend that Jane follow a periodized RT program that integrates a variety low and high intensity sets that are performed short of MMF to optimize gains in strength and muscle mass while reducing fatigue, perceived effort, and risk of overtraining. As Jane becomes more experienced, failure sets may be periodized as a program variable for single-joint movements, machine-based exercises, or the final set of an exercise.

Case Study 2- John (20-year-old male baseball player with 4 years of RT experience)

Primary goal: John finished an off-season training block of hypertrophy/strength and is transitioning to a pre-season program to maximize power on the playing field.

Evidenced-based programming: Research indicates that upper-body power (10), lower-body power (13), and sprint speed (13) increase when non-failure sets of RT are performed with high-velocity (13) and moderate RPE (10). Because John is looking to increase his power while keeping his fatigue levels low, we recommend that the majority of John's training is performed with several repetitions in reserve (10) where he can focus on maximizing the quality of each repetition (i.e., high-velocity). Following the research by Karsten et al. (10), we would have John perform five repetitions per set while using an external load that corresponded with a 10-RM. The plan can be modified if heavier external loads are desired, in which three repetitions are performed with his 6-RM.

Apply It!

- In the case of both low and high-intensity resistance training (RT), fitness professionals should teach their clients to lift near failure without achieving complete momentary muscular failure (MMF), as indicated by a ratings of perceived exertion (RPE) value of 8-9 or repetitions in reserve (RIR) value of 1-2.
- MMF and volitional interruption (VI) elicit comparable improvements in strength and hypertrophy at high intensities (75%-85% 1-RM), so both may be integrated into a single training session (i.e., 4 sets of bench press, first three performed to VI, final set to MMF)
- Program failure training to align with your client's goals -- performing RT sets to failure is more effective for hypertrophy, while non-failure sets are more beneficial for power.

Bridging the Gap

Research has shown that taking sets of RT near MMF maximizes motor unit recruitment, sparking an intriguing debate on its effect on improving muscle strength and size. At both high and low intensities, performing RT sets near, but not to, MMF may be the best way to optimize adaptations for strength and hypertrophy. With consideration of important factors such as intensity, types of exercises, and training status, failure training can effectively be implemented into a resistance training program to help clients reach their goals.

Summary Statement

Recent research that compares resistance training performed to failure and non-failure with different intensities and tempos sheds light on how to effectively program failure sets to align with the individual training status and goals of each client.

Pulled Text

1. "The results indicated that when intensity is low (30% 1RM), it is important to perform sets of RT closer to failure. Conversely, when intensity is high (80% 1RM), training to failure provided no additional benefit for strength or hypertrophy."
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3. "Fitness professionals should also consider their client's primary training goal when prescribing failure and non-failure RT. For example, research has shown that failure-RT stimulates more hypertrophy while non-failure-RT is more effective for power (10). Above all, the choice between failure and non-failure RT does not need to be a binary decision."

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