AI-01901 Paper Resistance Training Load vs Effort

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Resistance Training Load vs. Adaptations: A Systematic Review and Meta-Analysis

Source: Schoenfeld, B. J., Grgic, J., Ogborn, D., & Krieger, J. W. (2017). Strength and hypertrophy adaptations between low- vs. high-load resistance training: A systematic review and meta-analysis. *Journal of Strength and Conditioning Research, 31*(12), 3508–3523.

Executive Summary

This meta-analysis comprehensively reviews 21 studies to compare the effects of low-load (≤60% 1RM) versus high-load (>60% 1RM) resistance training on strength and muscle hypertrophy, with all training protocols performed to momentary muscular failure. The key findings indicate that while **maximal strength (1RM) benefits significantly more from high-load training**, **muscle hypertrophy can be achieved equally effectively across a spectrum of loading ranges** when sets are performed to muscular failure. Isometric strength gains were similar between conditions, though this finding was less robust due to limited data. This study challenges the traditional "RM continuum" by demonstrating significant flexibility in loading parameters for muscle growth.

Key Themes and Findings

1. Strength Adaptations: Load-Dependent for Maximal Strength

- **1RM Strength:** High-load training consistently produces significantly greater gains in 1RM (one-repetition maximum) strength compared to low-load training.
- High-load training resulted in a mean ES of 1.69 (35.3% gain) compared to low-load training's ES of 1.32 (28.0% gain). The difference was statistically significant ($p = 0.003$).
- This aligns with the **principle of specificity**, where training closer to maximal loads yields the greatest transfer to maximal lift performance. As the authors state, "Considering the essence of 1RM testing is to lift maximal loads, it logically follows that training closer to one’s RM would have the greatest transfer to this outcome."
- While high loads are superior for maximal gains, "lighter loads promote substantial increases in this outcome as well."
- A sub-analysis suggested that the advantage of heavier loading for maximal isotonic strength might be even more pronounced in trained individuals, though more data are needed to confirm this.
- **Isometric Strength:** Both high-load and low-load training produced similar increases in isometric strength.
- Mean ES for high-load was 0.64 (22.6% gain) and for low-load was 0.55 (20.5% gain), with no significant difference ($p = 0.43$).
- The authors noted that sensitivity analysis showed one influential study skewed these results, suggesting a "likely benefit in favor of heavier loading, albeit of a relatively small magnitude" if that study were removed.
- This implies that when testing on a neutral instrument (not mirroring the lifting mechanics of training), the load might be less critical for force production gains.
- **Isokinetic Strength & Lean Body Mass:** The review found **insufficient studies** to draw definitive conclusions regarding the impact of loading on isokinetic strength and lean body mass changes.

2. Muscle Hypertrophy: Achieved Across All Loading Ranges

- **Similar Gains:** The most significant finding regarding muscle hypertrophy is that "changes in measures of muscle hypertrophy were similar between conditions."
- While there was a "trend toward a difference in mean ES between high and low loads ($p = 0.10$), with high load being slightly greater," the study-level analysis showed "no impact of load ($p = 0.56$)."
- Mean percentage gains were comparable: 8.3% for high-load vs. 7.0% for low-load training.
- Sensitivity analyses revealed that several studies unduly influenced the results, and their removal "markedly reduced the probability of a difference in mean ES."
- This leads to the strong conclusion that "both heavy and light loads can be equally effective in promoting muscle growth provided training is carried out with a high level of effort."
- **Momentary Muscular Failure is Key:** A critical commonality across all included studies was that "all sets in the training protocols being performed to momentary muscular failure." The authors emphasize that the applicability of these findings to training that does not go to failure is not assured, highlighting "the need for further research on the role of effort, fatigue, and failure in the relationship between training loads and changes in muscular strength and hypertrophy."
- **Muscle Fiber Type Adaptations:** Emerging research (though not conclusively proven in this meta-analysis due to insufficient data on muscle fiber size) suggests a potential fiber type–specific effect: "heavier loads showing greater increases in type II muscle fiber cross-sectional area and lighter loads showing greater increases in type I muscle fiber growth." This suggests a potential benefit to "training across a spectrum of repetitions when to goal is maximize hypertrophic adaptations."

3. Training Guidelines and Practical Applications

- **Challenge to Traditional Beliefs:** The findings contradict the traditional "RM continuum," which suggests specific repetition ranges (e.g., 6-12RM) are optimal for hypertrophy, and very low reps (1-5RM) for strength. This meta-analysis demonstrates that hypertrophy can be achieved outside these traditional ranges, provided effort is high.

- "Current resistance training (RT) guidelines profess that loads in excess of 70% 1 repetition maximum (RM) are required to maximize adaptations in muscular strength and hypertrophy. Similarly, the so-called 'RM continuum' purports that gains in muscular strength are optimal with loads of 1–5RM and hypertrophic gains are best achieved with loads of 6–12RM." This study challenges the hypertrophy aspect of this.
- **Flexibility in Program Design:** There is "significant flexibility in the loading ranges that can be prescribed to promote muscular strength and mass."
- For strength athletes, particularly those focused on maximal lifts, high-load training remains advantageous due to specificity.
- However, for general strength and hypertrophy, individuals have more options. This is especially useful in situations where high loads are not feasible or desired (e.g., injury, limited equipment, or preference).
- **Efficiency and Adherence:**
- High-load training may be more **efficient** because "low-load training to failure requires exercise volume (work) and time in excess of high-load training."
- Both high- and low-load training protocols demonstrated high levels of adherence (>87% of sessions), suggesting that perceived discomfort with lighter loads carried to failure does not necessarily impact compliance. The study found "both the types of training were equally effective regarding adherence to the training protocols."
- Both training types appeared equally safe, with only minor adverse effects reported in a small number of studies.

Methodology

- **Systematic Review and Meta-Analysis:** The study employed a systematic review and meta-analysis approach, searching PubMed/MEDLINE, Cochrane Library, and Scopus up to March 2017.

- **Inclusion Criteria:** Studies had to be experimental trials comparing low-load (≤60% 1RM) and high-load (>60% 1RM) training, with all sets performed to momentary muscular failure, lasting a minimum of 6 weeks, and involving healthy participants.
- **Sample Size:** A total of 21 studies were included in the final analysis, significantly more than previous meta-analyses on the topic.
- **Quality Assessment:** Studies were assessed using a modified PEDro scale, with a mean rating of 5.6 ("good to excellent quality").
- **Statistical Analysis:** A random-effects model with robust variance meta-regression was used to calculate effect sizes (ES) and mean percentage changes for 1RM, isometric strength, and muscle hypertrophy.

Limitations and Future Research

- **Training to Failure:** All included studies mandated training to momentary muscular failure. This limits the generalizability of findings to non-failure training protocols, which warrants further investigation.
- **Insufficient Data:** The analysis lacked sufficient data to draw firm conclusions on isokinetic strength, lean body mass, and muscle fiber size adaptations, indicating areas for future research.
- **Untrained vs. Trained Individuals:** While most studies involved untrained subjects, a sub-analysis suggested potential differences in strength adaptations for trained individuals, requiring more focused research.
- **Confounding Variables:** The authors noted some studies had confounding variables (e.g., differing rest intervals or repetition tempos between low and high-load groups), which could have subtly impacted results.
- **Fiber Type Specificity:** The intriguing hypothesis of load-specific fiber type adaptations needs more direct evidence.

Understanding Strength and Hypertrophy Adaptations: A Study Guide

This study guide is designed to help you review the key findings and methodologies of the article "Strength and Hypertrophy Adaptations Between Low- vs. High-Load Resistance Training: A Systematic Review and Meta-Analysis" by Schoenfeld et al. (2017).

I. Quiz (Short Answer)

Answer each question in 2-3 sentences.

1. What was the primary purpose of the systematic review and meta-analysis conducted by Schoenfeld et al.?
2. What were the two main types of resistance training protocols compared in the study based on load intensity?
3. Besides the load intensity, what was a crucial inclusion criterion for all training protocols in the studies analyzed?
4. Regarding 1RM strength gains, what was the main finding when comparing high-load and low-load training?
5. How did high-load and low-load training compare in terms of muscle hypertrophy, according to the study's findings?
6. What is the "principle of specificity" and how does it relate to the findings on 1RM strength?
7. Why did the authors temper conclusions drawn from surface electromyography (sEMG) studies regarding muscle recruitment?
8. What did the study conclude about the impact of training load on isometric strength?
9. What are some potential confounding variables identified by the authors in several included studies that might have influenced results?
10. The study highlights that all included studies used momentary muscular failure. What implication does this have for applying the findings to other resistance training programs?

II. Quiz Answer Key

1. The primary purpose was to conduct a systematic review and meta-analysis to compare changes in strength and hypertrophy between low-load and high-load resistance training protocols. They aimed to synthesize the current body of literature on this topic.
2. The two main types of resistance training protocols compared were low-load training (defined as ≤60% 1RM) and high-load training (defined as >60% 1RM). This distinction allowed for a direct comparison of their effects.
3. A crucial inclusion criterion was that all sets in the training protocols had to be performed to momentary muscular failure. This ensured a high level of effort and maximal muscle fiber recruitment within each set, regardless of load.
4. For 1RM strength gains, high-load training resulted in significantly greater increases compared to low-load training. However, both heavy and light loads still produced substantial increases in 1RM strength.
5. Changes in measures of muscle hypertrophy were found to be similar between high-load and low-load conditions. This suggests that both training intensities can be equally effective for muscle growth when performed to momentary muscular failure.
6. The principle of specificity states that the more a training program replicates the requirements of a given outcome, the greater the transfer. For 1RM strength, which involves lifting maximal loads, training with heavy loads (closer to 1RM) logically has the greatest transfer.
7. The authors tempered conclusions from sEMG studies because sEMG amplitude is influenced by factors beyond just muscle recruitment, such as rate coding, synchronization, propagation velocity, and exercise-induced fatigue. Therefore, sEMG amplitude does not always correlate with long-term strength or hypertrophy gains.
8. The study concluded that both high and low loads produced similar gains in isometric strength, with minimal differences in mean percentage changes. However, a sensitivity analysis suggested a likely, albeit small, benefit in favor of heavier loading for this outcome.
9. Potential confounding variables included differing interset rest intervals between high- and low-load conditions (e.g., 30 seconds vs. 3 minutes),

different repetition performance styles (e.g., without relaxation vs. paused isometric portions), and variations in repetition durations (e.g., 3s-0s-3s tempo vs. 1s-1s-1s tempo).

10. The implication is that the findings specifically apply to resistance training programs where sets are terminated at momentary muscular failure. Comparable results cannot be reasonably assumed for submaximal, non-failure training, highlighting a need for further research in that area.

III. Essay Format Questions

1. Discuss the "RM continuum" and the traditional guidelines for resistance training. How do the findings of Schoenfeld et al. (2017) challenge or support these established recommendations, particularly concerning muscle hypertrophy and maximal strength?
2. Explain the concept of muscle fiber recruitment and the "size principle." How do different perspectives on complete motor unit recruitment in low-load training, particularly when performed to momentary muscular failure, relate to the study's findings on hypertrophy?
3. Analyze the conflicting results observed by Schoenfeld et al. (2017) regarding the impact of training load on 1RM strength versus isometric strength. What factors might explain these differences, and what are the practical implications for training prescription?
4. The study mentions "influential studies" in its sensitivity analyses. Explain the purpose of sensitivity analysis in meta-analysis and discuss how the removal of influential studies affected the conclusions drawn regarding isometric strength and muscle hypertrophy.
5. Beyond the primary findings, what are some of the practical applications of this meta-analysis for individuals designing resistance training programs? Discuss the flexibility in loading ranges for hypertrophy and the importance of training specificity for strength gains, as highlighted by the authors.

IV. Glossary of Key Terms

- **1 Repetition Maximum (1RM):** The maximum weight an individual can lift for a single repetition with proper form. It is a common measure of maximal strength.

- **Concentric Failure (Momentary Muscular Failure):** The point during a resistance exercise set where the muscle can no longer concentrically contract (lift the weight) with proper form, despite maximal effort.
- **Cross-Sectional Area (CSA):** The measurement of the cross-section of a muscle, often used as an indicator of muscle size or hypertrophy.
- **Effect Size (ES):** A standardized measure that quantifies the magnitude of the difference between two groups or the strength of a relationship between two variables.
- **High-Load Training:** Resistance training protocols typically defined as using loads greater than 60% of an individual's 1RM.
- **Hypertrophy:** The increase in the size of muscle cells, leading to an overall increase in muscle mass.
- **Isometric Strength:** The force produced by a muscle when it contracts without changing length (e.g., holding a weight still).
- **Isokinetic Strength:** The force produced by a muscle at a constant velocity, typically measured with specialized equipment.
- **Lean Body Mass (LBM):** The total weight of the body minus all fat. It includes muscle, bone, organs, and water.
- **Low-Load Training:** Resistance training protocols typically defined as using loads at or below 60% of an individual's 1RM.
- **Meta-Analysis:** A statistical method that combines the results of multiple scientific studies addressing the same question. It aims to synthesize the findings to draw more robust conclusions.
- **Motor Units (MUs):** A single motor neuron and all the muscle fibers it innervates. Muscle contraction strength is influenced by the number and firing rate of recruited motor units.
- **Muscle Fiber Recruitment:** The process by which the nervous system activates different muscle fibers to produce force.

- **Muscular Strength:** The ability of a muscle or muscle group to exert force against resistance.
- **PEDro Scale:** An 11-point scale used to assess the methodological quality of randomized controlled trials, particularly in physiotherapy.
- **Principle of Specificity:** A training principle stating that the body adapts specifically to the demands placed upon it. To improve a specific fitness component (e.g., maximal strength), training should mimic that component.
- **Random-Effects Model:** A statistical model used in meta-analysis that accounts for variability between studies, assuming that the true effect size varies from study to study.
- **Repetition Maximum (RM) Continuum:** A theoretical concept suggesting that specific repetition ranges are optimal for different training adaptations (e.g., low reps for strength, moderate reps for hypertrophy, high reps for endurance).
- **Resistance Training (RT):** Any exercise that causes the muscles to contract against an external resistance, with the expectation of increases in strength, power, hypertrophy, and/or endurance.
- **Sensitivity Analysis:** A technique used in meta-analysis to assess how robust the results are by systematically varying assumptions or removing specific studies and observing the impact on the overall findings.
- **Size Principle:** A principle of motor unit recruitment stating that smaller, lower-threshold motor units are recruited first during muscle contraction, followed by larger, higher-threshold motor units as force requirements increase.
- **Systematic Review:** A comprehensive and rigorous review of the existing literature on a specific research question, using explicit and systematic methods to identify, select, and critically appraise relevant studies.
- **Surface Electromyography (sEMG):** A non-invasive technique used to measure and record the electrical activity produced by skeletal muscles. It provides insight into muscle activation.

Frequently Asked Questions on Load Resistance Training

1. What is the main purpose of this meta-analysis on resistance training?

The primary purpose of this meta-analysis was to systematically review existing literature and compare the effects of low-load (LRT) versus high-load resistance training (HRT) protocols on changes in muscular strength and hypertrophy. The study aimed to provide clear guidance on prescribing training loads for these adaptations, especially considering previous guidelines suggesting that only loads exceeding 70% of one-repetition maximum (1RM) were necessary for maximal adaptations.

2. How were "low-load" and "high-load" resistance training defined in this study?

In this study, "low-load" training was defined as using loads at or below 60% of one-repetition maximum (1RM). Conversely, "high-load" training involved loads greater than 60% of 1RM. For studies that reported loads as repetitions instead of percentages of 1RM, repetitions up to 15RM were considered high load, while repetitions greater than 15RM were classified as low load. A crucial criterion for inclusion was that all sets in the training protocols were performed to momentary muscular failure.

3. What were the key findings regarding the impact of training load on muscular strength?

The findings regarding muscular strength were nuanced and depended on the type of strength tested. For one-repetition maximum (1RM) strength, high-load training resulted in significantly greater gains compared to low-load training. While both approaches showed substantial increases in 1RM (35.4% for high-load vs. 28.0% for low-load), high loads were superior for maximal isotonic strength, aligning with the principle of specificity. However, for isometric strength, both high and low loads produced similar gains, suggesting that when testing occurs on a neutral instrument, increases in force production can be achieved equally regardless of the loading zone. Data for isokinetic strength were insufficient for a definitive conclusion.

4. How did different training loads affect muscle hypertrophy?

The meta-analysis indicated that changes in muscle hypertrophy were similar between high-load and low-load conditions. Although there was a slight trend favoring heavier load training, statistical analysis at the study level showed no significant impact of load, and mean percentage gains in muscle size were comparable (8.3% for high-load vs. 7.0% for low-load). This suggests that both heavy and light loads can be equally effective in promoting muscle growth, provided the training is carried out with a high level of effort, specifically to momentary muscular failure.

5. What is the "principle of specificity" and how does it relate to the study's findings on strength?

The "principle of specificity" dictates that the more closely a training program replicates the requirements of a given outcome, the greater the transfer of the training to that outcome. This principle is particularly relevant to the study's findings on 1RM strength. Since 1RM testing involves lifting maximal loads, it logically follows that training with heavier loads (closer to one's 1RM) would result in the greatest improvements in this specific type of strength, as was observed in the meta-analysis.

6. Does this study suggest any fiber type-specific adaptations based on loading zones?

Yes, the study mentions emerging research suggesting a potential fiber type-specific effect of loading zones. Heavier loads might lead to greater increases in Type II muscle fiber cross-sectional area, while lighter loads could show greater increases in Type I muscle fiber growth. This implies a potential benefit to training across a spectrum of repetitions or loading zones if the goal is to maximize overall hypertrophic adaptations, though the authors note that further research is needed to draw definitive practical inferences.

7. What is the significance of "momentary muscular failure" in the context of these findings?

A critical aspect of all studies included in this meta-analysis was that all training sets were performed to "momentary muscular failure" (concentric failure). This means that participants continued repetitions until they could no longer complete another concentric contraction with proper form. The authors emphasize that the application of these findings to resistance training programs *must* consider the contribution of training to failure. It cannot be assumed that similar results would be achieved with submaximal, non-failure training, highlighting the need for further research on the role of effort, fatigue, and failure in strength and hypertrophy adaptations.

8. What are the practical applications of these findings for individuals designing resistance training programs?

The findings offer significant flexibility in prescribing training loads. For maximal gains in 1RM strength, particularly for strength sports where heavy loads are required, high-load training is advantageous due to the principle of specificity. However, for general muscular strength development (including isometric strength) and muscle hypertrophy, both high-load and low-load training, when performed to momentary muscular failure, are highly effective. This means individuals can choose training loads based on personal preference, equipment availability, or to vary their training, potentially even training across a spectrum of loads to maximize hypertrophy based on emerging fiber type-specific adaptation research. It's crucial to remember that the effectiveness observed in this meta-analysis is contingent on training to momentary muscular failure.