International Platform of Registered Systematic Review and Meta-analysis Protocols

INPLASY

Do Resistance Training Protocols Performed to Concentric Muscle Failure Versus Non-Failure Produce Superior Chronic Adaptations in Maximal Strength and Muscle Hypertrophy in Trained Adults? A Systematic Review Protocol

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ADMINISTRATIVE INFORMATION

Support - None.

Review Stage at time of this submission - Preliminary searches.

Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 4 February 2026 and was last updated on 4 February 2026.

INTRODUCTION

Review question / Objective To evaluate, in trained adults (≥18 and ≤65 years, with a minimum of one year of resistance training experience and a minimum training frequency of ≥2 sessions per week during the last 6 months), whether resistance training protocols performed to concentric muscle failure (defined as the inability to complete an additional repetition while maintaining proper technique), compared with non-failure protocols (RIR = ≥1 and ≤3 repetitions in reserve), both lasting ≥8 weeks, produce superior chronic adaptations in maximal strength and muscle hypertrophy, based on randomized controlled trials.

Rationale Resistance training is widely recognized as an effective strategy to promote gains in muscular strength and hypertrophy. However, there is ongoing controversy in the scientific literature regarding the necessity of performing sets to concentric muscle failure to maximize these adaptations, particularly in trained individuals. Some authors argue that training to failure is required to maximize motor unit recruitment and hypertrophic stimulus, whereas others suggest that non-failure training can elicit similar gains with lower neuromuscular fatigue and improved recovery capacity.

Given the practical relevance of this topic, it is essential to systematically synthesize the available scientific evidence, as most existing studies do not adequately address this research question when the focus is on trained adults, interventions lasting ≥8 weeks, and adaptive outcomes related to maximal strength and muscle hypertrophy. A substantial proportion of frequently cited studies involve untrained individuals, have durations ≤6 weeks, focus on acute responses, fatigue, or indirect markers, or include mixed populations without stratified analyses.

Condition being studied The condition under investigation refers to chronic adaptations induced by resistance training programs in trained adults, comparing the performance of sets to concentric muscle failure with the voluntary termination of

sets before failure. This condition includes adult individuals with prior resistance training experience, exposed to interventions lasting eight weeks or longer, in which chronic adaptations in maximal strength and muscle hypertrophy are assessed using direct and validated measurement methods. The focus is exclusively on the effects of proximity to muscle failure on these adaptations, excluding acute responses, untrained populations, or individuals with clinical conditions.

METHODS

Search strategy Randomized controlled trials directly comparing resistance training protocols performed to muscle failure versus non-failure will be included. A systematic search will be conducted in the following databases: PubMed, Scopus, Web of Science, and SPORTDiscus, from database inception to the date of publication of this protocol.
The search strategy will combine terms related to resistance training, training to muscle failure, training cessation before failure (RIR or technical failure), and outcomes of maximal strength and muscle hypertrophy. Search terms will be adapted for each database and combined using Boolean operators (AND, OR). The search will be limited to studies conducted in humans and published in Portuguese or English.
The exclusion of grey literature may increase the risk of publication bias and should be considered when interpreting the final results.

Participant or population Adults of both sexes (≥18 and ≤65 years), trained, with a minimum of one year of resistance training experience and a minimum weekly training frequency of ≥2 sessions during the last 6 months.

Intervention Resistance training protocols performed to concentric muscle failure in all sets or only in the final set, defined as the inability to complete an additional repetition while maintaining proper technique. Protocols will be included regardless of relative intensity (%1RM), number of sets per exercise or per session, repetitions per exercise, rest intervals, or movement tempo (time under tension), provided the intervention duration is ≥8 weeks.

Comparator Resistance training protocols performed without reaching concentric muscle failure, characterized by the execution of sets with one or more repetitions in reserve based on self-report (RIR = ≥1 and ≤3), with similar volume, intensity, and training density characteristics.

Study designs to be included Parallel-group randomized controlled trials (RCTs) comparing resistance training performed to concentric muscle failure versus resistance training performed without muscle failure (RIR = ≥1 and ≤3).

Eligibility criteria Inclusion criteria:
• Parallel-group randomized controlled trials;
• Adults (≥18 and ≤65 years) with prior resistance training experience (≥1 year);
• Interventions lasting ≥8 weeks;
• Direct comparison between training to muscle failure and non-failure training in all sets or only the final set;
• Outcomes assessing maximal strength and/or muscle hypertrophy;
• Training performed using resistance training machines or free weights;
• Protocols including unilateral or bilateral exercises;
• Protocols with identical dietary conditions in both groups.

Exclusion criteria:
• Studies involving untrained participants;
• Participants younger than 18 years or older than 65 years;
• Participants with clinical pathologies;
• Studies including concurrent or combined interventions (e.g., cardiovascular training combined with resistance training);
• Systematic reviews, meta-analyses, observational studies, and case reports;
• Protocols without clear descriptions of intensity, volume, or effort control;
• Protocols with different dietary conditions between groups.

Information sources Electronic databases: PubMed, Scopus, Web of Science, and SPORTDiscus.

Main outcome(s) • Maximal muscular strength, assessed through direct 1RM testing, excluding isometric strength measures.
• Muscle hypertrophy, assessed by muscle thickness, cross-sectional area, muscle volume, or imaging methods such as ultrasonography or magnetic resonance imaging (MRI).

Additional outcome(s) Indicators of neuromuscular fatigue, when available.

Quality assessment / Risk of bias analysis Study quality will be assessed using the Cochrane Risk of Bias 2 tool (RoB 2). As a secondary and descriptive tool, the PEDro scale will also be used, as it has been validated in exercise-related

research. The PEDro scale ranges from 0 to 10 points, with higher scores indicating better methodological quality. Studies scoring ≥6 will be considered of moderate to high quality.

Strategy of data synthesis The following data will be extracted and coded: participant characteristics (age, sex, training status), study design, intervention characteristics (training type, failure definition, proximity to failure, training volume, weekly frequency, and intervention duration), assessed outcomes (maximal strength and muscle hypertrophy), assessment methods, and relevant information for risk of bias evaluation.

Quantitative analysis: When at least two clinically and methodologically homogeneous studies are available for a given outcome, a quantitative synthesis (meta-analysis) will be performed. For continuous outcomes, mean differences (MD) with 95% confidence intervals will be calculated when measurement units are equivalent, or standardized mean differences (SMD) when different assessment methods are used. Meta-analyses will be conducted using a random-effects model, assuming variability between studies. Statistical heterogeneity will be assessed using the I^2 statistic and interpreted according to conventional thresholds.

Qualitative analysis: For studies that cannot be included in the quantitative analysis, a structured narrative synthesis will be conducted. This analysis will consider the direction of effects, consistency of findings across studies, and relevant methodological and clinical differences, including participant characteristics, training protocols, and outcome assessment methods.

Subgroup analysis Subgroup analyses will be conducted according to participant sex/gender. Whenever possible, sex/gender-specific results (male and female) will be extracted and analyzed separately. When studies include mixed samples and report stratified results, each stratum will be analyzed independently. Studies with mixed samples that do not report sex/gender-specific data will not contribute to subgroup analyses but will be included in overall analyses.
Additional subgroup analyses will include:
• Volume-equated versus non-volume-equated protocols;
• High-load versus moderate-load training;
• Failure in all sets versus partial failure.

Sensitivity analysis Impact of data selection: Sensitivity analyses will be conducted by excluding
• Studies classified as high risk of bias (RoB 2) in any critical domain relevant to the analyzed outcomes;
• Studies in which training volume was not explicitly equated between intervention groups;
• Studies with ambiguous or insufficiently described definitions of muscle failure;
• Studies in which the non-failure group did not explicitly report proximity to failure.

Variation in analytical methods: Different statistical models will be tested to assess the robustness of the findings.

Assumption testing: The influence of different assumptions on the results will be examined, as well as whether variations in study design, sample characteristics, or intervention conditions affect overall conclusions. Studies relying on unverified or insufficiently reported assumptions will be excluded.

Sensitivity checks: Additional checks will be conducted to identify the influence of individual studies and outliers, including systematic comparisons between primary and sensitivity analyses, with reporting of any relevant changes in the direction, magnitude, or precision of the estimated effects.

Language restriction Studies published in Portuguese and English will be included.

Country(ies) involved Portugal.

Keywords resistance training; neuromuscular training; muscle failure; hypertrophy; maximal strength; trained adults.

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