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Neuromuscular Effects, Dose-Response Relationship, and Physiological Mechanisms of Strength Training: A Systematic Review

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ADMINISTRATIVE INFORMATION

Support - Kim Geok Soh.

Review Stage at time of this submission - Completed but not published.

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 23 August 2024 and was last updated on 23 August 2024.

INTRODUCTION

Review question / Objective This study is a review study: First, the subjects are healthy adult males or females who have or have not undergone systematic resistance training. The intervention method is simple resistance training, and the groups are divided into randomized controlled trials or non-randomized controlled trials. The results of the study should clearly reflect the muscle strength or muscle rapid force ability of the subjects at the starting point and the related neuromuscular adaptation results. Finally, the included literature is analyzed to find out the differences in maximum strength and rapid force and the related load weight, etc.

Condition being studied Muscle strength is crucial for athletic performance, and modern competitive sports demand greater strength from athletes. Strength training improves athletic performance by promoting both neural and muscle adaptations. Neural adaptation is predominant in the initial stages of training, with muscle adaptation becoming more significant as training advances. While the role of the nervous system in muscle strength development through strength training is well established, different training modes may induce specific adaptations in various parts of the nervous system. However, research has not yet reached a consistent conclusion.

METHODS

Search strategy Methods: On November 17, 2023, the Web of Science, Scopus, PubMed, EBSCOhost (SPORT discus), and CNKI databases were used. “Strength training” “strength” “resistance training” “strengthening programs” OR “progressive strength training” “resistance exercise” “weight lifting” “weight exercise” “strength exercise” “weight training” “intensive strength training” “Neuroadaptation” “Neuromuscular adaptations” “neuromuscular function” "muscle adaptation".

Participant or population Healthy subjects with or without resistance training experience.

Intervention This review aims to evaluate the dose-response relationship of different resistance training protocols, including variations in intensity, volume, frequency, and duration, on neuromuscular adaptations. It focuses on how training variables such as load (light, moderate, heavy), mode (isometric, isokinetic, dynamic), frequency (e.g., sessions per week), and total volume impact neural activation, muscle strength, and hypertrophy.

Comparator this review will compare the effects of various resistance training interventions across different target populations (e.g., young adults, older adults, males and females, athletes vs. non-athletes). These comparisons will focus on how different training variables (such as intensity, volume, frequency, and mode of training) influence neuromuscular adaptations within each group.

Study designs to be included Randomized Controlled Trials (RCTs): These will be prioritized as they provide high-quality evidence on the effects of various resistance training interventions.Quasi-experimental designs: Studies without random allocation will be considered to provide additional evidence on the effectiveness of interventions, especially in specific populations.Longitudinal Studies: These will track changes in neuromuscular adaptations over time in the same population to better understand the long-term dose-response relationship of resistance training.

Eligibility criteria 1.2.1 Entry criteria ①Studies must employ a randomized controlled design. The research subjects and methods must clearly define the experimental, control, and comparison groups, ensuring uniform distribution of samples by age, gender, etc., with random and parallel interventions. ②Study subjects should include three populations: well-trained competitive athletes, fitness enthusiasts with general training experience, and healthy adults with no training experience. ③The study design must involve pure resistance training, with detailed descriptions of training type, load volume, intensity, frequency, and cycle. ④The results section must include detailed data analysis tables showing pre- and post-training changes in physiological and biochemical indicators between experimental and control groups, along with statistical tests.

1.2.2 Exclusion criteria

①The literature lacks detailed experimental procedures, data, or result analysis. ②The study subjects are animals or patients. ③The experimental design employs non-resistance training methods. ④The documents include conference papers, review articles or duplicates. ⑤The literature does not specifically address neuromuscular adaptations related to maximal or explosive muscle strength.

1.3 Quality assessment and literature screening

The PEDro scale was used to assess the quality, reliability, and validity of the literature. This scale evaluated whether each retrieved article met the rating criteria, thus determining research quality. The PEDro scale ranges from 0 to 10 points. Two researchers independently rated each article, with discrepancies resolved by a third researcher. Higher PEDro scores indicate better research quality: articles scoring ≥5 were deemed high quality, while those scoring ≤4 were classified as low quality. Paper quality was judged based on the Oxford Centre for Evidence-Based Medicine (OCEBM) levels, including recommendation and evidence levels. In evidence-based medicine projects, the final level was determined by the third rater. Seventy-five high-quality papers were selected for analysis.

Information sources China National Knowledge Infrastructure, Wanfang Database, PubMed, Web of Science, SCOUPS, EBSCOhost (SPORT Discus) database.

Main outcome(s) 58 articles (43 on maximum strength and 15 on explosive strength) met the inclusion criteria. Conclusion: Neural adaptation mechanisms differ between maximum and explosive strength training. Maximum strength training increases V-wave amplitude, M-max, and H-reflex amplitude by enhancing neural drive and muscle fiber activation. However, presynaptic inhibition decreases while the resting H/M ratio remains unchanged. Explosive strength training focuses on increasing neuronal excitability and neural control precision. This is evidenced by a higher V/M ratio at rest, increased motor unit conduction velocity, a positive correlation between H-reflex amplitude and RFD, and elevated presynaptic inhibition. Muscle adaptations also differ between the two training types. Maximum strength training significantly increases muscle thickness and cross-sectional area, and alters the distribution of muscle fiber types, including Type I, Type IIAB, Type IIB, and Type IIa fibers. Specifically, the percentage of Type IIAB fibers increases, while Type IIB fibers decrease. Explosive strength training primarily affects the cross-sectional area of Type IIa and IIx fibers, increases the percentage of Type IA fibers, but does not significantly change the myosin heavy chain IIb.

Additional outcome(s) Neural adaptation mechanisms differ between maximum and explosive strength training. Maximum strength training increases V-wave amplitude, M-max, and H-reflex amplitude by enhancing neural drive and muscle fiber activation. However, presynaptic inhibition decreases while the resting H/M ratio remains unchanged. Explosive strength training focuses on increasing neuronal excitability and neural control precision. This is evidenced by a higher V/M ratio at rest, increased motor unit conduction velocity, a positive correlation between H-reflex amplitude and RFD, and elevated presynaptic inhibition. Muscle adaptations also differ between the two training types. Maximum strength training significantly increases muscle thickness and cross-sectional area, and alters the distribution of muscle fiber types, including Type I, Type IIAB, Type IIB, and Type IIa fibers. Specifically, the percentage of Type IIAB fibers increases, while Type IIB fibers decrease. Explosive strength training primarily affects the cross-sectional area of Type IIa and IIx fibers, increases the percentage of Type IA fibers, but does not significantly change the myosin heavy chain IIb.

Quality assessment / Risk of bias analysis The PEDro scale was used to assess the quality, reliability, and validity of the literature. This scale evaluated whether each retrieved article met the rating criteria, thus determining research quality. The PEDro scale ranges from 0 to 10 points. Two researchers independently rated each article, with discrepancies resolved by a third researcher. Higher PEDro scores indicate better research quality: articles scoring ≥5 were deemed high quality, while those scoring ≤4 were classified as low quality. Paper quality was judged based on the Oxford Centre for Evidence-Based Medicine (OCEBM) levels, including recommendation and evidence levels. In evidence-based medicine projects, the final level was determined by the third rater. Seventy-five high-quality papers were selected for analysis.

Strategy of data synthesis Data Extraction and Coding: Key variables will be extracted from the included studies, such as study design, participant characteristics, types and intensities of resistance training interventions, duration and frequency of training, and measures of neuromuscular adaptations. All data will be coded independently by two reviewers to minimize bias and ensure accuracy.
Quantitative Analysis: Meta-analyses will be performed using statistical software to calculate effect sizes (e.g., standardized mean differences, odds ratios) and their 95% confidence intervals. Heterogeneity will be assessed using the I^2 statistic.
Sensitivity Analysis: Sensitivity analyses will be conducted to examine the robustness of the results and identify any potential influencing factors.
Qualitative Analysis: For studies that cannot be included in quantitative analysis, a narrative synthesis approach will be employed, systematically comparing study designs, methodological quality, and findings to summarize the existing evidence.

Subgroup analysis Subgroup analyses will be conducted based on target populations (e.g., age, sex, training status) and intervention characteristics (e.g., intensity, frequency, duration). Sensitivity analyses will also be performed to examine the robustness of the results and identify any potential influencing factors.

Sensitivity analysis Impact of Data Selection: Excluding individual studies or data points to assess their impact on the overall effect size. For example, evaluating whether removing studies of lower quality or with inconsistent designs significantly alters the analysis results.
Variation in Analytical Methods: Repeating the analysis using different statistical methods or models to test the stability of the results. For instance, comparing the impact of different effect size calculation methods (e.g., standardized mean differences vs. raw mean differences) on the results.
Testing Assumptions: Assessing the influence of different assumptions on the results, such as evaluating whether variations in study design, sample characteristics, or intervention conditions affect the overall conclusions. Specifically, examining how different training intensities, frequencies, or durations impact the review's overall findings.
Sensitivity Checks: Performing various sensitivity checks to determine the robustness of the results. This includes analyzing factors such as study quality, sample size, and other potential influencing factors to ensure the consistency and reliability of the conclusions.

Language restriction Chinese and English literature were searched.

Country(ies) involved Malaysia.

Keywords Resistance Training; Maximal Strength; Explosive Strength; Neural Adaptation; Muscle Adaptation.

Contributions of each author

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