Journal of Carcinogenesis
Covering Genesis to Therapeutics
Journal of Carcinogenesis, ISSN: 1477-3163
2024; Vol 23: Issue 1, https://carcinogenesis.com/

From Brain to Muscle: Central and Peripheral Neural Adaptations Underlying Strength Gains Following Resistance Training

Danish Latif[1], Prof. Dr. Basit Ansari[2], Rabia Khan[3], Muhammad Wahaj ud din Sheikh[4], Uzair Javaid[5], Rameela Jabbar[6]

[1]Assistant Professor, Rawal Institute of Health Sciences, Islamabad, Pakistan

[2]Chairperson, Department of Health, Physical Education & Sports Sciences, University of Karachi, Karachi, Pakistan

[3]Assistant Professor, Bahria University of Health Sciences, Karachi, Pakistan

[4]Physiotherapist, Mickleham Physiotherapy Services, Mickleham (Melbourne), Australia

[5]Lecturer, Charles Darwin University, Darwin, Australia

[6]Physiotherapist, Emaan Hospital, Islamabad, Pakistan

Corresponding Author: Danish Latif

Email: latif_danish@yahoo.com, danishlatif@rihs.edu.pk

ABSTRACT

Objective: This study was conducted to evaluate the difference between the two resistance training methods in developing maximal strength in the upper extremity of healthy adults and investigate differences between training groups, sex and alterations in A/G ratio, CRP, EEG and NCS parameters.

Methods: The study was conducted as a parallel group randomized controlled trial in Shifa Neuro Clinic and Laboratory from August 2023 to September 2024, involving 100 healthy adults between the ages of 18-35 years. The participants were divided into two groups: an 8-12 repetitions resistance-training group and an 8 RM (1 repetition max) training group. Both groups exercised 2 times per week for 8 weeks. 1RM was used as an assessment of muscle strength and before/after training assessment for EEG, NCS, A/G ratio and CRP.

Results: 1RM strength increased significantly over time, $F(1,98)=301.758$, $p<0.001$. The group effect and time×group interaction were not significant ($p=0.479$ and $p=0.307$, respectively). The A/G ratio changed significantly over time ($p=0.002$) but its change did not differ between groups ($p=0.928$) and was not associated with strength gain ($\rho=0.043$, $p=0.668$). There were no significant differences found in EEG measures. For most NCS parameters, there was no change either, except for right median sensory onset latency ($p=0.014$) and left median motor elbow latency ($p=0.008$) which showed significant time×group interaction. Strength gain was not significantly affected by sex ($p=0.081$) nor was there significant interaction between group and sex ($p=0.631$). Throughout the study, the CRP was found to be negative.

Conclusion: In healthy adults, eight weeks of resistance training led to a significant increase in maximal strength of the upper extremities. The extent of improvement was similar in the hypertrophy-oriented and 1RM training groups with no significant difference between the two approaches. The A/G ratio varied throughout the time period but not in relation to strength gain. Overall, the results suggest that strength gains can be achieved without a significant change in most of the EEG and NCS parameters, indicating that early strength gain might involve a combination of interacting muscular, neural, motor-learning and task-specific mechanisms.

Keywords: *Resistance training, Muscle strength, 1RM, EEG, NCS, A/G ratio, C-reactive protein, Healthy adults.*

How to Cite: Danish Latif, Prof. Dr. Basit Ansari, Rabia Khan, Muhammad Wahaj ud din Sheikh, Uzair Javaid, Rameela Jabbar, (2024) From Brain to Muscle: Central and Peripheral Neural Adaptations Underlying Strength Gains Following Resistance Training, *Journal of Carcinogenesis*, *Vol.23*, *No.1*, 1182-1188

1. INTRODUCTION

Resistance training is commonly prescribed to improve muscular strength, physical performance and physical capacity. It is well-known for its benefits, it's used in exercise routines for healthy adults too and has a long history with athletic training. Several training variables affect the response to resistance training such as the amount of resistance used, number of sets and training frequency. A large systematic review and Bayesian network meta-analysis of 178 studies and 5,097 individuals suggested that resistance-training prescription was effective at increasing muscle strength and that higher load prescriptions had a greater potential for maximizing muscle strength. The same study also indicated that the same training program could lead to similar increases in muscle mass.(1)

The increase in strength after resistance training does not only come from an increase in muscle size. Particularly during the early stages of training, adaptations within the nervous system may contribute substantially to the ability to produce force. These adaptations include alterations to the recruitment of motor units, neural drive, corticospinal excitability, intracortical inhibition and coordination of movement.(2) Evidence from studies investigating the corticospinal responses to training has also shown that strength training can induce changes in corticospinal excitability, though the relationship between the two seems to vary depending on the type of strength training used.(3) Another recent study confirmed that changes in corticospinal excitability were related to strength gains in resistance training.(4)

Type and intensity of training can also affect strength development. While a variety of resistance training loads can produce strength and muscle hypertrophy, higher-load training seems to offer the greatest benefit when the primary training objective is to maximize strength.(1, 5) Additionally, repeated exposure to a strength testing method can have an effect on performance as the participants get more familiar with the exercise technique and the demands of maximizing the intensity of the effort. The effects of familiarization have been recently documented in repeated 1RM testing, especially when learning or familiarization with technically complex strength-testing tasks occurs during the early phase of the resistance training periodization.(6) Therefore, the gains in maximal strength may be due to muscular adaptation, neural adaptation, movement coordination and familiarity with the strength-testing task.

Another factor that could affect the interpretation of resistance-training responses is sex. In general, males have more absolute muscle strength and muscle size, but this doesn't imply that the relative training response is higher in males. A systematic review and meta-analysis reported that males and females showed broadly similar adaptations in muscle hypertrophy and lower-body strength while females demonstrated greater relative improvements in upper-body strength in the studies included in that analysis.(7) More recent evidence has similarly suggested that absolute increases in muscle size may be somewhat greater in males whereas relative changes in muscle size are generally comparable between males and females.(8) These studies suggest sex should be taken into account when studying strength adaptation, especially if upper-body strength is the primary outcome

Systemic biochemical markers may also change during resistance training exercises. C-reactive protein (CRP) is a marker of systemic inflammatory status and may have different responses to training depending on the characteristics of the population. In healthy adults, there have been conflicting reports of CRP changes after resistance training. For example, a study of young healthy men found that no significant changes in CRP were seen with either moderate or high-intensity resistance training, but rather, post-training high-sensitivity CRP levels were lower in these groups than in the control group.(9) In other studies, combined endurance and resistance training was associated with a decrease in plasma CRP in young women.(10) These results suggest that CRP may respond differently to training based on baseline inflammatory status, type and duration of exercise and participant characteristics.

Another biochemical value that can indicate changes in systemic physiological and inflammatory status is the albumin/globulin (A/G) ratio. Circulating plasma proteins, such as albumin and globulins, are important components and changes in either of these relative concentrations can affect the A/G ratio. There is limited evidence that A/G ratio specifically is associated with resistance training induced changes in muscle strength. Recently, an association between habitually aerobic exercise and a higher A/G ratio as well as lower inflammatory indices was reported suggesting that changes in inflammatory status in the system may be reflected in this ratio.(11) While the relationship between changes in the A/G ratio and an improvement in muscular strength after performing a structured resistance training exercise program has not been sufficiently proved.

This study compared the hypertrophy training method (8-12 reps) to repeated 1RM training method in healthy adults over an 8-week period. The study analysed the changes in maximal upper extremity strength and investigated if there were any differences between males and females. It also assessed the changes in selected central and peripheral nervous system parameters as well as the change in A/G ratio and CRP status to give a wider perspective into the physiological responses triggered by resistance training.

2. METHODS

This study was parallel-group randomized controlled and lasted for 8 weeks. The participants consisted of 100 healthy male and female from different universities and sports clubs. The study was conducted in Shifa Neuro Clinic and Laboratory from August 2023 to September 2024 Participants were 18–35 years of age, had a BMI of 18.5–24.9 kg/m² and had not participated in regular resistance exercise during the previous 6 months. Sealed envelope method was used to randomly allocate participants into two groups with 50 participants in each. Group A was given traditional resistance training with repetitions while Group B was given repeated 1RM training. Those who had gastrointestinal disorders, musculoskeletal injuries, neurological disorders, used medicines or tobacco products in the past 6 months were excluded. All participants gave informed consent to participate and confidentiality and anonymity were ensured during the study.

Baseline assessments were done prior to the intervention and after the 8-week training period. The primary outcome was maximal muscular strength of upper extremity using one repetition maximum (1RM) test. Biochemical parameters assessed were the albumin/globulin (A/G) ratio and C-reactive protein (CRP) and the 1RM was used to predict from Wilson et al. The A/G ratio was determined by the measured values of albumin and globulin; the measured value of CRP was reported according to the laboratory reporting method in the study. Strength gain was determined by subtracting the 1RM before training from the 1RM after training. Other assessments were conducted to assess the effects of the intervention on central nervous system (CNS) and peripheral nervous system (PNS) responses such as electroencephalography (EEG) and nerve conduction studies (NCS).

Both groups performed resistance exercises twice a week for 8 weeks. The Group A performed the bench press exercise starting with 1 set of 10 repetitions with no load to warm-up and 4 sets of 8-12 repetitions for the working sets. Rest periods of 90 seconds were given between sets and each repetition had a concentric phase duration of about 1.5 seconds and an eccentric phase of 1.5 seconds. Elbows were deemed to be fully stretched for a complete repetition. Group B completed repeated 1RM training of 5 attempts for maximum weight to complete 1 RM in each training session with the 90 second rest period between each attempt. This was progressively increased in incremental trials with the goal being to match or surpass the participant's previous 1RM. Each group participated in an 8-week intervention period and were assessed according to the same protocol (baseline and following the training program) with outcome measures recorded.

IBM SPSS Statistics was used for the statistical analysis. Data on participant characteristics and study variables were summarized using descriptive statistics. The Mann-Whitney U test was used to compare continuous variables between groups and the chi-square test was used to compare categorical variables between groups. Mixed repeated-measures analysis of variance with time as a within-group factor and training group as a between-group factor was used to examine changes in 1RM strength, A/G ratio, EEG measures and NCS parameters. The difference between the two training protocols was considered as the main indicator from the time×group interaction. A two-way analysis of variance was also conducted to look at the main effects of training group, sex and the group×sex interaction on strength gain. To determine the association between A/G ratio after intervention and strength gain, Spearman's correlation coefficient analysis was done. Partial eta squared ($\eta^2 p$) was used to express effect size and statistical significance was set at $p<0.05$. The results from the laboratories were used to analyze the findings of the CRP.

3. RESULTS

There were 100 participants who completed the 8-week resistance training, 50 were in each training group. The sample size was 50 males and 50 females. Most participants were aged 25–29 years (53%) followed by 18–24 years (28%) and 30–35 years (19%). Regarding BMI, 43% of participants were within 22.6–24.5 kg/m², 36% within 20.6–22.5 kg/m² and 21% within 18.5–20.5 kg/m².

The Mann–Whitney U test was used to determine if there were significant differences between the two groups for the variables measured in the baseline comparison, with no significant differences found for most of the variables measured. However, significant differences were noted for right median sensory nerve onset latency ($p=0.049$), right ulnar sensory nerve peak-to-peak amplitude ($p=0.042$) and left ulnar motor nerve onset latency at the elbow ($p=0.045$). No statistically significant baseline differences between groups were found for the other biochemical, EEG and NCS variables ($p>0.05$).

The mixed repeated-measures analysis showed that the strength of 1RM increased significantly over time, $F(1,98)=301.758$, $p<0.001$. However, the main effect of group was not significant, $F(1,98)=0.504$, $p=0.479$ and the time× group interaction was also not significant, $F(1,98)=1.055$, $p=0.307$, partial $\eta^2=0.011$. The results showed that both training methods led to an increase in maximal strength and that there was no significant difference between the two methods. The A/G ratio showed a significant change over time, $F(1,98)=10.632$, $p=0.002$. The group effect was not significant, $F(1,98)=0.069$, $p=0.793$ and the time×group interaction was not significant, $F(1,98)=0.008$, $p=0.928$. In addition, correlation between strength gain and A/G ratio after intervention was very weak and non-significant (Spearman $\rho=0.043$, p=0.668).

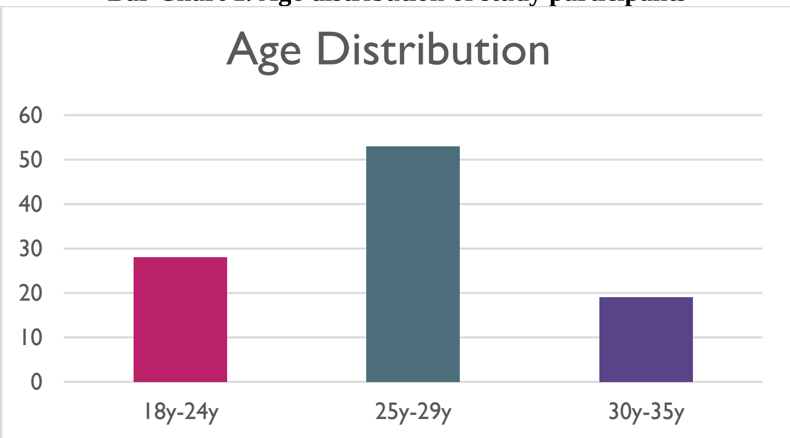
There was no significant change in the EEG parameters such as alpha waves, mental fatigue, cognitive function and mental alertness, respectively (all p>0.05). There were also no significant time or group effects in the majority of the NCS parameters measured. No significant time×group interaction effects were found for all the other NCS parameters except for right median sensory onset latency (p=0.014) and left median motor elbow latency (p=0.008).

There was no significant main effect of sex on the strength response as revealed by the 2-way ANOVA, $F(1,96)=3.105$, $p=0.081$, partial $\eta^2=0.031$. The training group effect was also non-significant, $F(1,96)=1.219$, $p=0.272$, partial $\eta^2=0.013$ and the group × sex interaction was not significant, $F(1,96)=0.232$, $p=0.631$, partial $\eta^2=0.002$. No significant associations were found for gender, handedness or energy-drink/coffee consumption (all p>0.05) in the case of categorical variables. No change in CRP status was observed at either assessment as CRP remained negative (<0.6) throughout.

Table 1. Participant characteristics

Variable	Category	n (%)
Age	18–24 years	28 (28.0)
	25–29 years	53 (53.0)
	30–35 years	19 (19.0)
Gender	Male	50 (50.0)
	Female	50 (50.0)
BMI	18.5–20.5 kg/m²	21 (21.0)
	20.6–22.5 kg/m²	36 (36.0)
	22.6–24.5 kg/m²	43 (43.0)

Bar Chart 1. Age distribution of study participants



Bar Chart 2. BMI distribution of study participants

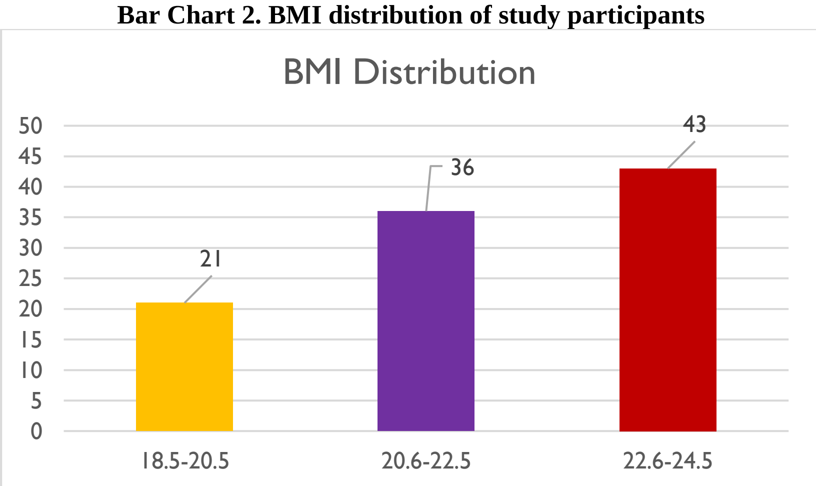


Table 2. Two-way ANOVA showing the effect of training group and sex on strength response

Source	df	F	p-value	Partial η²
Training group	1	1.219	0.272	0.013
Sex	1	3.105	0.081	0.031
Group × Sex	1	0.232	0.631	0.002

Table 3. Mixed Repeated-measures analysis

Outcome	Time p-value	Group p-value	Time × Group p-value
1RM Strength	<0.001	0.479	0.307
A/G Ratio	0.002	0.793	0.928
Alpha Waves	0.367	0.388	0.808
Mental Fatigue	0.367	0.388	0.808
Cognitive Function	0.367	0.388	0.808
Mental Alertness	0.367	0.388	0.808

Both resistance training methods resulted in a significant increase in the maximal strength overall. But there were no significant differences between groups or between the sexes in terms of amount of change. A/G ratio did not correlate with strength gain and varied greatly with time of sampling. The majority of these EEG and NCS parameters were not different between the groups but two NCS parameters had significant group by time interaction. The overall rate of CRP was negative during the intervention

4. DISCUSSION

The present study showed a clear improvement in upper-extremity maximal strength after 8 weeks of resistance training in healthy adults. Both the hypertrophy-oriented and repeated 1RM training groups improved; however, the time×group interaction was not significant ($F(1,98)=1.055$, $p=0.307$, partial $\eta^2=0.011$). This indicates that neither training approach produced a superior strength response. These findings are consistent with current evidence showing that resistance training improves strength across a range of training loads although higher-load protocols may provide an advantage when maximal strength is the primary goal.(1, 5, 12, 13) A large network meta-analysis including 178 studies and more than 5000 participants found that all resistance-training prescriptions improved strength compared with no exercise while higher-load training ranked highest for strength development.(13) Thus, the comparable improvement observed in the present study may be related to the fact that both protocols provided sufficient resistance, repeated practice and regular exposure to the bench-press movement.

The increase in strength may also reflect adaptations that occur before substantial muscular hypertrophy develops. Early resistance training improvements can involve motor unit recruitment, voluntary activation, coordination and movement efficiency. Recent systematic review evidence indicates that resistance training can modify corticospinal excitability and that these changes may be related to strength development although the response depends on the type of training performed.(4) The present study, however, did not demonstrate significant changes in the EEG measures. Therefore, the strength improvement cannot be directly attributed to measurable EEG changes. Instead, it is reasonable to consider that several neural and motor learning processes may have contributed to the observed increase in performance.

The specificity of the 1RM outcome is also important. Participants repeatedly practiced the bench-press movement during training and were exposed to maximal strength testing. Familiarity with the testing procedure, improved technique and better coordination may therefore have contributed to the increase in measured 1RM particularly because participants were previously untrained.(14) This may partly explain why both training approaches resulted in similar improvements despite their different repetition and loading schemes. Previous research has also emphasized that improvements in strength during the early stages of training cannot be explained solely by changes in muscle size.

The present findings are also consistent with evidence that meaningful strength gains can occur with different resistance-training prescriptions. Although heavier loads are generally advantageous for maximal strength, lower and moderate loads can also produce substantial strength improvements when training volume and effort are adequate.(1, 5, 15, 16) Therefore, the absence of a significant difference between the two groups does not suggest that the training protocols were ineffective. Rather, it indicates that within the 8 week period examined in this study, both approaches were capable of producing comparable improvements in maximal strength.

No significant sex effect was identified in the present study ($F(1,96)=3.105$, $p=0.081$) and the group×sex interaction was also not significant ($F(1,96)=0.232$, $p=0.631$). These findings suggest that males and females did not respond differently to the two training approaches. Although males commonly demonstrate greater absolute upper-body strength because of differences in body size and muscle mass, evidence indicates that relative responses to resistance training can be broadly similar between sexes.(7, 8, 17-19) A recent Bayesian meta-analysis found that absolute muscle size increases may slightly favor males whereas relative hypertrophic changes were similar between males and females.(8) The present findings therefore support the interpretation that sex did not significantly modify the strength response to either training strategy in this sample.

The A/G ratio showed a significant change over time ($F(1,98)=10.632$, $p=0.002$) but neither the group effect ($p=0.793$) nor the time×group interaction ($p=0.928$) was significant. Furthermore, the correlation between post-intervention A/G ratio and strength gain was very weak and non-significant (Spearman $\rho=0.043$, $p=0.668$). Thus, although the A/G ratio changed during the intervention, the present data do not support a direct relationship between this biochemical measure and improvement in strength. Albumin and globulin concentrations can be affected by several physiological and nutritional factors, meaning that the A/G ratio should not be regarded as a specific indicator of resistance-training adaptation.(20)

CRP remained negative (<0.6) at both assessment points. Consequently, no detectable change in CRP status was observed following the intervention. This finding should be interpreted in the context of the study population, because the participants were healthy young adults. Previous studies have reported reductions in CRP following exercise, particularly in individuals with elevated inflammatory or metabolic risk, but responses are influenced by baseline inflammatory status, age, body composition and exercise characteristics.(21) Therefore, the absence of a change in CRP in the present study does not indicate that resistance training cannot influence inflammatory markers; rather, it suggests that no measurable change in CRP status occurred under the conditions examined.

The NCS findings provide a further important aspect of the present study. Most sensory and motor NCS parameters did not demonstrate significant changes over time or between groups. However, significant time×group interactions were observed for right median sensory onset latency ($p=0.014$) and left median motor elbow latency ($p=0.008$). Because these findings were isolated among a large number of NCS comparisons, they should be interpreted cautiously rather than considered evidence of a generalized improvement in peripheral nerve conduction. Similarly, the absence of significant changes in most NCS variables suggests that the increase in strength was not accompanied by broad measurable changes in peripheral nerve conduction during the 8-week period.

Overall, the findings indicate that both resistance training approaches were effective for improving maximal upper extremity strength but neither approach demonstrated clear superiority. The lack of significant EEG changes and the largely unchanged NCS measures further suggest that improved 1RM performance cannot be explained by measurable changes in these neurophysiological outcomes alone. Instead, early strength development is likely to reflect a combination of muscular adaptation, neural coordination, movement familiarity and task-specific learning.(4) The significant change in A/G ratio occurred independently of strength gain while CRP status remained unchanged. Future studies using longer intervention periods, direct measures of muscle hypertrophy, quantitative CRP concentrations and more specific measures of cortical and neuromuscular adaptation may help clarify the mechanisms underlying resistance training induced strength development.

5. CONCLUSION

Maximal upper extremity strength has been significantly improved after 8 weeks of resistance training in healthy adults. There were no significant sex differences and strength gains were similar for both hypertrophy-oriented and 1RM training. The A/G ratio changed over time but was not related to strength gain while CRP remained unchanged. In general, strength gains seem to be the result of various neuromuscular and task specific changes, not any one training method.

Acknowledgement
None to declare.

Disclosure
None to declare.

Conflict of Interest
None to declare.

REFERENCES

[1] Currier BS, Mcleod JC, Banfield L, Beyene J, Welton NJ, D'Souza AC, et al. Resistance training prescription for muscle strength and hypertrophy in healthy adults: a systematic review and Bayesian network meta-analysis. British Journal of Sports Medicine. 2023;57(18):1211-20.

[2] Siddique U, Rahman S, Frazer AK, Pearce AJ, Howatson G, Kidgell DJ. Determining the Sites of Neural Adaptations to Resistance Training: A Systematic Review and Meta-analysis: U. Siddique et al. Sports medicine. 2020;50(6):1107-28.

[3] Kidgell DJ, Bonanno DR, Frazer AK, Howatson G, Pearce AJ. Corticospinal responses following strength training: a systematic review and meta-analysis. European Journal of Neuroscience. 2017;46(11):2648-61.

[4] Gomez-Feria J, Martin-Rodriguez JF, Mir P. Corticospinal adaptations following resistance training and its relationship with strength: A systematic review and multivariate meta-analysis. Neuroscience & Biobehavioral Reviews. 2023;152:105289.

[5] Schoenfeld BJ, Grgic J, Van Every DW, Plotkin DL. Loading recommendations for muscle strength, hypertrophy, and local endurance: a re-examination of the repetition continuum. Sports. 2021;9(2):32.

[6] Grgic J, Schoenfeld BJ, Skrepnik M, Davies TB, Mikulic P. Effects of rest interval duration in resistance training on measures of muscular strength: a systematic review. Sports Medicine. 2018;48(1):137-51.

[7] Roberts BM, Nuckols G, Krieger JW. Sex differences in resistance training: a systematic review and meta-analysis. The Journal of Strength & Conditioning Research. 2020;34(5):1448-60.

[8] Refalo MC, Nuckols G, Galpin AJ, Gallagher IJ, Hamilton DL, Fyfe JJ. Sex differences in absolute and relative changes in muscle size following resistance training in healthy adults: a systematic review with Bayesian meta-analysis. PeerJ. 2025;13:e19042.

[9] Ahmadi S, Gharibi F. Changes in cardiovascular risk factors and inflammatory markers of young, healthy, men after six weeks of moderate or high intensity resistance training. The Journal of sports medicine and physical fitness. 2011;51(4):695-700.

[10] Daray LA, Henagan TM, Zanovec M, Earnest CP, Johnson LG, Winchester J, et al. Endurance and resistance training lowers C-reactive protein in young, healthy females. Applied Physiology, Nutrition, and Metabolism. 2011;36(5):660-70.

[11] Tani S, Imatake K, Suzuki Y, Yagi T, Takahashi A. Association of aerobic exercise habits with higher albumin-globulin ratio and lower cellular immune-inflammatory markers: implication of the preventive effect of aerobic exercise on atherosclerotic cardiovascular disease. Heart and Vessels. 2025;40(6):509-22.

[12] El-Kotob R, Ponzano M, Chaput J-P, Janssen I, Kho ME, Poitras VJ, et al. Resistance training and health in adults: an overview of systematic reviews. Applied Physiology, Nutrition, and Metabolism. 2020;45(10):S165-S79.

[13] Grgic J, Schoenfeld BJ, Orazem J, Sabol F. Effects of resistance training performed to repetition failure or non-failure on muscular strength and hypertrophy: A systematic review and meta-analysis. Journal of sport and health science. 2022;11(2):202-11.

[14] Grgic J, Lazinica B, Schoenfeld BJ, Pedisic Z. Test–retest reliability of the one-repetition maximum (1RM) strength assessment: a systematic review. Sports medicine-open. 2020;6(1):31.

[15] Schoenfeld BJ, Grgic J, Ogborn D, Krieger JW. Strength and hypertrophy adaptations between low-vs. high-load resistance training: a systematic review and meta-analysis. The Journal of Strength & Conditioning Research. 2017;31(12):3508-23.

[16] Morton RW, Oikawa SY, Wavell CG, Mazara N, McGlory C, Quadrilatero J, et al. Neither load nor systemic hormones determine resistance training-mediated hypertrophy or strength gains in resistance-trained young men. Journal of applied physiology. 2016;121(1):129-38.

[17] Nuzzo JL. Narrative review of sex differences in muscle strength, endurance, activation, size, fiber type, and strength training participation rates, preferences, motivations, injuries, and neuromuscular adaptations. The Journal of Strength & Conditioning Research. 2023;37(2):494-536.

[18] Haizlip K, Harrison B, Leinwand L. Sex-based differences in skeletal muscle kinetics and fiber-type composition. Physiology. 2015.

[19] Ansdell P, Thomas K, Hicks KM, Hunter SK, Howatson G, Goodall S. Physiological sex differences affect the integrative response to exercise: acute and chronic implications. Experimental physiology. 2020;105(12):2007-21.

[20] Levitt DG, Levitt MD. Human serum albumin homeostasis: a new look at the roles of synthesis, catabolism, renal and gastrointestinal excretion, and the clinical value of serum albumin measurements. International journal of general medicine. 2016:229-55.

[21] Wang Y-H, Jiang H-C, Luo D-L, Jiang B-G, Shen Y-J, Zhou H-H, et al. Effect of resistance exercise on peripheral inflammatory biomarkers in healthy adults: a meta-analysis of randomized controlled trials. European Review for Medical & Pharmacological Sciences. 2022;26(21):7742.