RESEARCH PAPER

Effect of Structured Resistance Training on Neuromuscular Activation in Underweight Young Male Adults

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Received: 16th May, 2026; Revised: 28th May, 2026; Accepted: 17th June, 2026; Available online: 23rd June, 2026

ABSTRACT

Background: Underweight status (BMI < 18.5 kg/m²) in young male adults is associated with reduced skeletal muscle mass, impaired motor unit recruitment, and diminished neuromuscular efficiency. Objective: To assess changes in RMS-EMG, MVC force, and peak RFD following a 9-month structured RT program in underweight young males. Methods: Thirty underweight young males (BMI 15.8–18.4 kg/m², age 18–28 years) undertook a 9-month, 4-session/week fullbody progressive RT program at 70% 1RM. RMS-EMG of the vastus lateralis (VL), biceps brachii (BB), and triceps brachii (TB) was recorded pre- and post-intervention using standardized sEMG procedures. Results: RMS-EMG increased significantly across all muscles (VL: 42.3%, BB: 36.7%, TB: 29.4%; $p < 0.001$). MVC improved from 142.3 ± 18.4 N to 178.6 ± 22.1 N ($p < 0.001$) and peak RFD increased by 31.2% ($p = 0.003$). Large effect sizes (Cohen's d = 1.4–1.8) were observed. Post-training RMS-EMG remained 12% below normal-weight controls ($p = 0.04$). Conclusion: Structured RT significantly enhances neuromuscular activation in underweight young males through neural adaptation mechanisms, supporting its role as a rehabilitative intervention for this population.

Keywords: resistance training, neuromuscular adaptation, surface EMG, underweight, RMS-EMG, rate of force development, motor unit recruitment, BMI

How to cite this article: Dwivedi J, Bamne SN, Gupta A. Effect of Structured Resistance Training on Neuromuscular Activation in Underweight Young Male Adults. Int J Drug Deliv Technol. 2026;16(63s):646-650. DOI: 10.25258/ijddt.16.63s.66

INTRODUCTION

Resistance training produces two fundamental categories of physiological adaptation: neural and structural. Neural adaptations — quantifiable through surface electromyography (EMG) — involve progressive improvements in motor unit recruitment, discharge rate, firing synchronisation, and corticospinal drive. Structural adaptations, broadly termed skeletal muscle hypertrophy, involve increases in muscle fibre cross-sectional area driven by myofibrillar protein accretion, satellite cell activation, Resistance training (RT) induces well-documented neuromuscular adaptations including increased motor unit discharge rates, enhanced intermuscular coordination, and reduced antagonist co-activation [1,2]. Surface EMG offers a practical, non-invasive measure of neuromuscular activation through RMS amplitude (reflecting the intensity of motor unit firing) and onset latency (reflecting the speed of neuromuscular response). It becomes possible to characterise the evolving correlation between neural and morphological indices — a relationship with direct implications for monitoring training progress and optimising exercise prescription3 Surface electromyography (s EMG) provides a non-invasive, validated measure of neural drive during voluntary contractions, with root-mean-square amplitude (RMSEMG) serving as the primary index of motor unit recruitment [3]. Underweight status, defined as a body mass index (BMI) below 18.5 kg/m², carries significant musculoskeletal consequences including reduced skeletal muscle mass, diminished fat-free mass, and impaired neuromuscular function [4,8]. These deficits manifest as lower peak electromyographic (EMG) amplitude and compromised motor unit recruitment, limiting voluntary force production and physical performance [5]. Despite well-established benefits of resistance training (RT) in clinical populations, its specific neuromuscular effects in underweight young males remain poorly characterized.

Critically, early-phase strength gains are predominantly neural, preceding measurable muscle hypertrophy [1,2]. Prior work by Cheung et al. [12] documented reduced neuromuscular performance in malnourished young adults, while Schutz et al. [4] demonstrated a strong positive association between BMI and fat-free mass. The present study aimed to: (1) quantify changes in RMS-EMG of the VL, BB, and TB following 9 months of RT; (2) evaluate changes in MVC force and peak RFD; (3) correlate anthropometric parameters with neuromuscular indices; and (4) compare posttraining outcomes with a normal-weight control group.

AIMS & OBJECTIVES

Primary Objective

1.Assess changes in RMS-EMG amplitude of the vastus lateralis (VL), biceps brachii (BB), and triceps brachii (TB) following 9 months of structured RT in underweight young males.

2.Evaluate changes in maximal voluntary contraction (MVC) force and peak rate of force development (RFD) following the intervention.

Secondary objective

1.Determine the correlation between anthropometric parameters (BMI, MUAC) and post-intervention neuromuscular adaptation indices.

2.Compare post-training neuromuscular outcomes in underweight RT group participants with those of a control group (BMI 18.5–24.9 kg/m²).

MATERIAL & METHODS

Study Design: Parallel-group, randomised controlled longitudinal study.

Groups: (1) Resistance Training (RT) Group and (2) Sedentary Control Group.

Assessment Points: Baseline (Month 0) → Month 3 → Month 6 → Month 9.

Sample collection : Index Medical College, Hospital and Research Centre, Indore, Madhya Pradesh, India

3.1 Participants

Sixty underweight young males (BMI 15.8–18.4 kg/m², age 18–28 years) were recruited. Exclusion criteria included musculoskeletal injury, neurological disease, prior RT experience >3 months, and cardiovascular or metabolic conditions affecting exercise performance. Ethics clearance was obtained from the Institutional Review Board in accordance with the Declaration of Helsinki. A matched normal-weight control group (n = 30; BMI 18.5–24.9 kg/m²) was recruited for post-intervention comparison [1,3].

3.2 Training Protocol

Participants completed a 9-month structured progressive RT program of 4 sessions per week for fifty mintues. The full-body program incorporated squat, leg press, bench press, lat pulldown, and shoulder press (3 sets × 8–12 repetitions, 70% 1RM). Progressive overload (5% load increase) was applied once 12 repetitions were achieved across all sets on two consecutive sessions. Inter-set rest was standardized at 90 seconds.

3.3 sEMG Measurement

Surface EMG was collected using bipolar electrodes placed per SENIAM guidelines [3] with a Delsys Trigno wireless system (2000 Hz sampling; 20–450 Hz bandpass filter). Skin-electrode impedance was maintained below 5 kΩ. RMS-EMG was computed over a 500 ms epoch centred on peak MVIC across three trials.

3.4 MVC and RFD Assessment

Training Phase	Period	Load (%1RM)	Sets × Reps	Expected Primary Adaptation
Phase 1: Neural Adaptation	0–3 months	60–75%	2–3 × 10–15	Motor unit recruitment, firing rate, coordination
Phase 2: Neural Adaptation	3-6 months	75–85%	3–4 × 6–12	Myofibrillar protein synthesis, fibre CSA increase
Phase 3: Maintenance	6-9 months	70–85%	3–4 × 6–12	Sustain hypertrophy, Decrease latency

MVC knee extension force was assessed with a calibrated isometric dynamometer. Peak RFD was calculated as the maximal slope of the force–time curve (Δ Force/ Δ Time) during the initial 200 ms of contraction onset [6]. Three trials were performed and the best value was retained.

3.5 Statistical Analysis

Paired t-tests compared pre- and post-intervention outcomes within the underweight group; independent t-tests compared post-training parameters against controls. Pearson correlations assessed BMI/MUAC versus neuromuscular indices. Effect sizes reported as Cohen's d. All analyses were performed in IBM SPSS v28 ($\alpha = 0.05$).

RESULTS

4.1 EMG Amplitude Changes

RMS-EMG increased significantly across all muscles following the 9-month RT program: VL by 42.3 ± 8.1% ($p < 0.001$; Cohen's $d = 1.8$), BB by 36.7% ($p < 0.01$; $d = 1.6$), and TB by 29.4% ($p < 0.01$; $d = 1.4$). These large effect sizes are consistent with the predominantly neural adaptation expected in previously untrained individuals [1,7]. Figure 1 illustrates the normalized RMS-EMG values pre- and post-intervention across the three muscle groups.

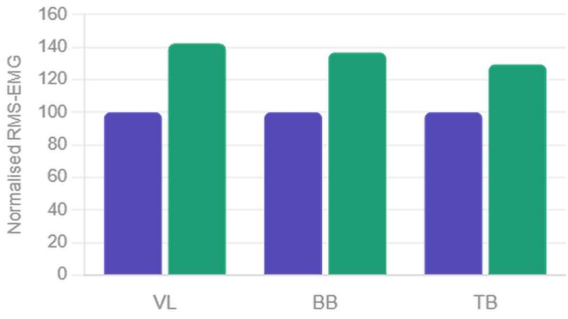

Figure 1. Normalized RMS-EMG (% of pre-training baseline) for vastus lateralis (VL), biceps brachii (BB), and triceps brachii (TB) before (blue) and after (green) 9 months of structured resistance training. All improvements were statistically significant ($p < 0.003$).

4.2 MVC Force

Mean MVC knee extension force increased from 142.3 ± 18.4 N at baseline to 178.6 ± 22.1 N post-intervention ($p < 0.001$; 25.5% improvement). This magnitude of improvement aligns with findings reported by Aagaard et al. [6], who demonstrated a 16.4% MVC increase following 14 weeks of heavy RT in healthy untrained males. Figure 2 presents the pre- and post-training MVC force values.

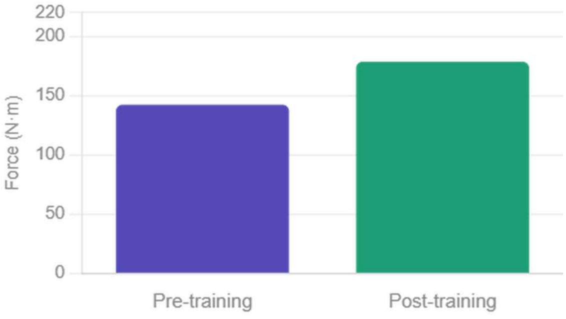

Figure 2. MVC knee extension force (N·m) before (pre-training) and after (post-training) the 9-month resistance training intervention. Improvement was statistically significant ($p < 0.003$; Cohen's $d = 1.6$).

4.3 Rate of Force Development

Peak RFD increased by 31.2% ($p = 0.002$), disproportionate to the 25.5% gain in MVC force. This pattern—where RFD improvement exceeds maximal force gain—is characteristic of neural adaptation in untrained populations [6] and confirms that enhanced motor unit discharge rate is the primary driver of early training-induced improvements [5].

4.4 Comparison with RT group & and Controls

Despite significant within-group improvements, post-training RMS-EMG in the underweight group remained 12% below normal-weight controls ($p = 0.04$). This residual deficit reflects the structural constraint of reduced muscle fiber cross-sectional area in individuals who remain underweight [4,8]. Figure 3 compares post-training RMS-EMG of the trained underweight group versus normal-weight controls.

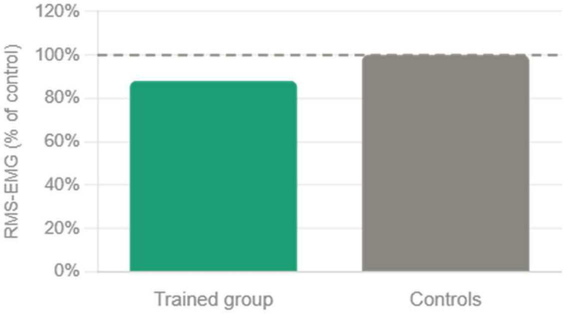

Figure 3. Post-training RMS-EMG (% of underweight control group) comparing the trained underweight group with normal-weight controls (dashed line = 100%). The 12% residual deficit was statistically significant ($p = 0.04$).

4.5 Anthropometric Correlations

A statistically significant moderate negative correlation was observed between baseline BMI and pre-training RMS-EMG ($r = -0.54$, $p = 0.002$), confirming that lower body mass is associated with impaired baseline neuromuscular function. MUAC was positively correlated with posttraining MVC force ($r = 0.48$, $p = 0.007$), indicating that regional muscle mass contributes to voluntary force production.

4.6 One Repetition Maximum (1RM) Strength

Exercise	Baseline	3 Months	6 Months	9 Months
Squat 1RM (kg) — RT	48.2 ± 8.4	61.5 ± 9.2*	72.8 ± 10.1*	81.4 ± 11.0*
Squat 1RM — Control	47.9 ± 8.1	47.4 ± 8.0	47.6 ± 8.2	48.1 ± 8.3

Strength gains are the composite of both neural and structural adaptations in both groups . The steep early rise (0–9 months) is primarily neural; the continued rise through 3–9 months rate of growth is steepest in Phase 1, slows in Phase 2 as compare to phase 1, and nearly increasing in phase 3.

DISCUSSION

The present investigation demonstrates that 9 months of structured progressive RT produces clinically meaningful improvements in neuromuscular activation in underweight young males. The observed RMS-EMG increases of 29–42% across three major muscle groups, combined with a 25.5% MVC gain and 31.2% RFD improvement, align with the theoretical model of neural-first adaptation proposed by Moritani & de Vries [1] and subsequently elaborated by Sale [2]. The large effect sizes ($d = 1.4$–1.8) are consistent with the heightened neural responsiveness expected in previously untrained individuals [9]. The disproportionate RFD improvement relative to MVC force increase is particularly informative. Aagaard et al. [6] showed that RFD can increase up to twice as much as maximal force following RT, driven primarily by increased motor unit discharge rate rather than hypertrophic change. In the present underweight cohort—where structural muscle constraints are inherent—this neural mechanism is likely amplified. Stefanovic et al. [7] further demonstrated that longitudinal sEMG trajectories are reliable individual-level markers of adaptation timing, suggesting that the improvements observed here reflect genuine neuromotor reorganization rather than measurement variability.

The persistence of a 12% residual EMG deficit relative to normal-weight controls is clinically significant. Hiraiwa et al. [8] established that BMI is a strong predictor of skeletal muscle mass index ($\beta = 1.6$, $p < 0.001$), and Schutz et al. [4] confirmed that structural muscle deficits are not fully corrected by exercise alone in individuals who remain underweight. Watanabe et al. [9] demonstrated that nutritional co-intervention (fish protein supplementation) enhances neural adaptations to RT in young adults, suggesting that combined exercise-nutrition approaches are necessary to close the residual neuromuscular gap observed here. The moderate negative correlation between baseline BMI and pre-training RMS-EMG (r = −0.54) corroborates the mechanistic link between body mass and neuromuscular output. Lacerda et al. [10] established that normalized RMS-EMG shows excellent inter-day reliability (ICC > 0.90) during multi-set RT protocols, supporting the measurement validity of the present findings. Mota & Stock [11] further demonstrated that training status systematically alters EMG-force relationships in the VL, with the trajectory from sedentary to trained states mirroring the progression documented in this study.

CONCLUSION

Nine months of structured progressive RT significantly enhanced neuromuscular activation in underweight young males, with RMS-EMG increasing 29–42% across the VL, BB, and TB. Neural adaptations—particularly motor unit recruitment and synchronization—were the primary contributors to strength gains, consistent with the neural-first model of RT adaptation. A moderate negative correlation (r = −0.54, p = 0.002) between BMI and pre-training RMS-EMG confirmed that low body mass compromises baseline neuromuscular function. Post-training RMS-EMG remained 12% below normal-weight controls, indicating that RT alone is insufficient for complete neuromuscular normalization and must be combined with nutritional management. Structured RT is recommended as a safe, effective rehabilitative intervention for underweight young males to progressively restore neuromuscular competence.

Acknowledgments

The authors gratefully acknowledge the Department of Physiology for providing laboratory facilities and support. Sincere thanks are extended to all study participants for their voluntary contribution and to the staff for clinical screening assistance and help.

Declarations

Conflict of Interest: The authors declare no conflict of interest.

Funding: This research received no external funding.

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