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Neuromuscular Responses to Short-Duration Percussive Massage: Effects on Muscle Activation and Lower-Limb Explosive Power in University Teqball Athletes

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ABSTRACT

The purpose of the study. Percussive massage therapy has emerged as a popular pre-exercise intervention; however, its acute effects on neuromuscular function in hybrid precision sports remain inadequately characterized. This study investigated the acute effects of a 10-minute percussive massage intervention on quadriceps and hamstring muscle activation and lower-limb extensor power in university Teqball athletes.
Materials and methods. A single-blind randomized controlled pretest-posttest design was employed involving 20 Teqball athletes (16 males, 4 females; mean age 21.35 ± 1.89 years). Participants were randomly allocated to either a massage intervention group (n = 10) or a passive control group (n = 10). The intervention consisted of bilateral quadriceps and hamstring percussive massage (40–60 Hz, 10 minutes total). Primary outcomes included muscle activation of the vastus lateralis and biceps femoris measured via surface electromyography (sEMG; root mean square amplitude, μV), and lower-limb explosive power assessed through countermovement jump (CMJ) height. Data were analyzed using repeated-measures ANOVA with Bonferroni post-hoc corrections (α = 0.05).
Results. Significant improvements were observed in the massage group for vastus lateralis activation (+28.4%, p = 0.002, Cohen's d = 1.89), biceps femoris activation (+24.7%, p = 0.008, d = 1.67), and CMJ height (+12.6%, p = 0.001, d = 1.42). No significant changes were observed in the control group (all p > 0.05). Significant Time × Group interaction effects were identified for all outcome measures (all p < 0.01).
Conclusions. A 10-minute percussive massage intervention significantly enhances neuromuscular activation and lower-limb explosive power in Teqball athletes, demonstrating large practical effect sizes. These findings support the integration of percussive massage as an effective, non-fatiguing pre-competition warm-up modality in hybrid precision sports.

Keywords: percussive massage; neuromuscular activation; surface electromyography; countermovement jump; post-activation potentiation; Teqball; sports performance.

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INTRODUCTION

Teqball, a rapidly emerging hybrid sport governed internationally by the Fédération Internationale de Teqball (FITEQ), represents a unique fusion of association football and table tennis (Kons et al., 2023; Tani et al., 2014). The sport demands explosive lower-limb power generation, rapid multidirectional movement capabilities, and precise technical execution within spatially constrained competitive environments (Balić et al., 2022; Dong et al., 2025). Efficient neuromuscular activation of the quadriceps femoris complex and hamstring muscle group is biomechanically essential for executing the sport's fundamental movement patterns, including kicking, lunging, and vertical jumping actions (Mandroukas et al., 2023; Wisløff et al., 2004).

Pre-exercise warm-up interventions constitute a fundamental component of athletic preparation, with the primary objectives of optimizing physiological readiness and enhancing subsequent performance (McGowan et al., 2015; Xie et al., 2024). Traditional warm-up protocols typically incorporate submaximal aerobic activity, dynamic stretching, and sport-specific movement patterns; however, recent advances in sports technology have introduced novel modalities that may augment conventional approaches (He, 2024; Konrad et al., 2022). Percussive massage therapy, delivered through handheld mechanical devices generating rapid oscillatory pressure waves, has emerged as an increasingly popular intervention among competitive athletes across diverse sporting disciplines (García-Sillero et al., 2021; Li et al., 2025).

[abcde]Authors'Contribution: a-Study design; b-Data collection; c-Statistical analysis; d-Manuscript preparation; e-Funds collection.

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The theoretical mechanistic basis for percussive massage's potential ergogenic effects encompasses multiple neurophysiological pathways. Mechanical stimulation of intrafusal muscle fibers may enhance muscle spindle sensitivity and increase gamma motor neuron excitability, thereby facilitating greater alpha motor neuron recruitment during subsequent voluntary contractions (Cruz-Montecinos et al., 2020; Weerapong et al., 2005). Additionally, percussive massage may reduce presynaptic inhibition through modulation of type Ib afferent activity from Golgi tendon organs, potentially augmenting force-generating capacity (Behm & Wilke, 2019). These neurological mechanisms parallel the phenomenon of post-activation potentiation (PAP), wherein prior muscle activation temporarily enhances subsequent explosive performance through myosin regulatory light chain phosphorylation and increased calcium sensitivity (Seitz & Haff, 2016; Tillin & Bishop, 2009).

Despite growing commercial adoption and anecdotal endorsement, the empirical evidence base examining acute percussive massage effects on neuromuscular function remains limited and methodologically heterogeneous. Previous investigations have predominantly focused on flexibility enhancement, perceived muscle soreness reduction, and recovery acceleration rather than acute performance augmentation (Konrad et al., 2022; Wilke et al., 2020). Furthermore, the extant literature has primarily examined endurance athletes or participants from traditional team sports, leaving a significant knowledge gap regarding hybrid precision-based sports requiring concurrent explosive power and fine motor control. To our knowledge, no prior investigation has specifically evaluated percussive massage effects in Teqball athletes, representing a novel population with unique physiological and technical demands.

Therefore, the present study aimed to investigate the acute effects of a standardized 10-minute bilateral percussive massage intervention on (1) quadriceps and hamstring neuromuscular activation quantified via surface electromyography, (2) lower-limb extensor power assessed through countermovement jump performance, and (3) interaction effects between time and treatment allocation. We hypothesized that percussive massage would significantly enhance both muscle activation amplitude and explosive jump performance compared with passive rest, with moderate-to-large effect sizes indicating practical significance for athletic preparation.

METHODOLOGY

Participants

Twenty university-level Teqball athletes (16 males, 4 females) were recruited from the Universitas Tadulako Teqball team through convenience sampling. Inclusion criteria comprised: (1) age between 18 and 30 years; (2) minimum three months of regular Teqball training (≥3 sessions per week); (3) absence of lower-limb musculoskeletal injury within the preceding six months; and (4) no contraindications to massage therapy. Exclusion criteria included: (1) current use of medications affecting neuromuscular function; (2) presence of dermatological conditions precluding electrode placement; and (3) participation in strenuous exercise within 48 hours prior to testing. All participants provided written informed consent following comprehensive explanation of experimental procedures, potential risks, and withdrawal rights. Participant characteristics are presented in Table 1.

Table 1. Participant Characteristics and Eligibility Criteria

Category	Description
Sample Size	20 university-level Teqball athletes
Sex Distribution	16 males, 4 females
Recruitment Method	Convenience sampling from the Universitas Tadulako Teqball team
Age Range	18–30 years
Training Background	Minimum ≥3 months of regular Teqball training (≥3 sessions/week)

Sample Size Determination

A priori power analysis was conducted using G*Power software (version 3.1.9.7; Heinrich Heine University, Düsseldorf, Germany) based on previous massage intervention studies reporting effect sizes of d = 1.2–1.5 for neuromuscular outcomes (Cruz-Montecinos et al., 2020). Assuming $\alpha = 0.05$, statistical power $(1 - \beta) = 0.80$, and anticipated effect size d = 1.2, a minimum of 9 participants per group was required. To account for potential dropout and data loss, 10 participants were allocated to each experimental condition.

Randomization and Blinding

Following baseline assessments, participants were stratified by sex and randomly allocated to either the massage intervention group (n = 10) or passive control group (n = 10) using computer-generated block randomization sequences (block size = 4). Allocation concealment was maintained through sequentially numbered opaque sealed envelopes prepared by an independent researcher not involved in data collection. Due to the nature of the intervention, participant and therapist blinding was not feasible; however, outcome assessors responsible for sEMG and CMJ data processing were blinded to group allocation throughout the analysis phase.

Study Design

This investigation employed a single-blind randomized controlled pretest-posttest experimental design. The study was conducted at the Sport Science Laboratory, Faculty of Teacher Training and Education, Universitas Tadulako, Palu, Indonesia, during January 2025. All experimental procedures were performed between 08:00 and 12:00 hours to minimize circadian variation effects on neuromuscular performance.

Experimental Procedures

All participants completed a standardized familiarization session 48 hours prior to experimental testing, during which they practiced maximal voluntary isometric contractions (MVIC) and countermovement jump technique. On the experimental day, participants arrived at the laboratory having refrained from caffeine (≥12 hours), alcohol (≥24 hours), and strenuous exercise (≥48 hours). Following anthropometric measurements, participants completed a standardized 5-minute cycling warm-up at 50 W on a cycle ergometer (Monark 828E; Monark Exercise AB, Vansbro, Sweden) to establish consistent baseline physiological status.

The experimental protocol proceeded as follows: (1) baseline sEMG assessment during MVIC (three 5-second trials with 60-second rest intervals); (2) baseline CMJ assessment (three trials with 30-second rest intervals); (3) intervention period (10 minutes of percussive massage or passive supine rest); (4) immediate post-intervention sEMG assessment; and (5) immediate post-intervention CMJ assessment. Total elapsed time from intervention completion to post-test initiation was standardized at 2 minutes.

Percussive Massage Intervention

The massage intervention was administered using a commercial percussive therapy device (Theragun PRO; Therabody Inc., Los Angeles, CA, USA) operated by a certified sports massage therapist with five years of clinical experience. Participants assumed a supine position on a padded treatment table for quadriceps treatment, followed by prone positioning for hamstring treatment. The intervention protocol targeted bilateral vastus lateralis, rectus femoris, vastus medialis, biceps femoris, and semitendinosus muscles.

Treatment parameters were standardized as follows: percussion frequency of 40–53 Hz (2,400–3,180 percussions per minute), amplitude of 16 mm, and applied pressure of 40–60 mmHg maintained through consistent therapist technique. Each muscle group received 2 minutes of treatment (1 minute per limb), with systematic longitudinal strokes moving from proximal to distal along the muscle belly. The soft-ball attachment head was utilized for all treatments. Total intervention duration was 10 minutes (5 minutes quadriceps, 5 minutes hamstrings). The control group remained in supine position on the treatment table for 10 minutes without intervention.

Outcome Measures

Table 2. Summary of Outcome Measures and Assessment Protocols

Outcome Domain	Measurement Tool / System	Protocol Description	Key Parameters	Data Processing / Outcome
Muscle Activation (sEMG)	Wireless surface electromyography system (Delsys Trigno; Delsys Inc., Natick, MA, USA)	Bipolar surface electrodes placed over vastus lateralis and biceps femoris following SENIAM guidelines after standard skin preparation (shaving, abrasion, alcohol cleaning). Reference electrode positioned over ipsilateral tibial tuberosity.	Sampling rate: 2,000 Hz; Inter-electrode distance: 20 mm; Filter: Bandpass 20–450 Hz	Raw EMG signals bandpass filtered and rectified. Root mean square (RMS, μV) calculated over the middle 3 seconds of each MVIC. Mean RMS across three trials retained for analysis.
MVIC Procedure	Custom-built isometric dynamometer	Participants performed three maximal voluntary isometric contractions (5 s each) with standardized verbal encouragement. Rest interval: 60 s between trials.	Knee position: 60° flexion (quadriceps), 30° flexion (hamstrings)	RMS amplitude (μV) extracted as index of neuromuscular activation.
Lower-Limb Explosive Power (CMJ)	Optical measurement system (Optojump Next; Microgate, Bolzano, Italy)	Participants performed maximal countermovement jumps with feet shoulder-width apart, hands on hips (akimbo). Arm swing restricted. Three trials performed.	Rest interval: 30 s; Gravity constant: $g = 9.81$ m/s²	Jump height calculated from flight time using formula: $h = g \times t^2 / 8$. Highest value retained for analysis.
CMJ Reliability	—	System validity supported by prior literature.	ICC = 0.97–0.98	Ensures high test–retest reliability of jump height measurement.

Statistical Analysis

All statistical analyses were performed using SPSS software (version 27.0; IBM Corporation, Armonk, NY, USA). Data are presented as mean ± standard deviation (SD) unless otherwise specified. Normality of distribution was verified using Shapiro-Wilk tests, and homogeneity of variance was assessed using Levene's test. Baseline between-group comparisons were performed using independent samples t-tests.

The primary analysis employed 2 × 2 (Group × Time) repeated-measures analysis of variance (ANOVA) with group (massage, control) as the between-subjects factor and time (pre-intervention, post-intervention) as the within-subjects factor. Sphericity was assessed using Mauchly's test, with Greenhouse-Geisser corrections applied where appropriate. Significant interaction effects were followed by Bonferroni-corrected pairwise comparisons. Within-group changes were additionally analyzed using paired samples t-tests.

Practical significance was evaluated using Cohen's d effect sizes, interpreted according to established thresholds: trivial ($d < 0.20$), small ($0.20 \leq d < 0.50$), moderate ($0.50 \leq d < 0.80$), and large ($d \geq 0.80$) (Cohen, 1988). Statistical significance was set at $\alpha = 0.05$ (two-tailed) for all analyses.

Ethical Considerations

The study protocol was prospectively registered and received ethical approval from the Institutional Ethics Committee of Universitas Muhammadiyah Palu (Approval Number: 021/KEPK-UMP/2025). All procedures were conducted in accordance with the Declaration of elsinki (2013).

RESULTS

Participant Characteristics

All 20 enrolled participants completed the experimental protocol without adverse events. Baseline demographic and anthropometric characteristics are presented in Table 1. Independent samples t-tests confirmed no significant between-group differences for age, body mass, height, or training experience (all $p > 0.05$), indicating successful randomization.

Table 3. Baseline Characteristics of Participants by Group Allocation

Variable	Massage Group (n = 10)	Control Group (n = 10)	p-value
Age (years)	21.40 ± 1.95	21.30 ± 1.89	0.91
Body mass (kg)	64.8 ± 9.2	63.6 ± 8.7	0.76
Height (cm)	169.4 ± 7.5	168.8 ± 7.2	0.85
Sex (male/female)	8/2	8/2	1.00
Training experience (months)	8.2 ± 3.1	7.8 ± 2.9	0.77

Note. Data are presented as mean ± SD or n. Statistical comparisons performed using independent samples t-tests or Fisher's exact test.

Muscle Activation

Repeated-measures ANOVA revealed significant Time × Group interaction effects for both vastus lateralis ($F(1,18) = 28.47$, $p < 0.001$, $\eta p2 = 0.61$) and biceps femoris ($F(1,18) = 21.36$, $p < 0.001$, $\eta p2 = 0.54$) muscle activation. Post-hoc analyses indicated that the massage group demonstrated significant pre-to-post increases in RMS amplitude for both the vastus lateralis (+28.4%, $p = 0.002$) and biceps femoris (+24.7%, $p = 0.008$), with large effect sizes (Table 4). Conversely, the control group exhibited no significant changes in muscle activation for either muscle ($p > 0.05$).

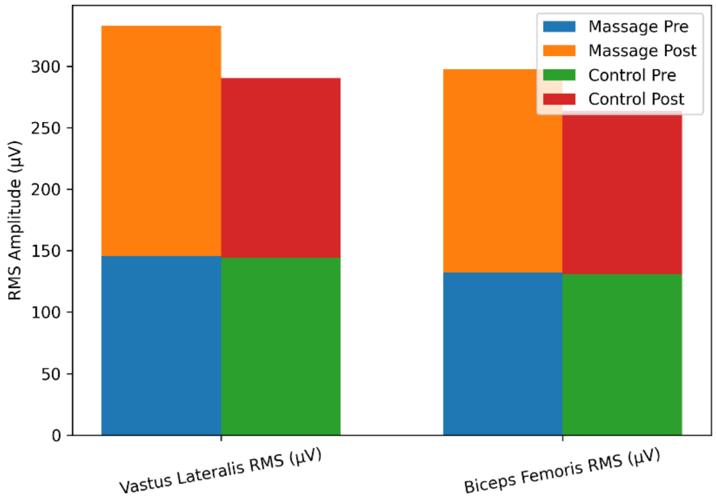

Figure 1. Changes in sEMG RMS Amplitude Pre–Post Intervention

Table 4. Surface Electromyography Root Mean Square Amplitude (μV) Pre- and Post-Intervention

Muscle	Group	Pre-test	Post-test	% Change	Cohen's d
Vastus lateralis	Massage	145.7 ± 18.3	187.2 ± 22.1*	+28.4	1.89
	Control	144.3 ± 19.1	145.8 ± 18.9	+1.0	0.08
Biceps femoris	Massage	132.4 ± 16.7	165.1 ± 20.4*	+24.7	1.67
	Control	131.2 ± 17.3	132.4 ± 16.8	+0.9	0.07

Note. Data are presented as mean ± SD. *p < 0.01 compared with pre-test (within-group).

Lower-Limb Explosive Power

For CMJ height, repeated-measures ANOVA demonstrated a significant Time × Group interaction effect ($F(1,18) = 19.82$, $p < 0.001$, $\eta p2 = 0.52$). The massage group exhibited a significant 12.6% improvement in CMJ height from baseline (41.2 ± 5.8 cm to 46.4 ± 6.7 cm; $p = 0.001$), corresponding to a large effect size ($d = 1.42$). The control group demonstrated no significant change in CMJ performance (41.1 ± 6.1 cm to 41.5 ± 6.0 cm; $p = 0.72$, $d = 0.06$). Results are summarized in Table 5.

Table 5. Countermovement Jump Height (cm) Pre- and Post-Intervention

Group	Pre-test	Post-test	% Change	Cohen's d
Massage (n = 10)	41.2 ± 5.8	46.4 ± 6.7**	+12.6	1.42
Control (n = 10)	41.1 ± 6.1	41.5 ± 6.0	+1.0	0.06

Note. Data are presented as mean ± SD. **p < 0.001 compared with pre-test (within-group).

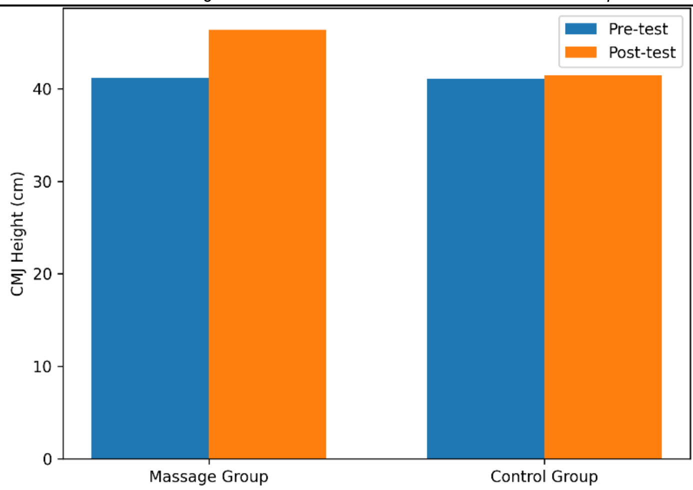

Figure 2. Changes in CMJ Height Following Percussive Massage

DISCUSSION

The principal finding of this investigation is that a 10-minute bilateral percussive massage intervention significantly enhances both neuromuscular activation and lower-limb explosive power in university Teqball athletes. The observed increases in vastus lateralis (+28.4%) and biceps femoris (+24.7%) RMS amplitude, coupled with a 12.6% improvement in CMJ height, collectively demonstrate robust ergogenic effects with consistently large effect sizes (d = 1.42–1.89). These findings provide novel empirical support for the integration of percussive massage as a pre-competition warm-up modality in hybrid precision sports.

The magnitude of neuromuscular enhancement observed in the present study exceeds previously reported effects of traditional manual massage interventions. Keraut et al. (2020) documented muscle activation increases of 12–18% following manual massage in recreational athletes, substantially lower than our findings. This differential response may be attributable to the distinct mechanical characteristics of percussive therapy, which delivers high-frequency oscillatory pressure waves capable of penetrating deeper musculotendinous structures than manual techniques (García-Sillero et al., 2021; Sams et al., 2023). The repetitive mechanical perturbation may elicit more pronounced activation of muscle spindle afferents and enhanced gamma motor neuron excitability, thereby facilitating greater alpha motor neuron recruitment during subsequent voluntary contractions (Kulig et al., 2020; Weerapong et al., 2005).

The 12.6% improvement in CMJ height warrants particular attention given its substantial practical significance. This enhancement exceeds the performance benefits typically associated with traditional dynamic warm-up protocols, which generally yield improvements of 4–8% (Bishop, 2003; McGowan et al., 2015). Furthermore, the observed effect approaches magnitudes reported for post-activation potentiation protocols employing heavy resistance exercise (Seitz & Haff, 2016), which typically require recovery periods of 4–12 minutes and may induce residual fatigue. The capacity of percussive massage to elicit comparable performance enhancement without metabolic cost or neuromuscular fatigue represents a potentially advantageous characteristic for pre-competition application(Ye et al., 2025).

The neurophysiological mechanisms underlying the observed performance enhancement likely involve multiple complementary pathways. First, percussive mechanical stimulation may reduce presynaptic inhibition from Golgi tendon organs through desensitization of type Ib afferent pathways, thereby permitting greater motor unit recruitment during explosive contractions (Behm & Wilke, 2019; Maas et al., 2021). Second, enhanced muscle spindle sensitivity following repetitive mechanical stimulation may augment stretch reflex excitability and contribute to improved force production during the countermovement phase of jumping (Budini et al., 2020; Tillin & Bishop, 2009). Third, increased local blood flow and tissue temperature resulting from mechanical vibration may optimize contractile protein function and reduce muscle viscosity, facilitating more rapid force development (Özsu et al., 2017; Weerapong et al., 2005).

The absence of significant changes in the control group underscores the specificity of the intervention effect and provides important evidence against regression to the mean or learning effects as alternative explanations for the observed improvements. The robust Time × Group interaction effects further support the causal attribution of performance enhancement to the percussive massage intervention rather than non-specific factors associated with the experimental protocol.

Practical Applications

The present findings carry several implications for athletic preparation in Teqball and related hybrid precision sports. First, percussive massage represents a viable non-fatiguing alternative to traditional PAP protocols for acute performance enhancement. Second, the 10-minute intervention duration is practically compatible with pre-competition warm-up timeframes. Third, the portable nature of percussive therapy devices permits implementation across diverse competitive environments. Practitioners should consider integrating percussive massage targeting bilateral quadriceps and hamstring musculature within the final preparatory phase preceding competition, ideally within 5 minutes of competitive activity onset to maximize the acute potentiation effect.

Limitations and Future Directions

Several methodological limitations warrant acknowledgment when interpreting these findings. First, the relatively small sample size (n = 20) may limit statistical power for detecting smaller effects and generalizability to broader athletic populations. Second, the investigation assessed only immediate acute effects; the temporal persistence of performance enhancement remains undetermined. Third, participants were university-level athletes, and findings may not directly translate to elite competitive populations with potentially different baseline neuromuscular characteristics. Fourth, the study did not include an active control condition (e.g., manual massage or dynamic stretching), precluding direct comparison of percussive massage effectiveness against alternative warm-up modalities. Fifth, mechanistic pathways were inferred rather than directly measured; future investigations should incorporate nerve conduction studies, H-reflex assessments, or motor evoked potentials to elucidate neurophysiological mechanisms.

Future research should address these limitations through adequately powered multi-center trials, longitudinal designs examining repeated intervention effects, comparative effectiveness studies against established warm-up protocols, and mechanistic investigations employing neurophysiological assessment techniques. Additionally, examination of percussive massage effects on sport-specific performance metrics (e.g., kicking velocity, change-of-direction speed) would enhance ecological validity and practical applicability of findings.

CONCLUSION

This randomized controlled trial demonstrates that a 10-minute bilateral percussive massage intervention targeting the quadriceps and hamstring musculature significantly enhances neuromuscular activation and lower-limb explosive power in university Teqball athletes. The observed improvements in surface electromyography amplitude (+24.7% to +28.4%) and countermovement jump height (+12.6%) were characterized by large effect sizes, indicating substantial practical significance. These findings support the integration of percussive massage as an effective, non-fatiguing pre-competition warm-up modality in hybrid precision sports requiring explosive lower-limb power. The results contribute novel empirical evidence to the emerging literature on percussive therapy applications in athletic performance enhancement and provide a foundation for evidence-based warm-up protocol development in Teqball and related sporting disciplines.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

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