Can boxing liniment boost knee muscle power? A randomized controlled trial in Muay Thai athletes

¿Puede el linimento para boxeo aumentar la fuerza muscular de la rodilla? Un ensayo controlado aleatorizado en atletas de Muay Thai

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Abstract

Objective: To evaluate whether a sport liniment (Namman Muay; NM) acutely improves knee extensor performance versus mineral baby oil control in Muay Thai athletes using isokinetic dynamometry.
Design: An exploratory randomized controlled trial with concealed allocation was conducted involving twenty-four male Muay Thai fighters, who were divided into two groups.
Methods: In the experimental group (NM), a single 5 mL application was applied to the dominant quadriceps, followed by a 20-minute absorption period. The control group (BO) received mineral baby oil with the same procedure. Outcomes measured included relative peak torque (N·m/kg) at 60°/s and 180°/s, torque at 180 ms, total work, first-third work, and peak power (W/kg).
Results: ANCOVA favored NM at 60°/s for relative peak torque [$F(1, 21) = 9.77$, $p = .005$, $\eta p^2 = 0.318$] and torque at 180 ms [$F(1, 21) = 15.08$, $p = .001$, $\eta p^2 = 0.418$]. At 180°/s, effects favored NM for relative peak torque [$F(1, 21) = 4.82$, $p = 0.040$] and torque at 180 ms [$F(1, 21) = 5.29$, $p = .032$]. Peak power at 60°/s also favored NM and is interpreted as exploratory, peak power [$F(1, 21) = 7.15$, $p = .014$, $\eta p^2 = 0.254$]. Exploratory metrics suggested a trend toward higher early torque and early-phase work proportions with NM compared to BO, though differences were not statistically significant.
Conclusions: NM liniment acutely enhances knee extensor torque in Muay Thai athletes, including time-locked torque at 180 ms, with the largest and most consistent effects at 60°/s. Peak power at 60°/s improved but should be interpreted cautiously and considered exploratory. Findings are preliminary and warrant confirmation in adequately powered trials.

Keywords

Ergogenic intervention; isokinetic dynamometry; peak torque; therapeutic intervention; torque–time characteristics.

Resumen

Objetivo: Para evaluó si un linimento deportivo (Namman Muay; NM) mejora de forma aguda el rendimiento de los extensores de la rodilla frente a un control con aceite mineral para bebés en atletas de Muay Thai mediante dinamometría isocinética.
Diseño: Se realizó un ensayo controlado aleatorizado exploratorio con asignación oculta, que incluyó a veinticuatro atletas varones masculinos de Muay Thai, divididos en dos grupos.
Métodos: En el grupo experimental (NM), se aplicó una dosis única de 5 mL del linimento sobre el cuádriceps dominante, seguido de un periodo de absorción de 20 minutos. El grupo control (BO) recibió aceite mineral para bebés con el mismo procedimiento. Los resultados medidos incluyeron el par máximo relativo (N·m/kg) a 60°/s y 180°/s, el par a los 180 ms, trabajo total, trabajo del primer al tercer tercio y potencia máxima (W/kg).
Resultados: El ANCOVA favoreció a NM a 60°/s en el par máximo relativo [$F(1, 21) = 9.77$, $p = .005$, $\eta p^2 = 0.318$] y para el par a 180 ms [$F(1, 21) = 15.08$, $p = .001$, $\eta p^2 = 0.418$]. A 180°/s, los efectos favorecieron a NM para par máximo relativo [$F(1, 21) = 4.82$, $P = 0.040$] y el par a los 180 ms [$F(1, 21) = 5.29$, $p = .032$]. La potencia máxima a 60°/s también favoreció a NM y se interpreta de manera exploratoria [$F(1, 21) = 7.15$, $p = .014$, $\eta p^2 = 0.254$]. Las métricas exploratorias sugirieron una tendencia hacia un mayor par inicial y mayor proporción de trabajo en la fase inicial con NM vs. a BO, aunque las diferencias no fueron estadísticamente significativas.
Conclusiones: El linimento NM mejora de forma aguda el par de los extensores de la rodilla en atletas de Muay Thai, incluido el par sincronizado a los 180 ms, con los efectos más grandes y consistentes a 60°/s. La potencia máxima a 60°/s mejoró, pero debe interpretarse con cautela y considerarse exploratoria. Los hallazgos son preliminares y requieren confirmación en ensayos con suficiente tamaño muestral.

Palabras clave

Intervención ergogénica; dinamometría isocinética; par máximo; intervención terapéutica; características par–tiempo.

Introduction

Muay Thai, a combat sport deeply rooted in culture and discipline, is rapidly gaining global recognition as international tournaments elevate its profile (James et al., 2016; Jukping, 2020). Given the sport's intense physical demands, particularly on the lower limbs, athletes continually seek strategies to optimize both performance and recovery. Muay Thai is striking-dominant, characterized by repeated high-intensity exchanges and explosive lower-limb actions (Raimondo et al., 2019; Gavagan & Sayers, 2017; Myers et al., 2013; Dzakiyyah & Widiyanto, 2025), such as roundhouse and front kicks, defensive checks, and dynamic transitions (Wasacz et al., 2022; Murdock et al., 2023; Trybulski, et al., 2024). Success in competition depends heavily on the ability to generate substantial knee extensor torque and to express this torque rapidly. Accordingly, objective diagnostic tools that quantify not only maximal torque, but also early-phase torque are critical for performance enhancement, injury prevention, rehabilitation, and informed return-to-play decisions in combat athletes (Cimadoro et al., 2019; Iossifidou & Baltzopoulos, 2000; Duarte et al., 2018; Thompson & Xu, 2023; de Lira et al., 2019).

Recent work in other athletic populations has reinforced the broader importance of targeted lower-limb strength interventions for both performance and knee joint health. For example, combined strength and flexibility training has been shown to reduce knee valgus and anterior knee pain in physically active young women (Verdugo et al., 2024), while unilateral hamstring strengthening can reduce inter-limb asymmetries and improve jump performance in sub-elite badminton athletes (Wiriawan et al., 2024). These findings highlight that relatively specific lower-limb strength adaptations can yield meaningful changes in pain, symmetry, and functional performance, supporting the relevance of examining acute interventions that might enhance knee extensor function in combat sports. Although field tests and handheld dynamometry are accessible methods, their results can be influenced by the rater's strength, stabilization techniques, and variability in positioning. Isokinetic dynamometry helps address these limitations by enforcing constant angular velocity and offering reproducible measurements across sessions (Duarte et al., 2018; Tuominen et al., 2023; Drouin et al., 2004; Impellizzeri et al., 2008). Beyond peak torque, total work and first-third work describe an athlete's ability to sustain torque throughout the range of motion, while torque at a fixed early time-point (e.g., 180 ms) indexes rapid torque development—closely aligned with sport-specific actions that unfold within 150–250 ms (Cimadoro et al., 2019; Tuominen et al., 2023; Amaral et al., 2014). Contemporary guidance positions isokinetic dynamometers as a criterion method for controlled torque assessment when standardized alignment, stabilization, gravity correction, and daily calibration are used, yielding good-to-excellent test–retest reliability for knee extension across common velocities (Tuominen et al., 2023; Drouin et al., 2004; Impellizzeri et al., 2008). In practice, topical counterirritant liniments have long been a traditional part of Muay Thai warm-up routines worldwide. Menthol activates the receptors to elicit cooling sensations and modulate thermal comfort, whereas methyl salicylate acts as a counterirritant that increases cutaneous blood flow; together these may affect pain perception, effort regulation, and central drive (Mickle et al., 2016; Craighead & Alexander, 2016). Despite widespread routine use among fighters, controlled laboratory evaluations remain limited.

Therefore, the present exploratory randomized controlled trial employed isokinetic dynamometry to evaluate whether a single application of NM, compared with control, acutely improved knee extensor performance, with baseline measurements collected prior to group allocation. Relative peak torque (N·m/kg) at 60°/s was pre-specified as the primary outcome. Secondary outcomes included relative peak torque at 180°/s, torque at 180 ms at both velocities, and additional work and power metrics, with power treated as exploratory given ongoing debate around isokinetic-derived power (Thompson, 2025). This study was analysed on baseline-adjusted between-group effects using ANCOVA, avoided within-group testing, and followed contemporary recommendations for effect-size reporting and interpretation (Lakens, 2013). Additionally, all outcomes were normalized to body mass to facilitate equitable comparisons in weight-class athletes (Tuominen et al., 2023).

Method

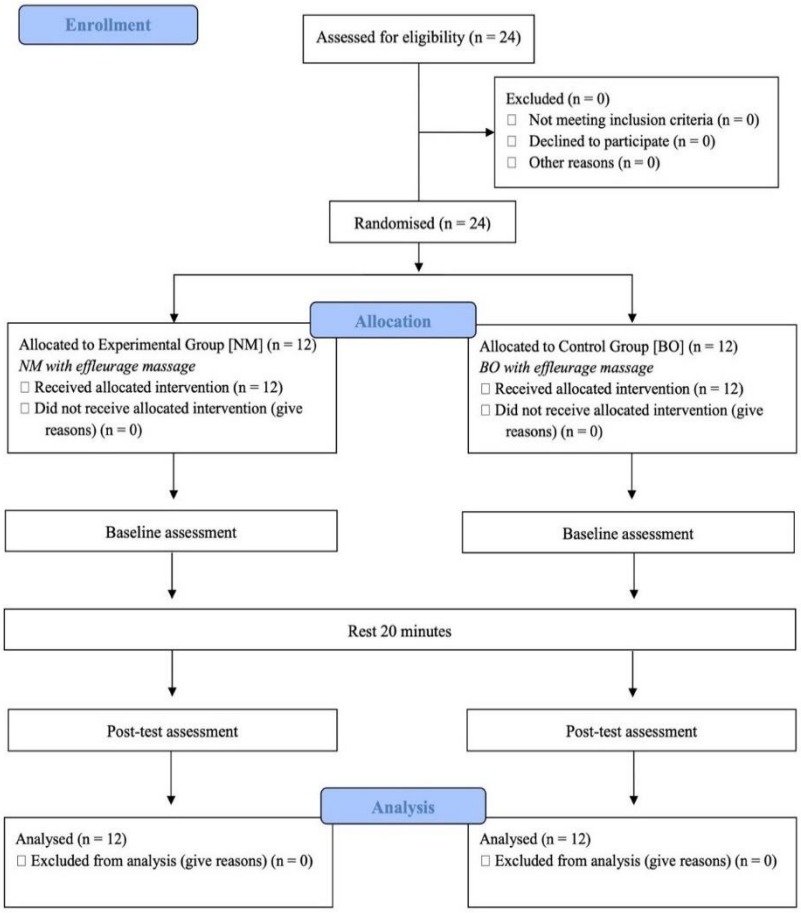
Study Design

This study employed a parallel-group randomized design with concealed allocation. The protocol was approved by the Centre for Ethics in Human Research, Khon Kaen University, Thailand (HE662203). All participants provided written informed consent prior to enrolment.

Participants

Given the absence of prior isokinetic evidence for topical liniments, a conventional a priori power analysis was not feasible. Instead, we followed the pragmatic "rule of 12 per group" heuristic (Julious, 2005), targeting 12 participants per condition (n = 24). This approach balances feasibility against the need for preliminary quantitative insights, permitting detection of large effects ($d > 0.8$) with approximately 70% power at $\alpha = .05$. Twenty-four male athletes from a single Muay Thai academy in Thailand were enrolled. Inclusion criteria were: age 19–37 years; licensed professional or pro-amateur status or at least 18 months of continuous training with three or more sessions per week; and no history of cardiac disease, recent musculoskeletal injury, or known allergy to aspirin or topical liniments. After a standardized five minute cycling warm up, participants drew sealed, opaque cards indicating group assignment (Namman Muay [NM] or baby oil [BO]). The cards were prepared by an investigator not involved in recruitment or data collection. Because NM has a distinctive scent and cutaneous sensation, blinding of participants and assessors was not possible; however, the data analyst worked with masked group codes (Figure 1).

Figure 1. Flow chart of participant progression through the trial



Interventions

A calibrated pipette (1,000 µl capacity; SCILogex LLC, Connecticut, USA) was used to apply 5 mL of either Namman Muay liniment (31% methyl salicylate, 1% L menthol; batch 56107) or mineral baby oil to an area of approximately 28×15 cm over the dominant quadriceps muscle. Application was standardized with a placement patch and a two-minute effleurage performed by the same investigator to ensure even coverage and consistent pressure. Adverse effects (burning, pruritus, dizziness) were solicited after application and after testing; none were reported. Following application, part*icipants rested supine for a 20-minute* absorption period before testing commenced.

Testing procedures

All testing took place in a temperature controlled laboratory (~25 °C) between 11:00 and 18:00. Isokinetic measurements were performed using a Biodex System 4 Pro dynamometer (Biodex Medical Systems, Shirley, New York). Standardized positioning included: seat inclination ~105°, trunk and thigh straps for stability, knee joint line aligned with the axis of rotation, and ankle cuff positioned ~5 cm proximal to the malleoli. Range of motion covered full extension (0°) to maximal tolerated flexion within 90–110°. The dynamometer was calibrated daily according to manufacturer instructions, with gravity correction applied as standard. All procedures followed the recommendations for dynamometer setup and operation to minimize measurement error and maximize reliability in knee extensor testing (Tuominen et al., 2023; Drouin et al., 2004; Impellizzeri et al., 2008).

Outcome measures

Familiarization included three submaximal repetitions at each velocity. Testing comprised five maximal voluntary knee extension/flexion repetitions at 60°/s, followed by five maximal repetitions at 180°/s, with one-minute seated rest between sets. Participants were instructed to exert maximal effort throughout the range of motion, with standardized verbal encouragement provided 'Hard and Fast' (Thompson & Xu, 2023; Baumgart et al., 2021). At each velocity, the dynamometer software calculated peak torque, total work, first-third work, and peak power, all normalized to body mass (N·m/kg; W/kg). Torque at 180 ms was extracted from torque–time data using linear interpolation to 1 ms resolution, anchored to movement onset (defined as 5% of peak torque) (Cimadoro et al., 2019; Tuominen et al., 2023; Amaral et al., 2014).

Data analysis

Between-group effects were estimated using analysis of covariance (ANCOVA), with post-intervention scores as the dependent variable, baseline as the covariate, and group (NM vs BO) as the fixed factor. Adjusted means with 95% confidence intervals, F-statistics, p-values, and partial eta squared (ηp^2) were reported. Baseline group comparability (age, height, weight, BMI) was examined with independent t tests. Model assumptions were evaluated using residual plots and Shapiro–Wilk tests; the homogeneity of regression slopes was tested via the group×baseline interaction term. Secondary outcomes were treated as exploratory, without multiplicity adjustment, and effect sizes were interpreted following current best-practice recommendations (Impellizzeri et al., 2008). Statistical analyses were performed using IBM SPSS Statistics (version 29 for Mac; Chicago, IL, USA) and Python (statsmodels). A two-tailed significance threshold of $p < .05$ was applied.

Results

All 24 enrolled athletes completed the protocol (n = 12 per group). There were no significant differences between groups in baseline characteristics, including age, height, body mass, and BMI (Table 1). Relative peak torque favoured the NM group, with a significant between-group effect ($p = .005$, $\eta p^2 = 0.318$). The adjusted difference represented an approximate 15% advantage for NM (Table 2). Torque at 180 ms also significantly favoured NM ($p = .001$, $\eta p^2 = 0.418$), indicating improved early force development. Other outcomes at this velocity showed directionally higher values for NM, with peak power reaching statistical significance ($p = .014$). Table 3 showed, at 180°/s, relative peak torque remained higher in NM ($p = .040$, $\eta p^2 = 0.187$), as did torque at 180 ms ($p = .032$, $\eta p^2 = 0.201$). The effects on total work,

first-third work, and peak power did not reach statistical significance; however, the estimates consistently trended in favour of the NM group at both testing speeds (Table 2, Table 3).

Table 1. Baseline characteristics of participants.

Variable	BO (mean ± SD) (n=12)	NM (mean ± SD) (n=12)	p
Age (years)	28.5 ± 5.9	25.4 ± 6.0	.22
Height (cm.)	172.2 ± 8.6	171.0 ± 4.7	.69
Weight (kg.)	64.3 ± 3.6	62.0 ± 4.9	.20
BMI (kg./m.^{2})	21.6 ± 1.2	21.2 ± 1.1	.46

Abbreviations: BO, baby oil (control); NM, Namman Muay (intervention); BMI, body mass index. Note: Values are presented as mean ± SD. Analyzed by Independent samples t-tests. *Significant difference: p < .05.

Table 2. Isokinetic knee extension outcomes at 60°/s (baseline-adjusted between-group by ANCOVA).

Outcomes	BO Adjusted mean (95% CI)	NM Adjusted mean (95% CI)	F (df)	p	ηp^2
Relative peak torque (N·m/kg)	3.100 (2.894–3.305)	3.560 (3.355–3.765)	9.77 (1, 21)	**.005	0.318
Torque at 180 ms (N·m/kg)	1.690 (1.295–2.085)	2.753 (2.358–3.147)	15.08 (1, 21)	**.001	0.418
Total work (J)	890.233 (806.081–974.385)	945.809 (861.657–1029.961)	0.93 (1, 21)	.346	0.042
First-third work (J)	317.475 (281.999–352.952)	355.775 (320.298–391.251)	2.50 (1, 21)	.129	0.106
Peak power (W/kg)	3.397 (3.100–3.695)	3.948 (3.651–4.246)	7.15 (1, 21)	**.014	0.254
T180/Relative peak torque (proportion)	0.623 (0.504–0.742)	0.726 (0.607–0.845)	1.64 (1, 21)	.215	0.072
Early work proportion (first-third/total)	0.360 (0.348–0.373)	0.372 (0.359–0.384)	1.69 (1, 21)	.208	0.075

Abbreviations: BO, baby oil (control); NM, Namman Muay (intervention); J, Joules; W/kg. (Watts/kilogram); ηp^2, partial eta squared. Note: Values are presented as mean ± SD. Normality was assessed with Shapiro–Wilk. Adjusted means (95% CI) are estimated at the grand mean of the baseline value using ANCOVA with the baseline measure as a covariate. *Significant difference: p < .05.

Table 3. Isokinetic knee extension outcomes at 180°/s (baseline-adjusted between-group by ANCOVA).

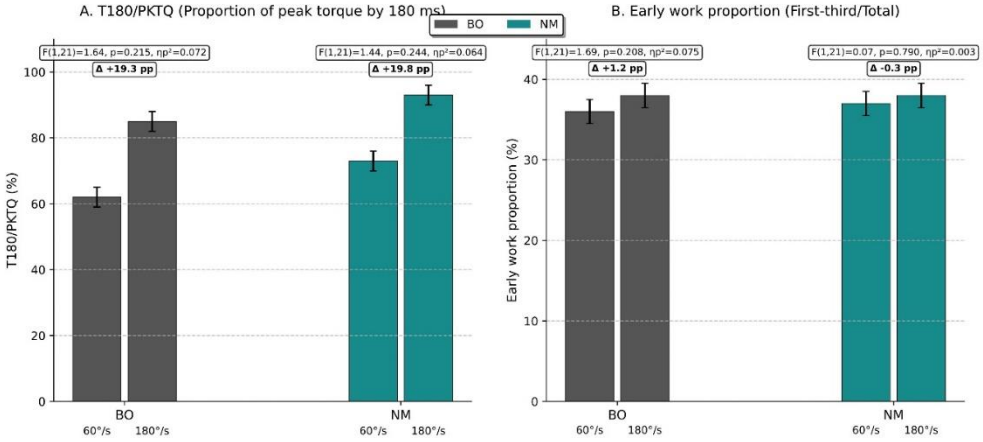
Outcomes	BO Adjusted mean (95% CI)	NM Adjusted mean (95% CI)	F (df)	*p*	ηp^2
Relative peak torque (N·m/kg)	2.295 (2.200–2.389)	2.443 (2.349–2.538)	4.82 (1, 21)	**.040	0.187
Torque at 180 ms (N·m/kg)	2.017 (1.868–2.167)	2.267 (2.118–2.417)	5.29 (1, 21)	**.032	0.201
Total work (J)	674.760 (615.611–733.910)	703.715 (644.565–762.864)	0.51 (1, 21)	.483	0.024
First-third work (J)	258.068 (233.578–282.558)	269.399 (244.908–293.889)	0.46 (1, 21)	.507	0.021
Peak power (W/kg)	6.867 (6.245–7.489)	7.511 (6.889–8.133)	2.04 (1, 21)	.168	0.089
T180/Relative peak torque (proportion)	0.883 (0.836–0.929)	0.921 (0.875–0.967)	1.44 (1, 21)	0.244	0.064
Early work proportion (first-third/total)	0.383 (0.370–0.395)	0.380 (0.368–0.393)	0.07 (1, 21)	0.790	0.003

Abbreviations: BO, baby oil (control); NM, Namman Muay (intervention); J, Joules; W/kg. (Watts/kilogram); ηp^2, partial eta squared. Note: Values are presented as mean ± SD. Normality was assessed with Shapiro–Wilk. Adjusted means (95% CI) are estimated at the grand mean of the baseline value using ANCOVA with the baseline measure as a covariate. *Significant difference: p < .05.

Expressed as a proportion of maximal torque, relative peak torque at 180 ms (T180/ relative peak torque) was higher in NM than BO at 60°/s (adjusted means 0.726 [95% CI 0.607–0.845] vs 0.623 [0.504–0.742]; ANCOVA F(1, 21) = 1.64, p = .215, ηp^2 = 0.072). At 180°/s, adjusted means likewise favoured NM (0.921 [0.875–0.967] vs 0.883 [0.836–0.929]; F(1, 21) = 1.44, *P* = 0.244, ηp^2 = 0.064). The proportion of work completed in the first third of the movement arc showed a similar pattern at 60°/s (0.372 [0.359–0.384] vs 0.360 [0.348–0.373]; F(1, 21) = 1.69, p = .208, ηp^2 = 0.075), with no between-group difference at 180°/s (0.380 [0.368–0.393] vs 0.383 [0.370–0.395]; F(1, 21) = 0.07, p = .790, ηp^2 = 0.003). These derived measures align with the primary and secondary outcomes by suggesting earlier

expression of usable torque and work with NM, while underscoring the exploratory nature of the present trial (Figure 2).

Figure 2. Derived early-phase metrics expressed as percentages A) T180/peak torque — proportion of peak knee extensor torque available by 180 ms (T180 divided by peak torque). B) Early work proportion — first third work divided by total work across the extension range of motion. Note: BO, baby oil (Control); NM, Namman Muay (Intervention)



Discussion

A single pre-test application of NM liniment produced acute improvements in knee extensor performance relative to a baby oil control. Benefits were largest for relative peak torque at 60°/s and for torque at 180 ms, with smaller but directionally consistent advantages at 180°/s. The pattern suggests that NM may help athletes reach higher maximal torque under controlled velocity while also promoting faster torque rise early in the contraction. Effects were largest and most consistent at 60°/s. The improvement in early-phase torque at both velocities suggests that NM may aid rapid torque development, which is relevant to the time-pressured actions of striking and checking (Cimadoro et al., 2019; Duarte et al., 2018; Thompson & Xu, 2023). The directionally consistent pattern across outcomes strengthens confidence that the observed effects reflect a true performance benefit rather than chance findings across isolated metrics. Moreover, the baseline-adjusted between-group differences observed for relative peak torque and torque at 180 ms are consistent with, and in many cases likely exceed, typical measurement error reported for knee extension on Biodex systems, supporting that these effects reflect true performance changes rather than instrument variability (Tuominen et al., 2023; Drouin et al., 2004).

To complement the primary and secondary outcomes, we examined two early-phase derived measures: (i) the proportion of peak torque available by 180 ms (T180/ relative peak torque), and (ii) the proportion of work completed in the first third of the movement arc. At 60°/s, both measures favoured NM (T180/relative peak torque adjusted means 0.726 vs 0.623; early work proportion 0.372 vs 0.360), with smaller differences at 180°/s; however, between-group effects did not reach statistical significance in this exploratory sample. These results align with the significant improvements in torque at 180 ms and suggest that NM may shift torque–time and work–range profiles earlier within the contraction and range of motion—an interpretation with face validity given Muay Thai's short time budgets (≈150–250 ms) for effective striking and checking (Cimadoro et al., 2019; Iossifidou & Baltzopoulos, 2000; Duarte et al., 2018; Thompson & Xu, 2023; de Lira et al., 2019). Given the small sample and correspondingly wide confidence intervals, these derived metrics should be viewed as supportive pattern evidence rather than confirmatory endpoints.

In applied sport, even modest improvements in normalized peak torque can influence readiness to execute demanding skills late in a session or bout. The observed percentage advantages at 60°/s and for

early-phase torque fall within ranges that practitioners often consider meaningful, especially when accumulated across multiple sets or integrated into periodized warm-up strategies. Enhanced torque at 180 ms is consistent with the short time budgets of Muay Thai techniques and may translate to crisper initiation, improved timing, and better maintenance of form under fatigue (Cimadoro et al., 2019; Iossifidou & Baltzopoulos, 2000; Duarte et al., 2018; Thompson & Xu, 2023; de Lira et al., 2019). These practical implications are compatible with findings from other athletic populations, where targeted lower-limb strength and flexibility programmes have reduced knee valgus and pain (Verdugo et al., 2024) and unilateral hamstring strengthening has improved inter-limb symmetry and jump performance (Wiriawan et al., 2024). Together, this body of work suggests that changes in knee strength profiles—whether achieved through chronic training or acute ergogenic strategies such as NM—may carry meaningful consequences for both performance and lower-limb function.

Prior studies of menthol or methyl salicylate have highlighted analgesic and perceptual effects alongside potential improvements in performance tasks that require sustained effort or high motivation. Our findings extend this literature to a controlled dynamometric context with explicit between-group inference. Importantly, the effects were not confined to a single metric but appeared for both maximal and early-phase torque, which strengthens the case for a true performance impact rather than an artifact of a specific endpoint (Mickle et al., 2016; Craighead & Alexander, 2016).

Menthol engages Transient receptor potential melastatin 8 receptors (TRPM8) and alters thermal sensation; methyl salicylate acts as a counterirritant and may increase skin blood flow. Together they could reduce pain and effort perceptions and facilitate central drive, particularly during task initiation when rapid rate coding and motor unit recruitment are critical (Mickle et al., 2016; Craighead & Alexander, 2016). Thermal comfort might also promote a more aggressive approach to maximal efforts. While these mechanisms are plausible, direct evidence requires mechanistic measures, such as skin blood-flow imaging, electromyography analyses of recruitment strategies, central activation ratio, and psychophysiological ratings.

We prioritized internal validity through standardized positioning, consistent instructions, pre-specified outcomes, and baseline-adjusted ANCOVA. By avoiding within-group tests and presenting effect sizes (ηp^2), we adhere to best practices for small, randomized trials (Sullivan & Feinn, 2012; Lakens, 2013). We also adhered to established dynamometer setup principles (axis alignment, stabilization, gravity correction, and calibration) known to minimize measurement error and to yield reproducible knee extension torque measurements (Tuominen et al., 2023; Drouin et al., 2004; Impellizzeri et al., 2008). However, our sample size was modest, which broadens confidence intervals and limits the ability to interrogate moderators such as training age or weight class. Because a priori power calculation wasn't possible in this understudied domain, we adopted the heuristic "rule of 12 per group." While pragmatic, this approach means the trial was not powered to detect small or moderate effects and raises the risk of both type II error and misinterpretation of effect magnitudes. Accordingly, findings should be regarded as preliminary benchmarks to inform adequately powered confirmatory research. The single-session design cannot determine whether effects persist across repeated applications or under fatigue. Participant and assessor blinding was not feasible given NM's sensory profile, raising the possibility of expectation effects; however, the baseline-adjusted analysis and objective dynamometer outputs mitigate this concern. Isokinetic testing, while reliable and informative, simplifies the multi-planar, reactive nature of combat-sport actions and may overestimate transfer to complex tasks. We did not track hydration or caffeine intake on the test day, nor did we quantify prior training load; future work should standardize or record these variables. Finally, secondary outcomes were not adjusted for multiplicity and should be interpreted as exploratory.

A pragmatic protocol is 5 mL applied over the quadriceps with standardized effleurage approximately 20–25 minutes before heavy strength sets, power-oriented work, or technical sessions emphasizing high-velocity kicking. Athletes should verify product compliance with local regulations, review any organizational policies, and screen for sensitivity to salicylates. Implementation should be individualized; some may experience stronger perceptual effects than others. Confirmatory trials should be preregistered and powered on the effect sizes observed here, with strategies to enhance blinding (e.g., scent- and thermal-matched control). Dose–response and time-course studies would identify optimal application volumes and intervals. Mechanistic sub-studies could quantify sensory, hemodynamic, and neurophysiological correlates to clarify whether the observed benefits arise from peripheral comfort, central

drive, or both. Field studies linking NM to instrumented kicking velocity, impact force, and bout-specific performance would strengthen ecological validity. Complementary field-facing assessments of movement quality (e.g., the qualitative analysis of single leg loading for single-leg squat/landing) could help link laboratory torque characteristics to lower-limb mechanics, with the caveat that inter-rater training is required to optimize reliability. Longer-term work could also explore whether repeated NM use acts synergistically with structured strength and flexibility programmes that have improved knee valgus and pain (Verdugo et al., 2024) or hamstring asymmetry and jump performance (Wiriawan et al., 2024). Although peak power at 60°/s favoured NM in this trial, isokinetic systems are optimized for torque measurement, and interpretation of derived power warrants caution; future work using isotonic or inertial methods that directly quantify power is recommended (Thompson, 2025).

Conclusions

Topical application of Namman Muay liniment produced acute, baseline-adjusted improvements in knee extensor performance among trained Muay Thai athletes, with the strongest and most consistent effects observed at 60°/s for peak torque and early-phase torque. These exploratory findings suggest potential benefits for rapid force generation in combat sport contexts and justify further confirmatory trials incorporating mechanistic measures and ecologically valid performance outcomes.

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