





Effects of applying sports liniment with massage on muscular relative strength of hip flexion and knee extension among male Muay Thai athletes: a randomised control trial

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Abstract

Background: Muay Thai, Thailand's national sport, widely practiced globally, is known for using sports liniment before training and fights. A popular product is 'Namman Muay', an iconic symbol of Thailand, though its direct impact on performance lacks research. **Objectives:** Investigate the impact of Namman Muay on the rectus femoris of the dominant leg. Focus on muscular strength exercises – seated hip flexion and supine knee extension – with relative strength as the primary outcome. **Material and Methods:** A randomised control trial with 24 male Muay Thai fighters, divided into 12 in the Baby Oil (BO) and 12 in the Namman Muay (NM) group. Both groups received effleurage massage on the dominant kicking legs, followed by a RAMP warm-up. Performance measurements using Lafayette Handheld Dynamometer evaluated two isometric strength tests. **Results:** NM intervention showed significant increases in hip flexion and knee extension strength. Within groups, a 3% decrease was seen in the BO and an 11.6% increase in NM for hip flexion strength, and 1% decrease in BO and 6.9% increase in NM for knee extension strength. **Conclusion:** This study provides valuable insight to Muay Thai fighters and trainers, showing that 5 ml NM boosts relative muscular strength of hip flexion and knee extension. This could improve male Muay Thai fighters' performance particularly when using kicking techniques.

Keywords: Martial arts; combat sports; Muay Thai; massage; Namman Muay; dynamometry; isometric strength.

Efectos de la aplicación de linimento deportivo con masaje sobre la fuerza muscular relativa de flexión de cadera y extensión de rodilla en luchadores masculinos de Muay Thai: un ensayo controlado aleatorizado

Resumen

Antecedentes: El muay thai, deporte nacional de Tailandia extendido por todo el mundo, es conocido por el uso de linimentos antes del entrenamiento y de los combates. Un producto popular es el linimento "Namman Muay", todo un icono de Tailandia, aunque sus efectos el rendimiento no se han investigado. **Objetivos:** Estudiar el impacto del

Efeitos da aplicação do linimento deportivo com massagem na força relativa muscular da flexão da anca e na extensão do joelho entre atletas masculinos de Muay Thai: um ensaio controlado randomizado

Resumo

Antecedentes: O Muay Thai, o desporto nacional da Tailândia e um desporto mundial, é conhecido pela utilização de linimentos antes dos treinos e dos combates. Um produto popular é o linimento "Namman Muay", um ícone tailandês, embora os seus efeitos no desempenho não tenham sido investigados. **Objetivos:** Estudar o

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Namman Muay en el recto femoral de la pierna dominante. El foco son test de fuerza muscular (flexión de cadera sentado y extensión de rodilla supina) con la fuerza relativa como resultado primario. *Material y métodos:* Ensayo controlado aleatorizado con 24 atletas masculinos de Muay Thai, 12 en el grupo Baby Oil (BO) y 12 en el grupo Namman Muay (NM). Cada participante recibió masaje *effleurage* en su pierna dominante de patada, seguido de un calentamiento RAMP. Las mediciones se realizaron mediante un dinamómetro portátil Lafayette. *Resultados:* El grupo NM mostró aumentos significativos en flexión de cadera y fuerza de extensión de rodilla. En la comparación intragrupal, hubo una disminución del 3% en el grupo BO y un aumento del 11,6% en el grupo NM en fuerza de flexión de cadera, y una disminución del 1% en el grupo BO y un aumento del 6,9% en el grupo NM en fuerza de extensión de rodilla. *Conclusión:* Este estudio proporciona información valiosa para atletas y entrenadores de Muay Thai, mostrando que la aplicación de 5 ml de NM aumenta la fuerza muscular relativa de flexión de cadera y de extensión de rodilla. Esto podría mejorar el rendimiento de los luchadores masculinos de Muay Thai, particularmente en la utilización de técnicas de patada.

Palabras clave: Artes marciales; deportes de combate; Muay Thai; masaje; Namman Muay; dinamometría; fuerza isométrica.

impacto do Namman Muay no músculo reto femoral da perna dominante. O foco está nos testes de força muscular (flexão da anca sentado e extensão do joelho em supino) com a força relativa como resultado primário. *Material e métodos:* Ensaio controlado aleatório com 24 atletas de Muay Thai do sexo masculino, 12 no grupo Baby Oil (BO) e 12 no grupo Namman Muay (NM). Cada participante recebeu uma massagem de *effleurage* na sua perna dominante de pontapé, seguida de um aquecimento RAMP. As medições foram efetuadas com um dinamómetro portátil Lafayette. *Resultados:* O grupo NM apresentou aumentos significativos na força de flexão da anca e de extensão do joelho. Na comparação intragrupo, houve uma diminuição de 3% no grupo BO e um aumento de 11,6% no grupo NM na força de flexão da anca, e uma diminuição de 1% no grupo BO e um aumento de 6,9% no grupo NM na força de extensão do joelho. *Conclusão:* Este estudo fornece informações valiosas para atletas e treinadores de Muay Thai, mostrando que a aplicação de 5 ml de NM aumenta a força muscular relativa de flexão da anca e extensão do joelho. Isto poderia melhorar o desempenho dos lutadores de Muay Thai do sexo masculino, particularmente na utilização de técnicas de pontapé.

Palavras-chave: Artes marciais; esportes de combate; Muay Thai; massagem; Namman Muay; dinamometria; força isométrica.

1. Introduction

Muay Thai, the national sport of Thailand, enjoys international recognition for its historical and cultural significance, accompanied by unique traditions. This combat sport demands sustained performance over five three-minute rounds, separated by two-minute breaks. Crucial factors in achieving success include cardiovascular health, muscle fibre type, training level, and overall physiological adaptations (Corcoran et al., 2024). Optimal performance in Muay Thai is derived from high relative strength, which is essential in power-to-weight ratio since it is a weight-class sport (Wasacz et al., 2022).

It is central to emphasize the significance of relative strength in Muay Thai performance. Relative strength, which measures force generation and movement efficiency in relation to an individual's body weight, profoundly influences power, speed, agility, and endurance — all integral components of a fighter's performance (Kostikadis et al., 2018; Barley et al., 2019; Wasacz et al., 2022). Strong relative strength provides a stable, balanced foundation for agile movements and accurate strikes, conferring a competitive advantage. Moreover, a comprehensive understanding of relative strength facilitates strategic training adaptations and may contribute to injury risk reduction (Aicale, Tarantino and Maffulli, 2018).

Muay Thai, a predominantly kicking-based sport in Thailand (Myers et al., 2013; Diniz et al., 2021), focuses on the dominant leg's hip flexors and knee extensor musculature. The rectus femoris muscle is a two jointed muscle action affecting hip flexion and knee extension, and affectionately known as the 'kicking muscle' (Murdoch et al., 2023). Handheld dynamometers (HDD) are portable handheld field testing isometric strength measuring tools. Validating HDD's inter-and intra-rater reliability is essential (Garcia et al., 2023; Grootwagers et al., 2022). Research often supports the method, frequently demonstrating favourable results. Dividing absolute isometric strength measurements by fighters' body mass produces the relative strength value.

A notable custom in Muay Thai is the application of NM, a renowned Thai sports liniment, before training or fights. Originating from Thailand, NM has gained global recognition as the go-to "boxing liniment" in the Muay Thai community. Its widespread popularity stems from two key pharmaceutical agents: methyl salicylate and L-menthol, which act as active pharmaceutical ingredients (APIs). Extensive research investigates the physiological effects of these APIs when applied topically, particularly for alleviating muscle soreness and mitigating muscular pain (Attiq et al., 2018; Wang et al., 2022).

The rubbing action when Muay Thai fighters apply sports liniment offers multiple indirect benefits. While a systematic review on massage effects on sport performance suggests uncertainty regarding its direct impact, massage aids athletes in remaining focused, relaxed, and supported during training and competition, potentially improving topical substances' penetration and is known as a mechanical enhancer (Dakic et al., 2023). Nanoparticles in NM, smaller than 500 Daltons, enhance the penetration of methyl salicylate and L-menthol active ingredients due to their vasodilatory effects (Lan et al., 2016). The combination of NM's nanoparticles and rubbing action, supports the promotion of skin barrier penetration, offering benefits for Muay Thai fighters (Lan et al., 2016) although some literature is contradictory (Li et al., 2019).

Research on the relationship between sports liniment and physical performance reveals limited findings. Chiam and Kong (2023) examined the effect of sports rub on physical performance using Tiger Balm, which contains the APIs methyl salicylate and L-menthol, applied to college athletes' quadricep muscles. While no significant difference in flexibility and balance was found, the standing broad jump saw a 1.7% improvement for the muscle rub group compared to the placebo. Examining the sole effect of a 10% menthol cream (single active pharmaceutical ingredient) by Ledford et al. (2016) on sprint cyclists and anaerobic power when applied topically to the anterior and posterior thighs. The cycling sprint tests groups using menthol demonstrated significantly increased peak power ($p = 0.021$) and fatigue index ($p = 0.022$) compared to the placebo group. The Rate of Perceived Exertion was reported as lower in the initial sprint; however, participants experienced fatigue during subsequent sprints, with no significant differences observed between groups. The study concluded that a topical menthol cream can enhance peak power output. Due to the ability of methyl salicylate and L-menthol to act as blood vessel dilators, (Wang et al., 2022), their application should correlate with increased SmO_2 availability to working muscles. This increase in oxygen availability may promote strength and performance (Perrey, 2022),

Despite the widespread use of sports liniment in the Muay Thai community, limited scientific evidence supports their direct enhancement of physical performance. Nevertheless, Muay Thai fighters often apply these liniments before activities, without a clear understanding of their effects on peak power (Ledford, Rogers and Williams, 2023), endurance and recovery (Mohamad et al., 2017). Therefore, the objective of this study was to determine the impact of NM sports liniment on the dominant kicking leg and relative strength outcomes when incorporated into the warmup protocol. It is hypothesized that applying 5 ml NM through effleurage massage will result in enhanced relative muscular strength of the hip flexors and knee extensors.

2. Methods

2.1. Participants

This randomised control trial studied 24 male Muay Thai fighters ($M_{age} = 25.4 \pm 5.6$ years; $M_{height} = 171.2 \pm 6.1$ cm; $M_{weight} = 61.2 \pm 6.0$ kg; $M_{BMI} = 21.1 \pm 1.6$ kg/m²) from the Muay Thai Academy in GumPun, Nakhon Ratchasima and Khon Kaen cities in Thailand. The study's sample size of 24 was determined on a pilot study involving 12 participants using G* Power version 3.1.9.4 with alpha error of 0.05, test power of 80% and effect size of 0.312. Inclusion criteria for participants were males aged between 19 to 37 years, categorised as Professional, Professional Amateur, or Amateur Muay Thai fighters, engaged in non-competitive periodised training schedule, within and from 30 days of competition, weighing between 49-66 kg. Additionally, participants had to confirm abstaining from alcohol or energy sport drinks in the past 24hrs. Exclusion criteria encompassed the absence of any disease or disorder effecting the heart rate variability (HRV), as well as specific conditions like musculoskeletal injuries within the last 6 months, hypertension, cancer, diabetes, uncontrolled blood sugar, or allergies to aspirin or liniment, or other contraindications. Also, currently serving a ban under the World Anti-Doping Agency (WADA) or serving a suspension under the World Muay Boran Federation (WMBF) and World Muay Thai Organisation (WMO) rules and regulations.

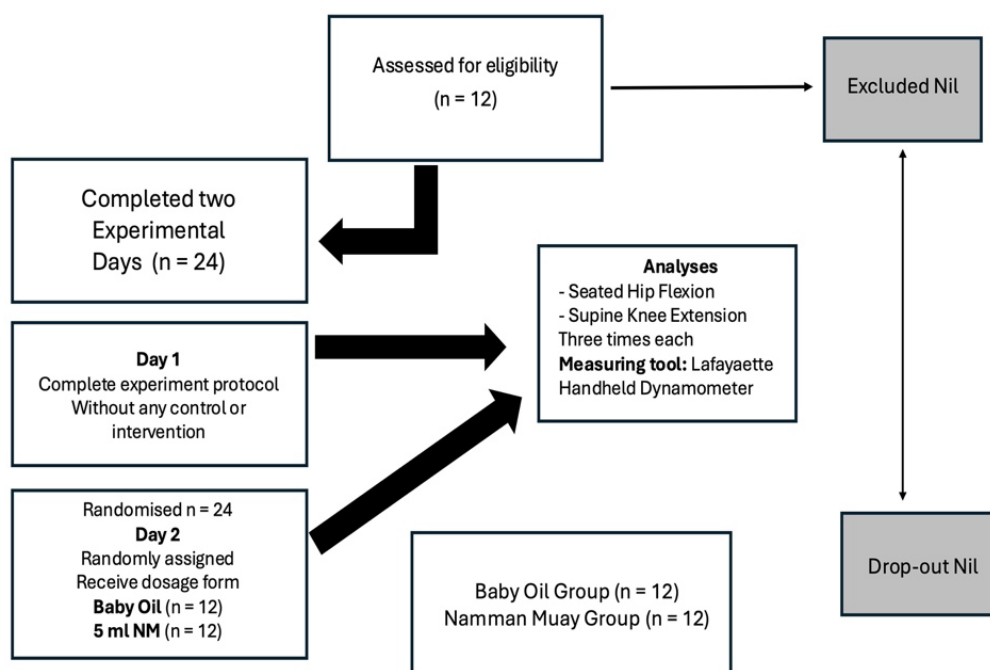
2.2. Experimental procedures

The study protocols were reviewed and approved by the Centre for Ethics in Human Research, Khon Kaen University, Thailand (Ref No: HE662203). All participants were informed about the experimental procedures, and signed consent was obtained.



Participants' initial assessments included weight, height, and health status by using the self-reported Physical Activity Readiness Questionnaire (PAR-Q+ 2023). Baseline measurements were gathered during the first day, following a 20-minute rest and a 15-minute RAMP warmup. Subsequent strength tests for seated hip flexion and supine knee extension deployed the HDD. Group selection was randomised. A 28 x 15 cm patch was placed on the dominant leg's quadriceps, treated with the chosen medium using the *effleurage* technique for two minutes, and left on the massage bed for 20 minutes. Subsequently, the same protocol as the first day was repeated, including the two strength tests for seated hip flexion and supine knee extension. Figure 1 shows a visual of the methodology through a flow chart, indicating 12 participants in each group BO and NM having baseline measurements taken on day 1 and randomly assigned into either group on day 2. The second day measurements can then be compared against the day 1 measurements within and between groups. In these tests, room temperature was set at 21°C, and they took place from 11.00 am to 6:00 pm.

Figure 1. Methodology Flow chart.



2.3. Interventions

On the second day of the study, rectangular patches measuring 28 cm x 15 cm were placed on the anterior thigh for both control group and intervention group participants, exposing the rectus femoris and quadriceps muscles. Using a pharmaceutical-grade pipette from SCILogex LLC (USA) with a 1000- μ l capacity, 5-ml dosages of NM or BO were administered to each participant. Dosages were applied precisely and uniformly within the rectangle boundaries, allowing for controlled and accurate treatment. NM liniment (batch No: 56107, expiry three years from start date) contained 31% methyl salicylate and 1% L-menthol.

2.4. Outcome measurements

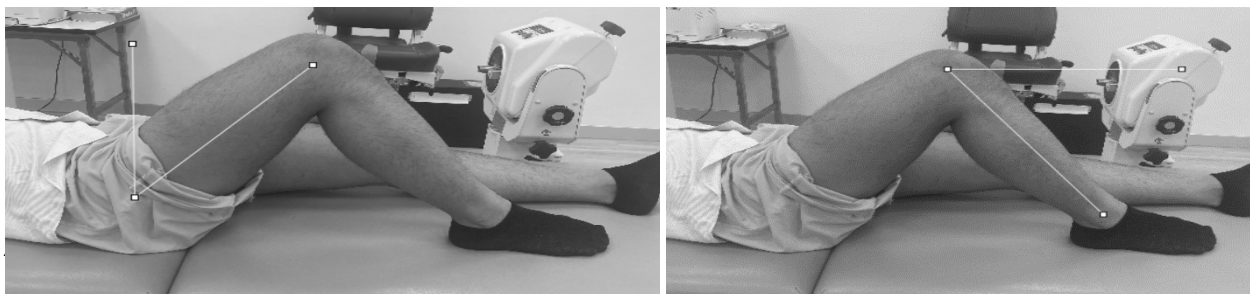
This study employed the Lafayette Handheld Dynamometer (HDD) to effectively measure absolute isometric strength in knee extension and hip flexion (Florencio et al., 2019; Chamorro et al., 2017; Mentiplay et al., 2015). It is recommended to perform multiple tests and calculate the mean value (Ramos et al., 2022), increasing the precision and accuracy of the individual's strength or force measurements. By doing this, the impact of random errors or muscle strength fluctuations between trials can be reduced, as well as accommodate performance inconsistencies, effort, and other factors. In a study by Morrin et al. (2023), three tests were carried out on HDD, where the coefficient of variation was calculated. Additional tests were performed if the variation exceeded 10% threshold. This study, Morrin's findings and methodology regarding HDD variations were considered and

incorporated for calculations and analysis. The precision of strength measurement is influenced by multiple factors, such as the evaluator, testing conditions, gravity, position, plane of motion and stabilisation methods (Bohannon et al., 2011). This study took some steps to address these variables, utilising a rigid strap to secure the non-assessed limb and using supine lying for knee extension and seated position for hip flexion strength (Baumgart et al., 2021).

Hip flexion and knee extension strength test

During the hip flexion strength tests, participants sat on the beds edge, arms crossed, with the HDD positioned on the rectus femoris muscle at the mid-point of the thigh. The principal investigator (PI) applied pressure, participants flexed against it, and the process was repeated three times. Averaging the three measurements improved accuracy. Knee extension tests followed similar steps, with the participant supine, hips flexed at 75° and knees at 50° (Figure 2) with the HDD 10 cm distal from the tibial tuberosity. Participants then pushed against the applied pressure. Again, the process was repeated three times, and the average measured. Researchers assessed intra- and inter-rater reliability of the HDD protocol (Morin et al., 2023), measuring 17 different muscle groups. Between two independent raters, at three distinct times, on 30 healthy adults, intra-rater ICC ranged from 0.90 and 0.99 (0.85-0.99), while inter-rater reliability varied from 0.89 to 0.99 (0.55 – 0.995). These findings reinforce the standardised HDD protocol as the preferred method for quantifying maximal isometric muscle strength. Florencio et al. (2019) explored reliability and validity of evaluating hip and knee strength via HDD testing. Researchers analysed intra-rater ICC, comparing belt-stabilisation (0.78 to 0.95) with examiner-provided stabilisation (0.83 to 0.97). Although the study confirmed the HDD's reliability, the comparison found no agreement between the two methods. However, the study noted lower errors and higher strength recordings when examiners stabilised the limb. These tests provided valuable data for assessing interventions effects on muscle strength.

Fig 2. Position of knee extension strength test in supine position hip flexion set at 75° and knee flexion set position.



2.5. Statistical analysis

The analyses included all participants with baseline data, as presented in Table 1. The results of the day 2 within group measurements were compared with the baseline using paired t-tests, as presented in Table 2. A series of t-tests were performed to identify muscle strength differences in seated hip flexion and supine knee extension tests. The mean values were calculated based on three recordings, and subsequently divided by the participants' body weight to determine the muscular relative strength mean. Independent t-test comparisons were used to determine the mean difference in-between groups on day 2. Percentile differences with standard deviation \pm were also analysed and reported as seen in Figure 3.

The Shapiro-Wilk test was employed to verify the normal distribution of data ($p < 0.05$) The Levene test was used to assess the equality of variances between the groups. Statistical analysis was performed using IBM SPSS software version 28 for Windows (SPSS Statistics Chicago, IL, USA). For analyses, the p-value was set to 0.05.

Cohen's d with Hedges g correction were used to assess the effect size; however, due to the small sample size both tests were used to reduce the biasness. Hedges g uses the following parameters suggested by Cohen (1992), 0.2 small effect, 0.5 medium effect and 0.8 large effect.

3. Results

The analysis involving 24 Muay Thai fighters featured an even distribution between BO and NM groups, as indicated in Table 1. This equilibrium ensures that any variances in results are due to the intervention rather than the initial differences in participants' characteristics. The normality of baseline characteristics, assessed using the Shapiro-Wilk test, further supported the study's validity.

Table 1. Baseline characteristics of participants by intervention (n = 12) and control group (n = 12).

Baseline characteristics	BO group (M± SD)	NM group (M± SD)	P-value
Age (years)	25.4 ± 6.1	25.3 ± 5.4	.48
Height (cm.)	172.2 ± 7.1	169.5 ± 4.7	.09
Weight (kg.)	61.8 ± 5.6	60.6 ± 6.6	.31
BMI (kg/m ²)	20.7 ± 1	21.2 ± 2	.23

Note. BO = Baby oil group. NM = Namman Muay group. BMI = body mass index.

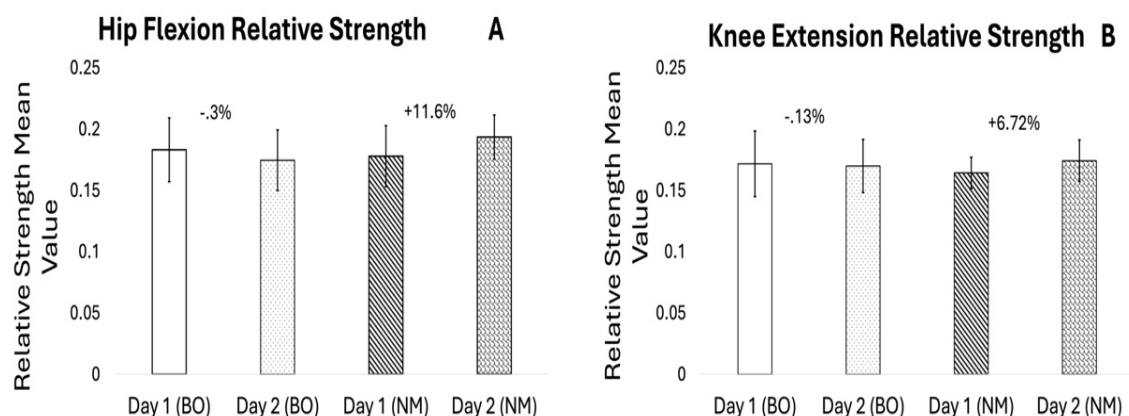
Table 2 details paired t-tests for relative hip flexion and knee extension strength, including M ± SD, p-values and confidence intervals (CI). Significant increases were observed in both hip flexion (11.6%) and knee extension (6.7%) in the NM group. Independent t-tests comparing the BO and NM groups on day 2 (Figure 3) including Levene test to assess the equality of variances across the groups showed that the 5 ml NM group had significantly higher outcomes in hip flexion (p < 0.001, Hedges g = 1.49) and knee extension (p = 0.006, Hedges g = 1.07).

Table 2. Comparisons of outcome measurements between intervention (n = 12) and control (n = 12) groups at baseline and day 2 with intervention.

Outcomes	Group	Day 1 (M± SD)	Day2 (M± SD)	^a p-value (95% CI) Within Groups	^b p-value (95% CI) Between Groups	ES (g)
Hip flexion relative strength	BO	0.175 ± 0.026	0.171 ± 0.025	.075 (-.002 vs .01)	< 0.001 (-.05 vs -.02)	1.49
	NM	0.183 ± 0.025	0.204 ± 0.018	< 0.001 (-.03 vs -.01)		
Knee extension relative strength	BO	0.165 ± 0.027	0.163 ± 0.021	.421 (-.01 vs .01)	.006 (-.04 vs -.01)	1.07
	NM	0.172 ± 0.012	0.185 ± 0.016	.005 (-.02 vs -.003)		

Note. ^a Paired t-test for within group comparison ^b Independent t-test for between group comparison. ES = Effect size; Hedges g correction was used to present the estimated effect size. BO = Baby oil group. NM = Namman Muay group.

Fig 3. A The relative hip flexion strength and **B** The relative knee extension strength between groups for both day 1 and day 2 as percentile differences.



Note. **A** Hip Flexion - BO group showed percentile decrease of .3% while the NM group showed a significant increase 11.6%. **B** Knee Extension - BO group showed a percentile decrease of .13% while NM group showed a significant increase of 6.7%. Mean values represented after calculating Absolute strength (Kg) / Body weight (Kg) giving relative strength.

4. Discussion

This study aimed to assess the impact of applying 5 ml of NM enriched with methyl salicylate and L-menthol on enhancing isometric strength of hip flexors in male Muay Thai athletes. The hypothesis posited that using NM during warmup would lead to an increase in isometric strength. The study findings confirmed this hypothesis, showing significant improvements in isometric strength values. The results provide compelling evidence for the efficacy of NM and its APIs in boosting isometric strength values. These outcomes highlight the potential of NM as a performance-enhancing topical treatment for athletes, particularly those in combat sports like Muay Thai. The observed strength gains can be attributed to factors such as the counter-irritation effect and vasodilatory properties of the APIs, which stimulate nerve endings and promote increased blood flow, potentially enhancing muscle function (Wang et al., 2022).

The vasodilatory effects of these APIs enhance blood circulation to the muscles. Methyl salicylate and l-menthol can widen blood vessels, improving blood flow. This enhanced circulation delivers more oxygen and nutrients to the muscle, promoting strength and performance (Perrey, 2022). However, recent research presents conflicting evidence. While Versteeg et al. (2024) challenge the blood flow-increasing properties of methyl salicylate, Wang et al. (2022) demonstrated that the combination of L-menthol and methyl salicylate effectively mitigates cold-induced vasoconstriction, facilitating heat dissipation during exercise-induced hyperthermia. This combination effectively reverses hyperthermic vasoconstriction into vasodilation. These findings highlight the need for further research to elucidate the specific mechanisms by which NM and its APIs influence blood flow and muscular strength. The combination of methyl salicylate and l-menthol in sports liniments may have potential synergistic effects compared to their individual use. However, these effects may depend on the formulation and concentration used in the sports liniment. Both methyl salicylate and l-menthol have demonstrated the ability to enhance the penetration of other active ingredients through the skin. When used together, they may synergistically enhance the absorption of other beneficial compounds present in the liniment formulation (Alhasso et al., 2022).

Methyl salicylate and L-menthol have analgesic properties, which means they can provide pain relief. By reducing pain and discomfort in the muscles and joints, individuals may be able to perform hip flexion and knee extension exercises with less inhibition, leading to improved strength gains (Guo et al., 2022; Li et al., 2022b). Furthermore, methyl salicylate, similar to aspirin and other NSAIDs, can inhibit the production of inflammatory mediators such as prostaglandins and thromboxane A₂. By reducing inflammation in the muscles and joints, individuals may experience less pain and stiffness, allowing for better range of motion and strength gains in hip flexion and knee extension (Zhang et al., 2011c).

The *effleurage* massage technique employed in this study merits consideration for its potential role in the observed effects. Sports liniments are generally applied via a rubbing/massage technique, which also serves as a mechanical enhancer of API permeation into underlying structures beneath the skin. Research indicates that massage increases blood flow (Gasibat & Suwehli, 2017). Specifically, Rodrigues et al. (2020) examined the effects of massage on local perfusion and hemodynamic, noting perfusion changes within massaged limbs. While Portillo-Soto (2014) reported increased blood flow in the lower legs following massage, attributing it to elevated skin temperature however, precise relationship between massage-induced heat generation and blood flow remains unclear. Massage induces a mechanical stress, triggering cellular responses in three components: mechanoreceptors, signal transducers and target activators (Liu et al., 2015). Interestingly, Kaushik and Keck (2021) suggested that massage pressure could increase stratum corneum density, potentially impeding topical substance absorption. However, the light, sweeping movements characteristic of the *effleurage* technique used in this study likely minimized this effect while reflecting a realistic application method for Muay Thai athletes. The combination of *effleurage* massage and sports liniment application in this study, may have synergistically enhanced API absorption and local physiological responses. This approach not only mimics real-world practices but also potentially optimises the therapeutic effects of sports liniment. The superior penetration of the APIs can be primarily attributed to their nano-particle design, featuring molecular weights below 500 Daltons and moderate lipophilicity (partition coefficient 10-1000), rather than the massage technique itself (Madawi et al., 2023). These properties facilitate efficient transdermal absorption, contributing to the observed strength enhancements.



Interestingly, hip flexion strength exhibited a more substantial relative increase compared to supine knee extension, contrary to expectations given the typically larger cross-sectional area of the quadriceps muscles (Ramos et al., 2022). This unexpected outcome may be partially explained by the positioning of the hand-held dynamometer (HDD) during testing. Placed 10 cm distal to the tibial tuberosity, the HDD's proximity to the knee joint potentially reduced the lever arm length for knee extension, offering a mechanical disadvantage that may have influenced the results. The apparent negative impact of BO on both hip flexion and knee extension strength, while not fully understood, could be attributed to its lubricating properties. The slippery surface created by the oil may have reduced skin friction with the HDD, compromising force generation and stability during testing and consequently affecting strength measurements.

The study design, incorporating a 20-minute pre-application period for the compound followed by a 15-minute warmup, allowed ample time for transdermal permeation while adequately preparing participants for the testing protocols. This methodological approach strengthens the validity of the observed results. Another notable strength of this research lies in its unique contribution to understanding the effects of NM liniment on relative muscle strength in seated hip flexion and supine knee extension, as measured by the HDD. The comparison between the NM and the BO groups not only revealed the efficacy of NM but also demonstrated the validity and reliability of the HDD as a measurement tool in this context.

Certain limitations warrant acknowledgment in this study. The positioning of the HDD and evaluator may have constrained the full mechanical lever potential for maximum force generation. Blinding participants in a study involving a product with a pungent smell and warming sensation upon application presents significant challenges. Furthermore, over-familiarisation with NM might have influenced participants to exert more effort or experience a psychological effect.

To address these limitations and further validate the findings, future research could employ laboratory-based methods, such as Biodex isokinetic dynamometer. This approach would provide more precise control and sensitive measurements of hip flexion and knee extension strength. Collaboration with a pharmaceutical science department to create odourless NM or other sports liniment products could mitigate some blinding issues. However, eliminating the sensations experienced by participants, which result from the API's ingredients, may remain challenging.

5. Conclusion

This study provides compelling evidence for the efficacy of NM in enhancing relative muscular strength, particularly in hip flexion and knee extension. The findings have significant implications for Muay Thai athletes and potentially other combat sport athletes, offering insights into performance enhancement strategies. Future research should aim to elucidate the specific mechanisms underlying these strength gains and explore the potential applications of NM in various athletic contexts.

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