



Sports massage or active exercise for DOMS relief? A systematic review and meta-analysis among healthy population

¿Masaje deportivo o ejercicio activo para aliviar el DOMS? Una revisión sistemática y metaanálisis en población sana

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Abstract

Background: Delayed-onset muscle soreness (DOMS) commonly appears 24–72 hours following eccentric exercise and can impair performance, recovery, and functional capacity. Sports massage therapy (SMT) and active exercise therapy (AET) are frequently prescribed interventions to alleviate DOMS symptoms, yet their comparative effectiveness remains unclear.

Objective: This systematic review and meta-analysis aimed to compare the effects of SMT and AET on muscle soreness, range of motion (ROM), and serum creatine kinase (CK) levels among healthy adults experiencing exercise-induced DOMS.

Methods: Four electronic databases (PubMed, Scopus, Web of Science, and Google Scholar) were systematically searched for randomized controlled trials published between November 2004 and October 2020. Eligible participants were healthy adults aged 18–60 years who received either SMT (manual massage techniques) or AET (light-to-moderate activity $\leq 70\%$ HRmax) following eccentric exercise. Data synthesis was conducted using Review Manager 5.4 and a random-effects model to calculate standardized mean differences (SMD) with 95% confidence intervals (CI). Methodological quality was assessed using the TESTEX tool, and heterogeneity was quantified using I^2 statistics.

Results: Thirty-nine RCTs ($n = 1,148$) met the inclusion criteria, comprising 27 SMT and 17 AET interventions. SMT significantly reduced muscle soreness compared to control conditions and demonstrated a stronger directional trend toward improved ROM and lower CK responses than AET. AET produced modest relief of soreness and ROM recovery but exhibited greater variability across studies. Overall methodological quality was moderate to high.

Discussion: SMT may provide superior short-term symptom relief following eccentric exercise, while AET offers additional movement-based benefits.

Conclusions: Both SMT and AET are effective recovery strategies for exercise-induced DOMS; however, SMT appears to yield more consistent short-term improvements in soreness, ROM, and muscle damage markers.

Keywords

Active exercise therapy (AET), creatine kinase (CK), delayed onset muscle soreness (DOMS), muscle recovery, range of motion (ROM), sports massage therapy (SMT).

Resumen

Introducción: El dolor muscular de aparición tardía (DOMS) suele manifestarse entre 24 y 72 horas después del ejercicio excéntrico y puede afectar negativamente al rendimiento, la recuperación y la capacidad funcional. La terapia de masaje deportivo (SMT) y la terapia de ejercicio activo (AET) se utilizan con frecuencia para aliviar los síntomas del DOMS; sin embargo, su eficacia comparativa sigue siendo incierta.

Objetivo: Esta revisión sistemática y metaanálisis tuvo como objetivo comparar los efectos de la SMT y la AET sobre el dolor muscular, el rango de movimiento (ROM) y los niveles de creatina quinasa (CK) en adultos sanos que presentan DOMS inducido por el ejercicio.

Metodología: Se realizaron búsquedas sistemáticas en cuatro bases de datos electrónicas (PubMed, Scopus, Web of Science y Google Scholar) para identificar ensayos controlados aleatorizados publicados entre noviembre de 2004 y octubre de 2020. Los participantes elegibles fueron adultos sanos de 18 a 60 años que recibieron SMT (técnicas manuales de masaje) o AET (actividad ligera a moderada $\leq 70\%$ de la FC_{máx}) tras ejercicio excéntrico. La síntesis de datos se realizó con Review Manager 5.4 utilizando un modelo de efectos aleatorios para calcular las diferencias de medias estandarizadas (SMD) con intervalos de confianza del 95% (IC). La calidad metodológica se evaluó mediante la herramienta TESTEX y la heterogeneidad se cuantificó con la estadística I^2 .

Resultados: Treinta y nueve ensayos ($n = 1,148$) cumplieron los criterios de inclusión, con 27 intervenciones de SMT y 17 de AET. La SMT redujo significativamente el dolor muscular en comparación con el control y mostró una tendencia más consistente hacia mejoras del ROM y reducciones de CK. La AET produjo un alivio moderado y una recuperación variable del ROM. La calidad metodológica general fue de moderada a alta.

Conclusiones: Tanto la SMT como la AET son estrategias eficaces para el DOMS inducido por ejercicio; sin embargo, la SMT parece ofrecer mejoras más consistentes a corto plazo.

Palabras clave

Terapia de ejercicio activo; creatina quinasa; dolor muscular de aparición tardía; masaje deportivo; rango de movimiento; recuperación muscular.

Introduction

Delayed onset muscle soreness (DOMS) generally appears 24–72 hours following unaccustomed or eccentric exercise and is defined by discomfort, stiffness, swelling, and a temporary decrease in muscular function (Cheung, Hume, & Maxwell, 2003; Clarkson & Hubal, 2002). Despite being temporary, DOMS can hinder subsequent performance and disrupt training consistency, highlighting the necessity of good recovery measures in both sports and general exercise contexts.

Among the numerous therapies, sports massage treatment (SMT) and active exercise therapy (AET) are two of the most prevalent and readily available approaches. SMT influences its effects by mechanical pressure, neuromodulatory responses, and autonomic nervous system modulation, potentially diminishing intramuscular tension, facilitating fluid exchange, and altering pain perception (Weerapong, Hume, & Kolt, 2005). In contrast, AET, which consists of light aerobic exercise, mobility drills, or dynamic stretching, may promote recovery mainly by improving blood flow, clearing metabolites, and reconditioning the affected muscles, which results in the rapid elimination of inflammatory mediators and the restoration of functional capacity (Dupuy et al., 2018). The divergent mechanistic routes indicate that SMT and AET may address different physiological facets of recovery.

Nonetheless, existing sports recovery guidelines and consensus statements lack clarity on which method should be prioritized for acute recovery after eccentric exercise. Initial research indicated greater pain alleviation with SMT (Hilbert, Sforzo, & Swensen, 2003), but later evaluations emphasized AET's capacity to enhance muscular function and flexibility (Dupuy et al., 2018). Recent research published in *Retos* (Martínez-Sánchez et al., 2025). This study has advanced this field by investigating adjunct modalities such as hydrotherapy, compression, and various massage techniques, demonstrating that treatment efficacy is contingent upon factors such as intervention timing, protocol standardization, and participant characteristics.

Given this inconsistency, an updated synthesis directly comparing SMT and AET is warranted. This systematic review and meta-analysis sought to examine the short-term (<72 h) effects of SMT and AET on DOMS recovery in healthy persons, concentrating on three primary outcomes: pain intensity, range of motion (ROM), and blood creatine kinase (CK) concentration. We expected that (i) SMT would produce more significant short-term decreases in soreness rating and CK levels, whereas (ii) AET would exhibit enhanced recovery in functional or ROM metrics owing to its active circulatory and conditioning effects. This study aims to elucidate the comparative practical benefits of various modalities by direct examination and to offer evidence-based recommendations for post-exercise recovery in healthy individuals.

Method

Study protocol

This systematic review and meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009). A review protocol was prepared a priori to define eligibility, search strategy, data extraction, and planned analyses.

Search strategy

A systematic literature search was performed across four electronic databases: PubMed, Web of Science, Scopus, and Google Scholar, covering publications from 1 November 2004 to 20 October 2020.

Two independent reviewers conducted the search, while a third reviewer adjudicated irregularities to assure consistency and dependability.

The search approach integrated controlled vocabulary (MeSH/EMTREE) and free-text keywords through Boolean operators (AND, OR) to pinpoint pertinent randomized controlled trials. The terms were categorized into three conceptual domains: intervention, condition, and research design.

The general Boolean structure was as follows (“massage” OR “sports massage” OR “acupressure” OR “active exercise” OR “active recovery” OR “stretching” OR “proprioceptive neuromuscular facilitation”

OR “cycling”) AND (“delayed onset muscle soreness” OR DOMS OR “muscle soreness” OR “exercise-induced muscle damage”) AND (random* OR “randomized controlled trial”)

Study selection

Eligibility criteria of participants were defined as healthy adults aged 18–60 years, operationalized as individuals without physician-diagnosed neuromuscular, cardiovascular, or metabolic disorders and not taking analgesics or anti-inflammatory drugs during the assessment period. Interventions were categorized as SMT (manual massage techniques, e.g., effleurage, petrissage, tapotement, deep tissue, acupressure) or AET (light-to-moderate activity such as cycling $\leq 70\%$ HRmax, stretching, mobility, or low-load resistance). Co-interventions (cryotherapy, compression, electrotherapy, pharmacological agents) were excluded unless applied equally across groups. Comparators were passive rest, sham procedures, or usual care. Outcomes included pain intensity (VAS/NRS), ROM, and serum CK. Only randomized controlled trials were included. The selection procedure was summed up in a PRISMA flow diagram. Post-intervention values were computed from baseline differences, and the results were examined as continuous data. Heterogeneity was taken into account using a random effects model, and RevMan 5.4 (The Nordic Cochrane Centre, Denmark) was used for statistical analyses, such as forest plots.

Data Extraction and Synthesis

Data extraction was conducted manually through a standardized sheet, focusing on three primary outcome measures: visual analogue scale (VAS) for muscle soreness, range of motion (ROM), and serum creatine kinase (CK) levels. For each study, the subsequent details were documented: author, year of publication, sample size, group allocation (massage, active exercise, or control), pre- and post-intervention mean scores, percentage change, weighted difference, and p-values. Data were structured into comparative tables, specifically comparing sports massage or active exercise against control settings. Each dataset had both raw values and computed mean differences to measure the impact of interventions. The extraction guaranteed consistency and completeness, facilitating precise synthesis for meta-analysis utilizing Review Manager (RevMan) software.

Study Quality

The methodological quality of included trials was assessed using the TESTEX tool (Smart et al., 2015). TESTEX was chosen over PEDro or Cochrane RoB because it is specifically validated for exercise-based trials, incorporating criteria such as adherence, exercise intensity monitoring, and reporting of exercise volume and energy expenditure. These domains are critical for recovery interventions, where fidelity to exercise prescription directly influences DOMS outcomes. While PEDro and Cochrane RoB capture important aspects of bias, they do not adequately address exercise-specific factors. Thus, TESTEX provides a more context-sensitive evaluation of methodological rigor in this field. Two independent reviewers scored all trials after calibration, with disagreements resolved by consensus. The quality score of the papers was based on tertiles, where 0–5 points were considered low quality, 6–10 points were considered medium quality and 11–15 points were considered high quality. Based on the TESTEX scores, the identified 39 studies obtained a median score of 12.

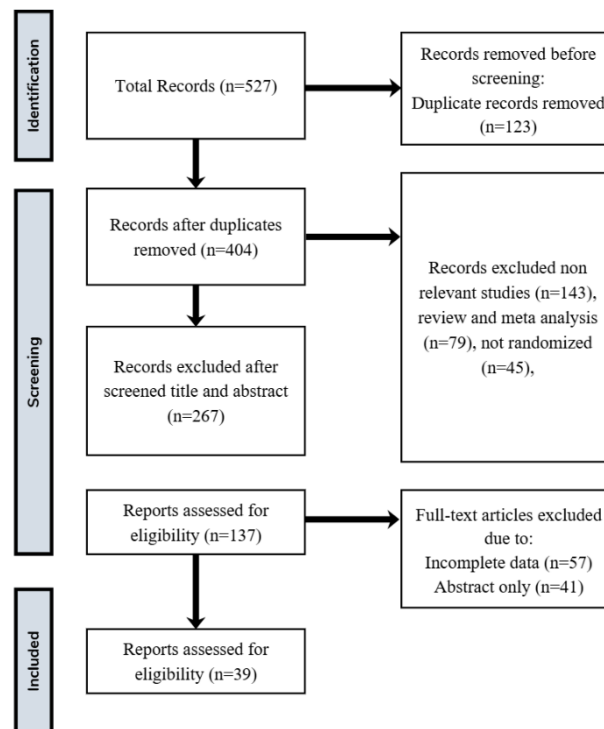
Statistical Analysis

This study calculated changes in post-intervention means by subtracting baseline from post-intervention values. This review consists of the continuous type of data where each individual's outcome is a measurement of a numerical quantity. Mean differences from baseline in these data were calculated. A random effects model was used in this review, as this model is appropriate for capturing uncertainty resulting from heterogeneity among studies. RevMan version 5.4 software (The Nordic Cochrane Centre Denmark) was used to construct forest plots and funnel plots. Continuous data are reported as mean \pm SD, 95% confidence interval, actual p values for pre-post intervention change for each group or if only the level of statistical significance $p < 0.05$ becomes $p = 0.049$, $p < 0.01$ becomes $p = 0.0099$ and $p =$ not significant becomes $p = 0.051$.

Results

A Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram for our literature search and selection is presented in Figure 1. The initial search identified 527 potentially relevant studies. After removing 123 duplicates, 404 records remained for screening. Of these, 267 were excluded based on title and abstract screening. From this, 143 were excluded as non-relevant, 79 were reviews or meta-analyses, and 45 were not randomized controlled trials. A total of 137 full-text articles were assessed for eligibility. An additional 96 articles were excluded due to incomplete data (n=57) or abstract-only availability (n=41). Ultimately, 39 studies met the inclusion criteria and were included in the final systematic review and meta-analysis.

Figure 1. PRISMA flow diagram



Characteristics of the included massage studies

A total of 27 randomized controlled trials involving 765 healthy participants were included in the analysis of massage interventions for DOMS. Among these studies, 29 used the Visual Analogue Scale (VAS) to evaluate muscle soreness, 14 tested serum CK levels as a marker of muscle injury, and 12 assessed ROM for evaluating functional recovery. Massage duration varied from 5 to 30 minutes and included techniques like effleurage, petrissage, tapotement, and deep tissue massage. Numerous investigations indicated substantial decrease in pain, however the impacts on CK and ROM had inconsistent outcomes.

Table 1. Characteristics of included massage studies.

Author & year	Massage Duration (min)	(n=)	Late Muscle Pain (DOMS induced)	Intervention Used	Dose Response (exercise protocol)	Evaluation Method	Intensity
Andersen et al. (2013)	10	20	Eccentric contraction of the upper trapezius using a Biodex dynamometer, targeting muscle fibers through slow to fast contraction speeds (30°/s to 90°/s).	Massage (petrissage and effleurage) and active exercise (TheraBand resistance)	Performed 10 sets of eccentric contractions on the trapezius, progressing from slow (30°/s) to high velocity (90°/s).	VAS, PPT	Moderate

Chang et al. (2020)	12	20	Repeated vertical jumping targeting the quadriceps and hamstrings through high-intensity eccentric loading during the landing phase.	Traditional Chinese Acupressure Massage (TCAM)	Repeated vertical jumps: 12 sets of 10 jumps (120 total) at 0.7 Hz, followed by 1-minute rest after each set. Blood lactate confirmed consistent exercise intensity.	VAS, AROM/PROM, CK	Moderate
Frey Law et al. (2008)	6	27	Eccentric wrist extensions performed with a 10-lb hand weight, targeting the forearm extensors to create muscle micro-tears and induce DOMS.	Deep-tissue massage vs superficial touch	3 sets of eccentric wrist extensions using a 10-lb weight until fatigue (inability to control weight for 3 repetitions). 1–2 minutes rest between sets.	VAS, PPT	Deep
Fuller et al. (2015)	10	38	Maximal eccentric knee extensions on a Biodex dynamometer, targeting the knee extensors with controlled angular velocity at 45°/s.	Sports massage and stretching (SSM) vs vibration therapy	100 maximal eccentric contractions of knee extensors at 45°/s on a Biodex dynamometer. Pre- and post-testing ensured consistent DOMS induction.	VAS, CK, CRP	Moderate
Hart et al. (2005)	5	38	Eccentric calf raises targeting the triceps surae (calf muscles), performed at 90% of the estimated 1-repetition max (1RM) using a calf raise machine.	Sports massage and active rest	4–5 sets of 35 eccentric calf contractions at 90% of concentric 1RM using a standing calf raise machine. A warm-up of 20 submaximal concentric contractions was performed.	VAS, girth measurements	Light
Hilbert et al. (2003)	20	18	Maximal eccentric hamstring contractions caused muscle micro-tears and inflammation, peaking soreness at 24-48 hours post-exercise.	Swedish massage (effleurage, petrissage, tapotement)	6 sets of 8 maximal eccentric hamstring contractions on an isokinetic dynamometer.	VAS, ROM, neutrophil count	Moderate
Hoffman et al. (2016)	20	48	Ultramarathon (161 km) resulted in extreme DOMS, fatigue, and muscle dysfunction with high creatine kinase (CK) levels post-race.	Massage and pneumatic compression	Completion of a 161-km ultramarathon with 5500 m ascent and 7000 m descent, causing severe eccentric damage to lower limb muscles.	VAS, CK, fatigue scores	Moderate
Imtiyaz et al. (2014)	15	30	Eccentric elbow flexor contractions caused localized DOMS with increased soreness and CK levels at 24-48 hours post-exercise.	Massage vs vibration therapy	30 repetitions of eccentric elbow flexor contractions with 80% pre-exercise maximal isometric force (MIF), lowering dumbbell over 4-5 seconds with 45-second rest intervals.	VAS, ROM, CK, LDH	Moderate (massage), Light (vibration)
Jakeman et al. (2010)	30	24	Plyometric drop jumps caused lower limb muscle damage, soreness, and reduced strength, peaking at 48 hours post-exercise.	Compression vs massage + compression	10 sets of 10 plyometric drop jumps from a 0.6-m box, landing at 90° knee flexion followed by maximal vertical jumps. Standardized 10-second intervals and 1-minute rest.	VAS, CK, isokinetic strength	Deep
Jay et al. (2014)	10	22	Stiff-legged deadlifts caused significant hamstring soreness and reduced ROM, peaking at 48 hours post-exercise.	TheraBand roller massage	10 sets of 10 repetitions of stiff-legged deadlifts, progressing kettlebell weights (12–32 kg) over sets, with 30-second rests between sets.	VAS, PPT, ROM	Moderate
Kargarfard et al. (2015)	30	30	Intensive resistance training (5-rep sets at 75–77% 1RM) targeting knee flexor and extensor muscles induced DOMS.	Sports massage vs passive recovery	Five repetitions per set at 75–77% 1RM of knee extensor/flexor exercises with rest intervals, creating significant muscle soreness and increased CK.	VAS, CK, vertical jump, agility tests	Deep
Kong et al. (2018)	16	36	Downhill running (-10° gradient) for 40 minutes increased muscle stiffness and DOMS, peaking at 24–48 hours post-exercise.	Swedish massage (effleurage, petrissage, tapotement)	Downhill running at -10° for 40 minutes at 80% HRmax. Stiffness measurements targeted rectus femoris, biceps femoris, tibialis anterior, and gastrocnemius.	VAS, MyotonPRO (muscle stiffness), CK	Moderate
Micklewright (2009)	10	20	Eccentric elbow extensions (4×20 reps at 80% 1RM) caused significant DOMS, with peak soreness at 24–48 hours.	Soft Tissue Release (STR) vs no treatment	Four sets of 20 eccentric elbow extensions at 80% 1RM, targeting flexor muscles of the arm. Soreness measured at multiple time points post-exercise.	VAS, ROM, arm girth measurements	Deep

Visconti et al. (2020)	10	38	Ski mountaineering (3-day race) involved prolonged eccentric muscle activity leading to DOMS in lower limbs during rest intervals.	Manual massage vs long-wave diathermy (LWD)	Ski mountaineering alternating uphill and downhill free skiing over 3 days. DOMS induced in the hamstrings, quadriceps, and gastrocnemius.	NPRS, PGIC	Moderate
Wiewelhoeve et al. (2018)	10	22	Half-marathon running caused prolonged DOMS and muscle fatigue in lower extremities, peaking post-race.	Massage vs cold water immersion (CWI) vs active recovery	Official half-marathon completion. Recovery interventions began within 15 minutes post-race, targeting lower body soreness and fatigue recovery markers.	VAS, CK, perceived recovery	Moderate
Zainuddin et al. (2005)	10	20	Eccentric elbow flexion caused localized DOMS in biceps brachii and brachialis muscles, with peak soreness at 48 hours post-exercise.	Deep tissue massage using effleurage and petrissage	10 sets of 6 maximal eccentric actions on an isokinetic dynamometer (90°/s), followed by a 3-hour post-exercise recovery phase.	VAS, ROM, CK, arm circumference	Deep
Dawson et al. (2004)	30	24	Half-marathon running (21.1 km) induced DOMS in quadriceps and hamstrings due to eccentric stress from prolonged running.	Sports massage performed by a licensed therapist	Participants completed a half-marathon race with evaluations of soreness, swelling, and strength on days 1, 4, 8, and 11 post-race.	VAS, thigh circumference, CYBEX torque	Moderate
Dawson et al. (2011)	Weekly 30-min sessions	34	Running training for a 10-km race caused progressive DOMS, with most runners reporting pain after weekly sessions.	Weekly proactive massage during training	10-week progressive training program for a 10-km race, with weekly group and individual runs averaging 4–5 runs/week.	Strength, pain scales, running journals	Moderate
Delextrat et al. (2013)	15	32	Basketball matches caused DOMS due to repeated high-intensity sprints and jumps with eccentric loading.	Sports massage vs intermittent cold-water immersion	Competitive basketball matches, followed by immediate recovery interventions and assessments at 24 hours.	VAS, countermovement jump, repeated sprints	Moderate
Mancinelli et al. (2006)	15	22	Preseason training for basketball/volleyball induced DOMS due to unaccustomed eccentric activities.	Effleurage, petrissage, vibration massage	Daily strength training, drills, and scrimmages for basketball and volleyball during preseason, with massage post-exercise for treatment group.	VAS, vertical jump, shuttle run times, PPT	Moderate
Nunes et al. (2016)	7	73	Ironman triathlon (226 km: swim 3.8 km, bike 180 km, run 42.2 km) caused significant fatigue and pain in lower limbs, especially quadriceps.	Effleurage, deep effleurage, petrissage, tapotement	Ironman triathlon race with extreme endurance demand causing fatigue and muscle damage.	VAS, pressure pain threshold	Moderate
Harahap et al. (2017)	12	20	Running and weight training caused musculoskeletal pain in the lower leg due to repeated eccentric contractions.	Sports massage (effleurage) after training	Weight training combined with 200 m running drills over 8 weeks, 3 sessions per week.	VAS, ANOVA	Moderate
Willems et al. (2009)	25	14	Downhill treadmill walking (-25% gradient) caused quadriceps muscle-specific DOMS with peak soreness at 48 hours post-exercise.	Effleurage, petrissage, tapotement	Downhill treadmill walking for 20 minutes at 6.4 km/h carrying a load (10% of body weight), targeting eccentric loading on quadriceps.	VAS, single-leg vertical jump	Moderate
Boguszewski et al. (2014)	20	29	Deep squat jumps caused significant quadriceps soreness, peaking at 24-48 hours post-exercise.	Sports massage (effleurage, rubbing, kneading, vibration)	5 sets of deep squat jumps, alternating between maximal effort and submaximal repetitions (60–80% RM), with final set at maximal effort.	VAS, vertical jump performance	Moderate
Jonhagen et al. (2004)	12	32	300 maximal eccentric quadriceps contractions caused DOMS with significant loss of strength peaking at 48 hours post-exercise.	Effleurage, petrissage	300 eccentric quadriceps contractions on a Kin-Com dynamometer at 180°/s targeting muscle fibers' sarcomeric damage.	VAS, isometric strength, long jump	Moderate
Lau et al. (2011)	30	30	Maximal eccentric elbow flexor contractions caused DOMS in the biceps brachii and brachialis, with swelling and	Vibration therapy vs control	10 sets of 6 maximal eccentric elbow flexor contractions on an isokinetic dynamometer, inducing muscle microtrauma.	VAS, ROM, PPT, CK	Moderate

soreness peaking at 48 hours.						
Naderi et al. (2021)	15	52	Calf strength training (eccentric focus) caused DOMS and impairments in balance and proprioception, peaking within 48 hours.	Massage vs cold water immersion (CWI)	Standing and seated calf raises (4×10 reps at 75% 1RM) targeting gastrocnemius and soleus muscles.	VAS, balance, strength, proprioception Moderate

Abbreviations: visual analog scale (VAS), pain pressure threshold (PPT), range of motion (ROM), creatine kinase (CK), delayed onset muscle soreness (DOMS)

Characteristics of the included active exercise studies

17 randomized controlled trials with 383 healthy participants were included to evaluate the impact of AET on DOMS. All 17 studies assessed muscle soreness using the Visual Analog Scale (VAS), while 9 measured serum CK levels as a marker of muscle damage, and 7 evaluated ROM to assess functional recovery. The exercise protocols ranged in duration from 8 to 45 minutes and included modalities such as aerobic cycling, eccentric strength training, plyometric exercises, running, and stretching techniques (static and PNF). Intensity levels varied from low-intensity recovery to high-intensity efforts attaining 90% VO_2max . Although most therapies significantly diminished felt soreness, the outcomes for CK and ROM were inconsistent, indicating varying physiological recovery responses dependent upon the type and intensity of exercise.

Table 2. Characteristics of included active exercise studies.

Author & year	Exercise Duration (min)	Late Muscle Pain (DOMS induced) (n=)	Intervention Used	Dose Response (exercise protocol)	Evaluation Method (VAS/ROM/CK)	Intensity of exercise
Andersen et al. (2013)	10	20	DOMS developed 48 hours after eccentric trapezius contractions; soreness and PPT measured at intervals.	Massage vs. active exercise (shoulder shrugs with elastic resistance)	10 reps x 10 sets with elastic bands, progression in resistance	VAS, Pressure Pain Threshold (PPT) Progressive resistance (TheraBand)
Chang et al. (2020)	12	20	DOMS induced by repeated high-intensity vertical jumps; assessed via ROM, pain, and inflammatory markers.	Traditional Chinese Acupressure Massage (TCAM) vs. active recovery (stationary cycling at 50 W)	12 repetitions of 10 consecutive jumps (120 jumps total)	VAS, ROM, MVC, leukocyte counts High-intensity jumping (eccentric)
Marquet et al. (2015)	15	22	DOMS evaluated post BMX interval and resistance training; tested via sprint power and fatigue ratings.	Passive, Active Recovery, Cold-Water Immersion (CWI), Nutrition	Maximal sprint power cycling tests before/after recovery strategies	Maximal-sprint power, DOMS scale (cycling tests) Maximal effort (cycling tests)
Olsen et al. (2012)	20	24	DOMS triggered by eccentric lunges; assessed at 24 and 48 hours using VAS and PPT.	Warm-up: cycling before exercise; Cool-down: cycling after exercise	5 sets of 10 lunges with 40%-50% body weight load	VAS, Pressure Pain Threshold (PPT), MVC Moderate-intensity aerobic (cycling)
Rey et al. (2012)	20	31	DOMS assessed post high-intensity soccer training; measured via TMG and soreness ratings.	Active Recovery: 12 min submaximal running + 8 min static stretching, Passive Recovery: 20 min seated rest	Standard soccer training + 2 recovery modalities	TMG, muscle soreness scale Submaximal (65% aerobic capacity)
Tufano et al. (2012)	20	16	Eccentric knee extensor actions; soreness measured up to 96 hours.	Low vs. moderate-intensity cycling vs. seated rest after exercise.	60 eccentric knee actions followed by recovery interventions for 20 minutes.	Pain scale, isometric/dynamic strength tests. Low (30% HR reserve) vs. moderate (70% HR reserve) aerobic cycling.
Wheeler et al. (2013)	10	20	DOMS induced via lunges with dumbbells (12%-18% body weight).	Whole-body vibration (WBV) vs. light walking post-exercise.	3 sets of 10 lunges; WBV for 10 minutes (incremental Hz program).	VAS for soreness, flexibility (sit-and-reach), and vertical jump power. WBV program (20-45 Hz) vs. walking at 3.5-3.7 mph.
Wiewelhove et al. (2018)	Varied	25	Fatigue from half-marathon; soreness and stress assessed over 24 hours.	Active recovery (ACT), cold-water immersion (CWI), massage (MAS), or passive recovery (PAS).	Recovery protocols immediately after half-marathon.	Perceived recovery, muscle soreness, creatine kinase, countermovement jump. ACT (low-intensity aerobic); CWI at 15°C; MAS (standard massage techniques).

Zainuddin et al. (2006)	20	20	Eccentric elbow flexor actions; soreness assessed for 7 days.	Light concentric exercise (LCE) vs. control (no exercise).	600 elbow flexion/extension actions, minimal force; repeated 4 days.	Isometric strength, ROM, muscle soreness, plasma CK levels.	Minimal force (isokinetic dynamometer).
Torres et al. (2013)	Varied	28	Eccentric quadriceps contractions until exhaustion; soreness measured 1-96 hours.	Single vs. repeated bouts of passive stretching post-exercise.	Stretching immediately and at 24, 48, 72 hours post-exercise; each stretch lasted 30 seconds.	VAS, muscle stiffness, concentric peak torque, plasma CK levels.	Eccentric contractions (isokinetic dynamometer).
Muanjai et al. (2015)	20	27	Plyometric training-induced DOMS assessed over 96 hours.	Stretching vs. cold-water immersion (CWI) vs. combined intervention.	20-min post-training interventions; 4-day follow-up.	VAS, flexibility, vertical jump performance.	High-intensity plyometric training.
McGrath et al. (2014)	Varied	37	Eccentric leg curls inducing DOMS.	PNF stretching vs. static stretching vs. control (no stretching).	Post-exercise stretching; effects assessed at 24 and 48 hours.	Pain scale, flexibility, recovery assessments.	Moderate-intensity eccentric leg curls.
Cooke et al. (2018)	45	17	Downhill running at 60% VO2max for 45 minutes.	Anti-gravity treadmill vs. conventional treadmill vs. static stretching.	Recovery methods performed 30 minutes post-exercise, repeated daily for 3 days.	Perceived soreness, isokinetic strength, mood states.	Submaximal eccentric running.
Ce et al. (2013)	8	18	Heavy-intensity cycling at 90% VO2max; recovery assessed post-exercise.	Static stretching, deep massage, superficial massage, active, and passive recovery.	10-min interventions followed by 1-hour recovery.	Blood lactate levels, MVC, EMG amplitude.	High-intensity cycling (90% VO2max).
Chen et al. (2011)	Varied	20	Eccentric exercise of the knee flexors using isokinetic dynamometer.	Static stretching (SS) and PNF training.	8-week training, 3 sessions per week, with stretching protocols pre and post-exercise.	ROM, muscle strength, soreness, plasma CK, and myoglobin levels.	Maximal eccentric contractions.
Harahap et al. (2017)	Varied	20	Musculoskeletal pain assessed 12-24 hours post-eccentric exercises.	Regular exercise with sports massage (RE+SM) vs. regular exercise (RE) vs. control.	Weight training followed by 12-minute massage using effleurage technique.	VAS	Moderate-intensity resistance training.

Abbreviations: visual analog scale (VAS), pain pressure threshold (PPT), range of motion (ROM), creatine kinase (CK), delayed onset muscle soreness (DOMS), maximum voluntary contraction (MVC), tensionmyography (TMG).

Study Outcome

Soreness Rating

Figure 2A. Forest plot of soreness rating comparison, outcome: A-Massage therapy. B-Active Exercise

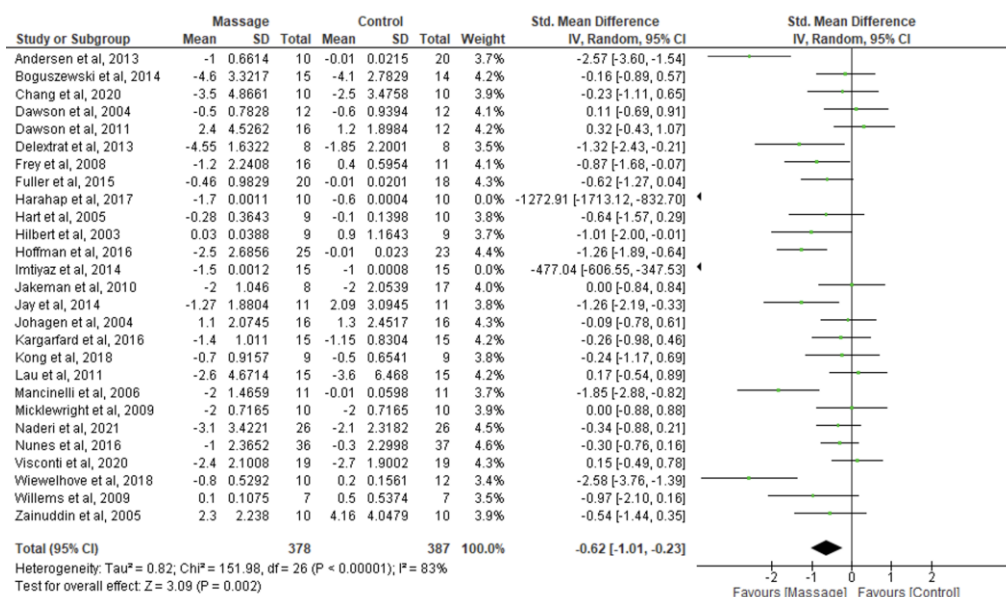


Figure 2B. Forest plot of soreness rating comparison, outcome: A-Massage therapy. B-Active Exercise

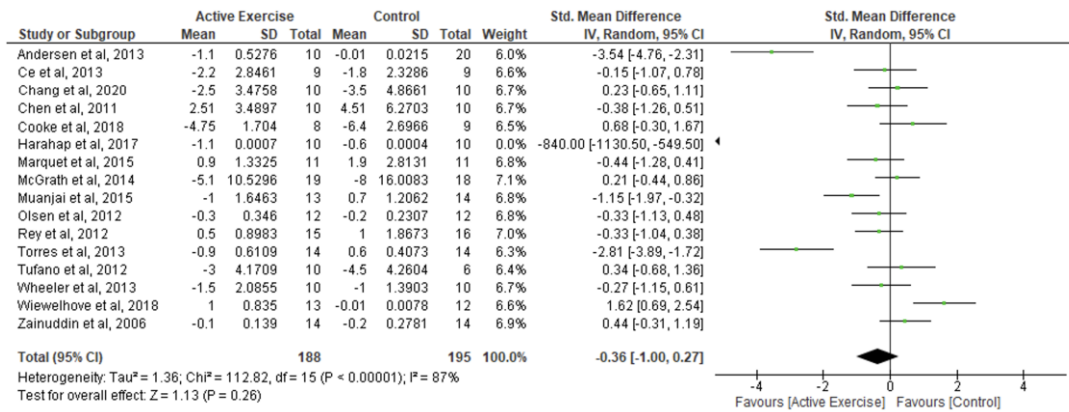


Figure 2A presents a forest plot with a pooled standardized mean difference (SMD = -0.62; 95% CI: -1.01 to -0.23; Z = 3.09; p = 0.002) derived from 27 randomized trials that compare SMT to passive control. The negative pooled effect indicates that participants receiving SMT reported significantly lower muscle soreness within 24–72 hours post-exercise compared with controls. This indicates a small-to-moderate positive impact of massage on the experience of soreness. Nonetheless, the heterogeneity among studies was high (I² = 83%; χ^2 = 151.98; p < 0.00001; τ^2 = 0.82), indicating significant diversity among the investigations. This variability likely indicates variations in massage techniques (e.g., effleurage, petrissage, or deep tissue), treatment duration, timing of intervention, and the attributes of the workout routine employed to produce DOMS.

Figure 2B presents a forest plot with a pooled standardized mean difference (SMD = -0.36; 95% CI: -1.00 to 0.27; Z = 1.13; p = 0.26) derived from 16 trials comparing active exercise therapy versus control groups. The negative mean difference suggests a trend of decreased soreness after AET; nevertheless, the 95% confidence interval includes zero, indicating that the effect lacks statistical significance. The studies exhibited considerable heterogeneity (I² = 87%; χ^2 = 112.82; p < 0.00001; τ^2 = 1.36), indicative of the variability in active recovery modalities (e.g., low-intensity cycling, stretching, walking), exercise intensities, and measurement intervals. The high heterogeneity and overlapping confidence ranges indicate that no definitive advantage of AET over passive recovery can be established when results are combined. Nevertheless, numerous individual investigations indicate a preference for AET, suggesting that its effectiveness may be contingent upon the particular strength, timing, and nature of the active recovery implemented.

Range of Motion (ROM)

Figure 3A. Forest plot of ROM comparison, outcome: A-Massage therapy. B-Active Exercise

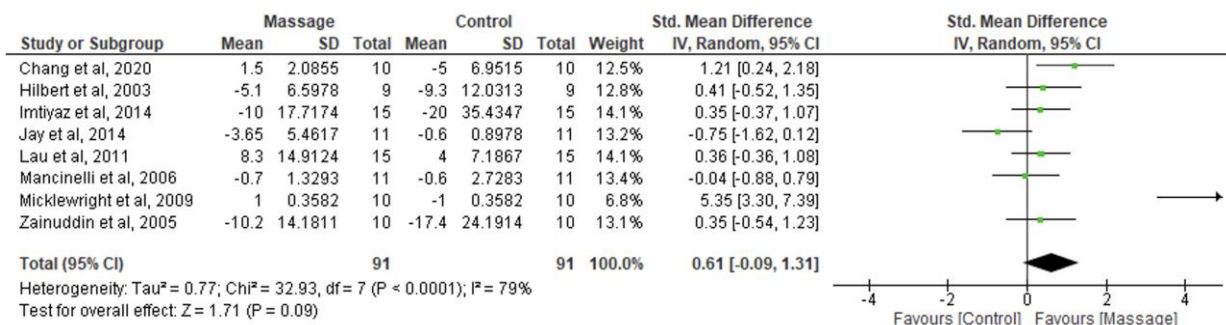


Figure 3B. Forest plot of ROM comparison, outcome: A-Massage therapy. B-Active Exercise

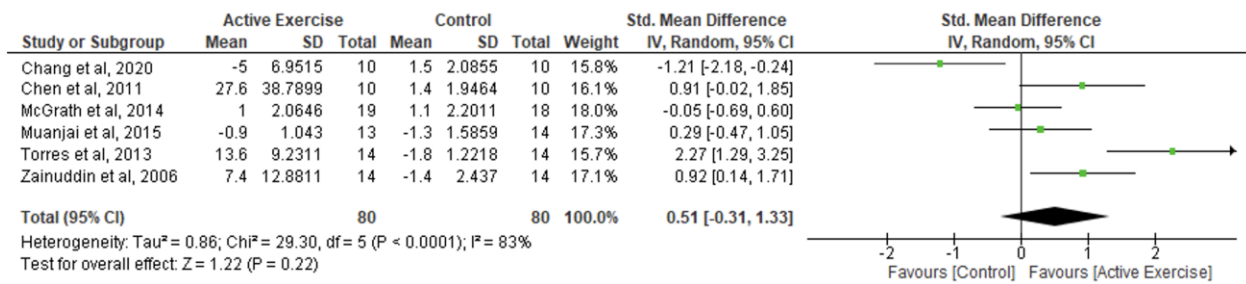


Figure 3A presents a forest plot illustrating the pooled standardized mean difference (SMD = 0.61; 95% CI: -0.09 to 1.31; Z = 1.71; p = 0.09) obtained from eight randomized studies assessing post-exercise ROM after massage therapy. Despite the pooled estimate favoring the massage group, the confidence interval intersects zero and the p-value surpasses 0.05, signifying that the enhancement in ROM was not statistically significant. The found heterogeneity was substantial (I² = 79%; χ^2 = 32.93, df = 7; p < 0.0001; τ^2 = 0.77), indicating considerable variation between studies. This inconsistency likely arises from differences in target muscles, measurement methods (e.g., goniometry vs inclinometer), timing of ROM assessment, and variability in massage duration and intensity across trials. Although lacking statistical significance, most studies indicate a directional enhancement in ROM following SMT, suggesting that SMT may possess a modest yet variable ability to restore movement flexibility after exercise-induced muscle injury.

Figure 3B shows the forest plot illustrating the pooled standardized mean difference (SMD = 0.51; 95% CI: -0.31 to 1.33; Z = 1.22; p = 0.22) derived from six randomized trials evaluating ROM improvement with AET. The total effect favors AET but is statistically non-significant, as the 95% confidence interval encompasses the null value. Inter-study heterogeneity was notably high (I² = 83%; χ^2 = 29.30, df = 5; p < 0.0001; τ^2 = 0.86), indicating variety in protocols, including the type and intensity of active exercise (e.g., cycling, stretching, mobility drills), timing post-exercise, and sample characteristics. The variability in effect sizes suggests that although certain studies noted enhanced ROM following aerobic exercise training, others documented minimal or inconsistent results.

Serum Creatine Kinase Reading

Figure 4A. Forest plot of serum CK reading comparison, outcome: A-Massage therapy. B-Active Exercise

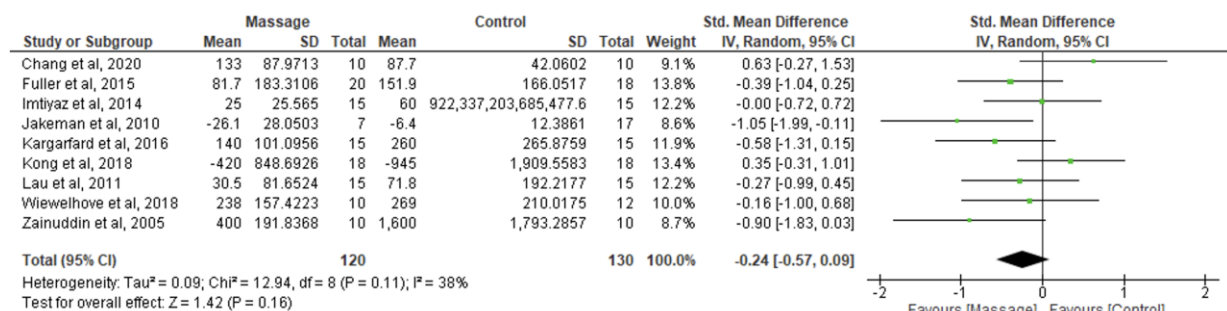
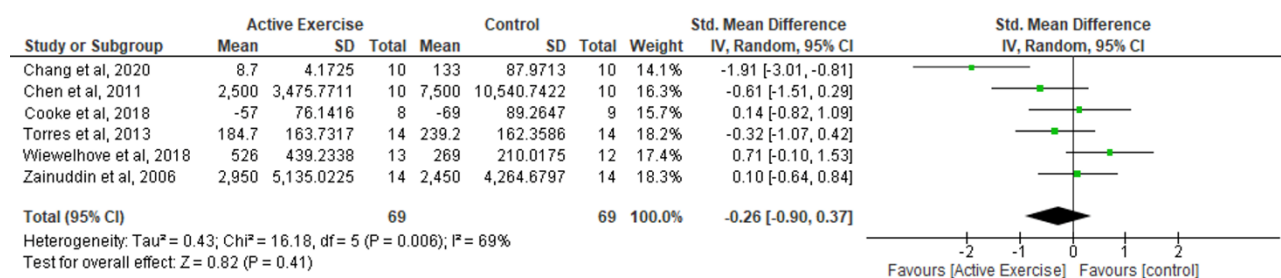


Figure 4B. Forest plot of serum CK reading comparison, outcome: A-Massage therapy. B-Active Exercise



The forest plot in Figure 4A summarizes nine randomized controlled trials comparing SMT with passive control on post-exercise serum CK. The pooled standardized mean difference was -0.24 (95% CI = -0.57 to 0.09 ; $Z = 1.42$; $p = 0.16$), signifying no statistically significant effect. While most individual trials indicated reduced CK readings in the massage groups, the confidence interval included zero. The heterogeneity was moderate ($I^2 = 38\%$; $\chi^2 = 12.94$, $df = 8$; $p = 0.11$; $\tau^2 = 0.09$), indicating generally uniform results across trials for soreness and ROM outcomes.

For active exercise (AET) (Figure 4B), six trials yielded a pooled standardized mean difference of -0.26 (95% CI = -0.90 to 0.37 ; $Z = 0.82$; $p = 0.41$). The overall effect was not significant, exhibiting substantial heterogeneity ($I^2 = 69\%$; $\chi^2 = 16.18$, $df = 5$; $p = 0.006$; $\tau^2 = 0.43$). Effect estimates were variable, ranging from minor reductions in CK to small differences between the AET and control groups.

Publication Bias

The quality of each study was evaluated using the TESTEX scale (Smart et al., 2015), revealing that the 39 included studies found a median score of 12 out of 15, signifying overall good quality. All studies were categorized within the medium to high tertiles (scoring 6–15), with none considered low quality. Common reporting limitations included lack of allocation concealment, absence of assessor blinding, and insufficient reporting on exercise intensity consistency and energy expenditure. While most studies attained adherence rates exceeding 85%, participants with inadequate compliance were eliminated and classified as dropouts.

Table 3. Study Quality Analysis using TESTEX Scoring Tools

Author, Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Andersen et al., 2013	/	/	/	/	/	/	/	/	X	/	/	/	/	/	/	14
Chang et al., 2020	/	/	X	/	/	/	/	/	X	/	/	/	/	/	/	13
Frey et al., 2008	/	/	X	/	/	/	/	/	X	/	/	/	/	/	/	13
Fuller et al., 2015	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	15
Hart et al., 2005	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	13
Hilbert et al., 2003	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	13
Hoffman et al., 2016	/	/	/	/	X	/	/	/	/	/	/	/	/	/	/	14
Imtiyaz et al., 2014	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Jakeman et al., 2010	/	/	X	/	/	/	X	/	X	/	/	/	/	/	/	12
Jay et al., 2014	/	/	X	/	/	/	X	/	X	/	/	/	/	/	/	12
Kargarfard et al., 2016	/	/	X	/	/	/	/	/	/	/	/	/	/	/	/	14
Kong et al., 2018	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	15
Micklewright et al., 2009	/	/	X	/	/	/	/	/	X	/	/	/	/	/	/	13
Visconti et al., 2020	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	15
Wiewelhove et al., 2018	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	15
Zainuddin et al., 2005	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Dawson et al., 2004	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Dawson et al., 2011	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Delextrat et al., 2013	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	15
Mancinelli et al., 2006	/	/	X	/	/	/	/	/	X	/	/	/	/	/	/	13
Nunes et al., 2016	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	15
Harahap et al., 2017	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Willems et al., 2009	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Boguszewski et al., 2014	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Jönhagen et al., 2004	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Lau et al., 2011	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12



Naderi et al., 2021	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	15
Marquet et al., 2015	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Olsen et al., 2012	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Rey et al., 2012	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Tufano et al., 2012	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Wheeler et al., 2013	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Zainuddin et al., 2006	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Torres et al., 2013	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Muanjai et al., 2015	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
McGrath et al., 2014	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Cooke et al., 2018	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Ce et al., 2013	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Chen et al., 2011	/	/	X	/	X	/	/	/	X	/	/	/	/	/	/	12
Median																12

Abbreviations: 1- Eligibility criteria specified, 2 - Randomization specified, 3 - Allocation concealment, 4 -Groups similar at baseline, 5 - Blinding of assessor, 6 - Outcome measures assessed in 85% of patient, if adherence > 85%, 7 - Outcome measures assessed in 85% of patient, if adverse events are reported, 8 - Outcome measures assessed in 85% of patient, if exercise attended is reported, 9 - Intention-to-treat analysis, 10 - Between-group statistical comparisons reported, primary outcome measure, 11 - Between-group statistical comparisons reported, secondary outcome measure, 12 - Point measures and measures of variability for all reported outcome measures, 13 - Activity monitoring in control groups, 14 - Relative exercise intensity remained constant, 15 - Exercise volume and energy expenditure.

Discussion

Soreness Rating

This meta-analysis revealed a statistically significant decrease in perceived muscle soreness after SMT compared to passive control (SMD = -0.62; 95% CI: -1.01 to -0.23; $p = 0.002$), indicating a small-to-moderate effect size. This result supports prior findings that massage alleviates delayed-onset muscle soreness (DOMS) via neuromechanical and circulatory modulation rather than structural repair (Martínez-Sánchez et al., 2025; Gómez-Pérez & Crespo-Ruiz, 2024). The mechanical compression and shear stress produced by massage activate mechanoreceptors and large-diameter afferent fibers, thereby suppressing nociceptive transmission at the dorsal horn through gate-control mechanisms. This sensory modulation is associated with enhanced microvascular perfusion and lymphatic drainage, facilitating the clearance of inflammatory mediators such as prostaglandins, bradykinin, and hydrogen ions that sensitize group III and IV afferents.

Moreover, massage facilitates autonomic rebalance favoring parasympathetic dominance, hence reducing sympathetic tone and catecholamine secretion. These processes diminish local ischemia and systemic stress responses, resulting in a quantifiable analgesic impact. The high heterogeneity ($I^2 = 83\%$) noted among SMT trials likely indicates diversity in technique, treatment duration, application timing, and the exercise models employed to generate DOMS. Comparable heterogeneity has been observed in other Retos meta-analyses of exercise regimens, where protocol inconsistencies affected the overall findings (Ilias et al., 2025). These data collectively indicate that SMT largely enhances subjective recovery via sensory and haemodynamic mechanisms, providing short-term comfort rather than expediting tissue regeneration.

Range of Motion (ROM)

Neither SMT (SMD = 0.61; $p = 0.09$) nor active exercise therapy (AET) (SMD = 0.51; $p = 0.22$) produced statistically significant pooled improvements in ROM. Post-exercise ROM restriction results from intramuscular oedema, connective tissue rigidity, and heightened neuronal reflex excitability subsequent to eccentric muscle injury. Massage is believed to improve mobility by decreasing fascial adhesion, restoring normal muscle spindle activity, and enhancing viscoelastic compliance. Nonetheless, these mechanical benefits are temporary and are highly contingent upon the dosage and time of treatment.

AET promotes active muscular contraction and capillary engagement, theoretically diminishing stiffness through enhanced oxygen supply and metabolite elimination. However, excessive or poorly planned exercise may induce mechanical strain, undermining potential benefits. High heterogeneity ($I^2 > 79\%$) across studies reflects inconsistency in measurement tools (goniometer vs. inclinometer), muscle groups assessed, and outcome timing (24–72 h post-exercise). Similar inequalities were also emphasized in Retos articles examining flexibility and mobility results in exercise rehabilitation scenarios (Fernández-García et al., 2024; Serrano-Gómez & Martínez-Aldao, 2023). The lack of substantial pooled effects indicates that neither SMT nor AET reliably recovers joint mobility during exercise-induced muscle



injury. Improvements in subjective comfort observed with massage may therefore not translate directly to functional recovery, a pattern echoed across other exercise-based meta-analyses within Retos (Ilias et al., 2025).

Serum CK Levels

Serum CK, a biochemical marker of sarcolemmal disruption, showed no significant pooled reduction after SMT (SMD = -0.24; $p = 0.16$) or AET (SMD = -0.26; $p = 0.41$). CK concentration generally reaches its peak 24–72 hours after exercise, indicating the release of intracellular enzymes due to mechanical microtrauma. The present findings demonstrate that neither intervention significantly modifies the biochemical recovery path of muscle fibers. Massage may slightly improve perfusion and diminish secondary inflammation; however, these benefits are inadequate to inhibit enzyme efflux or expedite myofibrillar repair. Similarly, low-intensity exercise may promote metabolic recovery while concurrently imposing slight extra strain, so constraining overall benefit.

Moderate heterogeneity for SMT ($I^2 = 38\%$) and substantial variability for AET ($I^2 = 69\%$) indicate that variations in blood-sampling intervals, exercise protocols, and participant fitness levels affect the biochemical response. Previous Retos reviews on recovery physiology have similarly emphasized that subjective relief and biochemical recovery are dissociable phenomena, reflecting distinct neural and cellular mechanisms (Navarro-Domínguez et al., 2022; Ilias et al., 2025). Consequently, while SMT and AET can reduce perceived discomfort, they should not be interpreted as interventions capable of reversing structural muscle damage or accelerating cytoskeletal stabilization.

Integrated interpretation and Implication

The current analysis suggests that SMT offers clinically meaningful yet moderate enhancements in perceived soreness, while AET demonstrates variable and non-significant effects across all assessed outcomes. Neither therapy significantly enhances ROM nor reduces serum CK levels during the immediate 24–72 hour period following eccentric exercise. Both therapies primarily function through neurophysiological modulation (afferent inhibition, autonomic regulation) and microvascular adaptation (improved flow and metabolite clearance), rather than through direct structural restoration.

These findings align with recent Retos research indicating that the effectiveness of interventions is significantly influenced by protocol fidelity, intensity regulation, and participant status (Ilias et al., 2025; Martínez-Sánchez et al., 2025). Future research should implement standardized reporting of exercise intensity, treatment dosage, and scheduling of measurements to minimize methodological variability. The integration of objective biomarkers (e.g., interleukin-6, tumor necrosis factor- α , oxidative stress indices) with perceptual results will enhance the understanding of the biological mechanisms involved in recovery. In practical terms, both SMT and AET remain valuable adjuncts for symptom management and athlete readiness, but their use should be guided by individualized response and integrated within multimodal recovery frameworks combining physical, nutritional, and physiological strategies.

Study Limitations

First, several limitations must be acknowledged when analyzing the results of this meta-analysis. The variability among the included trials was considerable, especially regarding soreness rating and ROM outcomes ($I^2 > 80\%$). This variability indicates variations in intervention parameters, including massage technique, pressure intensity, treatment length, timing post-exercise, and variations in AET modality or workload. Recent meta-analyses in Retos, conducted by Ilias et al. (2025) and Martínez-Sánchez et al. (2025), have underscored a comparable methodological variability in the investigation of recovery and exercise intensity effects, thereby highlighting the necessity for more standardized intervention protocols.

Secondly, despite all research comprising healthy people, there was insufficient consistency in training state, since some trials recruited recreationally active participants while others featured untrained individuals. The variability in neuromuscular adaptation and baseline conditioning may have led to differing recovery kinetics, hence contributing to the inconsistent findings among investigations (Gómez-Pérez & Crespo-Ruiz, 2024).

Thirdly, the timing of post-exercise evaluations varied significantly between 24 and 72 hours, perhaps overlooking the actual peak of physiological reactions, including soreness perception and serum CK re-

lease. Prolonged measurement intervals or irregular time points diminish the accuracy of effect estimation (Navarro-Domínguez et al., 2022).

Fourth, the analysis was limited to studies reporting acute outcomes; long-term or repeated-application effects of SMT and AET were not addressed. The existing evidence indicates short-term recovery effectiveness, and any extrapolation to chronic adaptation or performance improvement should be approached with caution.

Fifth, numerous trials were deficient in blinding participants and outcome assessors, a prevalent problem in exercise-based therapies that heightens the potential of performance and detection bias. While the TESTEX tool effectively encompasses exercise-specific reporting areas (Smart et al., 2015), subsequent research ought to implement other methodological precautions, including secret allocation, assessor blinding, and adherence monitoring.

The review encompassed trials published exclusively in English and Spanish and was limited to research available until October 2020, potentially excluding pertinent recent data. Notwithstanding these limitations, the synthesis offers an extensive summary of existing high-quality evidence and is consistent with previous Retos recommendations for transparent reporting and reproducible recovery research (Ilias et al., 2025; Fernández-García et al., 2024).

Conclusions

This systematic review and meta-analysis provide comprehensive evidence comparing SMT and AET for the management of DOMS in healthy adults. The overall findings indicate that SMT markedly alleviates muscle soreness rating within 24–72 hours following AET, showing a small-to-moderate analgesic impact predominantly driven by neuromechanical, circulatory, and autonomic processes. AET demonstrated non-significant and diverse outcomes, indicating that its recovery efficacy is significantly influenced by exercise modality, intensity, and time. Neither intervention significantly enhanced ROM nor decreased serum CK levels, suggesting that subjective recovery does not inherently align with structural or biochemical repair.

These data combined indicate that SMT and AET may be considered supplementary recovery techniques that improve perceptual comfort and short-term preparedness, rather than conclusive treatments for muscle restoration. Their clinical significance resides in the ability to alleviate discomfort and reinstate psychological preparedness for future exercise sessions. However, due to the high heterogeneity and short-term observation windows, results should be interpreted with caution.

Future research must prioritize standardized intervention protocols, uniform scheduling of outcome assessment, and the incorporation of both subjective and objective biomarkers (e.g., IL-6, TNF- α , oxidative stress indices) to elucidate the physiological mechanisms underlying recovery. Integration of SMT and AET within multimodal recovery frameworks which incorporating physical, nutritional, and psychological strategies that may offer more comprehensive benefits for performance and rehabilitation outcomes.

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