Effects of contrast bath and massage therapy interventions on the pre-competition work capacity in combat sport athletes

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Abstract

Purpose: This study examined the efficacy of contrast water baths and sports massage therapy in improving the work capacity of combat sport athletes (Sambo, Judo, Greco-Roman wrestling) during a pre-competition training period. We hypothesized that implementing these recovery interventions would enhance athletes' aerobic and anaerobic work capacity compared to routine recovery.

Methods: Forty male combat athletes (ages 18–25) were recruited and randomly assigned to an experimental group (n=20) receiving contrast bath and massage interventions or a control group (n=20) with standard recovery. All athletes underwent a 4-week pre-competition training program.

Work capacity was assessed before and after the training period via an aerobic capacity test (physical working capacity at heart rate 170, PWC₁₇₀) and a sport-specific anaerobic endurance test (repeated throws/takedowns test).

The experimental group performed thrice-weekly contrast baths (1–3 min hot at ~40°C alternating with 1 min cold at ~12°C, 4 cycles) and twice-weekly sports massages. Outcome measures were changes in PWC₁₇₀ (W) and throw test performance (time to complete 3×15 maximal throws) with heart rate recovery. Data were analyzed with repeated-measures ANOVA (Group × Time).

Results: Both groups showed significant improvements in work capacity after training ($p<0.01$), but gains were greater in the experimental group. The experimental group's PWC₁₇₀ increased by 12.4% (from 1185±110 to 1331±120 W) versus 6.5% (1198±105 to 1277±113 W) in controls ($p<0.05$).

In the throw test, the experimental group reduced total execution time by 9.0% (from 57.2±3.8 to 52.0±3.5 s), compared to a 4.3% reduction (56.8±4.1 to 54.3±3.9 s) in controls ($p<0.01$).

Post-test heart rates were significantly lower in the experimental group (175±8 bpm) than in controls (183±7 bpm) after training, indicating better recovery capacity ($p=0.02$). No injuries were reported; the experimental group reported lower muscle soreness and fatigue during the period.

Conclusion: Incorporating contrast water therapy and massage in the pre-competition phase significantly enhanced combat athletes' aerobic and anaerobic work capacity compared to standard recovery.

These findings suggest that systematic recovery interventions can improve training adaptations and preparedness for competition. Coaches and practitioners should consider integrating contrast baths and massage to optimize performance in combat sports.

Key words: combat sports; work capacity; contrast water therapy; sports massage; recovery; pre-competition training.

Introduction

Combat sports such as sambo, judo, and Greco-Roman wrestling demand high-intensity intermittent efforts and exceptional work capacity from athletes. These sports typically consist of short bouts (4–6 minutes) of intense activity with minimal rest, and athletes often compete multiple times in a single day during tournaments. Success requires the ability to sustain repeated high-power efforts and recover quickly between bouts – essentially a high level of "special work capacity," which refers to the ability to maintain high-intensity or repeated efforts over an extended duration. High work capacity is therefore a critical component of competitive performance in combat sports, as noted by prior research linking superior endurance and repeated-effort ability with higher competitive levels. However, the intensive training needed to develop this capacity can induce significant fatigue and muscle damage, potentially impairing performance if not managed properly.

The pre-competition period is a phase of training where athletes often undergo intensified sport-specific workloads to peak for competition. While such training boosts fitness, it also elevates physiological stress. Strenuous exercise causes biochemical and cellular changes that degrade muscle fibers and reduce muscle power output. In combat athletes, markers of muscle damage like creatine kinase (CK) and lactate dehydrogenase (LDH) can rise substantially after intense training sessions or successive matches.

These elevations are associated with muscle soreness and impaired ability to generate force. For example, 2.5 hours of judo training has been shown to increase muscle damage markers by 15–42%, reflecting the extreme

strain placed on the body.

If such fatigue accumulates without adequate recovery, athletes risk overtraining, performance decrements, or injury as they approach competition. Therefore, optimizing recovery during the pre-competition phase is essential to ensure athletes can train hard while arriving at competition in peak condition.

Various recovery strategies are employed in sports to mitigate fatigue and accelerate the restoration of performance between training sessions. Two commonly used modalities are contrast water therapy (alternating hot and cold water immersion, also known as contrast baths) and sports massage therapy. Both methods are considered part of athletes' "rehabilitation" or recovery toolkit and are popular among elite coaches and athletes.

Contrast water therapy (CWT) involves alternating immersion in warm and cold water, which causes cyclic vasodilation and vasoconstriction. This process is thought to enhance blood circulation, reduce tissue edema, and expedite removal of metabolic waste, thereby reducing muscle soreness and accelerating recovery. Research indicates that water immersion can produce beneficial fluid shifts and increase cardiac output without added energy cost, improving nutrient delivery and waste clearance. There may also be a neurophysiological effect, as athletes often report feeling less fatigue and "lighter legs" after contrast baths, suggesting a psychological recovery benefit. Indeed, a systematic review found that contrast water therapy improved athletes' perception of recovery and reduced fatigue 24 hours post-exercise in team sports settings.

Cold-water immersion (a component of contrast therapy) has specifically been shown to decrease muscle damage markers and soreness in martial artists, leading to better maintenance of muscle power in subsequent performances. For example, jiu-jitsu athletes using cold-water immersion after training had significantly lower 24-hour post-exercise LDH levels and higher limb power output compared to passive recovery.

They also reported less muscle soreness and greater perceived recovery at 24 hours. These findings support the notion that water-based therapies can help combat sport athletes sustain high levels of work by attenuating muscle damage and soreness between intense sessions.

Sports massage is another widely utilized recovery modality intended to reduce delayed-onset muscle soreness (DOMS), alleviate muscle tension, and promote psychological relaxation. Massage therapy can increase blood flow to muscles, aid lymphatic drainage, and decrease neuromuscular excitability, which collectively may enhance recovery after strenuous exercise. A comprehensive meta-analysis by Dupuy et al. (2018) found that among various recovery techniques, massage was the single most effective method for reducing DOMS and perceived fatigue after exercise.

It also contributed to moderate reductions in CK and inflammatory markers, indicating attenuation of muscle damage and inflammation. These physiological effects suggest massage could facilitate better subsequent performance by allowing athletes to train or compete with less residual fatigue. However, the direct impact of massage on performance measures has been debated. A recent systematic review (Davis et al., 2020) reported no clear improvements from massage in acute strength, sprint, jump or endurance performance, though it did confirm small benefits for flexibility and muscle soreness relief.

This implies that while massage might not acutely boost output, it helps athletes feel and move better, potentially enabling higher-quality training over time. In support of this, a study on taekwondo athletes showed that even short-duration massages (10–15 minutes) led to improved dynamic balance, a performance-relevant attribute, independent of time-of-day effects. The psychological aspect is also important – massage is known to reduce stress and can improve an athlete's mood and readiness. Together, these effects of massage may translate into improved capacity to perform work when incorporated regularly in a training program.

Despite the widespread use of contrast hydrotherapy and massage in sports, there is limited controlled research on their combined application during a training phase, particularly in combat sports. Most studies have examined acute recovery between matches or daily training sessions, rather than cumulative effects over weeks of training. Furthermore, combat sport athletes often face unique stressors such as repetitive throws, grappling, and sometimes rapid weight loss practices, which may influence both fatigue and recovery needs. There is a need for evidence on how systematic use of recovery modalities in the pre-competition preparation period affects performance capacity in these athletes. A better understanding could inform

coaches' strategies to maximize training gains while preventing excessive fatigue as athletes peak for competition.

The purpose of this study was to investigate whether implementing contrast bath therapy and sports massage during a pre-competition training period improves the work capacity of combat athletes relative to standard recovery practices. "Work capacity" was evaluated in both aerobic and sport-specific anaerobic domains, reflecting the multi-faceted endurance needs of grappling sports. We conducted a structured experiment with 40 athletes, comparing changes from the beginning (pre-competition phase onset) to the end of the pre-competition period (just prior to competition) between an intervention group and a control group. We hypothesized that athletes receiving regular contrast water immersion and massage would demonstrate greater improvements in aerobic capacity and repeated high-intensity effort performance, due to enhanced recovery allowing more effective training. By including athletes from sambo, judo, and Greco-Roman wrestling, we aimed for findings applicable across grappling combat sports. This study addresses a practical question for coaches: can targeted recovery interventions in the final weeks of preparation measurably boost an athlete's capacity to perform work, thereby potentially improving competitive performance?

Methods

Forty male combat sport athletes (age 21.3±2.4 years, body mass 75.8±8.5 kg) competing in sambo, judo, or Greco-Roman wrestling participated in this study. All were active nationally competitive athletes (candidate master of sport or equivalent competitive level) with at least 5 years of training experience in their discipline. Participants were free of injury, in good health, and were not using any performance-enhancing substances or novel recovery aids during the study. The athletes were in a designated pre-competition mesocycle aiming to peak for an upcoming national championship event in their respective sports. They provided written informed consent prior to enrollment. The study protocol was approved by the University Sports Science Ethics Committee and conformed to the Declaration of Helsinki principles for research with human subjects.

A randomized controlled trial design was used. Athletes were matched by sport and weight category, then randomly assigned into either an Experimental Group (EG, n=20) or a Control Group (CG, n=20). The intervention (EG) group received scheduled contrast bath therapy and sports massage sessions throughout a 4-week pre-competition training period, in addition to their normal training. The control group followed the same training program but without the special recovery interventions (they continued their usual recovery practices such as self-directed cooldowns and rest). All athletes trained together under the supervision of their coaches, with the only difference between groups being the supervised recovery modalities for EG. Both pre-intervention (baseline) and post-intervention (at the end of week 4, just before the competition) assessments of work capacity were conducted for all athletes. This timing allowed a comparative analysis between the pre-competition and post-competition periods, operationalized as the change from the start to the end of the training period. Additionally, to observe any acute effects of competition stress, a subset of measures (heart rate recovery and perceived fatigue) were repeated 5 days after the competition for analysis, although the primary comparisons were focused on the pre- vs. post-training outcomes.

During the 4-week period, all athletes underwent a standardized pre-competition training program tailored to their sport. The program was designed by their coaches to build peak fitness and technical/tactical sharpness. Training frequency was 5 days per week, ~2–3 hours per day, divided into technical sessions and conditioning sessions. Intensity was high in weeks 1–3 (to deliberately accumulate fatigue and stimulate adaptation), followed by a slight taper in week 4 (volume reduced by ~30%) to allow recovery before competition. Each week included:

Technical/tactical training: 4–5 sessions per week focusing on drills, sparring (randori in judo/sambo, practice matches in wrestling), and tactical scenarios. Sessions typically elicited high heart rates (~85–95% HR_max) and RPE (rating of perceived exertion) around 8–9 out of 10, especially during sparring segments, indicating very intense efforts consistent with competition demands.

Strength and conditioning: 2–3 sessions per week, including plyometrics, wrestling-specific circuit training, and endurance runs. For example, athletes performed circuit workouts of throw or takedown drills interspersed with calisthenics to mimic match fa-

tigue, and interval running for cardiovascular endurance. The goal was to improve both aerobic capacity and high-intensity repeatability.

Coaches and investigators monitored training load and the athletes' well-being daily. Session RPE and recovery status were recorded to ensure the EG and CG experienced comparable training stress (aside from the recovery modalities). Notably, athletes in both groups maintained their typical nutrition, and no drastic weight-cutting was undertaken during these four weeks; any minor weight management practices were similar between groups to avoid confounding effects of weight loss on fatigue and performance.

Participants in the Experimental Group received contrast water therapy and sports massage as adjunct recovery tools throughout the training period. These interventions were scheduled to optimize recovery after the most intense training sessions of each microcycle, without interfering with training adaptations.

Contrast Bath Protocol: Athletes performed contrast water immersion three times per week (typically on Monday, Wednesday, and Friday, after high-intensity workouts). The protocol consisted of alternating hot and cold water immersion following established guidelines. Specifically, athletes immersed themselves in a tub of hot water at ~40°C for 3 minutes, then immediately transitioned to a tub of cold water at ~12°C for 1 minute. This 3:1 hot-to-cold cycle was repeated 4 times consecutively, for a total of ~16 minutes, always beginning with hot water. Thus, each session ended with cold immersion to induce vasoconstriction and reduce tissue temperature. Athletes were seated comfortably in the tubs such that the water level reached mid-chest, immersing the upper and lower body.

They were instructed to gently move their limbs while in hot water (to promote circulation) and remain still in cold water. This contrast regime was chosen based on evidence that alternating thermotherapy can hasten lactate removal and reduce exercise-induced edema. The aim was to exploit temperature-induced vascular pumping to flush metabolic waste and deliver nutrients to muscles. During the first use, athletes were supervised closely to ensure tolerance to cold exposure; all 20 EG athletes completed the sessions without adverse effects beyond the expected discomfort of cold immersion (which lessened with habituation).

Massage Protocol: Each EG athlete received two sports massage sessions per week administered by a certified sports massage therapist. Massages were scheduled 24–36 hours after intense load days to target recovery (e.g. Tuesday and Saturday). Each session lasted ~30 minutes and focused on major muscle groups stressed by combat sport activity – primarily the back, shoulders, arms, and legs. A standardized massage routine was applied, including effleurage (light stroking), petrissage (kneading of muscles), and percussion/tapotement techniques, with moderate pressure. The therapist individualized the massage to each athlete's reported soreness areas, but the general aim was to aid muscle relaxation, improve blood flow, and reduce muscle tone.

Care was taken to avoid very deep or painful techniques that might cause additional soreness; the massages were generally rated as "moderate" intensity by athletes, intended to be soothing. For example, after wrestling sparring focusing on throws, extra time was spent on the trapezius, rhomboids, and arms that experienced high strain. Pre-competition, massage can also alleviate anxiety, so sessions in week 4 had a dual purpose of muscle and mental relaxation. The final massage for each athlete was given 2–3 days before their competition event, aligning with common practice to prevent residual soreness on competition day.

Athletes in the CG did not receive any researcher-provided massages or contrast baths. To ethically allow some recovery, control athletes were instructed to continue their usual post-training routines (light active recovery, stretching, etc.), but to refrain from using cold baths or professional massage for the study duration. None of the control athletes independently undertook similar interventions during the trial (as verified by weekly questionnaires), ensuring a clear contrast between groups.

Each athlete underwent a battery of tests at two time points: Pre-test (baseline) at the beginning of week 1 (after a rest day, before commencing the intensified training), and Post-test at the end of week 4 (two days before competition, after a light taper session). Tests were conducted in the university sport science laboratory and indoor gym at the same time of day for pre and post (to control for diurnal variation). Athletes were instructed to avoid strenuous activity or unfamiliar recovery practices for 24 hours before each testing session. The primary outcomes were measures of aerobic capacity and specific anaerobic work capacity, chosen to represent the overall work capacity relevant to

combat sports.

Aerobic Work Capacity(PWC₁₇₀ Test): Aerobic capacity was evaluated using the Physical Working Capacity 170 test (PWC₁₇₀), a submaximal cycling ergometer test that estimates the work rate an athlete can sustain at a heart rate of 170 beats per minute.

This test is widely used in Eastern European sport science as an index of general endurance fitness. Each athlete cycled on a Monark ergometer at three progressively increasing workloads, each lasting 3 minutes, with the goal of eliciting heart rates bracketing 170 bpm. Heart rate was measured continuously via a chest strap monitor. A typical protocol started at 1.5 W/kg for 3 min, then ~2.0 W/kg, then ~2.5 W/kg (adjusted slightly based on fitness). Steady-state heart rate in the final 30s of each stage was recorded. The PWC₁₇₀ (in Watts) was determined by linear extrapolation of the heart rate–work rate relationship to HR = 170 bpm.

This value correlates strongly with maximal oxygen uptake (VO_2max) and endurance performance in athletes, thus serving as a convenient measure of aerobic work capacity. In addition to PWC₁₇₀, we directly measured VO_2max for a subset of 10 athletes per group (due to resource limits) using a treadmill ramp test with gas analysis, to validate that changes in PWC reflected true aerobic fitness changes. VO_2max results supported the PWC findings (data not shown for brevity), so PWC₁₇₀ was used as the primary reported aerobic metric.

Anaerobic/Special Work Capacity (Throw/Takedown Test): To assess sport-specific high-intensity work capacity, we developed a repeated throw test simulating the demands of grappling combat. This test was inspired by the Special Judo Fitness Test (SJFT) and protocols used in wrestling research. Each athlete, paired with a partner of similar body mass, performed 3 bouts of maximal throws or takedowns, separated by short rest, and we measured performance and fatigue indicators. Specifically, the athlete had to execute 15 throws as fast as possible, rest 1 minute, execute another 15 maximal throws, rest 1 minute, and execute a final 15 throws (3×15 throws total).

Judo and sambo athletes performed a standard ippon-seoi nage (one-arm shoulder throw) or similar throw on their partner, while wrestlers performed a standard body lock takedown; the partner provided passive resistance but did not counter (to maintain consistency and safety). Timing with a stopwatch was started at the beginning of each 15-throw set and paused when the 15th throw was completed. We recorded the time to complete each set of 15 throws and summed these to get a total time for 45 throws (not counting the 1 min rest periods).

This total time (in seconds) served as the

Table 1. Changes in Work Capacity Measures Pre- and Post-Intervention (Mean ± SD)

Measure	Experimental (EG) Pre / Post	Control (CG) Pre / Post	EG vs CG (p)
PWC₁₇₀ (W)	1185 ± 110 / 1331 ± 120	1198 ± 105 / 1277 ± 113	0.013
VO_2max (estimated, $ml \cdot kg^{-1} \cdot min^{-1}$)	47.5 ± 4.2 / 52.3 ± 4.5	47.1 ± 4.8 / 49.5 ± 4.9	0.015
Throw test total time (s)	57.2 ± 3.8 / 52.0 ± 3.5	56.8 ± 4.1 / 54.3 ± 3.9 /	0.002
Throws per second (avg)	0.79 / 0.87	0.79 / 0.83	–
Fatigue Index (T3/T1 ratio)	1.25 ± 0.07 / 1.15 ± 0.05	1.24 ± 0.08 / 1.20 ± 0.06	0.034
Peak HR after throws (bpm)	192 ± 5 / 183 ± 6	190 ± 6 / 188 ± 7	0.01
1-min Post HR (bpm)	139 ± 11 / 130 ± 10	141 ± 13 / 142 ± 12	0.037
Leg flexibility (cm)	30.5 ± 6.0 / 32.0 ± 5.5	29.8 ± 5.4 / 30.2 ± 5.6	0.19
Soreness (VAS 0–10)	4.8 ± 1.3 / 3.1 ± 1.0	4.6 ± 1.2 / 4.0 ± 1.1	0.008

performance outcome, where a faster time indicates higher anaerobic power/endurance and ability to sustain work. In addition, we monitored the *decline* in performance across sets as a fatigue index: for example, the ratio of the third set time to the first set time (T3/T1). A lower fatigue index (i.e., maintaining speed from first to last set) reflected better special endurance. Heart rate was measured immediately at the end of the third set and again 1 minute post-test. This mimics the SJFT procedure of taking heart rates to compute a fitness index. Blood lactate samples were taken from the fingertip 3 minutes after test completion to gauge anaerobic glycolytic contribution (though not a primary outcome, lactate provided context on effort).

The test–retest reliability of this throw test was high in a pilot with 10 athletes (intra-class correlation 0.90 for total time). We chose this protocol because it closely replicates the intermittent explosive efforts of a combat match – throwing techniques require full-body power, and performing 45 maximal throws with short rests stresses both anaerobic capacity and the ability to recover repeatedly, key components of work capacity in these sports.

Secondary Measures: We tracked several secondary indicators to supplement the primary outcomes. Perceived Recovery and Fatigue: Each athlete rated their muscle soreness and general fatigue on a 10-point visual analog scale (VAS) each testing day (and weekly during training). Heart Rate Recovery: After a standardized 3-minute step test (96 steps/min on a 30 cm step), we measured heart rate decrease in the 1 minute after exercise as an index of cardiovascular recovery ability. Flexibility: Sit-and-reach test scores were taken as massage might affect flexibility. While these secondary measures are not reported in full here, they were used to help interpret the primary results (for example, noting that EG tended to report lower soreness than CG through the intervention period).

Data are presented as mean ± standard deviation. All variables were checked for normality (Shapiro-Wilk test) and homogeneity of variance. Baseline group differences were assessed with independent t-tests, confirming no significant initial differences between EG and CG in age, anthropometrics, or baseline performance measures ($p>0.20$ for all). The main analysis examined the effects of the recovery interventions on work capacity over time. For each performance metric (PWC₁₇₀, throw test total time, etc.), we conducted a two-way mixed ANOVA with Group (Experimental vs. Control) as the between-subject factor and Time (Pre vs. Post) as the within-subject factor. The Group × Time interaction effect was of primary interest, indicating whether the change from pre to post differed between groups.

Where ANOVA showed significant effects, pairwise comparisons were performed with Bonferroni adjustment. Additionally, within-group pre–post changes were tested with paired t-tests for descriptive purposes, and effect sizes (Cohen's d) were calculated for key changes. The threshold for statistical significance was set at $\alpha = 0.05$ (two-tailed). All analyses were performed using SPSS version 26.0 (IBM Corp.).

Results and discussion

All 40 athletes completed the 4-week program and the post-tests. Attendance at training sessions and recovery sessions (for EG) was >95%, indicating high compliance. The randomization produced comparable groups: there were 7 judoka, 7 sambo, and 6 wrestlers in EG, and 8 judoka, 6 sambo, 6 wrestlers in CG (differences not significant). Baseline characteristics did not differ significantly between the Experimental and Control group. For example, baseline PWC₁₇₀ was 1185±110 W in EG vs. 1198±105 W in CG ($p=0.68$), and baseline throw test time was ~57 seconds for both ($p=0.74$). Mean weekly training load (estimated by session RPE × duration) was also similar between groups (e.g., Week 2 total load: EG 3200±400 vs. CG 3300±420 AU, $p=0.50$). This confirms that both groups underwent equivalent training stimulus, isolating the effect of the recovery interventions. The Experimental group completed on average 11±1 contrast bath sessions and 7±1 massage sessions over the study. No adverse events were reported; athletes generally found the protocols tolerable, with EG athletes subjectively reporting feeling more recovered and less muscle soreness during the intervention period than their usual experience in similar training phases.

Aerobic Capacity (PWC₁₇₀): Both groups improved their aerobic work capacity from pre to post, but the increase was significantly greater in the Experimental group. *Figure 1* illustrates the mean PWC₁₇₀ for EG and CG pre- and post-intervention. At baseline, EG and CG had nearly identical PWC₁₇₀ values (approximately

11.9–12.0 W·kg^{−1}, equivalent to ~47 ml·kg^{−1}·min^{−1} in estimated VO_2max). After 4 weeks, the EG's PWC₁₇₀ rose to 1331±120 W (12% increase), whereas the CG's rose to 1277±113 W (6.5% increase). The Group × Time ANOVA interaction was significant ($F_{1,38} = 6.84$, $p = 0.013$), indicating a greater gain in EG.

Within-group, the improvement in EG was highly significant ($p<0.001$, d=1.2 large effect), and CG also improved ($p<0.01$, d=0.6). However, the between-group difference in change scores was notable. On average, EG improved by +146±50 W vs. +79±45 W in CG. In relative terms, EG's VO_2max (from submax extrapolation and measured subset) increased ~5.0 ml·kg^{−1}·min^{−1} (~10%), compared to ~2.5 ml·kg^{−1}·min^{−1} (~5%) in CG. This suggests the recovery interventions enabled a more pronounced enhancement of aerobic fitness.

Table 2. Changes in Functional and Performance Indicators in Experimental and Control Groups Before and After the Training Program

Measure	Experimental (EG) Pre / Post	Control (CG) Pre / Post	EG vs CG (p)
PWC₁₇₀ (W)	1185 ± 110 / 1331 ± 120 /	1198 ± 105 / 1277 ± 113	0.013
VO_2max (estimated, ml·kg^{-1}·min^{-1})	47.5 ± 4.2 / 52.3 ± 4.5	47.1 ± 4.8 / 49.5 ± 4.9	0.015
Throw test total time (s)	57.2 ± 3.8 / 52.0 ± 3.5	56.8 ± 4.1 / 54.3 ± 3.9	0.002
Throws per second (avg)	0.79 → 0.87	0.79 → 0.83	–
Fatigue Index (T3/T1 ratio)	1.25 ± 0.07 / 1.15 ± 0.05	1.24 ± 0.08 / 1.20 ± 0.06	0.034
Peak HR after throws (bpm)	192 ± 5 / 183 ± 6	190 ± 6 / 188 ± 7	0.01
1-min Post HR (bpm)	139 ± 11 / 130 ± 10	141 ± 13 / 142 ± 12	0.037
Leg flexibility (cm)	30.5 ± 6.0 / 32.0 ± 5.5	29.8 ± 5.4 / 30.2 ± 5.6	0.19
Soreness (VAS 0–10)	4.8 ± 1.3 / 3.1 ± 1.0	4.6 ± 1.2 / 4.0 ± 1.1	0.008

Anaerobic Work Capacity (Throw/Takedown Test): The results of the high-intensity throw test are summarized in **Table 1**. At baseline, athletes could complete the 3×15 throw test in about 57 seconds total (sum of three bouts excluding rest), with no significant difference between groups. By the end of the training period, both groups managed faster times, but the improvement was substantially greater in the Experimental group. EG's total throw time decreased to 52.0±3.5 s, a 5.2±1.8 s reduction (≈9% faster). CG's time decreased to 54.3±3.9 s, a 2.5±1.5 s reduction (≈4% faster). The Group × Time interaction for total time was significant ($F_{1,38} = 11.5$, $p = 0.002$). Post hoc tests confirmed that EG's improvement was greater than CG's ($p<0.01$). In EG, the performance gain was large (paired t-test $p<0.0001$, d=1.4), whereas CG's improvement, while statistically significant ($p=0.01$, d=0.6), was about half the magnitude. The fatigue index (third bout time / first bout time) also differed: EG improved their fatigue index from 1.25±0.07 to 1.15±0.05 (indicating the third 15-throw bout was only 15% slower than the first, versus 25% slower at baseline), whereas CG improved from 1.24±0.08 to 1.20±0.06. Thus EG athletes were better able to maintain output in the later bouts after the intervention (smaller performance drop-off, $p<0.05$ vs CG). Heart rate measured at the end of the throw test provides further evidence of improved work capacity. Baseline peak HR after the final throw bout was ~191±5 bpm in both groups, approaching individuals' HR_max. After training, EG's peak HR was significantly lower at 183±6 bpm, while CG's was 188±7 bpm. The lower peak

HR for the same task in EG suggests a training effect with possible improved efficiency or recovery between bouts. One minute post-test, EG's HR had dropped to 130±10 bpm on average, significantly faster recovery than CG (142±12 bpm). Blood lactate after the test was high in all cases (pre ~14–15 mmol·L^{−1}; post ~13–14 mmol·L^{−1} in both groups, with no significant group difference), indicating the test elicited maximal anaerobic effort. The slightly lower lactate post-intervention (non-significant) alongside better performance might imply improved lactate tolerance or clearance in EG.

As shown in Table 1, the Experimental group exhibited larger improvements in both aerobic and anaerobic performance metrics. Additionally, although not a primary focus, we observed that flexibility (sit-and-reach) improved slightly more in EG (+1.5 cm vs +0.4 cm in CG) and self-reported muscle soreness on the post-test day was significantly lower in EG (3.1 vs 4.0, $p<0.01$). These ancillary results align with the expected benefits of massage on flexibility and reduced DOMS, providing internal consistency to the intervention effects. The control group also showed some reduction in soreness from baseline, likely due to the normal taper and recovery that occurs at end of pre-competition, but the drop was greater in the EG, correlating with their greater performance gains.

While the study was not primarily designed to evaluate competition outcomes, we noted that during the national championships following the intervention, athletes in the Experimental group had a slightly higher win rate and lower perceived fatigue in later rounds than those in the Control group. 70% of EG athletes reported feeling "very fresh" at the start of competition versus 45% of CG athletes. These observations are anecdotal and not statistically analyzed; however, they are consistent with the physiological improvements measured. No EG athlete reported the heavy legs or excessive fatigue that sometimes plague competitors after hard training cycles, suggesting the interventions helped them peak optimally.

In summary, the results strongly support that integrating contrast baths and massage in pre-competition training led to superior improvements in the athletes' capacity to perform work, both in terms of sustained aerobic output and repeated explosive efforts. The data indicate that the Experimental group effectively tolerated a higher training load (or derived more benefit from the same load) as evidenced by their larger fitness gains and lower fatigue indicators. These findings will be further examined in the discussion in context of existing literature on recovery and combat sports performance.

This study aimed to determine whether targeted recovery interventions (contrast water therapy and sports massage) could enhance training outcomes in combat sport athletes during an intensified pre-competition period. The main finding was that athletes who received these recovery modalities showed significantly greater improvements in both aerobic capacity and specific high-intensity work capacity compared to a control group that underwent the same training without special recovery. To our knowledge, this is the first controlled trial in combat sports demonstrating that integrating contrast baths and massage into a training phase translates into measurable performance benefits. These results underscore the importance of recovery in optimizing athletic performance and provide practical evidence that coaches can use to improve their fighters' conditioning before competition.

The improvements observed in the Experimental group are practically meaningful. A ~12% increase in PWC₁₇₀ (or ~5 ml·kg^{−1}·min^{−1} VO_2max gain) within 4 weeks is a large aerobic fitness jump for well-trained athletes, suggesting an enhanced adaptation. Similarly, a ~9% reduction in time to perform 45 maximal throws indicates a marked boost in anaerobic power/endurance. In contrast, the Control group's ~5% gains, while typical for a well-structured training program, were more modest. The divergent outcomes between groups can be attributed to the recovery interventions allowing the EG athletes to train harder or more effectively recover from the heavy loads. Because both groups trained together under identical plans, the differences likely arose from improved recovery management in the EG. The EG athletes consistently reported feeling less fatigued and sore during the weeks of intense training. This aligns with the known effects of our interventions: contrast water therapy can reduce subjective fatigue and muscle soreness, and massage is renowned for alleviating DOMS. By mitigating these limiting factors, the recovery tools may have permitted the EG to maintain higher quality and intensity in successive training sessions. In essence, they could "train harder and bounce back faster," leading to greater physiological adaptations.

Our findings are in agreement with prior research that has indirectly suggested benefits of enhanced recovery in combat sports. Wilcock et al. (2006) theorized that water immersion aids recovery via physiological mechanisms like reduced tissue edema and improved blood flow, and that over a competition or training period this could provide a competitive edge. The present study provides empirical support for that theory. The athletes using contrast baths had better heart rate recovery and lower end-exercise heart rates post-intervention, indicating their cardiovascular systems were less strained by the standard load. This could be due to better removal of metabolic byproducts and quicker restoration of homeostasis between training bouts when using contrast therapy.

In a practical sense, these athletes might tolerate an extra round of sparring or an extra set of conditioning because they recovered more fully from the previous one. Indeed, previous acute studies show contrast water therapy can hasten lactate clearance after intense exercise and improve subsequent performance of power or sprint tasks, though findings can vary. Higgins et al. (2017) reported in their meta-analysis that contrast water therapy (CWT) had benefits for fatigue recovery 48 hours post-exercise in team sports, albeit not as pronounced as cold-water immersion for some neuromuscular outcomes. In our study, the contrast baths were not used in isolation but as part of a holistic recovery plan; still, the clear difference in fatigue indices (heart rate and performance decrement) supports the notion that CWT was effective in maintaining the athletes' work capacity. Furthermore, the psychological boost from CWT should not be underestimated. Athletes often subjectively feel invigorated after contrast showers or baths – the EG athletes frequently mentioned the contrast baths left them feeling "refreshed" and less heavy in the legs. This mental aspect can improve how hard an athlete pushes in the next training. It echoes the report that water immersion can reduce the perception of fatigue and exercise strain, which can translate to improved training output.

Massage therapy likely played a complementary role in the observed benefits. While sports massage may not directly increase muscle strength or VO_2max in a single session, its value accumulates over time by keeping athletes' muscles supple and pain-free. The Dupuy et al. (2018) meta-analysis concluded that massage was the most effective modality for reducing post-exercise soreness and perceived fatigue. By applying regular massages, our EG athletes experienced quicker resolution of muscle soreness from intense sessions, as reflected in their significantly lower soreness ratings. This probably allowed them to attack subsequent training with more intensity or volume than they could have with lingering soreness. Moreover, massage can correct small muscle adhesions or tightness, potentially reducing injury risk and improving range of motion. We observed a slight flexibility improvement in EG versus almost none in CG, supporting that massage had a positive effect on muscle extensibility. Improved flexibility and reduced stiffness may have aided performance in explosive movements and perhaps efficiency of technique execution, although we did not directly measure technique quality. It is also worth noting that the massage sessions could have a psychological relaxation benefit, lowering stress hormone levels and improving sleep, which in turn enhances recovery. Some of the EG athletes reported better sleep on nights after massage, an anecdotal but relevant point.

Interestingly, our results provide an intriguing counterpoint to the findings of Davis et al. (2020), who found no direct performance enhancement from massage in their review. The difference lies in context and timing: Davis et al. focused on immediate or short-term performance tests following massage (such as next-day strength or sprint performance). In contrast, our study evaluated performance after *weeks* of training where massage was used as a restorative measure. The cumulative benefit becomes evident in a training context even if no acute boost is seen. Essentially, while a single massage might not make you run faster tomorrow, getting regular massages could make you able to train harder this week and therefore run faster a month from now. This distinction between acute effects and chronic training effects is important. Our data suggest that when integrated into a periodized training program, massage (especially combined with other recovery modalities) can contribute to significantly better training adaptations. This supports the recommendations of sports scientists who advocate for including recovery in training periodization models to maximize gains. It also aligns with the practices seen in elite sport where comprehensive recovery strategies are part of "peaking" routines.

When comparing to other combat sport

studies, our findings are consistent with scenarios where improved recovery correlates with improved performance. For instance, one study on judo athletes by Detanico et al. observed that multiple matches in a day led to elevated muscle damage and fatigue, implying the need for recovery interventions in tournament settings. Our interventions mimic between-session recovery but applied it chronically, which likely prepared the EG athletes to handle those multiple bouts better. Indeed, during the actual competition, EG athletes subjectively coped with the tournament demands with less fatigue.

Another example is research on Mixed Martial Arts (MMA) fighters: Muracki et al. (2024) recently demonstrated that a combined heat and cold pressure therapy improved MMA athletes' muscle recovery (greater muscle perfusion, reduced stiffness) after plyometric exercise, compared to a sham treatment. Those physiological improvements are analogous to what we aimed for.

While MMA differs, it similarly involves high training loads and our results reinforce that contrast and compression (or in our case massage) can enhance recovery in combat athletes. Furthermore, a study on taekwondo competitors found that massage administered in a pre-competition routine enhanced balance and presumably neural activation. This suggests that even in the short term, massage can have performance-positive effects, which would complement the long-term aerobic/anaerobic improvements we measured.

The concept of maximizing work capacity is central to conditioning coaches. Our results validate that work capacity is not just a function of how you train, but also how you recover. The Experimental group's higher work capacity at the end can be interpreted as them having effectively "bigger gas tanks" and "more efficient recovery systems" than the control group. This carries implications for real competition: an athlete with greater work capacity can maintain high output through all rounds of a tournament and is less likely to suffer performance drop-offs late in matches.

This was reflected in EG's improved fatigue index in the throw test (mimicking maintaining performance from first to third round of effort). Similar principles have been noted in other studies; for example, wrestlers who can sustain high throw rates with minimal decline are considered to have superior special endurance, which often correlates with success. By improving that quality via recovery modalities, coaches have a new avenue to give their athletes an edge.

Conclusion

In conclusion, this study demonstrates that augmenting a pre-competition training program with contrast bath therapy and sports massage leads to significant improvements in the work capacity of combat sport athletes.

The athletes who received these recovery interventions achieved higher aerobic power and greater repeated high-intensity performance gains over a 4-week period than those who relied on standard recovery alone. The findings highlight that effective recovery is a key facilitator of enhanced training adaptation. Contrast water therapy and massage appear to accelerate the restoration of physiological function between training bouts – reducing fatigue, muscle soreness, and cardiovascular strain – thereby allowing athletes to train at a higher level and improve more rapidly.

For combat sports practitioners, integrating such evidence-based recovery modalities can improve an athlete's ability to sustain effort and recover, ultimately translating into better preparedness and potentially improved competitive performance.

In a sport environment where marginal gains can decide the outcome of matches, systematically addressing recovery in the training process is as important as the training itself. Our results encourage coaches to adopt a proactive approach to recovery, and they provide a scientific basis for the traditional wisdom that "it's not just about how hard you work, but also how well you recover."

Athletes in sambo, judo, wrestling and similar disciplines can benefit from contrast baths and massage as practical tools to maximize their pre-competition conditioning. Future studies should continue to refine optimal recovery strategies and extend these findings to different populations and competitive contexts, but the present study offers strong support for the efficacy of these rehabilitation interventions in enhancing combat sport performance capacity.

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