International Journal of
Disabilities Sports and Health Sciences
e-ISSN: 2645-9094

REVİEW ARTICLE

The Effect of Contrast Therapy in Exercise Recovery: A Meta-Analytical Approach

Hyunseok CHOİ[1], Il-Young CHO[*2] and Yong HONG[3]

[1]Jeonju University, MS student, Department of Sports Medicine, Jeonju / South Korea
[2]Jeonju University, Faculty, Convergence Research Center for Medical Sciences, Jeonju / South Korea
[3]Jeonju University, Faculty, Department of Exercise Prescription, Jeonju / South Korea
*Corresponding author: chirotrust@jj.ac.kr

Abstract
Contrast therapy's effects have varied across studies, necessitating an examination of its effect size. Therefore, this study aimed to validate the efficacy of contrast therapy on post-exercise recovery through a meta-analysis of exercise performance and physiological variables. Searches were conducted in electronic databases with the keywords "contrast therapy," "exercise performance," and "recovery”. Then articles were screened according to PRISMA guidelines. Fifteen articles were included in the meta-analysis. The results indicated significant differences in sprint (g=0.3811, p<.05), muscle soreness (g=0.7192, p<.01), perceived fatigue (g=0.7384, p<.01), and blood CK (g=0.7043, p<.05), demonstrating the effectiveness of contrast therapy compared to passive recovery. However, no significant differences were found in jump (g=0.0866, p=.7083), flexibility (g=0.0585, p=.7531), thigh circumference (g=0.1636, p=.5654), and perception of recovery (g=0.3254, p=.0661), although there was a slight trend favoring contrast therapy over passive recovery. Given this, contrast therapy could be beneficial for sports that involve frequent sprints or repeated high-intensity exercise with short rest periods. Additionally, considering psychological aspects like muscle soreness and perceived fatigue for optimal performance, we believe contrast therapy positively affects post-exercise recovery compared to passive recovery. However, the quality of the studies was low, and there were not as many studies that included contrast therapy for each dependent variable as expected. As more studies are conducted in the future, it is expected that a more in-depth analysis can be conducted by improving the quality of the literature and reflecting various results.

Keywords
Contrast Therapy, Exercise Performance, Exercise Recovery, Meta-Analysis

INTRODUCTION

Post-exercise recovery is regarded as an important means of returning to body homeostasis status (Mujika et al., 2018). Particularly for athletes who compete continuously, recovery is essential both physiologically and psychologically (Reilly & Ekblom, 2005). Because fatigue and muscle damage from playing and training in sports can affect subsequent performance and quality of training (Mujika et al., 2018). Post-exercise recovery is also important for non-athletes, as they also participate in and enjoy a variety of sports activities (Kim et al., 2010). Inappropriate recovery might cause a vicious cycle such as a decline in exercise performance, a rise in injury risk, and an extension of recovery periods (Belza, 1994; van et al., 2017). Appropriate balance of exercise stress stimuli and their adaptations are key factors in recovery and an improvement of performance (Meeusen et al., 2006).

Participating in exercises is connected with metabolic and mechanical stresses on body tissues (Thorpe, 2021). Mechanical stresses by continuous contraction of muscles, particularly eccentric contraction, lead to a temporary reduction of muscle function, an increase of intramuscular proteins in the blood, a rise in muscle soreness and perceived fatigue, and elevation in edema (Howatson &

Received: 26 February 2024 ; **Revised** ; 17 April 2024 ; **Accepted:** 03 May 2024; **Published:** 25 May 2024

How to cite this article: Choi, H., Cho, II-Y., and Hong, Y. (2024). The Effect of Contrast Therapy in Exercise Recovery: A Meta-Analytical Approach. *Int J Disabil Sports Health Sci*;7(3):686-700.https://doi.org/10.33438/ijdshs.1442968

Someren, 2008). During exercise and physical activities could lead to various physiological stresses such as muscle damage, inflammation, and exhaustion of stored energy. Therefore, adaptation to the body's mechanical and physiological stress is also highly relevant to recovery.

Recovery interventions such as massage, compression garments, electrostimulation, stretching, cryotherapy, thermotherapy, and contrast therapy have been used or suggested to enhance post-exercise recovery (Prentice, 1999; Costello et al., 2012; Kovacs & Baker, 2014). Among these methods, temperature-based interventions such as cryotherapy, thermotherapy, and contrast therapy have been studied for post-exercise recovery studies (Jakeman et al., 2009; Broatch et al., 2014). Recently lots of attention has been paid to contrast therapy, which alternates between two treatments to utilize the benefits of cold and hot. Contrast therapy is a commonly used recovery intervention due to its feasibility and accessibility to athletes' ordinary training environment (Simjanovic et al., 2009). Contrast therapy has been proposed to important role in injury management such as reducing injury site edema by encouraging constriction and dilation of peripheral blood vessels (Prentice, 1999). Other physiological effects have been suggested as well, such as a decline in muscle spasms, pain, inflammation, and improvement of range of motion (Lehmann et al., 1974; Myrer et al., 1994; Cochrane, 2004). Since then, contrast therapy has been widely used for post-exercise recovery, as it has been suggested that contrast therapy eliminates metabolic wastes, reduces post-exercise edema, and increases blood flow to fatigued muscles (Prentice, 1999; Cochrane, 2004). However, it has not yet been established mechanism that contrast therapy improves post-exercise recovery and there is a lack of evidence-based consensus (Bieuzen et al., 2013).

Post-exercise recovery is significant for maintaining exercise performance so the application of reliable and effective interventions is needed. The effectiveness of the proposed contrast therapy has been reported with varying effects throughout a number of studies, and therefore it is necessary to evaluate the effect size. In fact, there have been meta-analysis studies on this topic, and this study is worthwhile because it differs from previous ones in two ways. The first is the inclusion of non-athletes, which is important because many non-athletes participate in and enjoy various sports activities, providing a more comprehensive perspective on the effects of contrast therapy. Secondly, we believe that updating the research on this topic will provide more accurate results.

In the studies that used contrast therapy, measurements of sprint, jump, and flexibility were mainly used as exercise performance variables. In addition, physiological variables were muscle soreness, thigh circumference, perceived fatigue, perception of recovery, and blood CK (Creatine Kinase). Therefore, the purpose of this study was to analyze the effects of contrast therapy in exercise recovery and to validate the efficacy of this therapy.

MATERIALS AND METHODS

The systematic review protocol has been registered on the International Platform of Registered Systematic Review and Meta-analysis Protocols (INPLASY) with the registration code INPLASY202340047. This protocol describes the objectives, methods, and analysis plan of the study in detail according to the reporting categories for systematic reviews and meta-analysis protocols.

Literature Search

The systematic review was conducted according to the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) guidelines (Fig. 1). Searches were conducted in five electronic databases: EBSCOhost ASC, MEDLINE, Cochrane, Web of Science, and CINAHL. The search encompassed terms related to or describing keywords such as contrast therapy, exercise performance, and recovery.

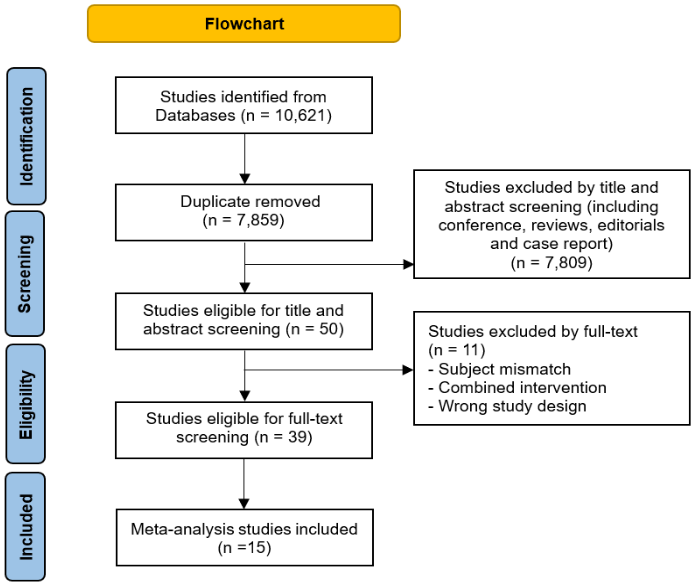

Figure 1. Flowchart of search strategy

Screening and Eligibility Criteria

The inclusion criteria for selecting studies were: individuals engaging in physical exercise or sports, not limited to professional athletes but including any active individuals, free from injury or illness; studies employing randomized controlled trials or randomized crossover designs that compared contrast therapy as a post-exercise recovery intervention to at least one control or alternative treatment group. We excluded studies involving individuals with physical or mental injuries, assessments of exercise or physical performance without integrated recovery interventions, and studies where contrast therapy was combined with other interventions that could confound the outcomes, such as compression garments or active recovery strategies.

After screening the articles, the following eligibility criteria were used. Inclusion criteria included that studies were published in English and measured exercise or physical performance before and after the intervention. Exclusion criteria included conference abstracts that did not include primary data, review articles, editorials, and case reports with fewer than five cases.

Data Extraction

The pre- and post-intervention means and standard deviations for the two groups presented in the individual studies were extracted into an Excel file. Publication details (author, year of publication, study type, sample size), participant information (age, gender, BMI), recovery intervention information (water temperature, number of repetitions, immersed time, extent of immersed), measured variables (performance and physiological variables), timing of measured, and exercise-induced physiological stressors (i.e., exercise protocol) were extracted**.**

Literature Quality Assessment

Two assessment tools, the Modified Jadad Scale and the Newcastle-Ottawa Scale, were used to assess the quality of the studies that the three researchers selected.

Data Synthesis and Analysis Methods

The pre- and post-intervention means and standard deviations of both groups were extracted into Microsoft Excel (2016) and analyzed with the R(version 4.3.0) (Balduzzi et al., 2019). The effect size was calculated by Hedges' g value considering the problem of overestimating Cohen's d value (Borenstein et al., 2021), and 95% confidence intervals were calculated for each of the exercise performance and physiological variables. The random-effects model was selected after testing for homogeneity among studies and considering the characteristics of the studies. In addition, homogeneity was tested for each dependent variable and if there was heterogeneity, subgroup analysis was conducted to identify the causality.

Publication bias was utilized as a funnel plot and Egger's regression test was used to quantify it.

RESULTS

Study Characteristics

The characteristics of the studies for the final analysis are shown in Table 1. The characteristics of the studies included author and year of publication, type of study, number of subjects, age, BMI, exercise protocol, temperature, total immersion time, extent of immersion, variables extracted during data analysis, and timing of measured variables.

Effect Size Analysis (Sprint)

Compared to the passive recovery group, the recovery of post-exercise sprint ability in the contrast therapy group showed a small to moderate effect and a statistically significant difference (g=0.3811, p=.0473, Fig. 2). There was a small to moderate effect of heterogeneity (Q(3)=4.26, p=.2349, I^2=29.5%).

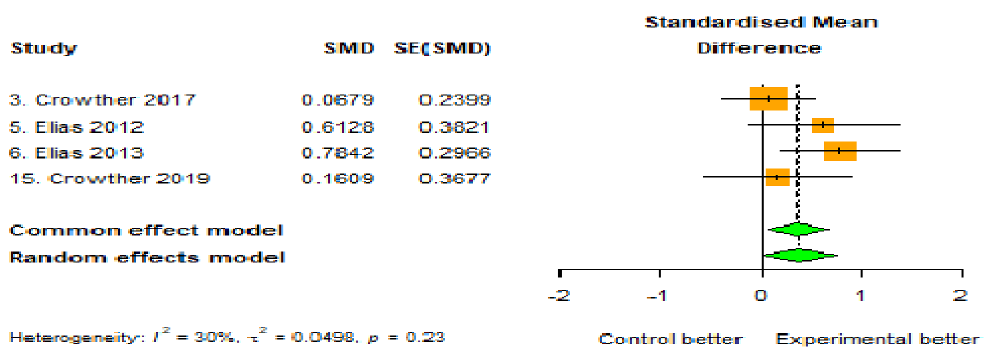

Figure 2. Forest plot for contrast therapy vs control in sprint

Table 1. Study characteristics

Study	Study type	N	Age	BMI	Exercise protocol	Temperature	Immersed time	Extent of immersed	Extract variable	Timing of measured
Ahokas et al., 2019	Parallel	9(M)	26(3.7)	24	Short-term exercise protocol (2×5×10 unilateral long jumps, 2×3×60m running, 2×200m run at maximum speed)	10℃ & 38℃	10min (alternate 1min)	Xiphoid process	MS	1h, 24h, 48h
Argus et al., 2017	Parallel	13(M)	26(5)	25.2	Resistance training protocol (3×5 deadlift, 3×10 back squat, 3×10 bench press, 3×10 BB Lunge, 3×10 BB bent over row)	15℃ & 38℃	14min (alternate 1min)	Full body	MS, PF	0h, 2h, 4h
Crowther et al., 2017	Parallel	34(M)	27(6)	24.7	3×15min simulated team-game circuit	15℃ & 38℃	14min (alternate 1min)	Shoulder	Sprint, flexibility, MS, POR	1h, 24h, 48h
Crowther et al., 2019	Crossover	14(M)	26(6)	25	3×Simulated rugby bout	15℃ & 38℃	14min (alternate 1min)	Shoulder	Sprint, MS, POR	5min, 75min
Dawson et al., 2005	Crossover	17(M)	24.2(2.9)	23.9	Football match	12℃ & 45℃	14min (alternate 1min(cold) & 2min(hot))	Waist	Jump, flexibility, MS	15h, 48h
Elias et al., 2012	Crossover	14(M)	20.9(3.3)	23	Australian Football training protocol	12℃ & 38℃	14min (alternate 1min)	Xiphoid process	Sprint, MS, PF	1h, 24h, 48h (sprint: 24h, 48h)
Elias et al., 2013	Parallel	24(M)	19.9(2.8)	23.3	Australian Football match	12℃ & 38℃	14min (alternate 1min)	Xiphoid process	Sprint, MS, PF	1h, 24h, 48h (sprint: 24h, 48h)
French et al., 2008	Parallel	26(M)	24.1(3.2)	24.6	6×10 parallel back squats(load: 100% body mass) + 5sec eccentric back squat(load : predicted 1RM)	8-10℃ & 37-40℃	13min (alternate 1min(cold) & 3min(hot))	50cm depth	CK	1h, 24h, 48h
Higgins et al., 2013	Parallel	24(M)	19.5(0.8)	25.7	Simulated rugby union game	10-12℃ & 38-40℃	10min (alternate 1min)	ASIS	Flexibility, TC, MS	1h, 48h, 72h, 96h, 144h
Ingram et al., 2009	Parallel	11(M)	27.5(6)	23.9	Simulated team sport exercise (4×20 min intermittent running, beep test shuttle runs until failure)	10℃ & 40℃	15min (alternate 2min)	Umbilicus	MS, CK	0h, 24h, 48h (MS: 24h, 48h)
Juliff et al., 2014	Crossover	10(F)	20(1)	23.2	Netball specific circuit exercise	15℃ & 38℃	14min (alternate 1min)	Full body	PF	0h, 5h, 24h
Kinugasa and Kilding, 2009	Crossover	28(NR)	14.3(0.7)	19.6	Soccer match	12℃ & 38℃	9min (alternate 1min(cold) & 2min(hot))	Mesosternum	Jump, POR	0h, 24h (jump: 24h)
Nardi et al., 2011	Parallel	18(M)	15.5(1)	20.1	Daily training protocol (warm-up, performance test, 30min football technical and tactical improvement schemes, 4×4min small sided games)	15±0.5℃ & 28±0.5℃	8min (alternate 2min)	Iliac spine	Jump, CK	Jump: day1, 2, 3, 4 CK: 24h
Vaile et al., 2007	Crossover	13(M&F)	26.2(5.8)	24.8	DOMS-inducing exercise protocol (5×10 eccentric bilateral leg press@1RM 140%)	8-10℃ & 40-42℃	15min (alternate 1min(cold) &	ASIS	MS, CK	MS: 15min, 24h, 48h, 72h

							2min(hot))			CK: 0h, 24h, 48h, 72h
Vaile et al., 2008	Crossover	38(M)	NR	NR	DOMS-inducing exercise protocol (5×10 eccentric bilateral leg press@1RM 120% + 2×10 eccentric bilateral leg press@1RM 100%)	15℃ & 38℃	14min (alternate 1min)	Full body	TC, CK	0h, 24h, 48h, 72h (TC: 24h, 48h, 72h)

Effect Size Analysis (Jump)

There was no statistically significant difference in the recovery of post-exercise jump ability in the contrast therapy group compared to the passive recovery group (g=0.0866, p=.7083, Fig. 3). There was no indication of heterogeneity (Q(2))=0.11, p=.9893, I2=0.00%).

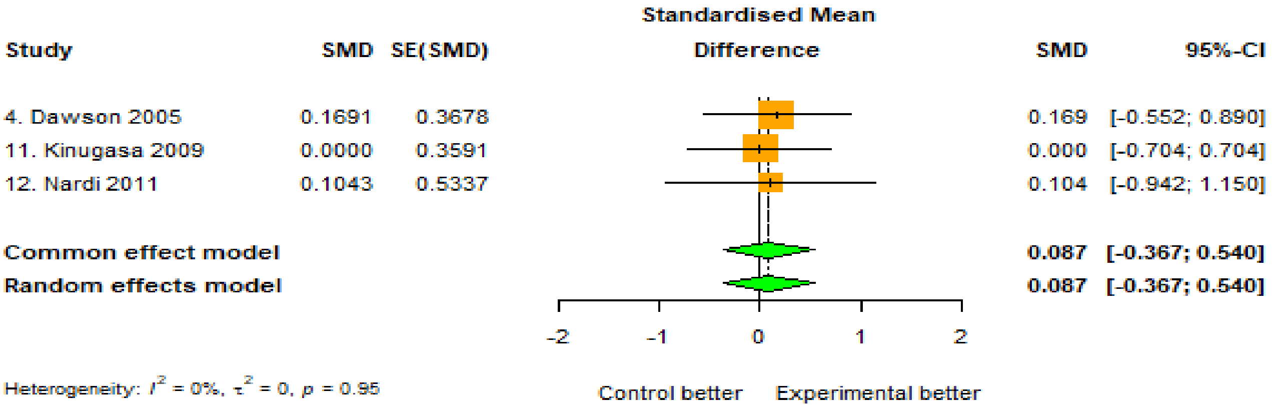

Figure 3. Forest plot for contrast therapy vs control in jump

Effect Size Analysis (Flexibility)

There was no statistically significant difference in the recovery of post-exercise flexibility ability in the contrast therapy group compared to the passive recovery group (g=0.0585, p=.7531, Fig. 4). There was no indication of heterogeneity (Q(2))=0.01, p=.9963, I^2=0.00%).

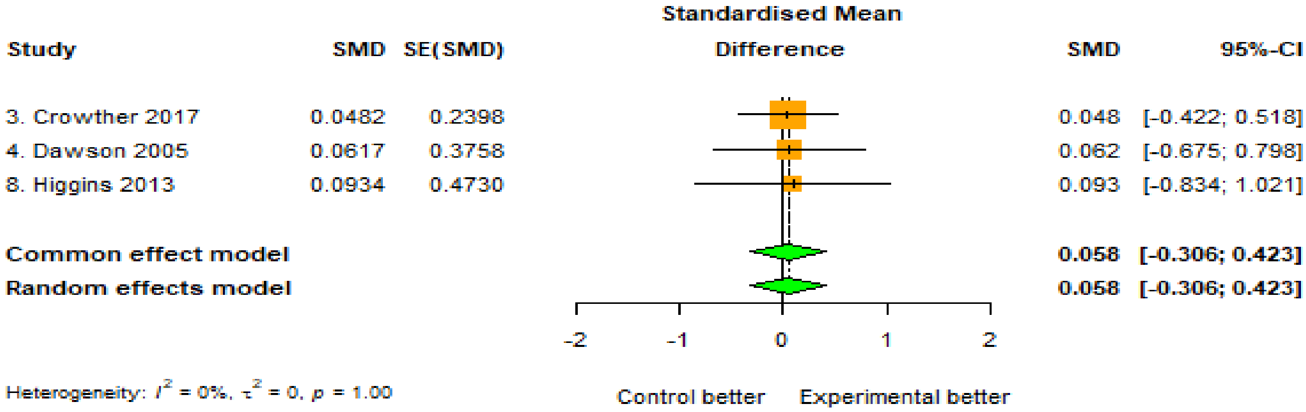

Figure 4. Forest plot for contrast therapy vs control in flexibility

Effect Size Analysis (Thigh Circumference)

There was no statistically significant difference in the recovery of post-exercise thigh circumference in the contrast therapy group compared to the passive recovery group (g=0.1636, p=.5654, Fig. 5). There was no indication of heterogeneity (Q(1))=0.03, p=.8671, I^2=0.00%).

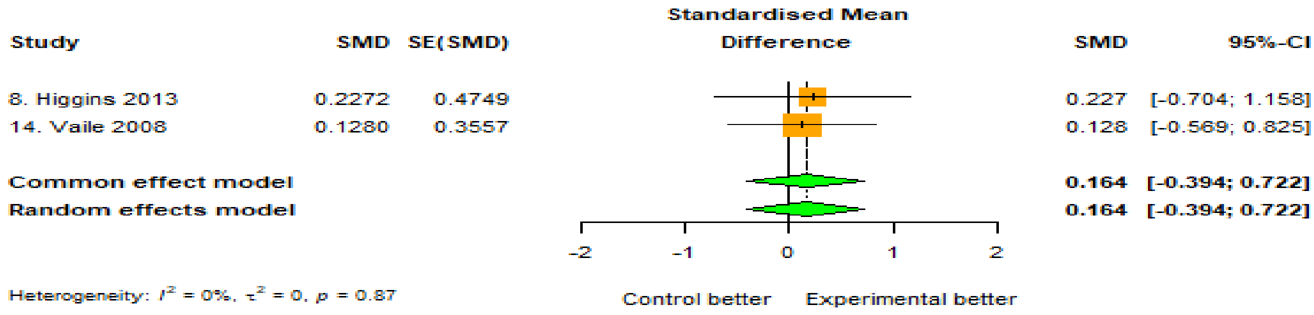

Figure 5. Forest plot for contrast therapy vs control in thigh circumference

Effect Size Analysis (Blood CK)

Compared to the passive recovery group, the recovery of post-exercise blood CK in the contrast therapy group showed a large effect and a statistically significant difference (g=0.7043,p=.0205, Fig. 6). There was small to moderate heterogeneity (Q(3)=5.16, p=.1604, I^2=41.9%).

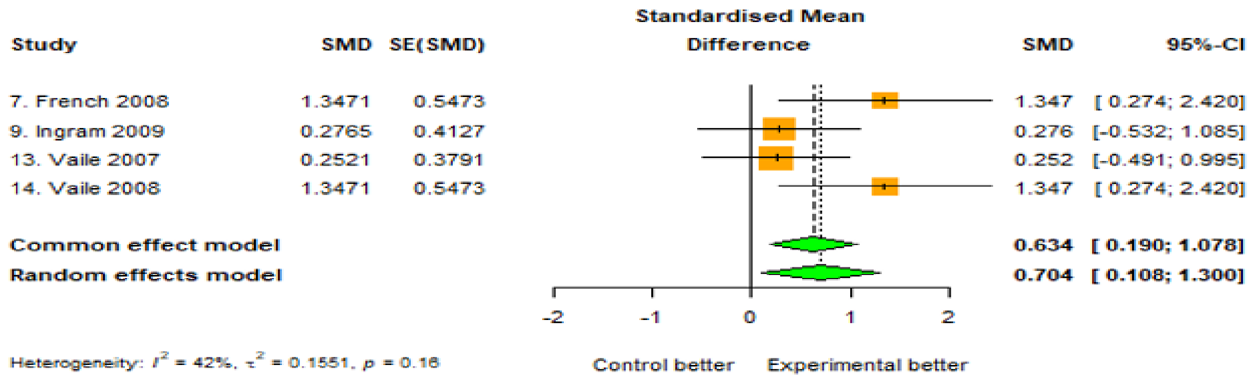

Figure 6. Forest plot for contrast therapy vs control in blood CK

Effect Size Analysis (Perceived Fatigue)

Compared to the passive recovery group, the recovery of post-exercise perceived fatigue in the contrast therapy group showed a moderate to large effect and a statistically significant difference (g=0.7384, p<.01, Fig. 7). There was no indication of heterogeneity (Q(3)=2.84, p=.4170, I^2=0.00%).

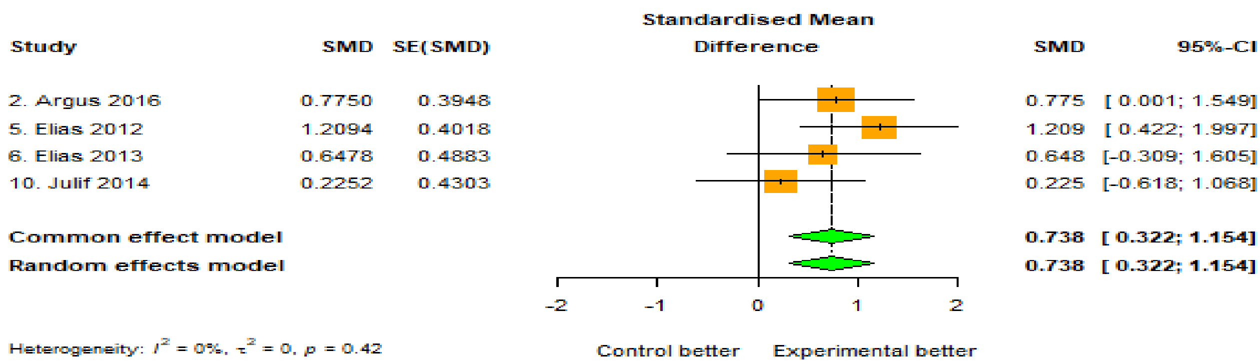

Figure 7. Forest plot for contrast therapy vs control in perceived fatigue

Effect Size Analysis (Perception of Recovery)

There was no statistically significant difference in perception of recovery in the contrast therapy compared to the passive recovery group (g=0.3254, p=.0661, Fig. 8). There was no indication of heterogeneity (Q(2)=0.02, p=.9887, I^2=0.00%).

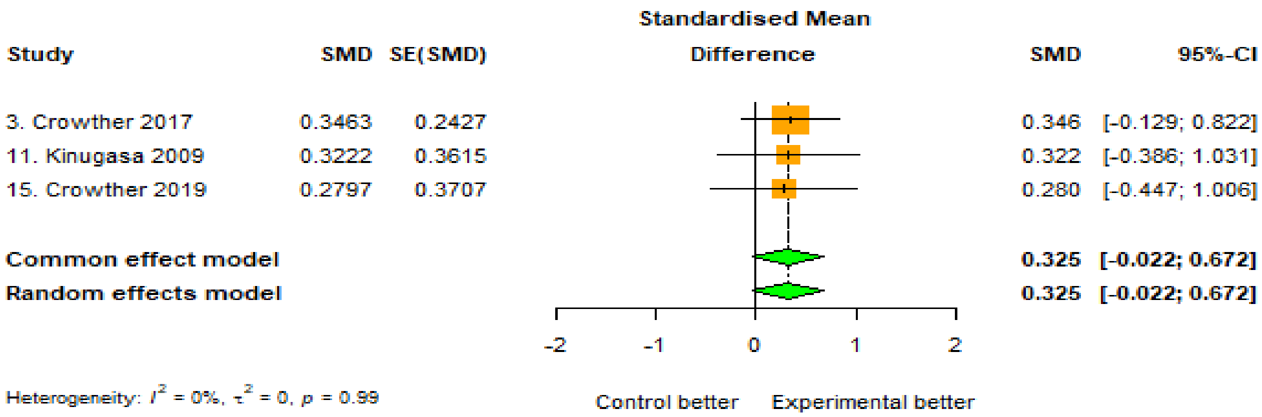

Figure 8. Forest plot for contrast therapy vs control in perception of recovery

Effect Size Analysis (Muscle Soreness)

Compared to the passive recovery group, the recovery of post-exercise muscle soreness in the contrast therapy group showed a moderate to large effect and a statistically significant difference (g=0.7192, p<.01, Fig. 9). There was small to moderate heterogeneity (Q(9)=13.87, p<.01, I^2=35.1%).

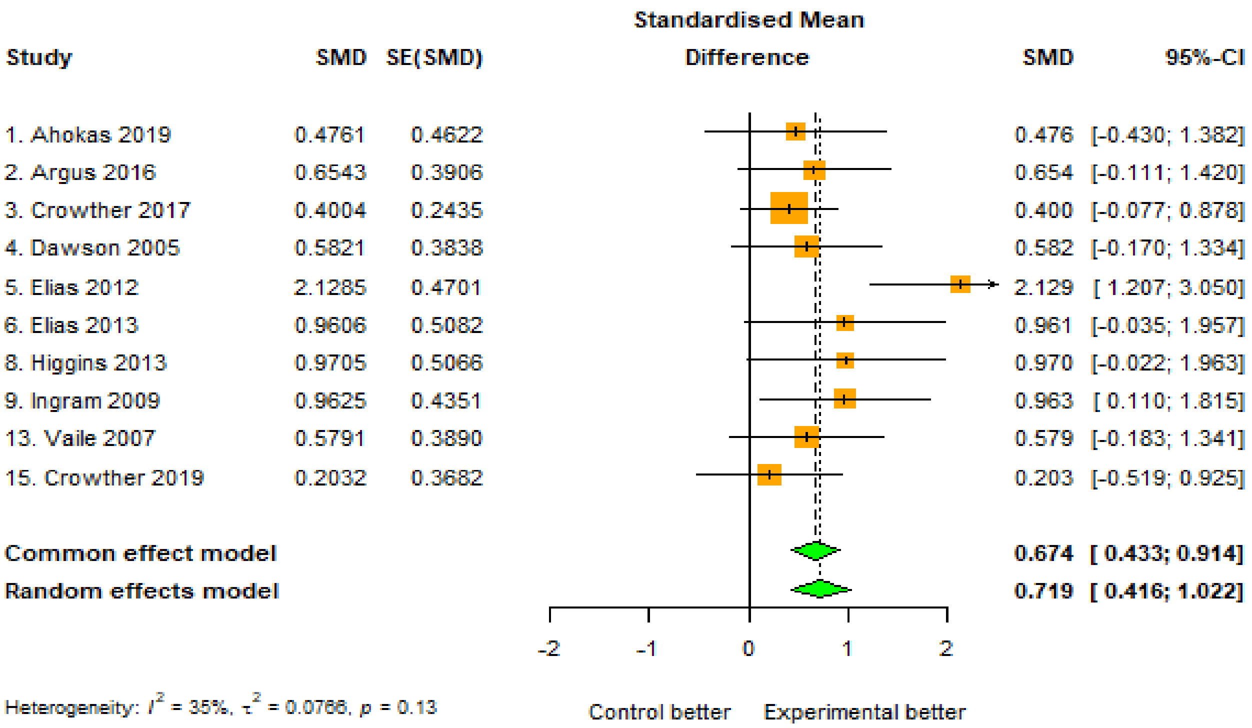

Figure 9. Forest plot for contrast therapy vs control in muscle soreness

Subgroup Analysis of Muscle Soreness

The homogeneity test for each dependent variable revealed some amount of heterogeneity in the sprint (Q(3)=4.26, p=.2349, I^2=29.5%), muscle soreness (Q(9)=13.87, p<.01, I^2=35.1%), and blood creatine kinase (Q(3)=5.16, p=.1604, I^2=41.9%). Although there was no significant heterogeneity, subgroup analysis was performed considering that new hypotheses could be generated for future research (Shin, 2015). However, two variables (sprint and blood CK) were excluded from the subgroup analysis. This is because the number of studies was insufficient, which can reduce statistical power (Shin, 2015).

A subgroup analysis was conducted by dividing into two categories: study type (Crossover vs Parallel), age (11~20 vs 21~30), the temperature of cold treatment in contrast therapy (1~10℃ vs 11~15℃), and the temperature of hot treatment in contrast therapy (38~40℃ vs 41~45℃).

Subgroup Analysis by Study Type

Subgroup analysis by study type showed that crossover studies (g=0.838) were more effective than parallel studies (g=0.628), but there was no group difference between study types (Q(1)=0.23, p=.6305, Table 2, Fig. 10).

Table 2. Subgroup analysis by study type on muscle soreness

Subgroup	Effect size		95% CI		Heterogeneity			
	n	g	LL	UL	Q	df	p	I^2
Crossover	4	0.8376	0.0413	1.6340	11.19	3	0.01	73.2
Parallel	6	0.6283	0.3228	0.9338	2.46	5	0.78	0
Total between					0.23	1	0.6305	

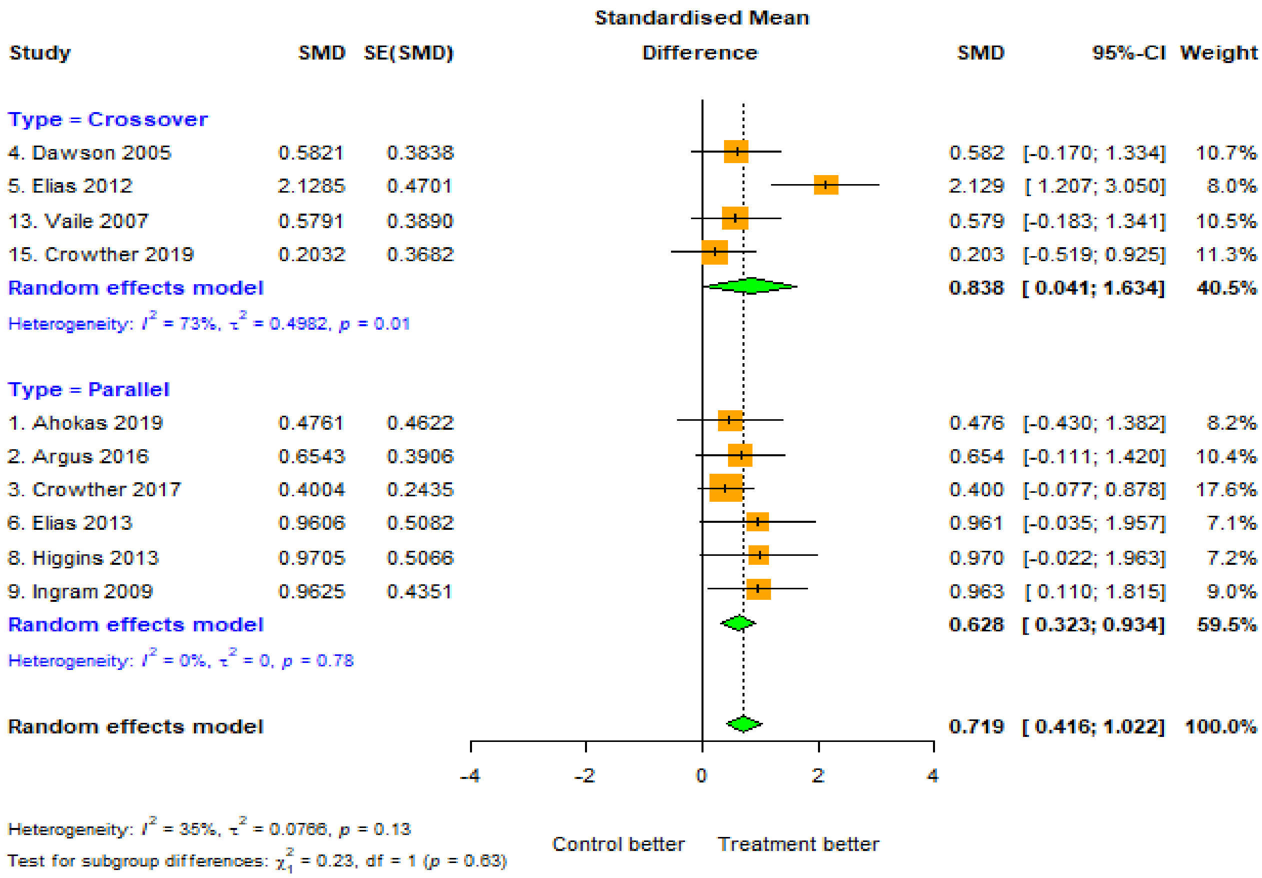

Figure 10. Subgroup analysis by study type on muscle soreness

Subgroup Analysis by Age

Subgroup analysis by age showed that 20 and under(g=0.966) were more effective than 20 and over(g=0.689), but there was no group difference by age (Q(1)=0.47, p=.4916, Table 3, Fig. 11).

Table 3. Subgroup analysis by age on muscle soreness

Subgroup	Effect size		95% CI		Heterogeneity			
	n	g	LL	UL	Q	df	p	I^2
<20	2	0.9655	0.2624	1.6687	0	1	0.99	0
>20	8	0.6889	0.3325	1.0454	13.12	7	0.07	46.7
Total between					0.47	1	0.4916	

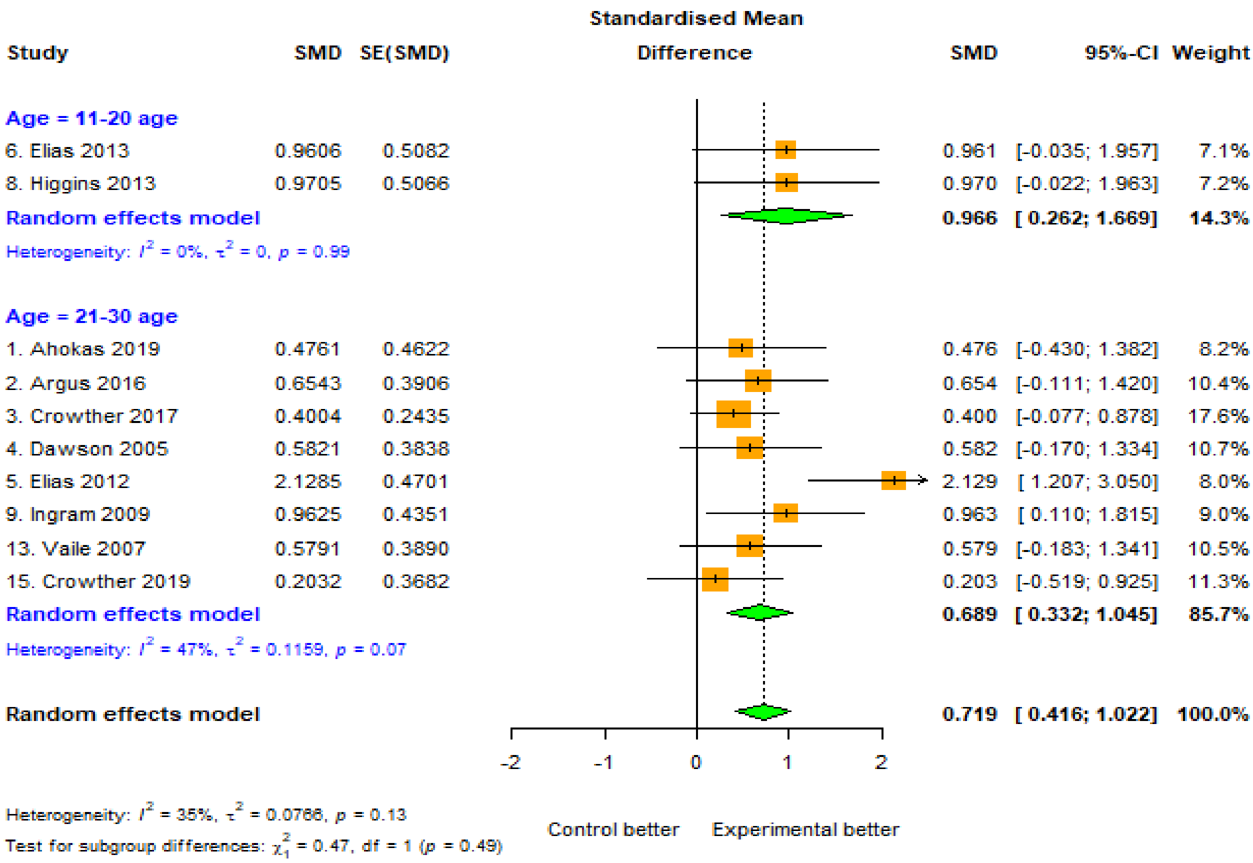

Figure 11. Subgroup analysis by age on muscle soreness

Subgroup Analysis by Temperature of Cold Treatment during Contrast Therapy

Subgroup analysis by temperature of cold treatment during contrast therapy that 11~15°C (g=0.773) was more effective than 8~10°C (g=0.672), but there was no group difference by temperature (Q(1)=0.09, p=.7611, Table 4, Fig. 12).

Table 4. Subgroup analysis by temperature of cold treatment during contrast therapy

Subgroup	Effect size		95% CI		Heterogeneity			
	n	g	LL	UL	Q	df	p	I^2
1~10℃	3	0.6722	0.1907	1.1537	0.68	2	0.71	0
11~15℃	7	0.7735	0.3326	1.2143	13.19	6	0.04	54.5
Total between					0.09	1	0.7611	

Subgroup Analysis by Temperature of Hot Treatment during Contrast Therapy

Subgroup analysis by temperature of hot treatment during contrast therapy showed that 38~40°C (g=0.782) was more effective than 41~45°C (g=0.581), but there was no group difference by temperature (Q(1)=0.35, p=.5544, Table 5, Fig. 13).

Table 5. Subgroup analysis by temperature of hot treatment during contrast therapy

Subgroup	Effect size		95% CI		Heterogeneity			
	n	g	LL	UL	Q	df	p	I^2
38~40℃	8	0.7819	0.3836	1.1803	13.73	7	0.06	49.0
41~45℃	2	0.5806	0.0451	1.1161	0	1	1.00	0
Total between					0.35	1	0.5544	

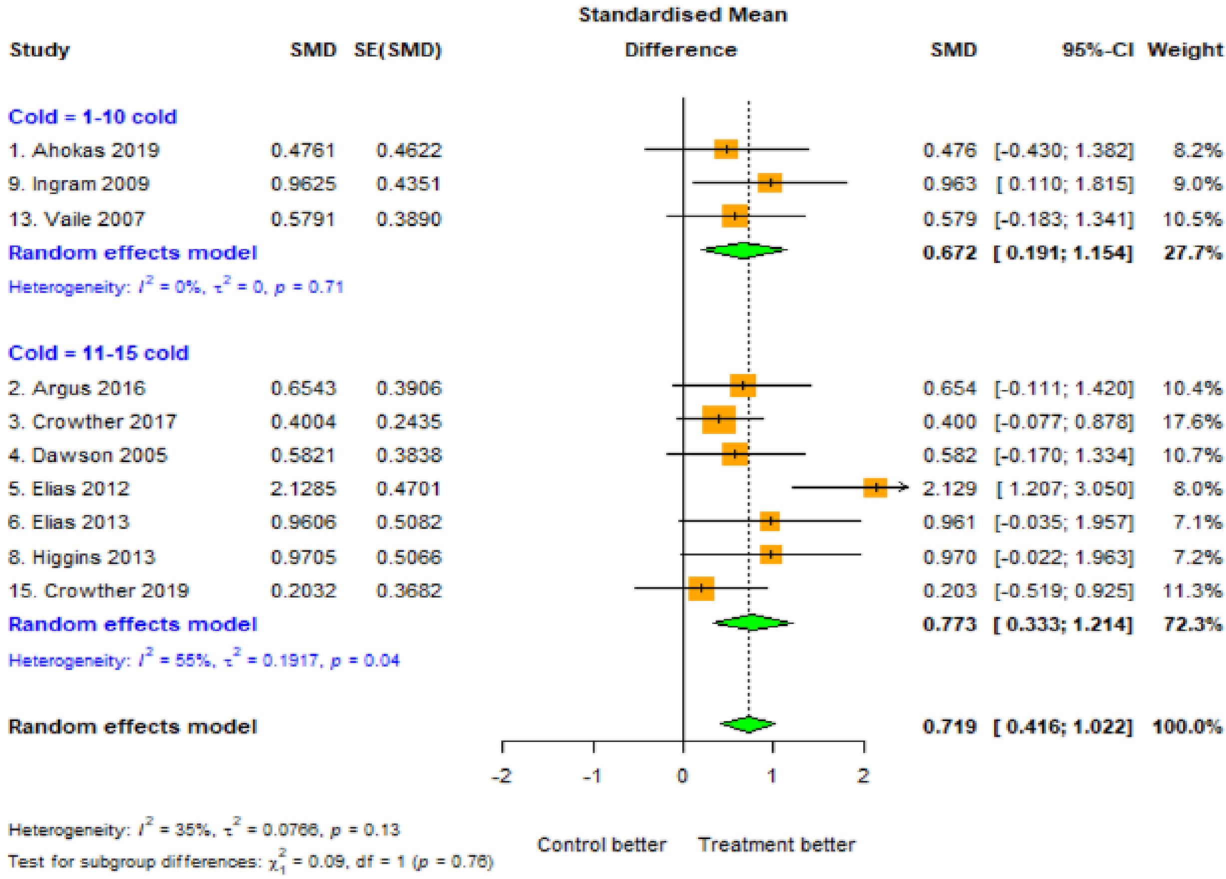

Figure 12. Subgroup analysis by temperature of cold treatment during contrast therapy

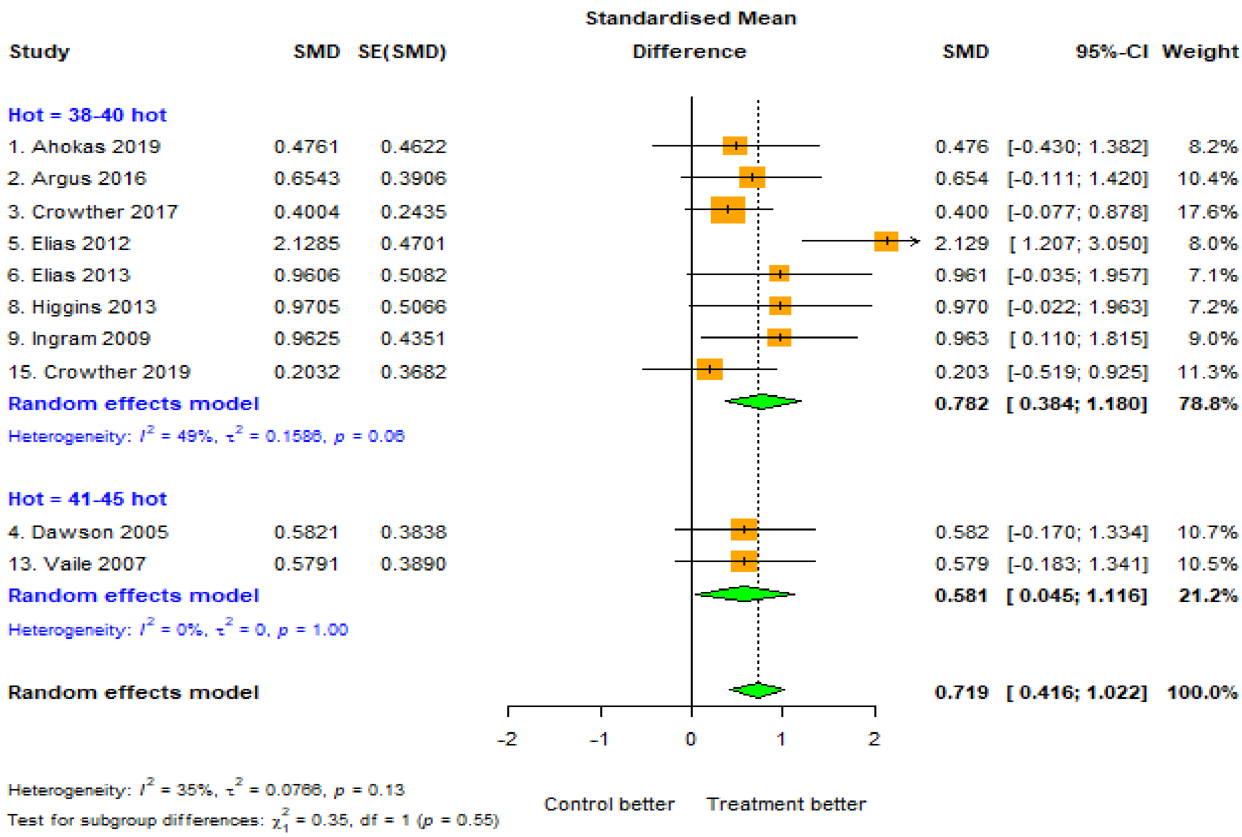

Figure 13. Subgroup analysis by temperature of hot treatment during contrast therapy

Publication Bias

Based on the funnel plot (Fig. 14) and Egger's regression test of all literature analyzed in this study, there was no publication bias (β=0.1549, p=.2348).

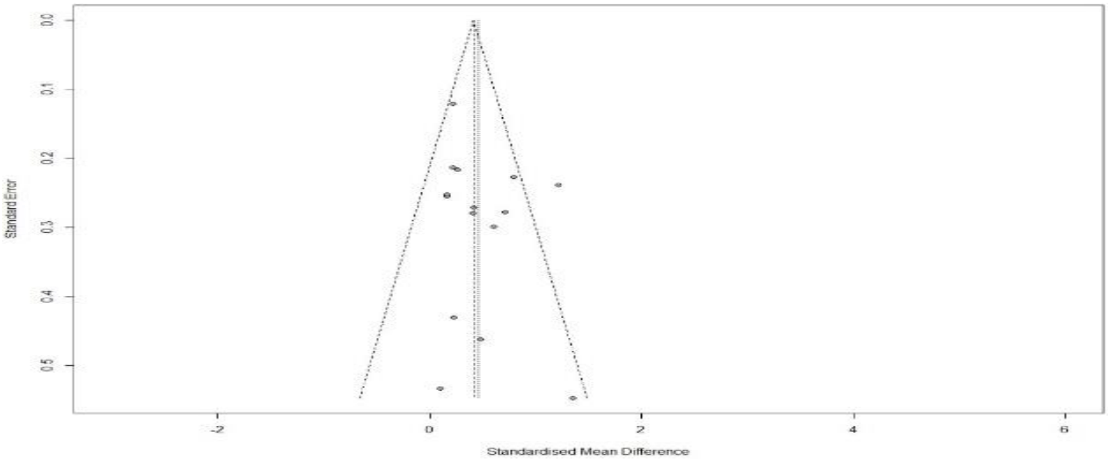

Figure 14. Funnel plot for publication bias

Literature Quality Assessment

Fifteen articles were included in the meta-analysis, two were randomized controlled trials and 13 were non-randomized controlled trials. The two randomized controlled trials were rated as low and high quality using the Modified Jadad Scale (Table 6). Thirteen non-randomized controlled studies were rated as low quality using the Newcastle-Ottawa Scale, with 11 scoring 3 and 2 scoring 2 (Table 7).

Table 6. Quality assessment results of randomized controlled trial studies via Modified Jadad Scale

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Scores
Argus et al., 2018	Yes	Not described	No	Not described	No	No	No	Yes	2
Crowther et al., 2017	Yes	Not described	Yes(single-blind)	Not described	Yes	Yes	No	Yes	4.5

Table 7. Quality assessment results of non-randomized controlled trial studies via Newcastle-Ottawa Scale

Study	Selection				Comparability	Outcome			Total Scores
	1	2	3	4	5	6	7	8	
Ahokas et al., 2019	★	★		★					3
Crampton et al., 2011	★	★		★					3
Crowther et al., 2019	★	★		★					3
Dawson et al., 2005	★	★		★					3
Elias et al., 2012	★	★		★					3
Elias et al., 2013	★	★		★					3
French et al., 2008		★		★					2
Higgins et al., 2013	★	★		★					3
Ingram et al., 2009	★	★		★					3
Juliff et al., 2014	★	★		★					3
Kinugasa and Kilding, 2009	★	★		★					3
Nardi et al., 2011	★	★		★					3
Sayers et al., 2011	★	★		★					3
Vaile et al., 2007		★		★					2
Vaile et al., 2008	★	★		★					3

DISCUSSION

Accelerating the time course of the natural recovery process through post-exercise recovery intervention is important to prepare for the next training or competition (Barnett, 2006). Among the various recovery interventions, contrast therapy, which has recently been applied as a method of post-exercise recovery, has been reported with varying effects between studies, thus it was necessary to examine the extent of the effect size. Therefore, in this study, we conducted a meta-analysis of the exercise performance and physiological variables to verify the efficacy for the effect of contrast therapy on post-exercise recovery.

The results showed that four of eight variables (blood CK, sprint, muscle soreness, and perceived fatigue) were statistically significant differences, which indicated the effectiveness of contrast therapy compared to passive recovery. The remaining four variables (jump, flexibility, thigh circumference, and perception of recovery) showed a slight trend in favor of the contrast therapy compared to the passive recovery, but no statistically significant differences.

First, Contrast therapy was observed to be effective in the post-exercise recovery of blood CK compared to passive recovery. Creatine kinase is known to be produced in response to muscle tissue damage from high-intensity exercise (Brancaccio et al., 2007), and peak levels of CK have been documented to increase on average even up to 96 hours after physiological stress (Ehlers et al., 2002). It has been suggested that interventions that lower levels of creatine kinase after exercise could reduce overall damage to skeletal muscle and promote rapid recovery (Hing et al., 2008). Vaile et al. (2007) suggested that the tendency for creatine kinase concentrations to decrease after contrast therapy was due to changes in perfusion to the muscle through vasoconstriction and vasodilation, which decreased the immune response leading to diminished myocyte damage. The results of our study also suggest that contrast therapy was effective in the post-exercise recovery of creatine kinase for the same reason.

The exercise performance variables in this study were sprint, jump, and flexibility, which are commonly measured in the literature. Sprint and jump performance are closely related to the function of skeletal muscles and their ability to generate force quickly (Bissas & Havenetidis, 2008; Young et al., 2011). Flexibility is related to athletic performance because of patterns specific to certain sports and positions within those sports (Gleim & McHugh, 1997), and long-term static stretching has been shown to positively influence strength, power, and hypertrophy (Bouguezzi et al., 2023). Among the performance variables, only sprint, excluding jump and flexibility, showed an effect of the contrast therapy compared to the passive recovery. This difference is considered to be due to the different characteristics of the exercise stresses imposed on the body during sprint, jump, and flexibility measures. In this study, sprint was used as a measure of total sprint time for the 6x20m repeated sprint ability test in the literature. Repeated sprint ability refers to the ability to maintain and recover from maximal effort during a series of repeated sprints (Turner & Stewart, 2013), and the most commonly used test is six repetitions of a 20-meter distance with a 30-second rest between repetitions. These repetitions of sprint exercise are characterized by muscle soreness, increased blood CK, and decreased performance in response to exercise-induced muscle damage (Keane et al., 2015). On the other hand, the measure of jump ability consisted of no more than three maximal jumps, and the highest value was used for data analysis. A single maximal jump takes less than a second and does not completely deplete phosphagen reserves (Read & Cisar, 2001). In addition, flexibility was measured by a sit-to-stand forward bend test. Given this, we believe that measuring repetitive sprint ability may have imposed more stress on the body, such as muscle microdamage, than measuring jump and flexibility.

Meanwhile, muscle soreness showed that contrast therapy was effective compared to passive recovery. However, the perception of recovery was trended in favor of contrast therapy, but no statistically significant difference was found. Crowther et al. (2017) found that contrast therapy improved perceptions of recovery and perceived perceptual recovery, such as muscle soreness, and proposed two reasons for this. One is that the pumping effect of contrast therapy, caused by vasodilation and vasoconstriction of the capillaries, may have contributed to the perceived recovery by expelling metabolites out of the muscle and transporting new proteins and enzymes into the muscle. The other suggested that the perception of the presumed positive effect and a recognition of the widespread use of contrast therapy in many communities could be a partial placebo effect. Eventually, we believe that the differences between our results and Crowther et al. (2017) may reflect differences in individual experiences, environmental conditions, and other factors that influence perceptions of recovery.

Perceived fatigue showed that contrast therapy was effective compared to passive recovery. Perceived fatigue is distinct from physiological fatigue, which focuses on the ability of muscles to generate and maintain force, and refers to the subjective feeling of fatigue by the individuals (Gorman et al., 2015). Increased perception of fatigue due to the training and competition traits of sports reduces performance (Brownsberger et al., 2013; Loch et al., 2020). To achieve optimal exercise performance, recovery strategies need to consider these psychological aspects (Brownsberger et al., 2013). Sayers et al. (2011) found that contrast therapy reduced fatigue perception and delayed muscle soreness, which effectively addressed key aspects of physiological and psychological fatigue, which is consistent with the results of this study.

The recovery of thigh circumference showed a slight trend toward the effectiveness of contrast therapy, but no statistically significant difference. Thigh circumference is often used as an indirect measure of intramuscular and subcutaneous edema after exercise. Vaile et al. (2008) suggested that hydrostatic pressure increases the pressure gradient between the interstitial and intravascular compartments of the immersed body, which may lead to increased reabsorption of interstitial fluid and decreased edema. On the other hand, consistent with the present findings, Higgins et al. (2013) suggested that contrast therapy reflected a small effect related to the movement of osmotic fluids.

Consequently, subjective measure variables (muscle soreness, perceived fatigue), except for perception of recovery, showed the effectiveness of contrast therapy compared to passive recovery. Also, sprint, which can cause additional micro-damage to muscles after exercise, and blood CK, which is a marker of muscle damage, were found to be effective with contrast therapy. It is believed that contrast therapy could be beneficial for sports that involve frequent sprints or repeated high-intensity exercise with short rest periods. In addition, when considering psychological aspects such as muscle soreness and perceived fatigue for optimal performance, we believe that contrast therapy has a positive effect on post-exercise recovery compared to passive recovery.

For practical applications, our findings suggest that contrast therapy could be effectively integrated into recovery protocols for athletes in high-intensity sports. Regular sessions post-training could accelerate recovery and reduce muscle soreness. Coaches and sports health professionals might use these insights to enhance training schedules and develop injury prevention strategies that incorporate contrast therapy to support athlete performance and recovery. This approach not only helps in quick recovery but also prepares athletes better for subsequent training sessions and competitions.

As a limitation, our study faced several practical challenges. First, the number of studies that conducted contrast therapy on each dependent variable was lower than expected, which limited our ability to draw comprehensive conclusions. Additionally, the overall quality of the analyzed studies was not as high as desired, affecting the robustness of our findings. These issues were primarily due to variations in methodology and the lack of standardized protocols across studies, which made it challenging to compare results directly. To address these challenges in future research, it is essential to standardize the conditions under which contrast therapy is applied, such as temperature, the time ratio between cold and hot treatment, rest time between treatments, and immersion level. By establishing clearer guidelines for these variables, future studies can produce more reliable and comparable results. Moreover, increasing the number of studies focusing on specific dependent variables will enhance the robustness of the meta-analytic conclusions. Therefore, we recommend that future studies aim to improve the quality of the literature by conducting more rigorous trials with standardized protocols. Reflecting on various results from enhanced methodological approaches, it is expected that more in-depth analysis and a better understanding of the effects and mechanisms of contrast therapy can be achieved.

Conflict of Interest

No conflict of interest is declared by the authors.

Author Contributions

Study Design, Il-young Cho; Data Collection, Hyunseok Choi, Il-young Cho; Statistical Analysis, Hyunseok Choi, Il-young Cho; Data Interpretation,

Hyunseok Choi, Il-young Cho, Yong Hong; Manuscript Preparation, Hyunseok Choi, Il-young Cho; Literature Search, Hyunseok Choi, Il-young Cho, Yong Hong. All authors have read and agreed to the published version of the manuscript.

REFERENCES

Argus, C. K., Broatch, J. R., Petersen, A. C., Polman, R., Bishop, D. J., & Halson, S. (2017). Cold-water immersion and contrast water therapy: no improvement of short-term recovery after resistance training. *International journal of sports physiology and performance*, 12(7), 886-892. [**Pubmed**]

Ahokas, E. K., Ihalainen, J. K., Kyröläinen, H., & Mero, A. A. (2019). Effects of water immersion methods on postexercise recovery of physical and mental performance. *The Journal of Strength & Conditioning Research*, 33(6), 1488-1495. [**Pubmed**]

Belza, B. (1994). The impact of fatigue on exercise performance. *Arthritis & Rheumatism: Official Journal of the American College of Rheumatology*, 7(4), 176-180. [**Pubmed**]

Barnett, A. (2006). Using recovery modalities between training sessions in elite athletes: does it help?. *Sports medicine*, 36, 781-796. [**Pubmed**]

Brancaccio, P., Maffulli, N., & Limongelli, F. M. (2007). Creatine kinase monitoring in sport medicine. *British medical bulletin*, 81(1), 209-230. [**Pubmed**]

Bissas, A., & Havenetidis, K. (2008). The use of various strength-power tests as predictors of sprint running performance. *Journal of sports medicine and physical fitness*, 48(1), 49-54. [**Pubmed**]

Bieuzen, F., Bleakley, C. M., & Costello, J. T. (2013). Contrast water therapy and exercise induced muscle damage: a systematic review and meta-analysis. *PloS one*, 8(4), e62356. [**Pubmed**]

Brownsberger, J., Edwards, A., Crowther, R., & Cottrell, D. (2013). Impact of mental fatigue on self-paced exercise. *International Journal of Sports Medicine*, 34(12), 1029-1036. [**Pubmed**]

Broatch, J. R., Petersen, A., & Bishop, D. J. (2014). Postexercise cold water immersion benefits are not greater than the placebo effect. *Medicine & Science in Sports & Exercise*, 46(11), 2139-2147. [**Pubmed**]

Balduzzi, S., Rücker, G., & Schwarzer, G. (2019). How to perform a meta-analysis with R: a practical tutorial. *BMJ Ment Health*, 22(4), 153-160. [**Pubmed**]

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2021). *Introduction to meta-analysis*. John Wiley & Sons. [**CrossRef**]

Bouguezzi, R., Sammoud, S., Markov, A., Negra, Y., & Chaabene, H. (2023). Why Flexibility Deserves to Be Further Considered as a Standard Component of Physical Fitness: A Narrative Review of Existing Insights from Static Stretching Study Interventions. *Youth*, 3(1), 146-156. [**CrossRef**]

Cochrane, D. J. (2004). Alternating hot and cold water immersion for athlete recovery: a review. *Physical therapy in sport*, 5(1), 26-32. [**CrossRef**]

Costello, J. T., Algar, L. A., & Donnelly, A. E. (2012). Effects of whole- body cryotherapy(−110℃) on proprioception and indices of muscle damage. *Scandinavian journal of medicine & science in sports*, 22(2), 190-198. [**Pubmed**]

Crowther, F., Sealey, R., Crowe, M., Edwards, A., & Halson, S. (2017). Influence of recovery strategies upon performance and perceptions following fatiguing exercise: a randomized controlled trial. *BMC Sports Science, Medicine and Rehabilitation*, 9, 1-9. [**Pubmed**]

Crowther, F. A., Sealey, R. M., Crowe, M. J., Edwards, A. M., & Halson, S. L. (2019). Effects of various recovery strategies on repeated bouts of simulated intermittent activity. *The Journal of Strength & Conditioning Research*, 33(7), 1781-1794. [**Pubmed**]

Dawson, B., Gow, S., Modra, S., Bishop, D., & Stewart, G. (2005). Effects of immediate post-game recovery procedures on muscle soreness, power, and flexibility levels over the next 48 hours. *Journal of Science and Medicine in Sport*, 8(2), 210-221. [**Pubmed**]

De Nardi, M., La Torre, A., Barassi, A., Ricci, C., & Banfi, G. (2011). Effects of cold-water immersion and contrast-water therapy after training in young soccer players. *J Sports Med Phys Fitness*, 51(4), 609-15. [**Pubmed**]

Ehlers, G. G., Ball, T. E., & Liston, L. (2002). Creatine kinase levels are elevated during 2-a-day practices in collegiate football players. *Journal of Athletic Training*, 37(2), 151. [**Pubmed**]

Elias, G. P., Varley, M. C., Wyckelsma, V. L., McKenna, M. J., Minahan, C. L., & Aughey, R. J. (2012). Effects of water immersion on posttraining recovery in Australian footballers. *International journal of sports physiology and performance*, 7(4), 357-366. [**Pubmed**]

Elias, G. P., Wyckelsma, V. L., Varley, M. C., McKenna, M. J., & Aughey, R. J. (2013). Effectiveness of water immersion on postmatch recovery in elite professional footballers. *International journal of sports physiology and performance*, 8(3), 243-253. [**Pubmed**]

French, D. N., Thompson, K. G., Garland, S. W., Barnes, C. A., Portas, M. D., Hood, P. E., & Wilkes, G. (2008). The effects of contrast bathing and compression therapy on muscular performance. *Medicine and science in sports and exercise*, 40(7), 1297-1306. [**Pubmed**]

Gleim, G. W., & McHugh, M. P. (1997). Flexibility and its effects on sports injury and performance. *Sports medicine*, 24, 289-299. [**Pubmed**]

Gorman, G. S., Elson, J. L., Newman, J., Payne, B., McFarland, R., Newton, J. L., & Turnbull, D. M. (2015). Perceived fatigue is highly prevalent and debilitating in patients with mitochondrial disease. *Neuromuscular Disorders*, 25(7), 563-566. [**Pubmed**]

Howatson, G., & Van Someren, K. A. (2008). The prevention and treatment of exercise-induced muscle damage. *Sports medicine*, 38, 483-503. [**Pubmed**]

Hing, W. A., White, S. G., Bouaaphone, A., & Lee, P. (2008). Contrast therapy—A systematic review. *Physical Therapy in Sport*, 9(3), 148-161. [**Pubmed**]

Higgins, T. R., Climstein, M., & Cameron, M. (2013). Evaluation of hydrotherapy, using passive tests and power tests, for recovery across a cyclic week of competitive rugby union. *The Journal of Strength & Conditioning Research*, 27(4), 954-965. [**Pubmed**]

Ingram, J., Dawson, B., Goodman, C., Wallman, K., & Beilby, J. (2009). Effect of water immersion methods on post-exercise recovery from simulated team sport exercise. *Journal of science and medicine in sport*, 12(3), 417-421. [**Pubmed**]

Jakeman, J. R., Macrae, R., & Eston, R. (2009). A single 10-min bout of cold-water immersion therapy after strenuous plyometric exercise has no beneficial effect on recovery from the symptoms of exercise-induced muscle damage. *Ergonomics*, 52(4), 456-460. [**Pubmed**]

Juliff, L. E., Halson, S. L., Bonetti, D. L., Versey, N. G., Driller, M. W., & Peiffer, J. J. (2014). Influence of contrast shower and water immersion on recovery in elite netballers. *The Journal of Strength & Conditioning Research*, 28(8), 2353-2358. [**Pubmed**]

Kinugasa, T., & Kilding, A. E. (2009). A comparison of post-match recovery strategies in youth soccer players. *The Journal of Strength & Conditioning Research*, 23(5), 1402-1407. [**Pubmed**]

Kim, J. Y., Lee, C. H., Park, K. H., & Lee, J. H. (2010). Effect of Protein supplementation on exercise-induced muscle damage. *Korean J Sport Sci*, 21, 1298-314. [**CrossRef**]

Kovacs, M. S., & Baker, L. B. (2014). Recovery interventions and strategies for improved tennis performance. *British Journal of Sports Medicine*, 48(Suppl 1), i18-i21. [**Pubmed**]

Keane, K. M., Salicki, R., Goodall, S., Thomas, K., & Howatson, G. (2015). Muscle damage response in female collegiate athletes after repeated sprint activity. *The Journal of Strength & Conditioning Research*, 29(10), 2802-2807. [**Pubmed**]

Lehmann, J. F., Warren, C. G., & Scham, S. M. (1974). Therapeutic heat and cold. *Clinical Orthopaedics and Related Research®*, 99, 207-245. [**Pubmed**]

Loch, F., Hof zum Berge, A., Ferrauti, A., Meyer, T., Pfeiffer, M., & Kellmann, M. (2020). Acute effects of mental recovery strategies after a mentally fatiguing task. *Frontiers in Psychology*, 11, 558856. [**Pubmed**]

Myrer, J. W., Draper, D. O., & Durrant, E. (1994). Contrast therapy and intramuscular temperature in the human leg. *Journal of Athletic Training*, 29(4), 318. [**Pubmed**]

Meeusen, R., Duclos, M., Gleeson, M., Rietjens, G., Steinacker, J., & Urhausen, A. (2006). Prevention, diagnosis and treatment of the overtraining syndrome. *European Journal of Sport Science*, 6(1), 1-14. [**CrossRef**]

Mujika, I., Halson, S., Burke, L. M., Balagué, G., & Farrow, D. (2018). An integrated, multifactorial approach to periodization for optimal performance in individual and team sports. *International journal of sports physiology and performance*, 13(5), 538-561. [**Pubmed**]

Prentice, W. E. (1999). *Therapeutic modalities in sports medicine*. WCB/McGraw-Hill.

Read, M. M., & Cisar, C. (2001). The influence of varied rest interval lengths on depth jump performance. *The Journal of Strength & Conditioning Research*, 15(3), 279-283. [**Pubmed**]

Reilly, T., & Ekblom, B. (2005). The use of recovery methods post- exercise. *Journal of Sports Sciences*, 23(6), 619-627. [**Pubmed**]

Simjanovic, M., Hooper, S., Leveritt, M., Kellmann, M., & Rynne, S. (2009). The use and perceived effectiveness of recovery modalities and monitoring techniques in elite sport. *Journal of Science and Medicine in Sport*, 12, S22. [**CrossRef**]

Sayers, M. G., Calder, A. M., & Sanders, J. G. (2011). Effect of whole-body contrast-water therapy on recovery from intense exercise of short duration. *European Journal of Sport Science*, 11(4), 293-302. [**CrossRef**]

Shin, W. J. (2015). An introduction of the systematic review and meta-analysis. *Hanyang Medical Reviews*, 35(1), 9-17. [**CrossRef**]

Turner, A. N., & Stewart, P. F. (2013). Repeat sprint ability. *Strength & Conditioning Journal*, 35(1), 37-41. [**CrossRef**]

Thorpe, R. T. (2021). Post-exercise recovery: Cooling and heating, a periodized approach. *Frontiers in Sports and Active Living*, 3, 707503. [**Pubmed**]

Vaile, J. M., Gill, N. D., & Blazevich, A. J. (2007). The effect of contrast water therapy on symptoms of delayed onset muscle soreness. *The Journal of Strength & Conditioning Research*, 21(3), 697-702. [**Pubmed**]

Vaile, J., Halson, S., Gill, N., & Dawson, B. (2008). Effect of hydrotherapy on the signs and symptoms of delayed onset muscle soreness. *European journal of applied physiology*, 102, 447-455. [**Pubmed**]

Van der Does, H. T. D., Brink, M. S., Otter, R. T. A., Visscher, C., & Lemmink, K. A. P. M. (2017). Injury risk is increased by changes in perceived recovery of team sport players. *Clinical journal of sport medicine*, 27(1), 46-51. [**Pubmed**]

Young, W., Cormack, S., & Crichton, M. (2011). Which jump variables should be used to assess explosive leg muscle function?. *International journal of sports physiology and performance*, 6(1), 51-57. [**Pubmed**]