Accepted version, 09/08/2023 International Journal of Exercise Science

Title: Recovery Effects of Foam Rolling on Psychophysiological Responses in Thai National Male Ice Hockey Players

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ABSTRACT

We examined the short-term effects of foam rolling (FR), dynamic stretching (DS), and passive rest (PR) following simulated ice hockey exercise (IHE) on heart rate (HR), blood lactate (BL), leg choice reaction time (CRT_{leg}), rating of perceived exertion (RPE), and global rating of change (GRC) in elite ice hockey players. The study followed a randomized cross-over design. Fifteen national male ice hockey players were assigned to the FR, DS, or PR interventions for 10 mins following 35-min of simulated IHE. HR and BL were obtained at 0-, 5- and 10-min post-intervention. CRT_{leg} and RPE were assessed pre-and post-intervention. GRC was evaluated post-intervention. The PR decreased HR faster than the DS at 5 min post-treatment. Whereas the FR and DS reduced BL levels faster than the PR at 5- and 10-min post-treatment. There was no difference in CRT_{leg} among the FR, DS, and PR. The FR had lower RPE scores compared to the DS and PR post-treatment. As perceptual aspects, the FR was the most preferred treatment by ice hockey athletes. The FR and DS exerted more beneficial effects on BL but not on HR by the passive rest. The FR showed the most effective treatment on the psychological demands by improving RPE and perceptual responses over the DS and PR. Thus, the FR could be used as a choice for post-game recovery treatment on improving physiological and perceptual responses following an intense match-play in ice hockey players.

KEYWORDS: Self-myofascial release, dynamic stretching, active recovery, passive recovery, global rating of change

INTRODUCTION

Ice hockey is a physically demanding contact team skating sport in which players of two teams use their sticks to shoot a rubber puck into the opponent's net to score goals. The sport requires repeated high-intensity exercise bouts (32) and results in physiological and psychological fatigues after a competitive match that may adversely affect an athlete's performance in the following match. Therefore, the ability to recover rapidly is important for the players to compete again at an appropriate level (34, 36). Nowadays, the post-match recovery strategies for sport-specific players such as football (26), tennis (22), rugby (16), and soccer players (3) have been purposed to provide a performance benefit in the subsequent match.

Foam rolling (FR), an active recovery treatment, is a form of self-myofascial massage which aims to improve muscular fatigue, pain, BL removal, and soreness (2, 18, 19, 38). Jo et al. (19) reported the effects of FR treatment after strenuous activity by attenuating fatigue-related impairment of jump height and decreasing dynamic reaction time in 25 healthy individuals. Rey et al. (31) examined the acute effects of applying 20 mins of FR exercises on lower extremity muscles, e.g., quadriceps, hamstrings, adductors, gluteals, and gastrocnemius in 18 professional soccer players, and reported that the FR could enhance recovery after training by increasing agility and relieving muscle soreness. Furthermore, Rahimi et al. (30) reported executing 15 min FR after a futsal match was more beneficial than passive rest to expedite physical performance recovery and improve perceptions of subjective feeling in 16 youth players. Due to the potential cost-effective clinical massage of the FR, it might promise faster recovery by mitigating both physiological and psychological fatigue after high-intensity exercise. However, to the best of the authors' knowledge, possible effects of FR in a contact team sport such as ice hockey remain under investigated.

The other well-documented active recovery treatment is dynamic stretching (DS) which is commonly used for increasing flexibility and reducing stiffness, and delayed onset muscular soreness (DOMS) after physical exertion (33). The stretching activity performs by moving joints without holding and momentarily taking a limb to an extreme position, for example, the forward and backward swing of the leg at the hip joint in the sagittal plane. During DS exercise, some muscles are contracted actively and rhythmically to stretch the target muscle which could raise muscular temperature, cause postactivation potentiation, and further improve muscle performance (14, 39). Miladi et al. (24) compared 3 different recovery modes, i.e., active (using moderate exercise intensity), DS, and passive rest (PR) and reported that DS appeared as the best recovery treatment to enhance performance and cardiorespiratory and lactate responses during intermittent supramaximal exercise in 15 elite youth soccer players. Emphasizing an effective recovery tool when the time between matches in ice hockey is limited can be a very beneficial approach to accelerating physical ability. However, the recovery effects by the DS in ice hockey players is still lacking.

Recently, recovery treatments, i.e., active and passive recovery, have been challengedwhether one is better than the other (9, 11). Especially, in the contact sport of ice hockey, in which the post-match recovery is crucial, limited research exists to support the effectiveness of recovery treatments on psychophysiological responses. Therefore, this study aims to determine the short-term effects of FR and DS compared to passive rest (PR) following simulated ice hockey exercise on HR, BL, leg choice reaction time (CRT_{leg}), rating of perceived exertion (RPE), and global rating of change (GRC) in elite ice hockey players.

METHODS

Participants

Sample size estimates were calculated from Jo et al (19) using G*Power 3.1.9.2. with Cohen's f effect size of 0.5, an alpha of 0.05, and a power of 0.8. For each treatment, a sample size of 15 participants (12 plus 3 participants for an expected 20% dropout) was required. During the pre-season between May 2020 and August 2021, 15 professional male ice hockey players (mean±SD, age: 22±3 years, body mass: 75±14 kg, height: 175±8 cm, body mass index: 24.2±3.0 kg·m^{-2}, resting heart rate: 80±10 bpm, peak oxygen uptake ($\dot{V}O_{2peak}$): 52.0±5.9 mL·kg^{-1}·min^{-1}) were recruited from the Thai national ice hockey team via personal invitations. Participants had ice hockey training for more than 6 hours per week. All had right-leg dominance. Exclusion criteria included musculoskeletal disorders, hypertension, diabetes, or any other known medical conditions, and the use of prescription medications. After an explanation of the experimental procedures, benefits, and possible risks of the study, written informed consent was obtained. The study was approved by the Human Research Ethics Committee at [BLINDED FOR REVIEW].

Protocol

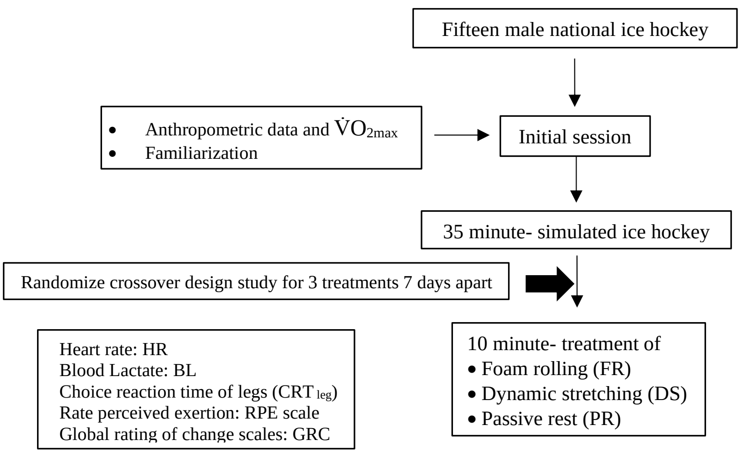
This research was carried out fully in accordance the ethical standards of Helsinki as well as the ethical standards of the International Journal of Exercise Science (25). The study had a randomized, cross-over design. Randomization was achieved by employing a computer program. Participants visited the Exercise Physiology laboratory four times with the first visit to collect participant characteristics, an incremental oxygen uptake test to volitional exhaustion, and familiarization with the 35-min simulated ice hockey exercise protocol. Subsequently, participants had three experimental visits 7 days apart with different recovery treatments following the 35-min simulated ice hockey exercise protocol. Each visit was performed in the laboratory at ~20° C between 1 and 4 pm.

First visit: During the first visit, height (cm), body mass (kg), and body mass index (kg·m^{-2}) were collected. The peak oxygen uptake ($\dot{V}O_{2peak}$) was assessed using an incremental cycling test (see below) to standardize the exercise intensity during the simulated ice-hockey exercise.

Peak oxygen uptake ($\dot{V}O_{2peak}$): The incremental cycling test was performed on a Monark cycle ergometer (Monark ergomedic 828e, Sweden), and expired air was sampled with a mouthpiece attached to an online gas collection system (Moxus modular oxygen uptake system; AEI Technologies, Inc, Pittsburgh, PA). The incremental cycling protocol began at 0.5 kiloponds (kp) at 60 rpm for 2 min; thereafter, the intensity increased by 0.5 kp every 2 min until volitional exhaustion. $\dot{V}O_{2peak}$ was recorded as the highest 30s average. Subsequently, participants were familiarized with the simulated ice hockey exercise protocol.

A 35-minute-simulated ice hockey exercise (IHE) protocol: The ice hockey exercise protocol was taken from Palmer et al. (29) and simulated a standard ice hockey game. The 35-minute protocol started with a 5-min warm-up at 50% of $\dot{V}O_{2peak}$, followed by alternating between 45-s cycling sprints and 135-s passive rest on the ergometer for 10 times (~3 min per time). To mimic the variable tempo of a hockey shift, participants modified the cadence of the 45-s cycling sprints as follows: 10-s at 108 rpm (~145% $\dot{V}O_{2peak}$), 10-s at 90 rpm (~100% $\dot{V}O_{2peak}$), 15-s at 101 rpm (~125% $\dot{V}O_{2peak}$), and 10-s at 90 rpm (~100% $\dot{V}O_{2peak}$). During the simulated IHE, water ingestion was allowed *ad libitum*.

Experimental visits: Seven days after the first session, participants arrived at the laboratory at 7:00 hours. They were instructed to refrain from additional exercise, alcohol, and caffeine intake for at least 48 h before each experimental visit. Breakfast was provided by the researcher at 7:15 hours, and consisted of a plate of chicken fried rice, 250 mL of water, and 250 mL of orange juice. Two hours after breakfast, the participants performed the 35-min of the simulated IHE protocol and then randomly underwent a 10-min of either 1) foam rolling treatment (FR), 2) dynamic stretching treatment (DS), or 3) passive rest treatment (PR). Heart rate and blood lactate were obtained at pre-treatment and 5- and 10 min post-treatment. The choice reaction time of the left and right legs (CRT_{leg}) and rating of perceived exertion (RPE) were assessed pre-treatment and 10-min post-treatment. After the treatments, the pain feeling was recorded using a global rating of change scale (GRC). The experimental procedures are shown in Figure 1.



0 min post-treatment	5 min post-treatment	10 min post-treatment
HR, BL, CRT_{leg}, RPE	HR, BL	HR, BL, CRT_{leg}, RPE, GRC

Figure 1 Experimental procedure

A 10 minute- recovery treatment: A 10-minute recovery treatment consisted of three treatments, as follows:

1. Foam rolling (FR) treatment

The FR treatment was self-administered via dynamic foam rolling using high-density foam (The Grid Foam Roller, Trigger Point Brand, USA). The grid foam roller with a length of 33 cm and diameter of 14 cm consists of a hard, hollow core PVC pipe hand-wrapped in EVA foam with a thickness of about 2 cm. The foam rolling treatment was performed on the hamstrings, quadriceps, calf, hip adductors, and the iliotibial tract for 30 s each side (slow movements at constant pressures between the origin and insertion of the muscle). (Figure 2)

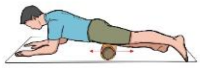
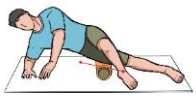
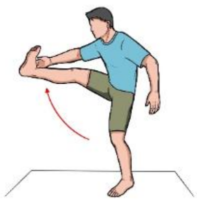
2. Dynamic stretching (DS) treatment

The dynamic stretch protocol incorporated 5 active dynamic exercises. All the exercises were performed while walking over a distance of 20 meters. The movements were carried out about 14 times for each exercise according to the procedures in Turki et al (35). (Figure 2)

3. Passive rest (PR) treatment

The PR was performed in a sitting position as seated rest for 10 minutes. (Figure 2)

Exercise form	Muscle areas	Posture	Exercise content
1. Foam rolling (FR) (10 minutes)			

Exercise form	Muscle areas	Posture	Exercise content
1.1 Starting position: Long sitting Action: Place the foam roller beneath the thighs and roll forward and backward from above the knee to below the buttocks.	Hamstring muscle		- Slow movements at constant pressures between the origin and insertion of the muscle - 30 s on each side and switch to another leg - 15 times
1.2 Starting position: Long sitting Action: Place the foam roller under that calf and roll forward and backward from the ankle to the knee cap.	Calf muscle		
1.3 Starting position: Prone lying Action: Place the foam roller beneath the thighs while lying face down and roll forward and backward from above the knee to the hip.	Quadriceps muscle		
1.4 Starting position: Prone lying Action: Place the foam roller on the side of the outstretched leg closest to the groin while lying face down and roll forward and backward along the inner thigh from the groin to above the knee.	Hip adductor		
1.5 Starting position: Side pushing Action: Place the foot of the leg in front of the leg on the floor. A forearm and another arm should be used to support the upper torso. Roll forward and backward on the outer thigh from the knee to below the hip.	Iliotibial tract		
2. Dynamic stretching (DS) (10 minutes)			
2.1 Maintain an extended knee and plantar flexion of the ankle while forcefully swinging the stretched leg forward into hip flexion until a stretch in the posterior thigh is felt.	Hamstring muscle		- 7 times for each leg - 14 times for each exercise form. - All the exercises were performed while walking 20 meters

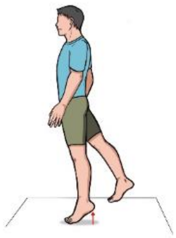
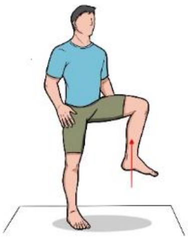
Exercise form	Muscle areas	Posture	Exercise content
2.2. Heel up. While going forward, rapidly kick your heels toward your buttocks.	Calf muscle		
2.3. Walking on your tiptoes.7 times Moving forward with each stride, alternating plantar flexion (tiptoe). The goal is to tiptoe as high as possible with the body.	Quadriceps muscle		
2.4. The hurdler is propelled forward by his knee. While walking ahead, the participant elevates the trailing leg and bends the hip at 90°of abduction and external rotation, with the knee flexed at 90°. In this posture, the limb is pulled forward as if the participants were stepping over a barrier somewhat below waist height, and then returned to the normal walking stride position.	Hip adductor		
2.5. Lean in the opposite direction from the front leg by crossing one leg in front of the other. Fingers make contact with the earth.	Iliotibial tract		
3. Passive rest (PR) (10 minutes) The PR treatment was performed in sitting position to relax the body.			

Figure 2 Details of the recovery treatments

Physical and physiological characteristics measures: Age (yrs), body weight (BW, kg), height (cm), and resting heart rate ($HR_{resting}$, bpm) were recorded on the first visit. Height and BW were measured with participants barefooted. Height was measured to the nearest 0.5 cm using a calibrated stadiometer. Body mass index (BMI) was calculated according to the formula of BW (kg) divided by the square of the body height (m). Heart rate was recorded using a telemetry strap positioned across the chest (RS800CX; Polar, Finland). Blood lactate (15) concentration was measured by analyzing capillary blood samples taken from finger pricks using a handheld lactate analyzer (L1 Lactate Monitoring System; TalDoc Technology Corp., Taiwan). The values of HR (in bpm) and BL (in mmol $\cdot L^{-1}$) were recorded at 0-, 5-, and 10 min post-treatment.

The choice reaction time of legs (CRT_{leg}): The unilateral choice-reaction speed was recorded using stimuli and three directions of a multi-choice reaction timer. Participants were instructed to deactivate the sensors indicated on the control box and hit the button with the leg as quickly as possible when seeing the stimuli using three directions left, center, and right. Fifteen trials were performed on each leg and testing was started with the dominant leg. Four trials were performed, and the fastest time was selected for statistical analysis. To reduce the occurrence of learning effects, participants performed a separate familiarization session before randomized group allocation.

Rating of perceived exertion (RPE): The RPE was measured using the 6–20 Borg scale for the evaluation of exercise intensity (5). RPE was monitored 2 times (pre-treatment and post-treatment). RPE values were classified according to the American College of Sports Medicine Position Stand (15); very light (<9), light (9–11), moderate (12-13), vigorous (14–17), and near maximal to maximal (>18). The values of CRT_{leg} (in milliseconds) and RPE (in scores) were recorded at 0- and 10- min post-treatment.

Global rating of change scales (GRC): The global rating of change scale (GRC), a self-reported measure, has been used in research as an outcome measure (21). After treatment, participants were asked that "With respect to your muscle pain, how would you describe yourself now compared to immediately after your exercising?". Then, participants scored this question on an 11-point global rating of change scale (− 5 to + 5) where 'a little bit' represented +1, 'somewhat' represented +2, 'moderately' represented +3, 'much' represented +4 to 'very much' better represented for +5, 0 represented unchanged, and (- 1 to - 5) represented 'a little bit' to 'very much' worse'.

Statistical Analysis

The participant's characteristics are presented as mean ± standard deviations (sd). The Shapiro-Wilk test revealed that data were normally distributed. The effect of the treatments FR, DS, and PR on HR, BL, CRT_{leg}, and RPE were presented as mean ± standard error of the mean (SEM). Since the data were normally distributed, The repeated measures ANOVA with groups factor (FR vs. DS vs. PR) and times factor (0- vs. 5- vs. 10- minutes (min) post-treatment for HR and BL. The Bonferroni test was used for posthoc analysis. The values of the magnitude of the differences (F value), the effect size partial eta-square (ηp^2), and the p-value were calculated. To account for differences in the PR at post-treatment, CRT_{leg}, and RPE values were analyzed with a paired t-test. One-way ANOVA was used to compare the rating score of GRC at 0-min post- treatment with FR, DS, and PR. A p-value < 0.05 was considered statistically significant.

RESULTS

No interaction between group and time was found for HR. A repeated-measures ANOVA determined an effect of time ($F_{(4,56)}=454.93$, $\eta^2p= .97$, $p<.001$) for HR, showing that the HR decreased between 0- and 5 min post-treatment and between 0- and 10 min post-treatment for all treatments ($p<.001$). In addition, the PR decreased HR greater than the DS at 5-min post ($p<.003$) (Figure 3).

For BL, a repeated-measures ANOVA found the main effect of recovery treatment ($F_{(2,28)}=8.62$, $\eta^2p=0.381$, $p=.001$) and time effect ($F_{(2,28)}=131.66$, $\eta^2p=0.904$, $p<.001$), showing that BL levels decreased between the 0-and 10-min post PR treatment, as well as between 0- and 5 -min, and 0-and 10-min post FR and DS treatments. In addition, the FR and DS reduced BL levels greater than the PR at 5-min (FR and PR, p=.019; DS and PR, p=.002), and 10-min post treatments (FR and PR, p=.016; DS and PR, p=.036) (Figure 3).

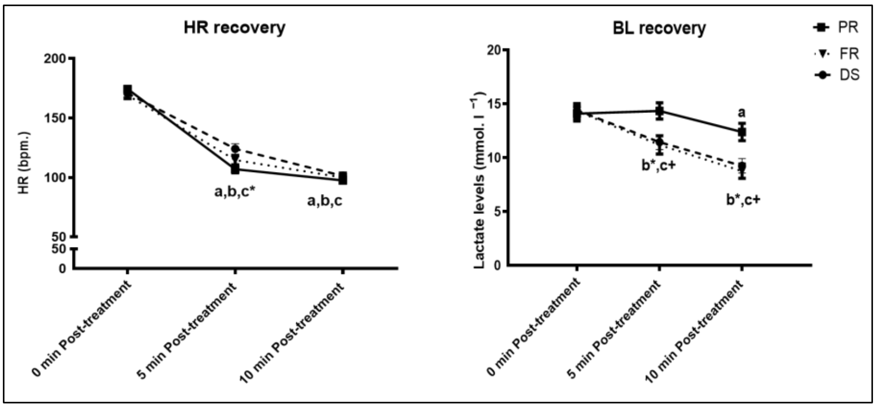


Figure 3 Heart rate and blood lactate recovery at 0 min, 5 min, and 10 min post-treatment with foam rolling (▼FR), dynamic stretching (●DS), and passive rest (■PR). Data presented as means ±SEM. n=15 for each treatment.

bpm, beat per minute; mmol · L^{-1}, millimole per liter. $p < .05$. *, DS different from PR; [+], FR different from PR.

[a], different from 0 min in PR group; [b], different from 0 min in FR group; [c], different from 0 min in DS group.

For the CRT $_{leg}$ of the right leg, there were no differences between the PR and FR (p=.16) and PR and DS (p=.49) at 0-min post treatment. For the CRT $_{leg}$ of the left leg, there were no differences between PR and FR (p=.05) and PR and DS at 0-min post treatment (p=.09). In addition, there were no differences between the FR and DS compared to PR (p=.74) at a 0-min post treatment (Figure 4).

For RPE, at a 10-min post, the FR had reduced PRE faster than the PR (p=.01). However, there were no differences between the DS and PR (p=.84). There was a difference in RPE changes between the FR and DS compared to the PR (p=0.04) (Figure 4).

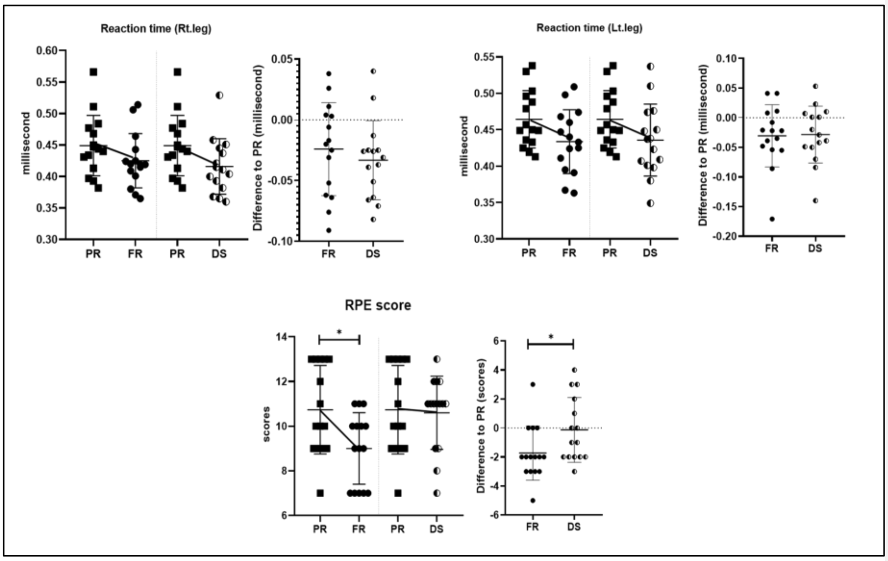


Figure 4 Interindividual differences at 0- min post-treatment in the foam rolling (●FR), dynamic stretching (◐DS), and passive rest (■PR). **A.** Choice reaction time of Right leg (Rt.CRT leg). **B.** Choice reaction time of Left leg (Lt.CRT $_{leg}$). **C.**

Rate perceived of Exertion (RPE) score. n=15 for each treatment. $p < .05$. *=sig different between groups.

For GRC, a self-reported outcome measure, the rating score after FR, DS, and PR treatments were 3±1, 1±0, and 2±0. There were differences between FR and DS ($p<.0001$) and FR and PR ($p<.001$) when measured at 10-min post treatment.

DISCUSSION

The purpose of this study was to compare the effectiveness of active recovery treatments, i.e., foam rolling (FR), dynamic stretching, and passive recovery treatment, i.e., passive rest (PR) following simulated ice hockey exercise (IHE) on heart rate, blood lactate, leg choice reaction time (CRT_{leg}), rating of perceived exertion (RPE) and global rating of change (GRC) in elite ice hockey players. Our findings showed that 1) $HR_{recovery}$ was reduced in the PR faster than that in the DS after 5 min of treatment, 2) BL levels were decreased in the FR and DS faster than those in the PR after 5- and 10-min treatment, and 3) RPE score and self-report feelings were improved in the FR better than the DS and PR.

$HR_{recovery}$ can be used to understand cardiovascular recovery after exercise (17). Our results showed that after 5-min and 10-min treatment, $HR_{recovery}$ decreased by ~39% and ~44% in the PR, ~32% and ~41% in the FR, and ~28% and ~39% in the DS, respectively. Additionally, a significantly lower $HR_{recovery}$ was obtained after 5-min treatment in players who underwent the PR compared to those who underwent the DS. Unsurprisingly, the results are consistent with previous studies (16, 17) indicating that passive recovery is more efficient on $HR_{recovery}$ after high-intensity exercise than active recovery strategies. However, on the other hand, the study of Burr et al. (6) indicated the advantageous effect of active treatment over passive rest to prevent the evident of sudden cardiac death in susceptible hockey players. They explained that delayed immediate reduction in HR after vigorous activities may be beneficial for promoting recovery of the working skeletal muscles by avoiding venous pooling and reducing myocardial perfusion. Notably, the intermittent nature of hockey requires high physical demands of the players which could increase cardiovascular risk in older people, and inactive or untrained individuals (4). Therefore, using active recovery, i.e., the FR or DS treatments instead of the PR might prevent adverse cardiac events following high-intensity exercise in those susceptible players.

Lactate removal following exercise appears to be of great importance in improving the subsequent performance, particularly when the exercise is repeated at high intensity (10, 24) like ice hockey. The reduced BL following the active recovery treatments of both FR and DS was greater than PR. This is consistent with the study of White et al. (37), who reported that active recovery could promote BL clearance faster than static recovery. Moreover, there were no significant differences in BL levels between the FR and DS. This finding implies that both FR and DS might utilize a similar mechanism to enhance BL clearance via promoting blood circulation around the working muscles. The self-massage using FR has been reported to increase blood circulation over the treated muscle group (1) since the rolling pressure over the treated muscle could remove the accumulated lactate in the muscles to blood circulation and significantly cause a drop in BL levels (20, 27, 30). By using the DS, the stretching activity performed by walking and rhythmically moving joints of the lower limbs could also promote blood circulation of the working muscles and may result in a faster return of BL (10, 24, 39). Therefore, our results indicated that both FR and DS are beneficial recovery treatments on BL levels for elite ice hockey players following IHE, of which were superior to PR.

CRT is the time that takes from the commencement of the stimuli until complete the task. Muscle contraction, sensory activation, conduction times, synaptic delays, and muscle functions are the key factors that contribute to RT (23). Since ice hockey requires a player’s reaction to the other’s movement and ball movement, it is one of the key components determining player's performance. In this study, post-recovery improvement of the FR on CRT was not different from the DS and PR treatments. The study of Jo et al. (19) found that the FR failed to exert an effect on direct performance ability, i.e., dynamic reaction time and jump height however it could improve kinematic factors, i.e., power and velocity. They indicated that the conservation of kinematic outcomes caused by form rolling was not strong enough to improve direct performance ability. Unfortunately, only reaction time, a direct performance test, was observed in this study, future studies should investigate other kinematic performance tests such as speed, agility, and muscle power to confirm the results.

It is well documented that RPE has remarkable value as a psychophysiological integrator that can be used to predict exercise capacity (12). The present study showed that the FR is the most effective to reduce the feeling of fatigue compared to the DS and PR. It is well documented that foam rolling treatments have been widely used by coaches and athletes, due to their muscular pain management via exerted massage-like mechanical pressure which potentiates analgesic effects during treatment (7, 8). Likewise, previous studies indicated the positive effect of foam rolling on fatigue-related muscular performance (13, 19). It is interesting to point out that the RPE score is lowest in the FR group as compared to the PR group, this might indicate the synergistic effects of form rolling treatment on both peripheral and central fatigue. The FR techniques may help to alleviate muscle tension and enhance BL clearance (17, 24, 26, 28). Also, when performing FR exercises, individuals may experience a feeling of relief and relaxation as the pressure of self-massage helps release knots and tightness in the muscles, which can lead to a decrease in RPE (11). Otherwise, PR refers to a period of inactivity where individuals are not engaging in any physical activity. Even though resting can be beneficial for recovery, it does not provide the same level of targeted muscle release and relaxation as caused by the FR. Therefore, individuals may still perceive a higher level of exertion during passive rest due to lingering muscle tension or discomfort. It's important to note that the RPE score can vary among individuals and may be influenced by factors such as fitness level and familiarity with the FR treatment. Therefore, our data also support the evidence of the effectiveness of the FR treatment in reducing the degree of exertion a person feels following simulated IHE.

For a self-reported measure using GRC, our results showed that athletes rated 'much better' (+3) for the FR, 'moderately better' (+2) for the PR, and 'somewhat better' (+1) for the DS, indicating that the FR is the most preferred recovery treatment compared to the PR and the DS. The FR is a self-massage treatment in which athletes can desire to apply pressure while rolling the form over the treated muscles. This might result in less pain and more relaxation compared to the DS and the PR. An improvement in perceptual responses following the FR treatment may be critical for athletes to restore their psychological fatigue and readiness to participate in the next match. For the DS, the active dynamic exercises were performed while walking over a distance of 20 meters which can make athletes get more tired and pain resulting in the least favored recovery treatment. Whereas the PR is resting by sitting down without muscle contraction resulting in less pain but no feeling better.

The following limitations need to be taken into account. First, the study contains small sample sizes, since only professional ice hockey players were included, which might result in reduced statistical power. Second, the study was not able to blind participants to the treatments due to the nature of the protocol. Thirdly, we did not control the intensity of form rolling, even though it seems not significantly influence the physiologic response. Fourth, the study cohort was not able to perform the physical demands of real ice hockey . However, the simulation ice hockey exercise used in this study had a similar intensity to the real situation (35) in a controlled environment for temperature and humidity. Finally, there were no outcomes for sports-related performance, future studies should take into account.

It is concluded that the active recovery treatments, i.e., FR and DS exerted more beneficial effects on BL, but not on $HR_{recovery}$, than the traditional passive treatment. However, the FR showed the most effective treatment on the psychological demands by improving RPE and perceptual responses over the DS and PR after high-intensity exercise in ice hockey players. Thus, the FR could be used as a choice for post-game recovery treatment on improving psychological responses in ice hockey. Further studies should compare or combine the effect of FR with other recovery treatments such as sports massage, electrical stimulation, whole-body vibration, or cold-water immersion.

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