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Original Article

Effects of stretching and cold-water immersion on functional signs of muscle soreness following plyometric training

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Abstract:
Delayed onset of muscle soreness is the unaccustomed activity, which may last for several days post-exercise due to impaired muscle performances. Stretching and cold-water immersion are an ordinary way to reduce muscle soreness. This study aimed to investigate effects of these treatments on functional signs of muscle soreness after plyometric training. Forty-five subjects, aged from 18 to 25 years, were randomized into three groups; stretching, cold-water immersion, and combine group. Participants performed the plyometric training. Treatments were given for 20 minutes. Soreness sensation, range of motion, quadriceps strength and vertical jump performance were measured at before exercise, after exercise, after intervention, 24, 48, 72, and 96 hour. All variables showed a significant time effect indicating the presence of muscle damage. Furthermore, they showed significant different between groups on vertical jump height, decreasing for combined intervention at 24 h, a lesser on range of motion in combine group compared with the stretching groups at 48 and 72 hours. These results suggest that either cold-water immersion or stretching can maintain impaired performance following the exercise in term of flexibility and vertical jump performance, whereas the combine one is not seem to be a practical strategy to alleviate functional signs of muscle soreness. Therefore, stretching or cold-water immersion alone is a common way to application for athletic recovery performance compared to the combine these techniques.
Key words: Cold-water immersion, Stretching, Delayed onset of muscle soreness, Plyometric exercise

Introduction

For athletic peak performance, regular training programs are integral parts of aerobic training, flexibility, weight training, and sport-specific training. Interestingly, weight training or resistance training is a training program for preparing muscular system via improves strength also muscular endurance. Especially, eccentric training exercise produces greater gains in muscle hypertrophy, strength and neuromuscular adaptation compared with isometric and concentric training exercise.

According to strenuous resistance training and plyometric training program for muscular power performance, which involves the stretch and recoil characteristics of skeletal muscle for sports that require powerful, propulsive movement that contributes to delayed onset of muscle soreness (DOMS). DOMS, one of the most common types of muscle pain is identified by a dull and aching pain, which begin 8-24 hours post exercise, and increases in intensity, it peaks at 24-72 hours and subsides within 5-7 days post exercise on individuals following unaccustomed exercise involving eccentric contractions during preseason training (Armstrong 1984; Connolly, Sayers & Mchugh, 2003). Other functional signs associated with DOMS are comprising of swelling, and loss in muscle strength. Therefore, it was due to interrupted muscle functional performance, and also was be a risk factor of unexpected injury and deconditioning of training or exercise.

According to Gremion G (2005), static stretching has become a popularly and safely used for muscle recovery method in competitive sport and prevention muscular injury. It is contribute to reduce pain perception, edema, muscle spasm (i.e. from pain- muscle spasm cycle), and also increase muscle elongation after induced muscle damage from eccentric exercise (Dain & Declan, 2006; Torres, Appell & Duart, 2007; Covert et al., 2007) . However, research examining about this is equivocal; some studies have shown no any change in the signs of muscle damage following stretching (Wessel & Wan, 1994; Maxwell et al., 1988; Herbert & Gabriel, 2002).

Interestingly, cryotherapy is one of the treatments commonly used to alleviate DOMS because it is contribute to reduce inflammation, tissue metabolism, pain sensation, edema, local blood flow, and muscle spasm. Attractively, one of the most efficient techniques for relieving DOMS is cold-water immersion (CWI) (Howatson, Goodall & Someren, 2009). It is a popular, convenient, a low cost and a simple method with advocated by hydrostatic pressure principle in reducing muscle tone, local swelling, soreness sensation, and also providing muscle blood flow. Significant reductions in soreness sensation of DOMS after CWI have been

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reported (Glasgow, Ferris & Bleakley, 2014; Júnior et al., 2014; Scott et al., 2004; Vaile et al., 2010; Bailey et al., 2007; Ingram et al.,2009). By the way, these results have been inconsistency effect on muscle soreness sensation and muscle performance yet (Sellwood et al., 2007; Jakeman, Macrae & Eston, 2009; Howatson, Goodall & Someren, 2009; Goodall & Howatson, 2008; Torres et al., 2012).

In addition, the majority of researches about effects of stretching or CWI alone on DOMS has received results controversy, inappropriate method protocol, and used small sample sizes, which limited the statistical power. However, the stretching is a popular, convenient, a low cost and be a simple active recovery method with advocated by reduce muscle stiffness and the CWI one is an effective optional recovery way, but it was influentially applied actions by hydrostatic pressure and analgesia power. By the way, it has not found any research comparison additional combine effects of stretching and CWI on functional signs of DOMS that it would be gain insight in these effects for DOMS management.

Therefore, the aim of the current study was to investigate the effects of static stretching, CWI and the combine treatments between static stretching and CWI on functional signs of muscle soreness of knee extensors following stimulated plyometric exercise in Thai male for being the optional ways and application to promote maximal athletic performance during pre-season training, which has done the same as a training program or sport likes this protocol.

Method

Forty-five Thai male (age, 20.9 ± 1.1 years; height, 168.6 ± 6.2 cm; body mass, 62.2 ± 9.0 kg) were recruited from sports sciences student in Burapha University, Thailand. This study was approved by the Human Ethical Committee of Burapha University. They consented to participate in the study. Participants did not resistance exercise regularly at least 3 months before investigation, had normal reference ranges of body mass index (BMI) 18.5-22.9 kg/m^2 and skinfold thickness of Quadriceps ≤ 20 mm, were not joining in sports and had no certified conditions listed in the exclusion criteria; sick or injured, had a problem associated with neuromuscular or skeletal in lower extremities, had contraindication for received cryotherapy or stretching from underlying condition (such as skin allergy, broken skin, cryoglobinaemia, Raynaud's disease or cold allergy). After the screening process, participants were randomly allocated into three groups; static stretching group, cold-water immersion group, and combine group.

Procedure and measurements

Prior to each test session, all participants were asked to refrain from vigorous physical activity and caffeine beverages. All test procedures and experimental protocols were explained, demonstrated and familiarized to participant. The same room temperature was kept at 25° C throughout data collections. The processes of research were separated into 3 variables. Soreness sensation, range of motion, quadriceps strength and vertical jump performance were measured 7 times; immediately before exercise, after exercise, after intervention, 24, 48, 72 and 96 h after exercise. All data were tested from knee extensor muscle of non-dominant leg (defined as the leg not used for kicking).

Soreness sensation assessment

Participants rated their muscle soreness using a 0-100 mm visual analogue scale (VAS) that they felt at knee extensor muscle during contraction (VAS MVC) (i.e. maximum voluntary contraction test) and lengthening (VAS passive quadriceps) (i.e. range of motion test). Distance from the left border of the line (0) to the marked point was measured in millimeters, and this value was used for the analysis.

Range of motion (ROM) assessment

Participants lay prone on a couch, and were asked to perform full active flexion at the knee of the non-dominant leg. The knee joint angle was determined between the lateral epicondyle of the femur, lateral malleous of fibula and greater trochanter using a goniometer. These bony landmarks were marked on the first day of testing with a permanent pen to ensure consistency on subsequent days. The mean of three measurements were used for data analysis.

Quadriceps Isometric strength test (MVC) assessment

Quadriceps muscle strength was examined while they were performing maximum isometric contraction by using MicroFET3 Combo Manual Muscle Tester (Patterson Medical, Nottinghamshire, UK). Participants sat against seatback tilt at 90° and knee flexed at 90°on NK-table. Participants performed slowly and smoothly a maximal leg extension effort exerted against a stationary dynamometer. For each trial was held for 4 sec and rested 30 sec (Howatson, Goodall & Someren, 2009). The best strength of quadriceps muscle from 3 trials was recorded in Kg. And the total force values were normalized based on body weight (weight normalized) in kg/BW.

Vertical jump performance assessment

Vertical jump displacement was assessed using a device known as the Vertec, (Swift Yardstick, Australia). The participants stood directly under the Vertec with the dominant upper extremity, reaching upward. They were then asked to jump as high as he could without taking a step, touching the highest bar possible. Three trials were performed for each participant and the best vertical jump displacement was recorded.

Test-retest reliability for measurements

Test- retest reliability was established by determining an instrument's capability of measuring a variable with consistency. The reliability data collected from the 15 participants (mean age of 20.3 ± 1.4 years) for the two pre-exercise measurements taken during the familiarization one and before plyometric training. The same investigator and period took all the measurements. . Testing in present study revealed *intraclass* correlation coefficient (ICC) =0.987, 0.903, and 0.986 for range of motion, quadriceps isometric strength, and vertical jump test respectively.

Exercise- induced muscle damage protocol

Muscle damage was induced through the use of the plyometric training protocol for gain in muscle power on practically used (Pomee, 2009). All participants were demonstrated the required technique before the plyometric exercise protocol and were coached during the protocol to ensure proper technique and maximal effort were maintained throughout. The plyometric training program consisted of 30 m single leg bound for 3 sets, 6 sets of 30 m double leg bounds, 6 sets of 10 m tuck jumps, and finally with 10 drop jumps on a 60 cm box for 5 sets. Participants performed in time with a set of recorded allowing 10 seconds rest between each jump and 2 minutes rest between each set. Upon this time sound of encouragement was stimulated participants through jumping protocol.

Intervention programs

Static stretching group (STRET group)

The stretching was done in a position suggested by Anderson and Burke (1991); the participants were standing on the non-dominant leg in knee flexion with the hip supported by a treatment table. The dominant leg was kept relaxed. Participants passively stretched the quadriceps by themselves, flexing the subject's knee and extending the hip to neutral position. If maximal knee flexion would not produce a sensation of stretch or resistance against the movement, hip extension would be added in order to increase the stretch in term of two joint muscle. They were elongated at this point for five repetitions each 30 seconds with a five-second rest between bouts in 2 sets totally with 1 min rest between sets.

Cold-water immersion group (CWI group)

The protocol was applied from previous studies (Howatson & Someren, 2008). Participants were long seated (the cold water level to the iliac crest) in an inflatable ice bath for a period of 20 min wearing short trousers and their legs were kept apart in the cold water to ensure a maximum surface area exposure after the plyometric exercise. The temperature of the water was maintained at 15 ± 1°C by adding crushed ice.

A combination of STRET and CWI group (COM group)

Static stretching and cold-water immersion were administered exactly as descripted above, but were combined so that 5 X 30 s of static stretching was followed by 20 min of cold-water immersion treatment.

Statistical Analysis

The results were shown as mean, mean different and standard deviation (S.D.). The results of range of motion, quadriceps strength and vertical jump performance were showed percentages change from baseline (i.e. relative % change). Normal distribution of data were assessed statistically using the Shapiro-Wilk procedure. The comparisons of all variables between three groups were analyzed with two-way repeated measure ANOVA and a Post hoc Bonferroni-Dunn's procedure was used to determine specific significant differences. An alpha level of .05 was used to determine statistical significance by using SPSS for Window version 22.0 (Chicago, IL, USA).

Results

Forty eligible healthy Thai male university students completed this study. There were no adverse effects reports. Five participants were excluded from the study because they could not completely perform the inducing exercise program (n=4) and missed follow-up from motorcycle accident (n=1). Baseline characteristics of the participants were shown in Table 1. The number of weekly exercise in COM group was reported lesser than others group while there were no group differences for other outcomes at baseline.

Table 1. Baseline characteristics in the current study

Characteristics	CWI (n=14)	STRET (n=13)	COM (n= 13)
Age (years)	21.1 ± 1.1	20.4 ± 0.9	21.2 ± 1.0
BMI (kg/m^2)	21.5 ± 1.9	22.5 ± 4.5	21.6 ± 2.1
Weekly exercise sessions (n)	4 ± 2.5	4 ± 1.4	2 ± 1.7*
Skinfold thickness of quadriceps (mm)	12.6 ± 5.6	10.9 ± 3.4	14.0 ± 4.0
Quadriceps strength (kg/BW)	0.38 ± 0.1	0.39 ± 0.1	0.37 ± 0.0
Knee flexion ROM (degree)	133.8 ± 4.4	131.7 ± 5.5	134.4 ± 6.4
Vertical jump height (cm)	54.6 ± 6.3	56.5 ± 8.9	51.7 ± 5.1

Values are Mean ± SD. BMI: body mass index, ROM: range of motion, CWI: cold-water immersion group, STRET: static stretching group, COM: combine group
* Significant different between groups between COM and CWI, STRET groups

A significant main effect of time and difference between assigned groups on perceived soreness with passive quadriceps and MVC test ($p<.05$) was observed (Fig. 1, 2). Soreness sensation of three groups were demonstrated a similar pattern immediately increased intensity after the exercise, peaked at 24 hours after exercise then they were gradually decreased into baseline level, especially completely full recovery at 96 hours after exercise. Interestingly, there was no statistical difference between three intervention groups at any time point.

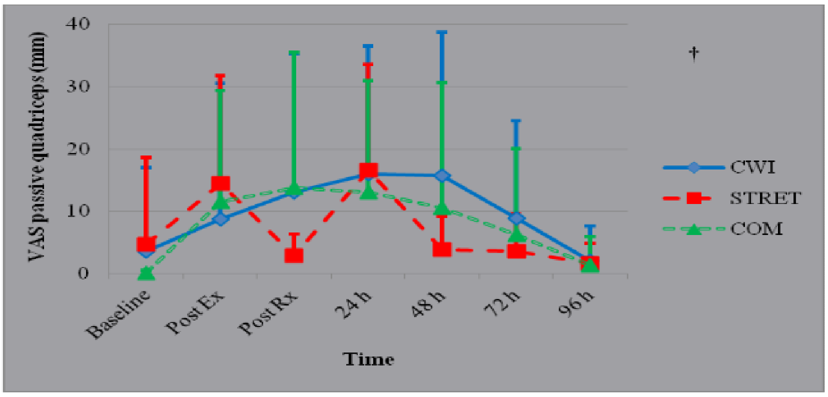

Fig. 1. Mean and standard deviation of soreness sensations with passive stretched quadriceps for the cold-water immersion (CWI ♦, n=14), static stretching (STRET ■, n=13) and combine (COM ▲, n=13) groups after stimulated plyometric exercise.

†: Significant time differ

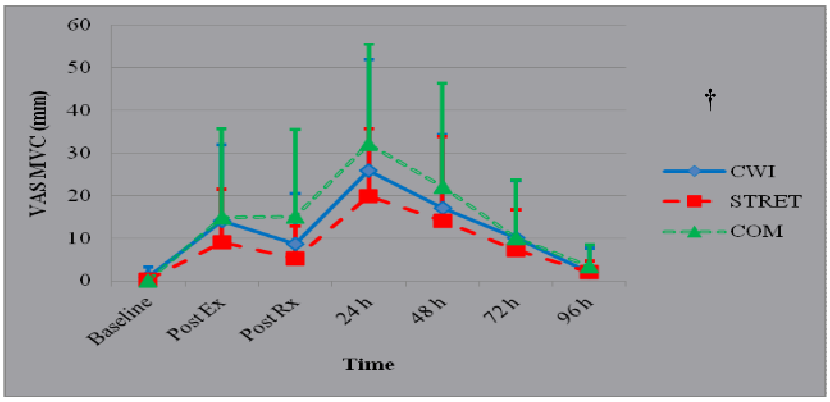

Fig. 2. Mean and standard deviation of soreness sensations with quadriceps isometric contraction (MVC test) for the cold-water immersion (CWI ♦, n=14), static stretching (STRET ■, n=13) and combine (COM ▲, n=13) groups after stimulated plyometric exercise.

†: Significant time different at post exercise to 72 h from baseline for all groups by two-way repeated measure ANOVA tests.

Kilogram per bodyweight and relative % change from baseline (Fig. 3) of maximal voluntary contraction (MVC) represented to knee extensors isometric strength test. All three groups there was a significant main effect of time ($p<0.05$) on knee extensors isometric strength. But a statistical difference between groups was not shown in this study. By the way, the MVC of knee extensors of 3 groups was showed the peak lowest percentage decrement at 24 hours from baseline measures for the STRET, COM and CWI group was 55%, 60.8% and 65.5% respectively and returning to baseline value at 48 h.

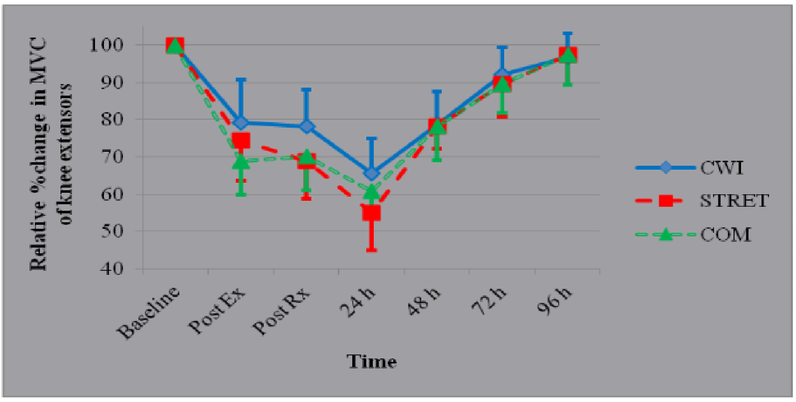

Fig. 3. Mean percentage change in quadriceps maximum voluntary contraction (MVC) for the cold-water immersion (CWI ♦, n=14), static stretching (STRET ■, n=13) and combine (COM ▲, n=13) groups after stimulated plyometric exercise.
†: Significant time different at post exercise to 96 h from baseline for all groups by two-way repeated measure ANOVA tests.

Range of motion and vertical jump performance were respectively expressed to relative % change from baseline (fig. 4, 5). All three groups there was a significant main effect of time ($p<.05$) on range of motion and vertical jump performance. The range of motion was showed the lowest percentage decrement at 24 hours after the exercise for the COM, STRET and CWI group was 92.4%, 94.1% and 94.3% respectively, and gradually returning to baseline value at 48 hours. Moreover, they showed a significant lessor on range of motion in COM compared with STRET groups at 48 and 72 h ($p=0.009$ and 0.023 respectively). For the vertical jump height, there was a significant decrease in CWI compared with STRET group ($p=0.006$) at post the exercise and COM compared with other two groups ($p<0.05$) at 24 hours after the exercise.

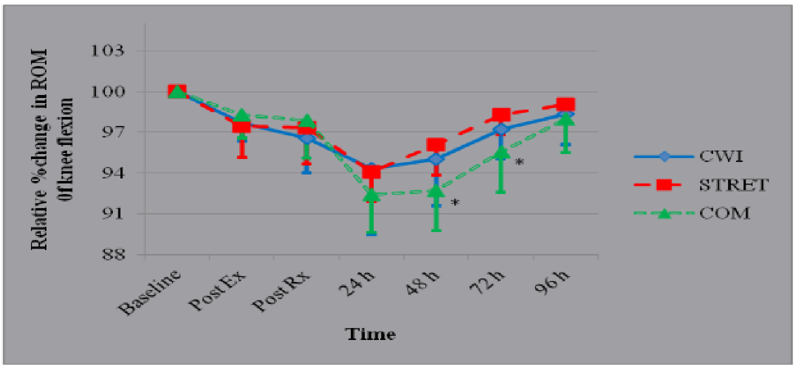

Fig. 4. Mean percentage change in knee flexion range of motion (ROM) for the cold-water immersion (CWI ♦, n=14), static stretching (STRET ■, n=13) and combine (COM ▲, n=13) groups after stimulated plyometric exercise.
†: Significant time different at post exercise to 96 h from baseline for all groups by two-way repeated measure ANOVA tests.
*: Significant different between groups between COM and STRET groups by two-way repeated measure ANOVA tests ($p<.05$).

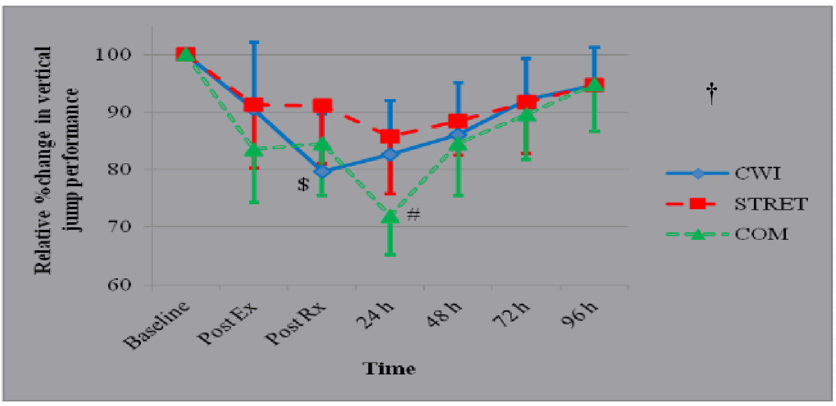

Fig. 5. Mean percentage change in vertical jump performace for the cold-water immersion (CWI ♦, n=14), static stretching (STRET ■, n=13) and combine (COM ▲, n=13) groups after stimulated plyometric exercise.
†: Significant time different at post exercise to 96 h from baseline for all groups by two-way repeated measure ANOVA tests.
#: Significant different between groups between COM and STRET, CWI groups by two-way repeated measure ANOVA tests ($p<.05$).
$: Significant different between groups between CWI and STRET groups by two-way repeated measure ANOVA tests ($p<.05$).

Discussion

The plyometric exercise was successful in inducing muscle damage, which was observed from the significant change of all variables from baseline to 24-72 hours follow the exercise in 3 groups and concurs with previous research that reported quite similar trends following a like mode of exercise (Howatson, Goodall & Someren, 2009; Goodall & Howatson, 2008).

Soreness sensation (VAS) with passive quadriceps and MVC test was showed a similar pattern immediately increased intensity after the exercise, peaked at 24 hours after exercise, then they were gradually decreased into baseline level, which is the same response in previous data (Howatson, Goodall & Someren, 2009; Goodall & Howatson, 2008). Additionally, the stretching group experienced the lowest in the soreness sensation (VAS passive quadriceps), comparing to the other group. This was implied the sense of "feel better" in term of increasing muscle compliance and decreasing muscle stiffness from acute effect of stretching. The current results further substantiate the findings of previous studies that the stretching would increase the blood circulation and also possible to assume that stretching assists in reduction macrophages at the damaged muscle. Therefore the synthesis of prostaglandin E_2 would be reduced which leaded to lesser pain after received stretching (Smith, 1991). Besides, Stretching the muscle was thought to restore blood flow to the muscle and interrupt the pain spasm-pain cycle. By the way, these changes were not observed for statistical difference in this study on both acute and delayed effects. Nonetheless, they may be a clinical significant which stretching group soreness scores were approximately more 20% lower than the group using the combination treatment and 20 min cold-water immersion at 15° C (Mean differences of 10.9 mm and 10.1 mm respectively) (Glasgow, Ferris & Bleakley, 2014). According to the review of Gulick et al. (1996), who investigated that there was no any different on soreness sensation between 20 min of ice massage and static stretching at 24 h after exercise with similar to this study. Conversely, Diong & Kamper (2013) mentioned that cold-water immersion had small to moderate effects to reducing pain and improving performance related with DOMS. But these sign changes were not observed in this study.

In contrast to previous studies (Wessel & Wan, 1994), this study demonstrated a significant greater on range of motion (ROM) in stretching compared to combine group. Therefore, the stretching exercise is a common way to increase muscle elongation, muscle flexibility, and joint range of motion, which concur in line with those of previous reports (Torres, Appell & Duart, 2007). A reduction in joint ROM has been appeared from a loss of strength or swelling within the perimuscular connective tissues after the exercise induced muscle damage (Howatson and Someren, 2008). So that, the further study should additionally investigate on some sign of swelling to determine the cold-water immersion effects.

Exercise-induced muscle tissue injury leads to impaired muscle performance. The modalities that promote soreness sensation away from the muscle, would be expected to result in more muscle function and improved physical performance. Accordingly, when comparing the effects between treatment groups on muscle strength, a significant difference did not show in this term. Similar findings were also reported in the study of Sellwood et al. (2007); Jakeman, Macrae & Eston (2009); Howatson, Goodall & Someren (2009); Goodall & Howatson (2008), who demonstrated that cold-water immersion, had significant decrease in swelling. In contrast to previous reports Cornwell et al. (2002) stated that CWI had no effect to reduce some swelling of the damaged muscle. The effects of low leg temperature and the "squeezing" effect of hydrostatic pressure from cold-water immersion are interesting to be a hypometabolism of the tissue, and a decreased blood flow (i.e. vasoconstriction) and haematoma formation that due to decreasing swelling (Leeder et al., 2011). This finding was not seen any change in this study. It could be explained that the contribution of hydrostatic pressure with the neck level immersion was been a reasonable factor to its positive effects on muscle power recovery (Vaile et al., 2008). Additionally, this study showed a significant decrease on vertical jump performance in COM compared with the other group at 24 h after the exercise. However, a large percentage decrement was found in three groups (i.e. 72-85.8%). For the stretching, there was no any difference between groups and they could not maintain decrement of muscle strength after the exercise. It would be correlated to both the force generation and stiffness relationship. This muscle stiffness reduction might also negatively impact maximum strength performance (Wilson, Murphy & Pryor, 1994). Similar to Winchester, Nelson & Kokkonen (2009) investigated that 30 seconds stretching seemed sufficient enough to reduce muscle contraction force and Fortier, Lattier & Babault (2013); Hough, Ross & Howatson (2009) who observed that 20-30 seconds stretchs could have negative effect on vertical jump height.

In practical, this study suggests that static stretching would be more effective to manage acute pain caused by muscle spasm follow the plyometric exercise. On the other hand, the combined stretching with cold-water immersion group provides clinical data that its effect does not have any additional benefit when compared to the separated treatment. In contrast to Denegar & Perrin (1992), they revealed that the ice bag and 4 x 30 s stretching were effective in treatment the pain and stiffness associated with DOMS. The result of this combination effect has been remained unclear in this study, however it might be from the characteristic difference on baseline performance (i.e. number of weekly exercise) which the number of weekly exercise in COM group had the smallest than others group. Thereby, the participants who were received the combine treatment might be responsively greater induced muscle damage. Moreover, it is suggested that the priority of the treatment method would be potentiated to functional sign alterations in clinical practice which the administration with cold-water immersion should be given before static stretching treatment. Anywise, The further study with a control group and reordering of combination intervention in the same kind of the exercise training is provided more information which the researcher can know for sure how effective static stretching and cold-water immersion are for treating DOMS.

Conclusion

These investigations reveal that static stretching can maintain muscle compliance whereas the combine static stretching and cold-water immersion does not have any additional benefit when compared to the separated treatment especially on joint range of motion and vertical jump performance following the plyometric exercise.

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