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Original Research study

The effect of cold-water immersion on physical performance

Daryoush Didehdar [a, *], Sobhan Sobhani [a, b]

[a] Department of Physical Therapy, School of Rehabilitation Sciences, Shiraz University of Medical Sciences, Shiraz, Iran
[b] Rehabilitation Sciences Research Center, Shiraz University of Medical Sciences, Shiraz, Iran

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ABSTRACT

Cold modalities are widely used after athletic injuries, with known physiological effects. The aim of this study was to determine the effects of cold-water immersion on physical performance.

Thirty healthy volunteers (average age of 19–23 years) took part in this pre-post interventional study. First, participants performed two tasks: a 40-yard dash run (to measure speed) and a vertical jump (to measure lower limb power). Then, both legs were immersed in a water bath at 5 °C for 15 min. Following cold-water immersion, the measurements were repeated after 2, 5, 10, 15, 20, 25 and 30 min.

Immediately (2 min) after cold-water immersion, there was a decline in both the vertical jump and 40-yard dash tests compared to pre-intervention scores. While this effect lasted up to 20 min after cryotherapy for the 40-yard dash test, for the jump test, the effect only remained up to 10 min.

The results showed a decrease in physical performance immediately and 20 min after immersion in cold water ($p < 0.05$). In addition, there was a gradual increase in the level of physical function over time. Therefore, before returning athletes to activity after the use of cold modalities, care should be taken.

1. Introduction

Cryotherapy is a common and acceptable modality in sports medicine. Most cold modalities are used to reduce pain, inflammation and disorders associated with minor trauma in athletes to help athletes quickly return to activity (Cochrane, 2004). While the benefits of cold modalities are universally acceptable, it is possible that physical performance can be affected due to induced physiological changes. Numerous studies have shown the adverse effects (reduced reaction time, etc.) of cold modalities on physical performance, such as power and speed (Bergh and Ekblom, 1979; Ferretti et al., 1992; Mattacola and Perrin, 1993; Schniepp et al., 2002; Richendollar et al., 2006; Patterson et al., 2008). A reduction in isokinetic strength has also been reported immediately after using a variety of cold modalities (Ferretti et al., 1992; Mattacola and Perrin, 1993; Hatzel and Kaminski, 2000; Patterson et al., 2008).

Two essential components for athletes is speed and power, which have not yet been investigated in detail after cold therapy (Bergh and Ekblom, 1979; Cross et al., 1996; Johnson and Bahamonde, 1996; Richendollar et al., 2006; Patterson et al., 2008; Fischer et al., 2009), but some studies have shown decreased physical performance after applying cold modalities on muscles (Cross et al., 1996; Patterson et al., 2008; Fischer et al., 2009). Although some previous studies showed changes in physical performance immediately after a few minutes of applying cold (Cross et al., 1996; Patterson et al., 2008). Since cold modalities are used in clinical sports medicine just after or during exercise, it is necessary to better understand the delayed and immediate effects of cold on physical performance.

In particular, cryotherapy with whirlpool is important because of its ability to treat larger areas, its analgesic effect, and its simultaneousness use of the pleasurable effects of exercise therapy and cryotherapy as a therapeutic modality; thus, its use is rising in the general population. Therefore, our aim in this study is to examine the immediate and delay effects of cold therapy in whirlpool on physical performance and the recovery time of possible changes.

2. Materials and methods

2.1. Experimental approach to the problem

This study is a repeated measures pretest-posttest design. Each participant was required to complete two tests measuring physical

* Corresponding author. School of Rehabilitation Sciences, Abiverdi 1 Avenue, Shiraz, Iran.
E-mail address: daryoush1383@yahoo.com (D. Didehdar).

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performance: the vertical jump test and the 40-yard dash. All volunteers received information about the conditions, how to do the test, and what to do at each stage. Before carrying out the pretest, each volunteer practised the test 4 to 6 times (40-yard dash and vertical jump) at less than maximum capacity (almost 50%). After practising the test, they were allowed to rest for 60 s, followed by the next test. They were told to complete the pretest at their best. The volunteers were immediately told to sit in a relaxed manner on top of the tank and dip both lower limbs, as high as the tibial tuberosity, into the whirlpool at 5 °C for 15 min.

Following cryotherapy, participants were given towels for drying their lower limbs, and socks and shoes were worn. Shortly after, a stopwatch was switched on to monitor the time.

The first measurement was taken after 2 min of cold therapy, and six subsequent tests were repeated at 5, 10, 15, 20, 25 and 30 min. Between the repetitions of the test, candidates were not allowed to stretch their muscles. Moreover, candidates were only allowed to have minimal activity or relaxation between repetitions of the test. The purpose of these restrictions was to measure different aspects of the physical performance of athletes during exercise.

2.2. Participants

Thirty healthy volunteers with the physical properties shown in Table 1 took part in this study. The volunteer assessed by physical therapist. People who had experienced lower extremity injuries in the last 6 months were excluded from the study. In addition, people who were sensitive to cold or who had Raynaud's disease following physical activity were excluded from this study.

2.3. Power

To measure power, the vertical jump test was used(Sayers et al., 1999). A Vertec® device was used, which had cells of 1.5 cm intervals longitudinally and was sensitive to touch. The touch panel was manufactured by German Rhein Company. The participants were instructed to stand with their legs at shoulder-width distance apart and to raise their hands to touch the Vertec® slate, and the number was recorded. Then, the participants were asked to jump up with full power and touch the Vertec® slate, and the number was recorded again. Participants had permission to jump only once, and the difference between the two recorded numbers was then used for statistical analysis.

2.4. Speed

To measure the speed, the 40-yard dash was used. The 40-yard dash is used in many sports activities to assess the speed ability of athletes (Pauole et al., 2000; Gough, 2006). The 40-yard dash has acceptable reliability in measuring the average speed (Pauole et al., 2000). This test was done indoors with specific start and end points. Before the test and to warm up, all candidates ran slowly approximately 4–6 times around the sports hall (200 m). No dynamic or static stretching was allowed. After the warm-up, a 60-s rest was given. All volunteers were then asked to run between the two marked points with maximum effort, and the time was recorded by the stopwatch for statistical analysis.

Table 1
Description of data sample data.

Gender	N.	Weight (kg)	Height (m)	Age (years)
Male	15	77.5(±11.1)	1.83(±0.09)	20.4(±1.4)
Female	15	67.3(±11.6)	1.67(±0.07)	20.8(±1.2)
Total Average (±SD)	30	71.2(±11.5)	1.84(±0.10)	20.6(±1.2)

2.5. Treatment procedure

All participants immersed their lower limbs up to the tibial tuberosity, which was marked by a cross, into a whirlpool with a temperature of 5 °C for 15 min. The reason for choosing a depth up to the tibial tuberosity was to cool the major joints and muscle groups (such as ankle joints and calf muscle). The water temperature was monitored with a digital thermometer. The time between test sessions was almost an hour. Thirty participants successfully finished the tests.

2.6. Statistical analysis

All statistical tests were performed using SPSS version 19. Mean and standard deviation calculations were used for the statistical descriptions of age, height, and weight. Separate one-way repeated measures analysis of variance (ANOVA) procedures were used to analyse speed (40-yard dash) and power (vertical jump) over time. The significance level was set at $p < 0.05$ for all tests.

3. Results

Table 1 shows the subjects' details, including age, height, weight, and gender. There were no significant differences among any of the male and female subject demographics ($p > 0.05$).

3.1. Power

The average height of the vertical jump at all stages of the posttest showed significantly lower values compared to that of the pretest. After 20 min, no significance difference was observed (see Table 2).

3.2. Speed

The average time of the 40-yard dash at 2, 5 and 10 min increased after cryotherapy, as shown in Table 3. The average time of the 40-yard dash at the posttest at 15, 20, 25 and 30 min after cryotherapy immersion in the whirlpool was not significantly different from that of the pretest (see Table 3).

4. Discussion

The results indicate that if a cryotherapy whirlpool with a temperature of 5 °C is applied to the lower limbs for 15 min, it brings about immediate decline in physical performance. Vertical jumps, at least 25 min after the cold application, did not return to their levels at the pretest stage. Until after 15 min of cryotherapy time, 40-yard dash performances did not immediately return to their initial states.

The immediate reduction in the height of the vertical jump following cryotherapy is consistent with findings from several studies (Bergh and Ekblom, 1979; Ferretti et al., 1992; Cross et al., 1996; Markovic et al., 2004; Patterson et al., 2008; Fischer et al., 2009; Nuhmani et al., 2012). Patterson et al. (2008) assessed the effect of cold modalities (10 °C) on physical performance immediately, 17 min, and 32 min after cold application. They reported a 17.5% decrease in high jump performance immediately after applying cryotherapy with a water whirlpool for 20 min, in which the lower limbs were immersed up to the head of the fibula (Patterson et al., 2008). However, in this study, a 37% jump height reduction was observed immediately after cryotherapy. The

Table 2
High jump for men and women.

Height jump (cm)	Test stages							
	Before test	2 min after	5 min after	10 min after	15 min after	20 min after	25 min after	30 min after
	48.31 ± 5.3	30.21 ± 5.12 *	33.31 ± 5.25 *	35.25 ± 5.42 *	37.95 ± 4.5 *	38.25 ± 4.14 *	42.45 ± 5.22	44.91 ± 4.32

Mark * represents $p < 0.05$ compared to the pre-test, mean(±SD).

Table 3
40-yard dash for men and women.

Time of 40-yard dash (seconds)	Test stages							
	Before test	2 min after	5 min after	10 min after	15 min after	20 min after	25 min after	30 min after
	6.12 ± 0.51	7.86 ± 0.37 *	7.48 ± 0.42 *	7.18 ± 0.52 *	6.56 ± 0.64	6.23 ± 0.61	6.19 ± 0.65	6.18 ± 0.61

Mark * represents $p < 0.05$ compared to the pre-test, mean(±SD).

delayed effect of the cold modality on the performance (vertical jump height) was significant and decreased 10.8% and 6.3% at 17 min and 32 min, respectively (Patterson et al., 2008). Similar to findings from the previous study, in this study, there was a 22% and 20% decrease in high jump performance at 15 min and 20 min posttest, respectively, compared to the pretest positions. It is clear that there is a positive relationship between muscle temperature and the height of jumps. Bergh and Ekblom (1979) found that for each 1 °C reduction in muscle temperature, the jump height reduces by 4.2% (Bergh and Ekblom, 1979). The reduction in the height of the jump could be due to changes in dynamic power after applying cold. Ruiz et al. (1993) reported that applying ice causes a significant reduction in muscle contractility for a longer period of time and shortened capacities of the quadriceps for 20 min (Ruiz et al., 1993). The study showed that the reduction in the force of the shortened contraction occurred for a short time and showed no significant differences with quiet training afterward, whereas the capacities of a long contraction continue to show a clear reduction after the practice (Ruiz et al., 1993). Howard et al. (1994) studied the use of floating ice on athletes' power and concluded that the power in high-speed movements required by athletes during sports activity is reduced (Howard et al., 1994).

Speed is the component of agility; further investigation of its details is necessary after the cryotherapy. Bergh and Ekblom (1979) were the first researchers who attempted to determine the quality of the effect of temperature on the speed of muscle (Bergh and Ekblom, 1979). They found that the speed of riding a fixed bicycle significantly reduces with decreases in muscle temperature (Bergh and Ekblom, 1979). In a study by Richendollar et al. (2006) of the impact of cold application on 40-yard dash performance, it was found that applying a cold water bag on the anterior part of the thigh decreases running speed (Richendollar et al., 2006).

In our study, deceleration with power changes could be due to the increased stiffness of the joints and tissues. Applying cold on connective tissue increases stiffness and reduces the elasticity of the tissue (Giesbrecht and Bristow, 1992; Patterson et al., 2008). In our study, the ankle joint and calf muscle were cooled with whirlpool. However, it is not clear that joint stiffness is a result of the stiffness of the connective tissues and muscles or a reduction in the viscosity of joint synovial fluid (Hunter et al., 1952; Hunter, 1984; Giesbrecht and Bristow, 1992; Patterson et al., 2008). In this regard, Hunter et al. (1952) reported that increased resistance to movement was closely connected with a reduction in movement speed due to a reduction in viscosity and an increase in the adhesion of synovial fluid (Hunter et al., 1952).

The decline in physical performance observed in our study may be related to a stretch reflex phenomenon. Davies and Young(1983) stated that the inability of the muscle spindle in the stretching reflex may reduce the potential elasticity created in the contraction phase of the longer muscle (Davies and Young, 1983). Moreover, the study by Bergh and Ekblom (1979) showed that the speed of muscle contraction and power production capacity are reduced by applying cold (Bergh and Ekblom, 1979). The physiological effects listed are attributable to the negative impact of cold (such as changes in strength, firmness, and stretch reflex) on physical performance.

Performance in physical exercise speed returned to the initial state more quickly than that of the high jump. This rapid reversal may be due to the increase in the tissue temperature due to blood flow to the muscles involved in the exercise. Many studies have clearly expressed the increase in tissue temperature after slow exercise (Palmer and Knight, 1996; Myrer et al., 2001; Patterson et al., 2008). In our study, each test run of the 40-yard dash was longer than that of the high jump and may be due to increased blood flow, thus further increasing in tissue temperature (rewarming). In a study evaluating the relationship between cold modalities, active warm-up and physical function, it was concluded that 6.5 min of warm-up is needed to neutralize the impact of physical function decline after 20 min of applying an ice bag to the front of the thigh (Richendollar et al., 2006).

There are limitations to this study. Fatigue is a major factor in speed, but based on our findings and the selection of the dependent variable (anaerobic exercise), fatigue was not a very effective factor in our study. Also the muscles of the shin area have been cryotherapy, which is recommended in future studies all muscles of the lower extremity are examined. Another limitation of this study is the absence of knowledge about muscles and joint temperature (due to their temperature not being recorded), but what is evident is the cold-water whirlpool effect in reducing muscle and joint temperature. We suggest that future research identify the actual temperature change in tissue during treatment and its impact on physical performance variables.

5. Conclusion

In sports settings, it is seen that after applying cold modalities, athletes return to maximum physical performance relatively quickly. Our results show that the significant reduction in power and speed remains for 20 and 10 min after applying a cooling modality respectively. These findings are of clinical relevance to sports medicine specialists and physical therapists and indicate the need to take precautions before allowing athletes to return to intense physical activity after applying a cold modality whirlpool.

Conflicts of interest

The authors declare no conflicts of interest.

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