Functional Performance Following an Ice Immersion to the Lower Extremity

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Abstract:

Cryotherapy is a widely accepted component of treatment for acute injuries. It has recently re-entered the later stages of rehabilitation as a contributing modality. Cryotherapy's depressive effects on the body's physiological systems have generated concern among many health care practitioners about its effect on motor activity. This study examined the effects of an ice immersion on three functional performance tests: the shuttle run, the 6-m hop test, and the single-leg vertical jump. Twenty volunteers from Division Ill soccer and football teams who had not sustained an injury to the lower extremity within the past 6 months were randomly assigned to either an experimental or control group. Subjects in the experimental group performed three trials of each functional performance test before and after the application of a 20-minute ice immersion (13°C) to the lower leg. Subjects in the comparison group followed the same procedure except that a 20-minute resting period replaced the cold treatment. A mixed design analysis of variance was used to analyze the data. Vertical jump scores decreased in the experimental group (41.4 ± 6.8 cm to 39.3 ± 6.1 cm) but not in the control group (45.2 ± 5.5 cm to 45.7 ± 5.9 cm) as a result of the treatment. Shuttle run times decreased in the experimental group (6.5 ± 0.3 seconds to 6.7 ± 0.4 seconds) but not in the control group (6.8 ± 0.4 seconds to 6.8 ± 0.4 seconds). Six-meter hop test values were not affected. We suggest that clinicians should carefully consider the immediate effects, potentially, of cold on motor activity.

Since the time of Hippocrates, cold therapy has been documented as beneficial treatment for acute injuries.[22] Due to the depressive effects cold has on many physiological systems, such as the myotatic reflex, nerve conduction velocity, and force production, the practice of applying a cold modality to an injury site before rehabilitative exercises or athletic competition has been questioned.[16,23,24] Much has been written about the effects of cryotherapy on individual physiological systems, such as the nervous system [12,15,16,23-25,35] and the muscular system.[12,16,21,23-26]

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Functional performance tests allow the athletic trainer to observe the athlete's performance on physical activities that simulate the muscular and joint stresses encountered during athletic events.[2,10,18-20] Investigators have proposed that many of these tests are reliable indicators of lower extremity function due to their relatively high test-retest intraclass correlations (ICCs) and low standard error of measurements (SEMs).[6,20] These tests may be more useful to the practicing athletic trainer than specific physiological measures because fewer inferences need to be made concerning their effect on performance. In the research setting, recent studies concerning functional bracing have used such testing protocols.[5,11],[29] The purpose of this study was to assess the effects of ice immersion to the lower extremity on functional performance.

METHODS

We used a pretest-posttest design with an untreated control group. Subjects were randomly assigned to one of two conditions: the ice immersion or resting period. Before and immediately following the treatment, subjects performed three functional performance tests: the shuttle run, the 6-m hop test, and the single-leg vertical jump.

To minimize the effects of fatigue and to equalize the diminishing effects of the cold treatment during the testing session, the order that subjects performed the three tests was counterbalanced. Twenty male subjects (age = 19.3 ± 1.2 yr, ht = 69.0 ± 2.7 in, wt = 168.3 ± 21.1 lb) from a Division III college participated in this study. The subjects were volunteers from the college's soccer team and the football team's skill positions. Only those subjects who had not injured either lower extremity within 6 months were permitted to participate in the study. In addition, an informed consent form describing the experimental procedures and potential risks and benefits was read and signed by all of the subjects before participation in the study.

Procedures

Subjects wore T-shirts, short pants, socks, and tennis shoes. Each rode a stationary bike at a low intensity for 5 minutes as a warm-up and performed one stretch for the quadriceps muscle group, hamstrings muscle group, and the triceps surae. All subjects performed three functional performance tests: shuttle run, 6-m hop, and single-leg vertical jump.

To ensure that the same leg would be used during the single-leg tests, subjects performed three practice trials on each leg for the 6-m hop and single-leg vertical jump. Upon completion of the trials, they were asked to choose the leg that they felt most comfortable with during both tests. The chosen extremity was used for the pretest and posttest trials and received the treatment.

To administer the shuttle run, we placed two strips of tape on the floor 6.1 m apart. Subjects were told to sprint to the line in front of them, touch it with their foot, and sprint back to the starting line twice for a total of 24.4 m.

For the 6-m hop test, two strips of tape were placed on the floor 6 m apart. We asked the subjects to begin on one strip of tape in a crouched position on one foot and hop to the next line as fast as possible on the same foot.

For both the shuttle run and 6-m hop, we asked subjects to begin each trial with one foot on the starting line and to start when they heard the word "go." At this point, we started the stopwatch. Upon completion of the last lap, the trial ended and the clock was stopped. For both tests, before each practice and test trial, we encouraged subjects to complete the test in the minimum amount of time. No encouragement or knowledge of results were given during or after practices or test trials.

The single-leg vertical jump was measured on the Vertec (Sports Imports, Columbus, **OH).** After we measured subjects' standing reach, we instructed them to begin in a crouched position on one leg under the Vertec's slivers and jump as high as possible off the same leg and knock the slivers backward at the top of their jump. The difference between the height of the subjects' jump and their standing reach was recorded in centimeters as the trial score. Before each trial, we encouraged subjects to give maximal effort and to jump when ready. We gave no encouragement or knowledge of results during or after practice and test trials.

Subjects completed one practice trial and three test trials for each functional performance test during both the pretest and the posttest. They rested 45 seconds between each trial. The three tests required approximately 20 minutes to complete.

Following the pretest session, all subjects reported to the athletic training room and removed the shoe and sock from the foot which they chose to use in the functional performance tests. Those in the control group relaxed in a chair for 20 minutes. Experimental group subjects immersed their leg to the level of the fibular head in a cold whirlpool of 13°C for 20 minutes. We constantly monitored and controlled the water temperature to insure the desired temperature. Additionally, we turned on the whirlpool turbine to negate any possible insulatory effects.

After the 20-minute period, all subjects put their shoes and socks back on and quickly returned to the testing area to perform the posttests. This relocation took approximately 2 minutes. Subjects stretched the triceps surae muscle group three times for 15 seconds using the runner's stretch. The posttest procedures were performed as previously described.

Statistical Analysis

The average of the three test trials for each functional performance test was used for comparison. A mixed design analysis of variance, with one between subjects' factor (treatment group) and one within subjects' factor (occasion), was used to determine whether an ice immersion would cause significant differences among functional performance scores on the three different functional performance tests. The alpha level was preset at 0.05.

The stability of the measures obtained between trials for each of the functional performance tests was examined using the ICC calculations (formula 2,1) established by Strout and Fleiss.[33] This method was selected because: 1) each measurement trial was considered a random sample from a larger population of trials, and 2) each measure on each trial was derived from a single value rather than a composite score.[33]

RESULTS

Mean and standard deviations for the two groups' performances on the three functional performance tests are listed in Table 1. The vertical jump was significantly reduced following cold application [F(1,18) = 7.53, *p* = .01; Fig 1] and the shuttle run times were significantly slower following the cold treatment [F(1,18) = 8.17, *p* = .01; Fig 2]. There were no differences between groups in the hop test [F(1,18) = 3.36, *p* = .08; Fig 3].

The ICC and SEM for each functional performance test are listed in Table 2. The relatively high ICC for each test confirms an acceptable systematic and error variance, which corresponds to the reliability of measures.

DISCUSSION

Cold's effects on the muscle spindle and the myotatic reflex is of great importance when considering the muscle's physiology. When reductions in intramuscular tissue temperature occur, the neuronal discharge and sensitivity of the muscle spindles are impeded.[12,16,23-26] Additionally, even if stimulation from the muscle spindle activates the reflex arc, the neuronal message for increased muscle excitability may be inhibited due to a significant decrease in the motor end plate's potential.[23]

Mecomber and Herman[25] clinically validated these findings by noting a decrease in the amplitude of action potentials, twitch contraction, and nerve conduction time following maximal tendon taps of precooled Achilles tendons. Consequently, the resultant force development within the muscle and the myotatic reflex's protective mechanism may be negatively influenced.

For more practical application, muscle strength following a cold treatment has also been investigated. Conflicting results regarding the effects of cold on isometric strength have been reported by investigators.[3,4,7,22,27,28] Significant decrements in muscle function have been reported, however, when isokinetic devices, which more accurately quantify muscle performance, are used to assess cryotherapeutic effects on muscle function.[21]

Table 1. Performance Scores for the Single-Leg Vertical Jump, Shuttle Run, and the 6-m Hop Test (Mean ± SD)

	Experimental				Comparison			
	Pretest		Posttest		Pretest		Posttest	
Vertical jump (cm)	41.44	(6.80)	39.33	(6.14)	45.17	(5.45)	45.72	(5.89)
Shuttle run (s)	6.54	(.27)	6.71	(.39)	6.78	(.38)	6.75	(.43)
Hop test (s)	2.07	(.16)	2.17	(.14)	2.11	(.22)	2.11	(.19)

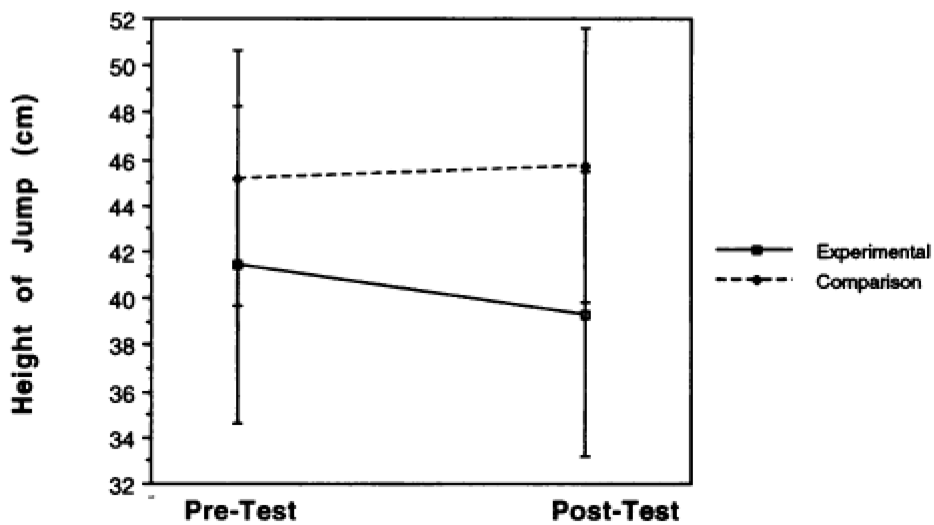

Fig 1. Grouping by occasion interaction for the single-leg vertical jump.

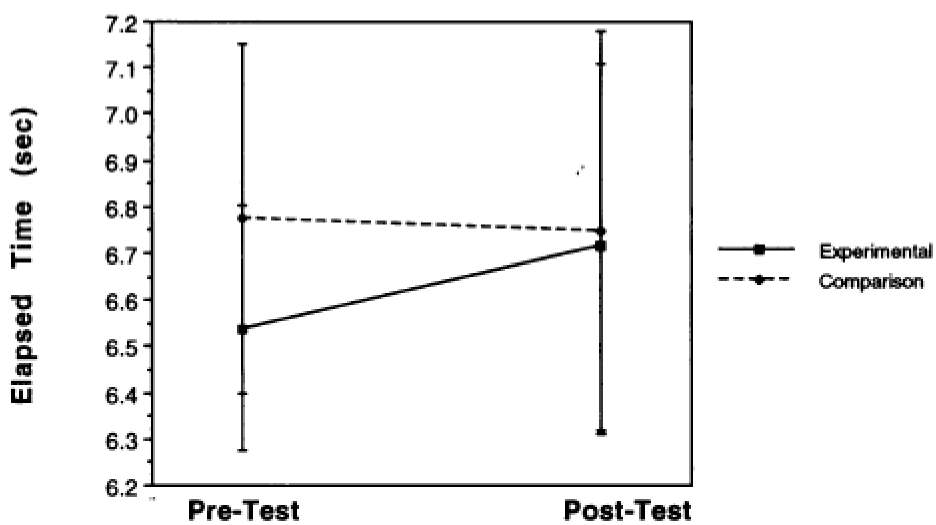

Fig 2. Grouping by occasion interaction for the shuttle run.

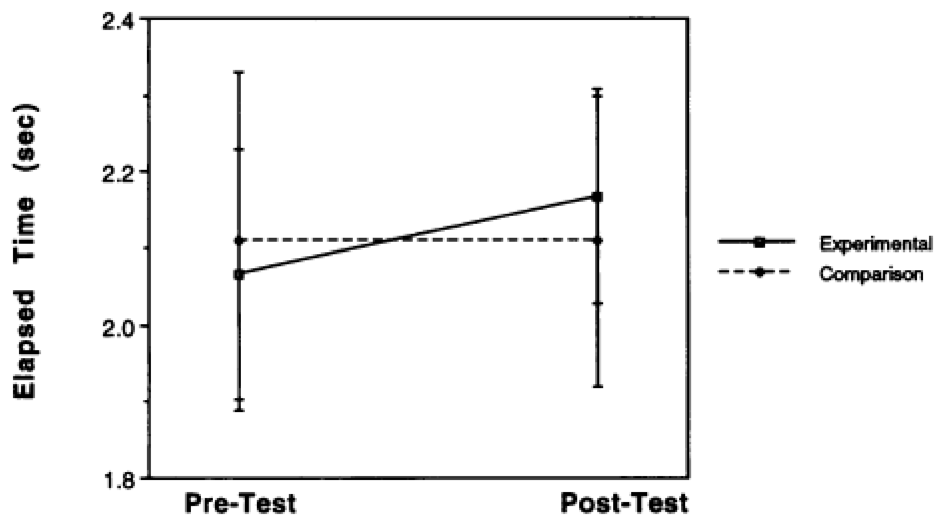

Fig 3. Grouping by occasion interaction for the six-m hop.

Table 2. ICCs and SEMs for the Single-Leg Vertical Jump, Shuttle Run, and the 6-m Hop Test

	ICC	SEM
Vertical jump	0.83	2.15 cm
Shuttle run	0.90	0.10 s
Hop test	0,76	0.09 s

Muscle contraction speed and force-generating capacity[4] are reduced by cold. Davies and Young[8] noted that, when the intramuscular tissue temperature of the triceps surae was reduced 8.4°C by a cold immersion, the time to peak tension and half-relaxation were significantly increased. Also, the tetanic tension at an electrically stimulated frequency of 40 Hz, the maximal voluntary contraction, and the peak and average power output were significantly reduced. These performance detriments were attributed to a loss of electrically evoked force generation and contractile capacities.[8]

The positive dependence of the velocity of adenosine triphosphate (ATP) splitting on muscle temperature may also be a factor in the decreased maximal muscle activity.[9] Our selection of 45 seconds of rest between trials appeared to permit subjects to sufficiently recuperate. However, due to the negative effects of cold treatments on ATP resynthesis, subjects' energy supply in the treated extremity may not have had adequate time to rebuild.

To determine when an athlete may begin playing after an injury, manufacturers of several examination devices, such as isokinetic equipment, have introduced normative data produced by their devices for reference. These same norms have been used to assess the effects of cold therapy on various physiological mechanisms, such as force production.[21] Unfortunately for the practicing athletic trainer, recent research has questioned if a significant relationship exists between measurements obtained from these devices and an athlete's functional ability.[2],[19,20,34] As a result, many functional performance tests have been developed to help determine an athlete's functional ability.

The vertical jump is a time-honored mode of determining an athlete's functional ability.[1] It has been specifically used to assess an athlete's anaerobic power and to screen participants for athletic or other physically demanding activities.[13,32] This test is particularly useful for measuring the triceps surae's power output as this muscle group is a primary power source, second to the hip extensors, for vertical displacement.[31]

In the present study, we wanted to isolate the treated extremity to control for external factors such as overcompensation with the nontreated leg. As a result, we elected to have the subjects perform a single-leg vertical jump instead of the standard double leg. This choice of methodology is supported by Risberg and Ekeland[30] who suggested that two-leg tests are associated with the ability to perform daily functions, whereas single-leg tests are more closely associated with the functional stability encountered during more demanding activities.

Our findings of a decrease in jumping height in the experimental group following the cold treatment was congruent with those of Davies and Young.[8] Many physiological effects had the potential of negatively affecting the experimental group's performance. As previously discussed, impairment of the muscle spindle's ability to invoke the myotatic stretch reflex during the preparatory crouch may have decreased the amount of "recoil" energy which could be elicited.

Also, we observed that, following the cold treatment, subjects in the experimental group often had difficulty maintaining their balance on the treated extremity. Thus, we feel the subjects' support bases were not always stable before their trial jumps. This apparent loss of stability is difficult to explain considering the recent research which denies a significant loss of proprioception following a cold treatment.[14,17] Nevertheless, a variety of factors potentially created an environment unsuitable for maximal power output during this test.

We feel that the 6-m hop test did not permit an accurate analysis of the elapsed time differences between the experimental and comparison groups, No significant decrement in performance was statistically found; however, we believe that this may be due in part to the hop test's low statistical power of 0.411. It is our impression that the primary cause of this low power was the short duration of each trial that averaged 2.11 seconds, Thus, we suggest that 6 m may not be an adequate distance to effectively assess functional performance by the hop test for time.

According to Risberg and Ekeland,[30] the shuttle run is not a very reliable method of assessing functional stability and muscle strength, because it uses both the injured and noninjured (treated and nontreated) extremities, However, we found that, following the treatment, the experimental group finished the trials at a significantly slower time than the comparison group, as did Bergh and Ekblom[4] who reported a positive relationship in their subjects' sprinting performances and muscle temperatures. Again, previous discussions of cold's negative influences on muscle contractility may explain this detriment in performance.

When referring to this study, readers should note the limitations of the subject sample and the treatment application. Subjects were selected from a healthy population of athletes who had not injured either lower extremity within the past 6 months. Obviously, members from this population rarely receive cold treatments before activity, Thus, these findings may not apply to an injured population who receive cold treatments on a daily basis.

Also, immersion of a joint and large muscle group in cold water before vigorous activity may not be deemed applicable to a sports environment; submersion tanks are rarely present along the sidelines of playing facilities. It is common to apply a cold treatment only to a joint and the immediate surrounding area that will not affect the musculature. Future research should attempt to define the effects of a more common cold application on functional performance. Nevertheless, our findings of decreased performance following a lower extremity ice immersion should not be undervalued. Athletic trainers should carefully consider the possible consequences of cold therapy before returning treated athletes to competition.

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