Cryotherapy and Sequential Exercise Bouts Following Cryotherapy on Concentric and Eccentric Strength in the Quadriceps

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Abstract: *We investigated the effects of cryotherapy followed by sequential exercise bouts on concentric and eccentric strength of the quadriceps. Nineteen males (18–27 years) participated in a two-stage design involving four sequences: ice and exercise, ice and rest, no ice and exercise, and no ice and rest. We gathered concentric and eccentric strength measures (torque) using a kinetic communicator (KIN-COM) prior to exercise, immediately following treatment, and 20- and 40-minutes post-treatment. There were significant decreases in concentric and eccentric strength immediately following the 25-minute cryotherapy treatment. This suggests that applying ice immediately prior to participation or returning an athlete to competition immediately following cryotherapy treatment may adversely affect his/her ability to perform. It appears that the reduction in strength following cryotherapy is of short duration (less than 20 minutes). The delayed effect of the ice treatment and sequential exercise appears to affect concentric and eccentric strength differently. Ice did not have a delayed effect on concentric strength, but there was a significant difference in eccentric values. This difference was a failure to improve during post-tests at the rate of those not treated with ice. Exercise did not have a significant effect on eccentric strength recovery, but there was a significant difference in concentric values. Moderate exercise following cryotherapy appears to help the recovery of concentric strength.*

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Cryotherapy is an important component in the established management of acute musculoskeletal injuries.[5,6,10,11,15] Trauma during practices or games may require that ice treatment be applied, usually for 20 to 30 minutes.[6,11,15] If the evaluation of the injury reveals it to be minor, the individual is usually returned to play.

Most research concerning strength changes following cold applications has been limited to isometric contractions.[2,3,9,14,16] The results of these studies are not conclusive; strength may increase[2,14,16] or decrease[3,9] following cold application. Only one study documenting the effect of cold on concentric strength was found. Cote[4] reported that a 30-minute cold-pack application to the quadriceps had no effect on the time required to reach constant velocity, nor on the peak torque produced on an isokinetic dynamometer.

Possible strength changes following cryotherapy should be a concern of sports medicine practitioners. If isotonic strength deficits are evident immediately following cold applications, we need to be aware of this, as well as the duration of the effects. We felt it was also of interest to investigate whether moderate intensity exercise by the treated musculature affects the rate of recovery of isotonic strength following cryotherapy treatment. Returning the athlete to competition before any cryotherapy-induced decrement in strength has disappeared could negatively affect the athlete's ability to perform.

The purposes of this study were primarily to determine the immediate effects of cryotherapy on concentric and eccentric strength of the quadriceps, and, secondarily, to investigate the effects of sequential exercise bouts and the delayed effects of cryotherapy on concentric and eccentric strength of the quadriceps.

Methods

We used a two-stage design with four sequences (Table 1). Each subject participated in each of the four sequences in a randomly selected order. All sequences started at the same time of day and were separated by 48 hours. Our dependent variables were concentric and eccentric strength (represented by the mean of the differences in mean peak torque in newton meters between the pretest and each of the post-tests) of the quadriceps as measured on the KIN-COM dynamometer.

Nineteen male intercollegiate wrestlers volunteered to participate (21.6 ± 2.5 years). They met the criteria of having no history of injury or leg pain, as well as being pain-free throughout their complete knee range of motion.

Table 1.—Experimental Design

Sequence	Pretest	Immediate effects			Delayed effects			
		Exercise, 15 min	Treatment, 25 min	Test 2	Exercise (E) or rest (R)	Test 3	Exercise or rest	Test 4
I	X*	X	Ice	X	E	X	E	X
II	X	X	Ice	X	R	X	R	X
III	X	X	No ice	X	E	X	E	X
IV	X	X	No ice	X	R	X	R	X

*** X = all subjects in the sequence participated**

All subjects attended an orientation session 2 days before the pretest, during which they signed an informed consent, were randomly assigned a sequence order, set up on the bicycle ergometer, and familiarized with the actual testing procedure on the dynamometer.[8]

We first pretested all subjects. Next, they exercised for 15 minutes. We then treated them with ice or nothing (Table 1). Subjects then performed Test 2, either rested or exercised as assigned, performed Test 3, rested or exercised again, and then performed Test 4 (Table 1).

We administered the treatments as follows:

Ice

We filled a 10″ × 25″ × 4″ plastic bag with ice and placed it directly on the right quadriceps for 25 minutes. The filled bag weighed 5 lb. We held the bag in place with a 6″ × 5′ elastic wrap.

Exercise

Subjects rode a bicycle ergometer at 960 kpm/min for 15 minutes. We judged this rate of cycling to be approximately 60% of VO^2 max for college-age wrestlers.[17]

Rest

Subjects rested, sitting in a chair, for 15 minutes.

No ice

We did not apply ice to the right quadriceps during the 25-minute treatment time.

We administered the isokinetic strength testing as previously outlined.[1,7] Subjects were attached to the testing seat with velcro straps across the chest, pelvis, and the distal aspect of the right thigh. Subjects gripped the side of the table during testing to maximize stability.

Subjects performed four submaximal warm-up repetitions before each test to familiarize themselves with the velocity and sensations of the unit. They then rested for 2 minutes. We set the dynamometer at 60°/s in the concentric/eccentric mode. The subjects then performed six maximal extension and flexion movements of the right knee. We averaged the peak torques of the six maximal repetitions in each direction for each strength testing period to calculate each subject's torque production. Because we were interested in strength change within individuals, we used the differences of the mean peak torque between the pretest and Tests 2 through 4 to determine the effects of ice and exercise.

We tested the immediate effects of cryotherapy, using two separate (concentric and eccentric strength) repeated measures 1 × 2 analysis of variance (ANOVA) with ice versus no ice as the two levels of the independent variable and the difference in strength between the pretest and Test 2 as the dependent variable. Individual subject's scores for groups I & II and III & IV were combined for this analysis since the subjects had not yet rested or exercised; subject and ice interaction was the error term.

To test the delayed effects of ice and the effects of exercise on recovery, we used two (concentric and eccentric strength) 2 × 2 repeated measures multivariate analyses of variance (MANOVA). The dependent variables were the difference between the pretest and Test 3, and the difference between the pretest and Test 4. The two independent variables were ice (yes or no) and exercise after the initial ice treatment (yes or no).

Results

Individual cell means and standard error of the mean are presented in Table 2. There was no difference between experimental groups on the pretest for either concentric ($F(1,18) = .47$, $p = .71$) or eccentric ($F(1,18) = .15$, $p = .93$) strength. There was a significant immediate decrease in strength (pretest to Test 2) for both concentric ($F(1,18) = 16.21$, $p < .01$) and eccentric ($F(1,18) = 9.72$, $p < .01$) strength due to cryotherapy (Table 3).

The delayed effect of ice on concentric and eccentric strength varied. There was no delayed effect on concentric strength ($F(1,18) = .42$, $p = .53$), but there was on eccentric strength ($F(1,18) = 4.99$, $p = .04$; Table 3).

Exercise had no effect on the recovery of eccentric strength ($F(1,18) = 2.16$, $p = .16$), but it did affect concentric strength recovery ($F(1,18) = 6.45$, $p = .02$; Table 4).

Discussion

Strength changes following cold applications have been primarily studied with regard to isometric strength.[2,3,9,14,16] Our results concur with the majority of studies that have investigated the immediate effect of cryotherapy on isometric strength.[2,3,9] We do, however, disagree with McGown,[14] Oliver and Johnson,[16] and the only previous study[4] we found dealing with concentric strength following cryotherapy. Cote[4] reported that a 30-minute cold pack application to the quadriceps had no effect on the time required to reach constant veloci-

Table 2.—Strength Scores for Experimental Treatments (Peak Torque; Mean ± SE)

Sequence	Ice Exercise I	Ice Rest II	No ice Exercise III	No ice Rest IV
Concentric				
Pretest	213.1 ± 9.1	210.6 ± 10.3	200.1 ± 9.0	213.1 ± 7.4
Test 2	192.6 ± 7.9	184.4 ± 8.4	202.3 ± 8.6	207.1 ± 8.7
Test 3	214.9 ± 9.0	202.2 ± 8.5	200.8 ± 9.4	210.4 ± 7.3
Test 4	216.7 ± 9.1	200.9 ± 8.1	202.2 ± 9.7	206.5 ± 7.2
Eccentric				
Pretest	257.5 ± 18.1	255.9 ± 22.4	240.9 ± 19.6	251.2 ± 18.2
Test 2	245.0 ± 18.6	232.9 ± 17.7	254.0 ± 20.4	257.5 ± 20.1
Test 3	255.7 ± 18.7	250.7 ± 19.0	252.7 ± 19.0	260.4 ± 16.5
Test 4	257.7 ± 17.5	244.4 ± 18.2	252.8 ± 18.5	259.2 ± 18.3

Table 3.—Effects of Ice on Quadriceps Strength are Illustrated as Differences in Strength Between the Pretest and Post-tests for Ice and No-ice Conditions. Data for Groups I & II and III & IV were combined (Torque; Mean ± SE).

	Source	N	Ice effects pre to Test 2	20-min Delay pre to Test 3	40-min delay pre to Test 4
Concentric	Ice	38	−23.3 ± 4.0*	−3.3 ± 3.9	−3.0 ± 3.6
	No ice	38	−1.6 ± 2.2	−1.0 ± 2.3	−2.3 ± 2.8
Eccentric	Ice	38	−17.7 ± 5.4*	−3.5 ± 5.1†	−5.6 ± 4.8†
	No ice	38	9.7 ± 4.4	10.6 ± 5.4	10.0 ± 4.4

* $p < .01$, ANOVA between ice and no ice.
† $p < .05$, MANOVA.

Table 4.—Effects of Exercise on Previously Cooled Quadriceps are Illustrated as Differences in Strength Between the Pretest and Second and Final Post-tests of Exercise and Rest Conditions. Only data for Groups I and II were used here (Torque; Mean ± SE).

	Source	N	20-min post ice application, pre to Test 3	40-min post-application, pre to Test 4
Concentric	Exercise	19	1.8 ± 5.0*	3.6 ± 3.9*
	Rest	19	−8.4 ± 5.8	−9.7 ± 5.8
Eccentric	Exercise	19	−1.7 ± 6.5	0.2 ± 6.6
	Rest	19	−5.2 ± 8.0	−11.5 ± 7.1

* $p < .05$, MANOVA between exercise and rest.

ty nor in the peak torque produced on an isokinetic dynamometer. A recent study of the effect of cold water submersion on isokinetic strength of the plantar flexors also confirmed our results.[13]

We conclude that both eccentric and concentric strength is decreased immediately following a 25-minute ice treatment. Therefore, we recommend that the clinician avoid applying ice immediately before participation or immediately returning athletes to competition following musculoskeletal cryotherapy (ie, within 10–15 minutes). The immediate strength decrement following ice-pack treatment may adversely affect the athlete's ability to perform, but specific research on this point is lacking.

We have no definitive conclusions concerning the delayed effects of ice following cryotherapy treatment and the effect of sequential exercise involving the iced musculature on the recovery of strength. We suggest, however, some interesting areas for further exploration. First, it appears that the duration of the strength loss following cryotherapy is not long. By Test 3, administered 20 minutes after the ice treatment, the concentric and eccentric values were not significantly lower than the pretest values (Table 3). This agrees with Coppin[3] but Oliver and Johnson[16] reported strength increased 40 to 80 minutes after treatment. Further research is needed to establish the minimum time required to regain pretreatment strength.

Second, the delayed difference in eccentric values between those treated with ice and those not treated was not a strength decrease below pretest values, but rather a failure to improve in the post-tests at the rate of those not treated with ice (Table 3). The no-ice group experienced a substantially increased strength score by Test 2 which was maintained in Test 3 and Test 4. The iced group experienced a significant decrease in strength at Test 2, but by Test 3 were almost back to their pretest scores, and remained virtually unchanged at Test 4. We do not have an explanation for this. Measurement error is a possibility, but, because the pattern is consistent over two testing periods, this is unlikely. Although reliability coefficients are consistently lower between occasions than among repetitions, the overall reliability of the KIN-COM has been found to be very high.[7] Perhaps there was a learning effect associated with repeated eccentric testing in the no-ice group that was inhibited in the ice group due to the cold.

Third, the effects of sequential exercise by the involved musculature following cryotherapy were also different for concentric and eccentric strength. Exercise did not have a significant effect on eccentric strength recovery, but it did for concentric strength. Interestingly, those who rested had decreased values from those who exercised (Table 4). Exercise appears to speed recovery in concentric strength.

We recommend further research to investigate the noted differences in the delayed response to cryotherapy and exercise evidenced in concentric and eccentric contractions.

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