Ankle and Thigh Skin Surface Temperature Changes With Repeated Ice Pack Application

Janice E. Palmer, MA, ATC; Kenneth L. Knight, PhD, ATC

Objective: Most of the research on cold applications has been performed on nonexercising supine subjects during a single cold pack application. Most athletic injuries occur during exercise, which increases skin temperature. Exercise before ice application will also increase ankle skin temperature during the rewarming phase. The purpose of this study was to examine the effects of activity on subsequent ice pack applications and rewarming using standard immediate care procedures.

Design and Setting: Three experimental conditions (20-, 30-, and 40-minute ice pack applications) were applied to 12 subjects in a repeated measures design. Subjects rode a bicycle ergometer for 15 minutes before ice application to the ankle and opposite thigh, and were active (walking with crutches, simulated showering and dressing) for 20 minutes following application. Subjects rested with the limb elevated for an additional 40 minutes. Ice packs were then reapplied for the appropriate time (20, 30, or 40 minutes) followed by 60 minutes of rest with the limb elevated.

Subjects: Twelve (8 males, 4 females) college-aged volunteers. Only subjects with good-to-high fitness levels were accepted for this study.

Measurements: Ankle skin, thigh skin, and atmospheric temperatures were measured every minute using an Isothermex (Columbus Instruments, Columbus, OH).

Results: Thigh temperature changes during the first ice application were greater during the 30- and 40-minute conditions than the 20-minute condition. Ankle and thigh temperature changes during the first ice application and rewarming, and for the entire trial were greater during the 40-minute condition than the 20- or 30-minute conditions. Throughout the first ice application and rewarming, and the entire trial, thigh temperature changes were greater during the 30-minute condition than the 20-minute condition.

Conclusions: During immediate care procedures following injury, ice packs should be reapplied immediately following showering, changing clothes, and returning home.

Key Words: ice application, cryotherapy, ankle and thigh, skin surface temperatures

Cryotherapy has become the most widely accepted modality for the immediate care of acute sport injuries.[3,4,12,13,21] Ice applications reduce the magnitude of secondary hypoxic injury by decreasing tissue temperature. This decrease reduces the rate of metabolism and the need for oxygen,[4] resulting in quicker healing, rehabilitation, and recovery.[15]

Skin and subcutaneous tissue temperatures decrease immediately with ice application.[2,5,6,11] Deep tissue temperature decreases at a slower rate than surface temperatures.[8,11,12] To maintain lowered skin temperatures, an application-reapplication protocol is followed, reducing the chances of secondary hypoxic injury. The majority of individuals disagree on their recommendations for time on and time off.[22] Knight[15] suggested an intermittent application protocol of 30-minutes on and 90-minutes off for the acute stage of injury to help maintain a lowered tissue temperature.

Most of our knowledge of the body's response to cold applications is the result of research on nonexercising supine subjects during a single cold pack application.[19,22,24,28] In nonexercising individuals, the second application of an ice pack lowers temperatures to a greater extent than the first and results in lower temperatures during rewarming.[24] Most athletic injuries occur during exercise, which increases skin temperatures.[9,18,25,26] Indeed, exercise before ice pack application will increase ankle skin temperature during the postapplication or rewarming.[19]

Protocols for most research in this area have required the subject to be supine.[19,22,24,28] In real life, an injured athlete will shower, change clothes, and return home after icing the injured part. It seems that this activity would increase the rate of rewarming, but this has not yet been examined. This study examined the effects of activity following ice pack application on tissue rewarming and the effect of the activity on subsequent ice pack applications and rewarming.

METHODS

The design of this experiment was a 2 × 3 factorial with repeated measures on both factors. Skin surface temperatures were measured in the ankle and opposite thigh while subjects underwent three conditions (20, 30, and 40 minutes of ice application and reapplication). On 3 separate testing days, at least 48 hours apart, subjects lay supine for 5 minutes, rode an exercise bike for 15 minutes, had ice packs applied for the specified time, simulated showering for 20 minutes, rested supine for 40 minutes, had the cold pack reapplied for the specified time, and rested without cold packs for 60 minutes. Treatment orders were established according to two balanced 3 × 3 Latin squares and subjects were randomly assigned to these orders.

Eight males (age = 23.6 ± 1.2 yr; ht = 70.6 ± 2.0 in; wt = 179.5 ± 29.5 lb) and 4 females (age = 22.0 ± 0.8 yr; ht =

Janice E. Palmer has just finished physiotherapy school at the University of Halifax in Halifax, Nova Scotia, Canada.
Kenneth L. Knight is now professor of physical education at Brigham Young University in Provo, Utah.

64.8 ± 1.3 in; wt = 147.7 ± 17.9 lb) participated. During an orientation session prior to testing, subjects gave informed consent and were screened for any contraindications to the treatments, including cold allergies and any previous heart conditions.

During testing, subjects were supine on a table with their ankles elevated 6 inches. During the preapplication period, six thermocouples (TX 31; Columbus Instruments, Columbus, OH) were taped in place with 1/2-inch × 1-inch Dermiclear (Johnson & Johnson, New Brunswick, NJ) so that the tip of the thermocouple remained exposed. The thermocouples on the ankle were positioned over the anterior talofibular ligament. The thermocouples on the anterior thigh were positioned 7 cm above and 7 cm below a point midway between the tibial tuberosity and the anterior superior iliac spine. All positions were marked with a felt tip pen so that the thermocouples were applied to the same position each day. The thermocouples were attached to a electronic temperature measuring device (Isothermex; Columbus Instruments, Columbus, OH) interfaced with a 386 computer.

Subjects performed a submaximal bicycle stress test.[1] From these results, maximal oxygen consumption (predicted maximum was VO_2 = 40.8 ± 8.4 L/min for males and VO_2 = 35.5 ± 4.4 L/min for females) and fitness level were predicted. Subjects were classified into fitness levels using oxygen uptake capacity (mL/kg × minute) predicted from heart rate and workload. All subjects scored in the good-to-high fitness level range.

Temperature recording began when the thermocouples were attached. Ankle, thigh, and atmospheric temperatures were measured every minute except during the second exercise period. The subjects performed a 15-minute ride on a bicycle ergometer (Fitron; Cybex, Ronkonkoma, NY) using a target heart rate range of 60% to 80% of their age-predicted maximum heart rate.[20]

A 20-, 30-, or 40-minute ice pack application followed the first exercise period. One ice pack was applied to the lateral aspect of the ankle and another to the anterior aspect of the opposite thigh. In both instances, they were centered over and covered the thermocouples and were secured with 6-inch elastic wraps. The ice packs were manually compressed every 5 minutes to minimize the thermal gradient.[28]

Following the first application, the ice pack and elastic wrap were removed for 20 minutes, during which subjects simulated showering and changing clothes. For 5 minutes each subject walked slowly on crutches using a partial weight-bearing four-point gait (100 m at 1.41 m/sec), followed by 5 minutes of balancing on one leg (while showering), then 5 minutes of minimal activity while standing (dressing), and finally 5 minutes of slow crutch walking. The elastic wraps were then reapplied to the ankle and thigh for 40 minutes.

A second ice pack was applied 60 minutes after removing the first. The second ice pack application was equal in duration of time to the first ice application. The second ice pack was then removed and the elastic wrap was immediately reapplied for 60 minutes.

Data were analyzed using SPSS-X on a Vax computer. A Multivariate ANOVA was significant; therefore, one-way ANOVAs and Duncan's tests were used for post-hoc analysis.

RESULTS

Skin temperature decreased immediately and rapidly after ice application and continued to decrease gradually for the duration of the application (Tables 1 and 2). The temperatures at time = 0 were different between the ankle and thigh ($F(1,11) = 32.3$, $p = .0005$) and between the three ice pack application conditions ($F(2,22) = 3.4$, $p = .05$). Due to this difference, temperature changes (from beginning to end of time period) were computed and used for subsequent analysis (Table 3). Temperature changes during exercise were not significantly different between conditions ($F(2,22) = 1.0$, $p = .38$).

The thigh temperature changes during the first ice application were greater during the 30- and 40-minute conditions than during the 20-minute condition ($F(2,22) = 11.9$, $p = .0005$, Duncan post hoc $p < .05$). Temperature changes were not different between conditions in the ankle during the first ice pack application ($F(2,22) = 3.0$, $p = .07$) or during the second ice pack application in the ankle ($F(2,22) = 1.6$, $p = .23$) or thigh ($F(2,22) = 1.5$, $p = .24$).

The temperature changes were not different between conditions during the first rewarming of the ankle ($F(2,2) = 2.8$, $p = .13$) or thigh ($F(2,22) = 1.2$, $p = .32$) nor during the second rewarming of the ankle ($F(2,22) = .7$, $p = .51$). Thigh

Table 1. Ankle Skin Temperature During Three Conditions of Ice Pack Application (n = 12, Mean ± SD, °C)

		Length of Application of Cold Pack		
Condition	Time	20 min	30 min	40 min
Exercise	−15	30.2 ± 1.0	30.7 ± 1.4	30.7 ± 1.0
Ice application	0	29.6 ± 1.2	30.1 ± 1.0	29.9 ± 1.6
	1	18.6 ± 2.2	18.7 ± 2.4	19.4 ± 3.0
	10	7.9 ± 1.9	9.3 ± 3.5	8.7 ± 2.8
	20	5.9 ± 2.0	5.5 ± 1.2	6.3 ± 1.8
	30		5.2 ± 1.4	5.2 ± 1.2
	40			4.4 ± 1.2
Activity				
First rewarming	21	26.4 ± 1.7	25.8 ± 1.7	24.5 ± 1.9
	30	27.4 ± 1.8	26.8 ± 1.9	24.9 ± 2.2
	40	28.2 ± 1.9	27.9 ± 1.9	25.7 ± 2.2
	50	28.9 ± 1.9	28.6 ± 2.0	26.5 ± 2.2
	60	29.2 ± 1.9	29.0 ± 1.9	26.9 ± 2.3
Ice application	1	17.1 ± 2.0	18.4 ± 3.0	16.8 ± 2.7
	10	7.2 ± 1.7	7.8 ± 2.9	7.0 ± 2.4
	20	5.3 ± 1.3	5.0 ± 1.5	4.5 ± 1.8
	30		4.8 ± 1.8	3.8 ± 1.3
	40			3.8 ± 1.3
Second rewarming	1	10.3 ± 1.0	9.4 ± 1.5	8.3 ± 1.3
	10	16.3 ± 1.8	15.6 ± 1.8	14.1 ± 1.0
	20	19.2 ± 2.4	18.5 ± 2.2	16.8 ± 1.2
	30	20.9 ± 2.5	20.3 ± 2.3	18.5 ± 1.4
	40	22.2 ± 2.6	21.7 ± 2.4	19.9 ± 1.7
	50	23.3 ± 2.8	22.8 ± 2.4	20.9 ± 1.8
	60	24.1 ± 2.8	23.7 ± 2.4	21.9 ± 1.8

Table 2. Thigh Skin Temperature During Three Conditions of Ice Pack Application (n = 12, Mean ± SD, °C)

		Length of Application of Cold Pack		
Condition	Time	20 min	30 min	40 min
Exercise	−15	32.0 ± 1.0	32.1 ± 0.6	32.1 ± 1.0
Ice application	0	31.6 ± 0.9	32.0 ± 0.9	32.0 ± 0.9
	10	6.6 ± 1.5	7.5 ± 2.5	6.8 ± 2.0
	20	4.8 ± 1.0	5.2 ± 1.4	4.8 ± 1.0
	30		4.2 ± 0.9	3.8 ± 0.7
	40			3.5 ± 0.6
Activity				
First rewarming	21	27.6 ± 1.9	26.8 ± 1.8	26.0 ± 2.4
	30	28.8 ± 1.8	27.8 ± 1.9	26.7 ± 2.2
	40	29.9 ± 1.6	28.7 ± 1.8	27.7 ± 1.9
	50	30.8 ± 1.5	29.6 ± 1.7	28.6 ± 1.8
	60	31.1 ± 1.3	30.2 ± 1.5	29.2 ± 1.6
Ice application	1	16.4 ± 2.1	17.4 ± 2.4	15.9 ± 3.2
	10	5.6 ± 0.9	6.6 ± 1.7	5.2 ± 1.5
	20	4.6 ± 1.0	5.1 ± 1.4	4.4 ± 1.2
	30		4.6 ± 1.2	3.8 ± 1.2
	40			3.5 ± 1.3
Second rewarming	1	10.2 ± 1.2	9.7 ± 1.3	8.9 ± 1.0
	10	20.4 ± 1.2	19.6 ± 1.8	18.4 ± 1.1
	20	23.5 ± 1.3	22.6 ± 1.7	21.6 ± 1.3
	30	25.5 ± 1.4	24.4 ± 1.7	23.4 ± 1.5
	40	27.1 ± 1.4	25.7 ± 1.7	24.7 ± 1.6
	50	28.2 ± 1.4	28.8 ± 1.6	25.8 ± 1.8
	60	29.0 ± 1.4	27.9 ± 1.5	26.7 ± 1.8

temperature changes during the second rewarming were significantly different ($F(2,22) = 4.5$, $p = .02$, Duncan post hoc $p < .05$), with a greater temperature change during the 20-minute ice pack application than during 30- and 40-minute conditions. The temperature changes during second ice pack application and second rewarming were not significantly different between conditions in the ankle ($F(2,22) = .3$, $p = .73$), or thigh ($F(2,22) = .4$, $p = .68$).

Both ankle and thigh temperature changes during first ice pack application and rewarming were different between conditions. In the ankle, the 40-minute condition was greater than the 20- or 30-minute conditions ($F(2,22) = 12.8$, $p = .0005$, Duncan post hoc $p < .05$). In the thigh, the 40-minute condition was greater than the 20- or 30-minute conditions, and the 30-minute condition was greater than the 20-minute condition ($F(2,22) = 28.9$, $p = .0005$, Duncan post hoc $p < .05$).

The ankle temperature changes for the entire trial were greater during the 40-minute condition than during the 20- or 30-minute conditions ($F(2,22) = 6.9$, $p = .005$, Duncan post hoc $p < .05$). The thigh temperature changes were greater during the 30- and 40-minute conditions than during the 20-minute condition, and the 40-minute condition was greater than the 30-minute condition ($F(2,22) = 19.3$, $p = .0005$, Duncan post hoc $p < .05$).

Atmospheric temperatures were different between conditions ($F(2,3633) = 2.2$, $p = .0005$) but were within an acceptable range (25.2°C, 25.1°C, 25.3°C).

DISCUSSION

The rapid decrease in the ankle and thigh skin temperatures during the first few minutes of, and the slow and steady decline for the duration of, the ice pack application was in agreement with others.[5,19,23,24,28] The ankle temperature changes during the first rewarming were greater than those previously recorded by Post,[24] but were within the same range at the end of the second rewarming. The simulated activity associated with showering, changing clothes, and returning home on crutches caused the body parts to warm more quickly than previously thought.

Our ankle temperatures following 30 minutes of ice application and subsequent rewarming were 2°C to 10°C greater than recorded in previous studies (29.0° ± 1.9°C now vs 19.8° ± 1.9°C to 27.5° ± 3.1°C previously).[19,22,24] It is possible that the heat of the shower may have intensified this rewarming. Ice reapplication protocols have not considered the effects of activity following ice application. A reapplication protocol of 30 minutes on and 90 minutes off[15] is suitable for supine individuals or an athlete once he/she has returned home, but if an athlete is showering or returning home, this protocol delays reapplication too long. Ice should be reapplied immediately after the athlete showers and/or returns home.

Decreases in ankle skin temperature changes were midway between those previously reported[19,22,24,28] (Table 4). The reason for these differences is not apparent. Mancuso et al,[19] whose temperatures were lower than ours, suggested that atmospheric temperature may have affected their skin temperatures. Post[24] disagreed because there was not a direct relationship between limb and atmospheric temperature. The differences may be due to differences in the temperature-measuring instruments: Isothermex in this study and a telethermometer (Model 44TD; Yellow Springs Instruments (YSI), Yellow Springs, OH) and temperature probes (YSI Model 402) in the previous study. Our thigh temperature changes during ice application were within the range as previously reported research from our lab using the Isothermex[14] device (Table 4).

Thigh temperature change during ice pack application is faster than change in the ankle or forearm, but slower than in the fingers. The fingers rewarm at a faster rate than the forearm and ankle.[16,17] Finger temperature returned to preimmersion temperature within 15 minutes of ice pack removal. Recovery periods of up to 7 hours have not been sufficient for temperatures to return to preapplication levels.[5] Rewarming of the ankle and forearm were reported to take in excess of 2 hours. Similar results have been reported in the lower leg.[23] Calf temperatures following immersion in 12.5°C to 15°C water for 30 minutes resulted in a temperature 3.6°C less than preimmersion after 180 minutes and about 2°C less after 6 to 7 hours.

Ankle temperature increases due to exercise before ice pack application were less than those found by Mancuso,[19] but similar to Edwards.[9] Mancuso[19] reported an increase of 2.1°C and 2.3°C in skin temperature during 15 and 30 minutes of treadmill running at 60% to 80% VO_2 maximum. Our subjects increased 0.7°C (ankle) and 0.2°C (thigh) during a 15-minute bicycle ride at 60% to 80% VO_2 maximum. Edwards[9] reported an increase of 1.0°C (at an atmospheric temperature of 28°C)

Table 3. Temperature Change During Selected Time Periods at the Ankle and Thigh (°C)

Condition	Length of Application of Cold Pack		
	20 min	30 min	40 min
Ankle			
Exercise	−.6 ± 1.5	−.6 ± 1.1	−.8 ± 1.2
First ice pack application	−23.7 ± 2.6	−25.0 ± 2.1	−25.5 ± 2.1
Second ice pack application	−23.9 ± 2.5	−24.2 ± 2.2	−23.2 ± 2.5
First rewarming	+23.3 ± 3.0	+23.8 ± 2.8	+22.5 ± 2.2
Second rewarming	+18.8 ± 3.0	+18.9 ± 2.0	+18.2 ± 1.9
First ice pack application and first rewarming	−.4 ± 1.7	−1.1 ± 1.8	−3.0 ± 1.7*
Second ice pack application and second rewarming	−5.0 ± 2.1	−5.3 ± 1.6	−5.0 ± 1.4
Entire trial	−5.4 ± 3.0	−6.4 ± 2.5	−8.0 ± 2.0*
Thigh			
Exercise	−.4 ± 1.0	−.1 ± 1.0	+.1 ± 1.0
First ice pack application	−26.8 ± 1.4	−27.8 ± 1.4	−28.5 ± 1.3†
Second ice pack application	−26.5 ± 1.2	−25.6 ± 1.5	−25.6 ± 1.9
First rewarming	+26.3 ± 1.4	+26.0 ± 1.3	+25.6 ± 1.5
Second rewarming	+24.4 ± 1.2	+23.2 ± 1.6	+23.2 ± 1.3§
First ice pack application and first rewarming	−.5 ± 1.3	−1.8 ± 1.4	−2.9 ± 1.7‡
Second ice pack application and second rewarming	−2.1 ± 1.0	−2.4 ± 0.9	−2.4 ± 1.3
Entire trial	−2.6 ± 1.6	−4.2 ± 1.3	−5.3 ± 1.8‡

Temperature increased during time period (+); temperature decreased during time period (−).
* 40- minute greater than 20- and 30-minute conditions ($p < .05$).
† 40- and 30-minute greater than 20-minute condition ($p < .05$).
‡ 40- and 30-minute greater than 20-minute condition, and 40-minute greater than 30-minute condition ($p < .05$).
§ 30- and 40-minute less than 20-minute condition ($p < .05$).

Table 4. Temperature Change in Various Sites During First Ice Application (°C)

	Measuring Device	Length of Ice Application		Atmospheric Temperature	
		20 min	30 min	40	45
Ankle					
Urban (28)	YSI	26.0	28.7		24.0
Mlynarczyk (22)	YSI	26.8	28.0	28.9	25.9
Mancuso (19)	YSI		21.9		24.8
Post (24)	YSI	22.1	23.1		24.0
		22.3	23.7		
Present Study	Isothermex	23.7	24.0	25.5	25.2
Thigh					
Knight					
DKZ (unpublished)	YSI	23.6	24.3	24.9	
DKA (unpublished)	Isothermex	26.2	26.8		
DKB (unpublished)	Isothermex	25.7	26.0	26.2	
Present Study	Isothermex	26.8	27.8	28.5	25.2

in ankle skin temperature during a 30-minute bicycle ride at 40% to 60% VO_2 maximum. This difference was probably due to a combination of two facts: bicycle riding is an exercise specific to the lower extremities, while treadmill running is more general and requires the use of the entire body.[27] Second, the duration of the ride was less. The increase in thigh temperature may have been different than the ankle because of better heat dissipation due to a larger surface area and increased vascularity of muscle.

Ankle and thigh temperature changes are greater after 40-minute ice applications than after 20-minute ice applications. Mlynarczyk[22] reported that ankle temperature changes were greater after a 20-minute condition than after a 45-minute condition. Thigh temperature following the first ice application, and both the ankle and thigh following the second ice application, showed a similar trend.

These data confirmed Post's[24] report that ankle temperatures were lower in all conditions during the second cycle of ice pack application and rewarming. Thigh temperature changes during second ice pack application, however, did not demonstrate this trend. Temperatures were lower at the end of rewarming. Cooling during the second ice application did not cause the temperature change during the second rewarming to be lower than the first rewarming, which is in agreement with Post.[24]

Subjects complained of pain a number of times throughout the treatment sessions, but they experienced the most pain during the 40-minute application. Two subjects claim to have suffered ill effects as a result of the treatment sessions. A week later they

began experiencing a "pins-and-needles" sensation in the lateral aspect of the ankle and into the fourth and fifth toes with light touch. Nerve palsy is thought to be induced by cold application, tight elastic wraps, or a combination of the two.[7,10] One of the subjects had mentioned that the elastic wrap was very tight. She had participated in previous cold studies with no adverse effects. The possibility of a delayed effect of cold and/or elastic wraps has not been discussed and needs further investigation.

Repeated ice applications are a common and appropriate treatment for acute injuries. The critical factor appears to be the exercise following ice pack application. It appears that ice should be reapplied immediately after activity rather than being delayed. The body part that is to be iced determines the length of ice pack application. Further research is needed in the area of specific application protocols for specific body parts.

REFERENCES

1. Adams GM. *Exercise Physiology Laboratory Manual.* Dubuque, IA: William C Brown Publishers; 1990:43–53.
2. Bierman W, Friedlander M. The penetrative effect of cold. *Arch Phys Ther.* 1940;21:584–592.
3. Bing JH, Watts N. Effects of cooling on the triceps surae reflex. *Am J Phys Med.* 1962;42:240–251.
4. Borken N, Bierman W. Temperature changes produced by spraying with ethyl chloride. *Arch Phys Med Rehabil.* 1955;36:288–290.
5. Bugaj R. The cooling, analgesic, and rewarming effects of ice massage on localized skin. *Phys Ther.* 1975;55:11–19.
6. Cohn BT, Draeger RI, Jackson DW. The effects of cold therapy in the postoperative management of pain in patients undergoing anterior cruciate ligament reconstruction. *Am J Sports Med.* 1989;17:344–349.
7. Collins K, Storey M, Peterson K. Peroneal nerve palsy after cryotherapy. *Physician Sportsmed.* May 1986;14:105–108.
8. Cote DJ, Prentice WE, Hooker DN, Shields EW. Comparison of three treatment procedures for minimizing ankle sprain swelling. *Phys Ther.* 1988;68:1072–1076.
9. Edwards RJ, Harrison MH, Mills FJ. Blood volume and protein responses to skin cooling and rewarming during cycling exercises. *Eur J Appl Physiol.* 1983;50:195–206.
10. Green GA, Zachzewski JE, Jordan SE. Peroneal nerve palsy induced by cryotherapy. *Physician Sportsmed.* Sep 1989;17:63–70.
11. Hocutt JE. Cryotherapy. *Am Fam Physician.* Mar 1981;23:141–144.
12. Hocutt JE, Jaffe R, Rylander R, Beebe JK. Cryotherapy in ankle sprains. *Am J Sports Med.* 1982;10:316–319.
13. Johnson DJ, Moore S, Moore J, Oliver RA. Effects of cold submersion on intramuscular temperature of the gastrocnemius muscle. *Phys Ther.* 1979;59:1238–1242.
14. Knight KL. *Cryotherapy in Sports Injury Management.* Champaign, IL: Human Kinetics; 1995:59–75.
15. Knight KL. Ice for immediate care of injuries. *Physician Sportsmed.* Oct 1982;10:137.
16. Knight KL, Aquino J, Johannes SM, Urban CD. A re-examination of Lewis' cold induced vasodilation—in the finger and the ankle. *Athl Train, JNATA.* 1980;15:248–250.
17. Knight KL, Elam JF. Rewarming of the ankle, forearm, and finger after cryotherapy: further investigation of Lewis' cold induced vasodilation. *J Can Athl Ther Assoc.* 1981;8:17–18.
18. MacDougall JD, Reddan WG, Layten CR, Dempsey JA. Effects of metabolic hyperthermia on performance during heavy prolonged exercise. *J Appl Physiol.* 1974;36:538–544.
19. Mancuso DL. *Effects of Prior Activity on Skin Surface Temperature Response of the Ankle During and After a 30-Minute Ice Pack Application.* Terre Haute, IN: Indiana State University; 1986. Thesis.
20. McArdle WD, Katch FI, Katch VL. *Exercise Physiology: Energy, Nutrition, and Human Performance.* Philadelphia, PA: Lea and Febiger; 1986:356–360.
21. McMaster WC, Liddle S, Waugh TR. Laboratory evaluation of various cold therapy modalities. *Am J Sports Med.* 1978;6:291–295.
22. Mlynarczyk JM. *Temperature Changes in the Ankle During and After Ice Pack Application of 10, 20, 30, 45, and 60 Minutes.* Terre Haute, IN: Indiana State University; 1985. Thesis.
23. Petajon JH, Watts N. Effects of cooling on the triceps surae reflex. *Am J Phys Med.* 1962;41:240–251.
24. Post JB. *Ankle Skin Temperature Changes with Repeated Ice Pack Application.* Terre Haute, IN: Indiana State University; 1990. Thesis.
25. Saltin B, Gagge AP, Stolwijk JAJ. Body temperature and sweating during thermal transients caused by exercise. *J Appl Physiol.* 1970;28:138–327.
26. Stolwijk JAJ, Saltin B, Gagge AP. Physiological factors associated with sweating during exercise. *Aerospace Med.* 1968;39:1101–1105.
27. Roberts JA, Alspauc JW. Specificity of training effects resulting from programs of treadmill running and bicycle ergometer riding. *Med Sci Sports.* 1972;4:6–10.
28. Urban CD. *Insulating Effect of Elastic Wraps Used During the Application of Ice, Compression, and Elevation to the Lateral Aspect of the Ankle.* Terre Haute, IN: Indiana State University; 1980. Thesis.