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Research article

THE EFFECT OF CRYOTHERAPY ON THREE DIMENSIONAL ANKLE KINEMATICS DURING A SIDESTEP CUTTING MANEUVER

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ABSTRACT

Although cryotherapy is commonly used in the treatment of acute and chronic athletic injuries, the deleterious effects of limb cooling, such as decreased nerve and muscle function, slowed sensation and inhibition of normal relaxes, may put an athlete at increased risk of additional injury. The purpose of this study was to determine the effects of cryotherapy on subtalar and ankle joint kinematics of healthy athletes performing a sidestep 45° cut. We hypothesized that greater joint displacements and velocities would be seen after icing. Twenty one subjects performed a 45° sidestep cut prior to and after limb cooling. Retroreflective markers were placed on the subject's shank and foot while 6 high-speed cameras were used to collect the kinematic data. In this test-retest controlled laboratory study, a repeated measures ANOVA was performed on the PRE and POST icing data for the minimum and maximum joint displacements and velocities. No statistical differences were noted between the PRE and POST icing conditions. The results indicate that a 10-minute icing treatment did not have an effect on either the movement patterns or angular velocities. Our results do not support any change in practice of icing injured ankles for ten minutes during halftime of athletic events.

KEY WORDS: Biomechanics, movement, range of motion, running, musculoskeletal system.

INTRODUCTION

Sidestep cutting movements are common in many sports, including basketball, soccer, tennis, and volleyball (Stacoff et al. 1996). This action occurs when a person, in the stance phase of the running stride, cuts toward the side of the body of the swinging leg. The sidestep cut maneuver has been called by several names, including the lateral cut, 'V' cut, open cut, and forward medial cut (McLean et al., 1999; Neptune et al., 1999; Simpson et al., 1999; Stacoff et al., 1996).

The kinematics of this movement have been studied by several investigators. Neptune et al. (1999) investigated the ankle kinematics of a 45° open cut. They reported minimal motion of the subtalar/ankle joint complex in the frontal plane, with subjects contacting the ground in approximately 20° of supination and remaining in this position throughout the stance phase. In the sagittal plane, subjects struck the ground in approximately 20° of dorsiflexion, plantarflexed until the foot reached a neutral position at 20% of the stance phase, dorsiflexed to approximately 25° at 70% of the stance phase, and then plantarflexed until toe off. The type of footwear worn by the subjects, if any, was not mentioned. In another study, Stacoff et al. (1996) reported that barefoot subjects struck the ground in a subtalar joint neutral position, and reached a maximum inversion angle of approximately 8°.

Ankle sprains account for approximately 20% of the total injuries sustained during intercollegiate athletics (NCAA, 1991). Cryotherapy, or icing and/or submersion of the foot and ankle in cold water, is a very popular treatment method for both acute and chronic athletic injuries because of its ability to reduce pain, inflammation, and muscle spasm (Meeusen et al., 1986). Athletes often receive cryotherapy treatment during the standard ten-minute period of halftime and then return to the playing field before the affected limb has the opportunity to return to normal temperature.

Swenson et al. (1996) reported few complications or side effects of cryotherapy. However, it may not be totally advantageous. The athlete may be at increased risk for additional injury if sensation or movement are affected by the treatment (Lephart et al., 1997; 1998). Limb cooling decreases nerve and muscle function, sensation, and slows or inhibits normal reflexes (Denys, 1991; Swenson et al., 1996; Schieppati et al., 1997). Afferent input from the dynamic stabilizer muscles surrounding the ankle joint may play a critical role in the prevention of ankle sprains (Neptune et al., 1999). If neuromuscular function is compromised by the treatment, the athlete may be at increased risk of sustaining a subsequent injury on the limb.

Only one study was found in the literature that has investigated the effect of cryotherapy on ankle joint biomechanics during functional activities. Hopper and coworkers (1997) suggested that the clinical application of cryotherapy is not deleterious to joint position sense and, assuming normal joint integrity, patients may resume exercise without the possibility of increased injury. However, no movement analysis data were reported from this study.

Despite the prevalence of ankle injuries in sports, few studies have been performed on the kinematics of the ankle during a sidestep cutting maneuver. Additionally, although cryotherapy is one of the primary treatments for acute and chronic ankle injury, its effects on the kinematics of the ankle/subtalar joint complex remain unexplored. Therefore, the purpose of this study was to determine the effects of cyrotherapy on ankle/subtalar joint range of motion, displacement and velocity of healthy athletes performing a 45º sidestep cut maneuver. The ultimate goal of this study was to provide insight as to whether or not an athlete is more at risk for sustaining an additional injury after their ankle has been treated with cryotherapy. We hypothesized that, after the ten-minute icing treatment, the three dimensional angular displacements, ranges of motion, and velocities of the foot with respect to the shank would increase, thereby making the ankle joint complex less stable than it was before the icing treatment.

METHODS

Subjects

Twenty-one young healthy subjects who were recreationally active or intercollegiately competitive participated in the study (14 females and 7 males, age: 21.6±1.5 yrs, height 170.28±7.9 cm, and mass 69.75±12.1 kg). All subjects were rearfoot strikers. Eight subjects reported to be right leg dominant and thirteen subjects reported to be left leg dominant. The dominant leg was defined as the leg that the subject would choose to kick a ball, making the non-dominant leg the stance leg during the kick (Wojtys et al., 1996). The non-dominant leg was chosen as the treatment leg in this study. None of the subjects had a lower extremity injury during the past year, nor did any subject report a history of ankle instability as indicated by a history of frequency ankle sprains. Individuals were who forefoot strikers were also excluded from the study.

Procedures

Data collection took place in the Biodynamics Laboratory in the Wenner-Gren Center for Biomedical Engineering on the campus of the University of Kentucky. After the subject's arrival in the laboratory, the experimental procedures were explained, and a university-approved informed consent was signed. The subject's height and weight were obtained using a calibrated stadiometer and scale (Continental Scale Corp., Chicago, IL). The subject's standing subtalar joint angle was obtained according to the method by Palmer and Eppler (1998). The mean standing subtalar position was 1.69±4.88° of rearfoot eversion. Each subject warmed up by walking at a self-selected pace on a treadmill for five to ten minutes. The subject was then instructed to perform several moderate stretches such as would be done prior to participation in an athletic event.

In order to analyze body movements, spherical retroreflective markers were placed on anatomical landmarks on the subject's lower leg and foot on their non-dominant limb (Figure 1). Markers were placed on the medial and lateral knee joint lines, and medial and lateral malleoli. A rigid triad of markers was placed on the lateral shank to define the lower leg. Markers placed on the head of the third metatarsal and medial and lateral aspects of the heel defined the foot segment. The markers were attached to the subject using Red Dot adhesive electrodes (3M Corporation, St. Paul, Minnesota). Joint movement data were collected with a 6-camera motion analysis system (Motion Analysis Inc., Santa Rosa, CA) sampling at 120 Hz. The video system accuracy was within ± 0.5º. Because it was not possible to have each subject wear identical footwear and because footwear can greatly affect movement of the ankle and subtalar joint during running, subjects were barefoot during data collection.

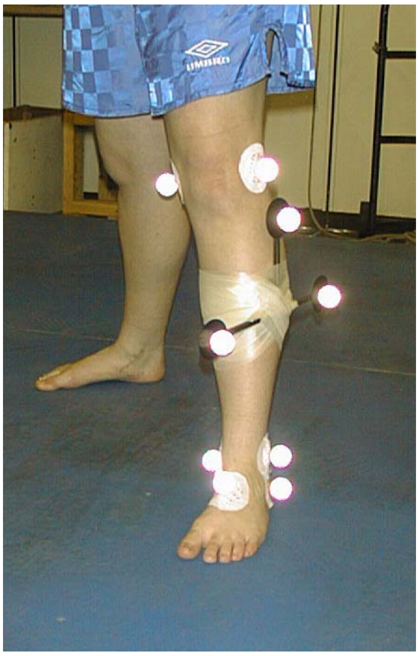

Figure 1. Marker placement. Please note that the marker on the medial heel is not shown in this figure.

In order to obtain a biomechanical model of the leg and foot, a static trial was collected with the subject standing in their relaxed upright stance position. The top of the lower leg was defined as the point midway between the medial and lateral knee markers. The point midway between the malleoli markers was defined as the center of rotation for the ankle and subtalar joints. In other words, flexion and extension, inversion and eversion, and internal and external rotation all occurred around a point midway between the malleoli markers. After the static trial was collected, the knee joint and malleoli markers were removed from the subject.

Subjects were instructed to run straight forward until their non-dominant leg struck a Kistler force plate (Winterthur, Switzerland) and then cut 45º medially toward a target located on their dominant side (Neptune et al., 1999). In order to ensure that the subject performed a sidestep cut of 45º, a line of masking tape was placed on the laboratory floor to act as a guide. Subjects were instructed to perform the above maneuver as quickly as possible. However, as timing lights were not used, we were unable to control for running speed. Subjects were given as many practice runs as they felt necessary to become comfortable with the maneuver.

Seven pre-treatment trials were collected. An investigator of the study watched each trial closely to make certain that the subject performed a sidestep cut of 45º without any visible alteration in gait mechanics, such as targeting the force plate. Subjects then underwent the cryotherapy treatment, which consisted of having a bag of ice placed on the medial and lateral aspects of their non-dominant ankle for a period of 10 minutes. During the icing treatment, the retroreflective markers on the medial and lateral heel were removed from the subject. However, the cloth adhesive backing remained on the subject in order for the two heel markers to be placed at the same locations again after the icing. Seven post-treatment trials were collected immediately after icing. All data collection was completed by five minutes after the icing treatment.

Data Analysis

The three dimensional video data were processed and analyzed using Eva 6.0 and Kin-Trak 6.2 motion analysis software (Motion Analysis, Inc., Santa Rosa, CA). Coordinate data were smoothed using a fourth order Butterworth low-pass filter with a cutoff frequency of 6 Hz. Euler angles of the foot with respect to the shank were calculated using the following order of rotations: plantarflexion/ dorsiflexion, internal/external rotation, inversion/ eversion. Maximum sagittal, frontal, and transverse plane displacements and velocities were calculated.

The data obtained from the force plate were used to define the stance phase of the running cycle. Video data were collected for 3 seconds during each trial. Video data were compared against the force data to determine the video frame numbers in which foot contact and toe off occurred. All kinematic data not associated with the stance phase of the running stride were eliminated.

Our dependent variables were sagittal, frontal, and transverse plane displacements and velocities. Our independent variable was condition (i.e. pre and post icing). A repeated measures ANOVA ($\alpha = 0.05$) was performed on each variable using SPSS 10.0 software (Chicago, IL).

RESULTS

Joint displacement was not affected by the icing treatment. The overall amount of displacement in the sagittal, frontal, and transverse planes was not significantly different between the pre and post icing conditions (Table 1). The average amounts of peak plantar flexion and dorsiflexion were 4.1±13.5º and 6.4±14.9º, respectively. Subjects displayed an average peak inversion of 7.5±17.5º, and average peak eversion of 6.2±14.4º. Transverse plane peak displacements were 7.0±30.7º of internal rotation and 1.2±30.8º of external rotation. Ranges of motion for each condition are displayed in Figure 2.

Movement velocity was also not different between the pre and post icing conditions. Sagittal

Table 1. Three dimensional displacement and velocity results for the pre and post icing conditions (n=21). Data are means (± standard deviation).

Variable	Pre-Treatment	Post-Treatment	p-value
	Displacement		
Plantarflexion (°)	6.21 (15.27)	6.56 (14.48)	.880
Dorsiflexion (°)	4.26 (13.76)	4.00 (13.26)	.652
Inversion (°)	6.26 (15.00)	6.07 (13.74)	.878
Eversion (°)	6.48 (17.26)	8.43 (17.67)	.856
External Rotation (°)	9.13 (43.16)	4.90 (18.16)	.487
Internal Rotation (°)	2.16 (43.89)	0.14 (17.68)	.110
	Velocity		
Plantarflexion (°/sec)	153.67 (288.31)	167.32±276.32	.880
Dorsiflexion (°/sec)	142.10 (337.74)	147.61±295.13	.710
Inversion (°/sec)	188.50 (355.08)	220.34±323.59	.214
Eversion (°/sec)	210.29 (323.78)	216.06±295.41	.778
External Rotation (°/sec)	158.29 (224.23)	157.86±203.94	.592
Internal Rotation (°/sec)	169.57 (226.94)	159.90±199.30	.461

plane peak plantar flexion velocity was 144.9±316.4º/sec. Average peak dorsiflexion velocity was 160.5±282.3º/sec. In the frontal plane, peak inversion and eversion velocities were 213.2 ±309.6º/sec and 204.4±339.3º/sec, respectively. The peak internal rotation velocity was 158.1±214.1º/sec, and peak external rotation velocity was 164.7 ±213.1º/sec.

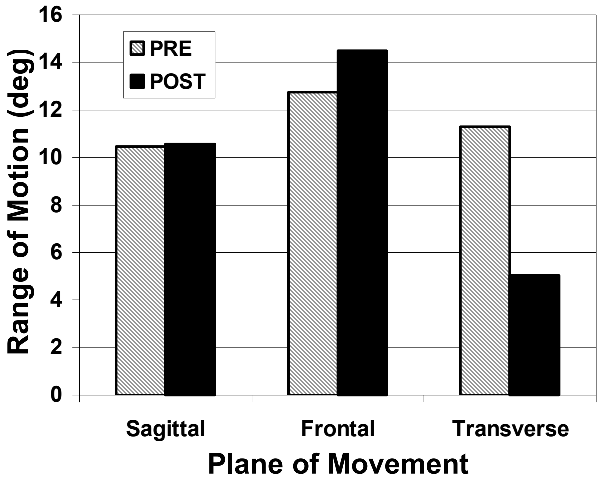

Figure 2. Three-dimensional range of motion (i.e. maximum – minimum displacement) for the pre and post icing conditions.

DISCUSSION

The purpose of this study was to determine the effects of cyrotherapy on ankle/subtalar joint displacement and velocity of a healthy athlete performing a 45º sidestep cut maneuver. The results of this study indicate that a 10-minute icing treatment did not have an effect on either of these parameters.

A post-hoc analysis of the data revealed that the majority of the subjects displayed one of two movement patterns. Six subjects utilized a predominantly sagittal plane movement pattern (Figure 3, Table 2) while eleven subjects displayed a frontal plane pattern (Figure 4, Table 3). The patterns of four subjects were unique to themselves. Because of limitations in statistical power, these patterns may only be discussed qualitatively. These two patterns were not dependent upon whether the subject contacted the ground with the heel or the forefoot as all subjects were rearfoot strikers. Subjects who exhibited a sagittal plane pattern demonstrated 26º of sagittal plane motion during foot contact, whereas their frontal plane range of motion was 17º. Conversely, subjects who demonstrated a frontal plane pattern displayed a 30º of subtalar eversion/inversion range of motion but only 15º of sagittal plane motion.

Only ankle and subtalar joint motions were analyzed in this study. Because we did not place markers on the thigh or pelvis, we are unable to determine hip movement during the sidestep cut. Six of the subjects exhibited a sagittal plane pattern with little motion in the frontal plane. We believe that these subjects may have externally rotated at the hip in order to propel themselves 45º in a medial direction. However, we are unable to prove this because that data that would do so were not collected.

Subtalar/ankle joint complex kinematics have been reported in several previous studies (Stacoff et al., 1996; Neptune et al., 1999; Simpson et al., 1999). The 17° frontal plane range of motion of subjects the sagittal plane group in our study is similar to that of the barefoot subjects of Stacoff et al. (1996). In that study, however, the maximum

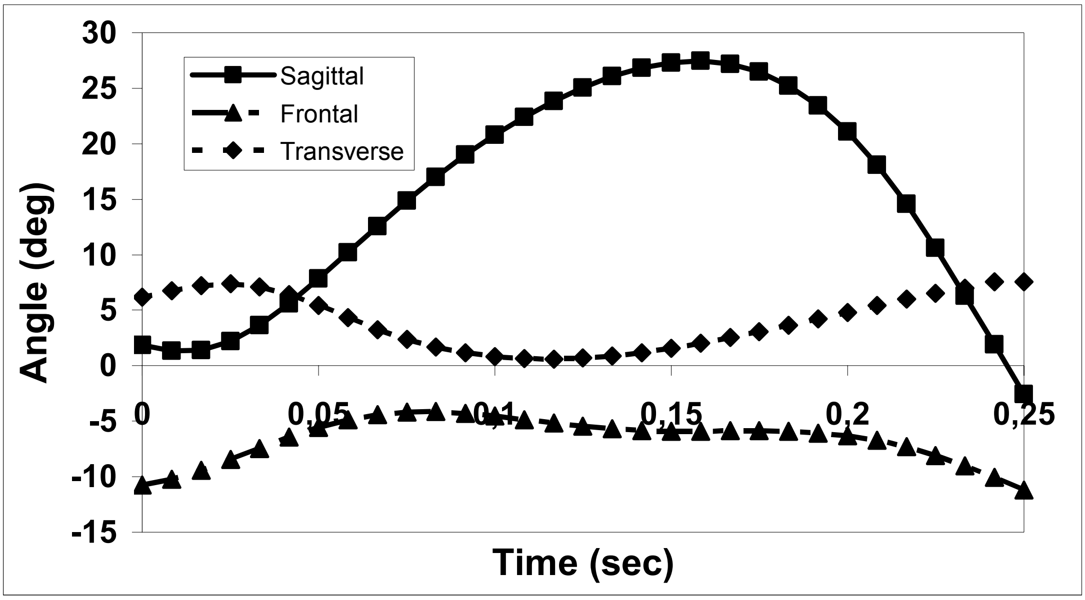

Figure 3. The sagittal plane movement pattern displayed by six subjects. This diagram is representative data of a single subject. The positive direction depicts dorsiflexion, inversion, and internal rotation.

inversion angle was as much as 30º if shoes were worn (Stacoff et al., 1996). Unfortunately, because sagittal plane data were not reported in that study, comparisons of plantar flexion and dorsiflexion cannot be made with our study. The subjects of Neptune, Wright, and van den Bogert (1999) appeared to exhibit a sagittal plane movement pattern. In that study, the plantarflexion/dorsiflexion range of motion was approximately 35°, but minimal inversion/eversion displacement was detected. It is not stated in that article what type of footwear, if any, was worn by the subjects. Neither of these studies have indicated that more than one movement pattern existed amongst their subjects.

In a study by Simpson and colleagues (1999), subjects contacted the ground in a neutral sagittal plane angle and in 15° of inversion. They reached a maximum 35° of dorsiflexion and inversion. A maximum of 5º of plantar flexion was achieved just after heel strike and at toe off, resulting in a 40° sagittal plane range of motion. The range of motion of the subjects in our sagittal plane group was 26°. Our subjects, regardless of whether they used a sagittal plane or frontal plane pattern, displayed much less range of motion than these subjects (Simpson et al., 1999). The peak inversion velocity of the subjects in our study is similar to that reported

Table 2. Three dimensional displacement and velocity results for the pre and post icing conditions for subjects (n=6) with a predominantly sagittal plane movement pattern. Data are means (± standard deviation).

Variable	Pre-Treatment	Post-Treatment
	Displacement	
Plantarflexion (°)	19.25 (8.01)	18.59 (8.70)
Dorsiflexion (°)	7.23 (12.90)	7.18 (12.10)
Inversion (°)	0.45 (6.01)	0.66 (6.46)
Eversion (°)	17.00 (7.78)	18.28 (9.83)
External Rotation (°)	4.86 (3.45)	6.29 (4.22)
Internal Rotation (°)	3.83 (3.13)	2.18 (2.92)
	Velocity	
Plantarflexion (°/sec)	345.68 (183.26)	364.80 (165.43)
Dorsiflexion (°/sec)	351.16 (161.08)	352.83 (146.66)
Inversion (°/sec)	336.78 (175.48)	338.81 (178.79)
Eversion (°/sec)	316.10 (104.53)	296.83 (92.07)
External Rotation (°/sec)	253.90 (130.19)	235.70 (114.17)
Internal Rotation (°/sec)	248.80 (129.60)	200.45 (117.89)

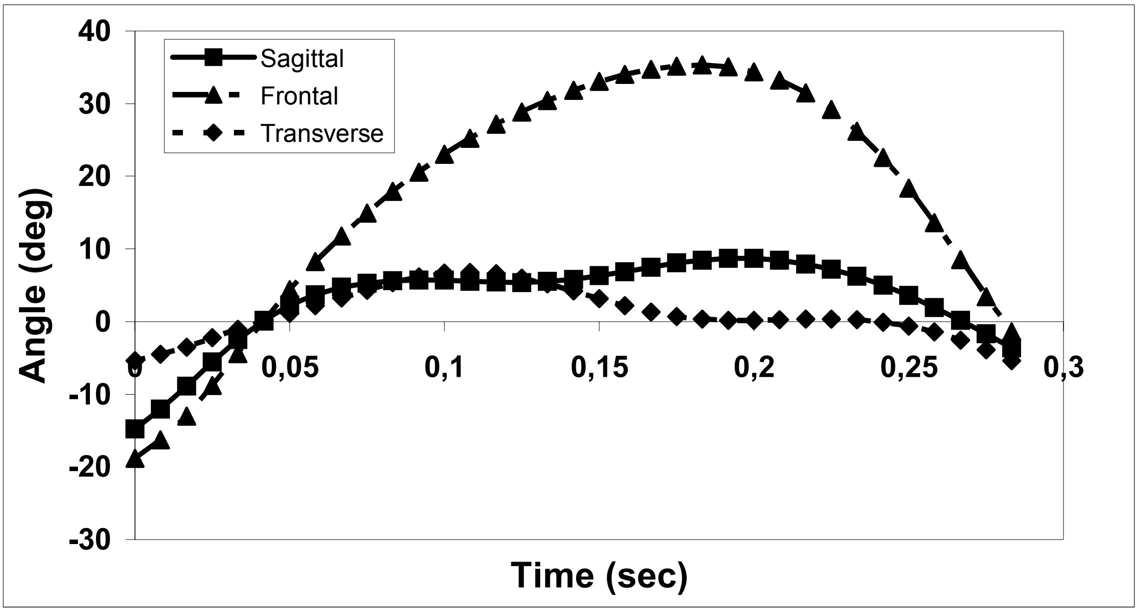

Figure 4. The frontal plane movement pattern displayed by eleven subjects. This diagram is representative data of a single subject. The positive direction depicts dorsiflexion, inversion, and internal rotation.

by Simpson et al. (Simpson et al., 1999).

There may have been several reasons as to why the icing therapy had minimal or no effect on the ankle joint movement in our study. The ten-minute icing period of the current study may not have been enough time to cool the joint area, resulting in minimal muscle cooling and slowing of the nerve impulses. Therefore, ankle motion would not be affected. We feel that the ten-minute period of the icing treatment was an appropriate intervention because during halftime of athletic events, ten minutes is considered a standard treatment time. Although the use of ice bags may not have provided enough cooling to provoke neuromuscular decrements, we selected this technique because it is a commonly used method used to treat ankle injuries during halftime of sporting events. An ice bath or boot may have been more effective in cooling the ankle joint. A greater amount of tissue cooling may be related to increased ankle instability (Denys, 1991).

Our research suggests that the standard ten-minute icing treatment method used during halftime is not related to ankle instability because no negative effects on ankle or subtalar joint movement patterns were noted. Our findings are consistent with those of other researchers who found that neither nerve conduction velocity nor joint position sense were affected by a fifteen minute ice therapy session (Halar et al., 1980; Hopper et al., 1997).

Table 3. Three dimensional displacement and velocity results for the pre and post icing conditions for subjects (n=11) with a predominantly frontal plane movement pattern. Data are means (± standard deviation).

Variable	Pre-Treatment	Post-Treatment
	Displacement	
Plantarflexion (°)	6.63 (8.80)	8.14 (9.55)
Dorsiflexion (°)	8.82 (10.11)	7.05 (10.52)
Eversion (°)	9.98 (10.63)	12.12 (9.07)
Inversion (°)	19.68 (10.10)	18.13 (7.23)
External Rotation (°)	4.94 (2.29)	5.79 (3.44)
Internal Rotation (°)	0.13 (61.60)	0.08 (25.18)
	Velocity	
Plantarflexion (°/sec)	203.66 (182.23)	211.71 (107.69)
Dorsiflexion (°/sec)	230.56 (120.55)	230.13 (105.29)
Eversion (°/sec)	396.24 (183.75)	390.60 (124.01)
Inversion (°/sec)	349.28 (237.23)	368.95 (157.53)
External Rotation (°/sec)	248.83 (175.01)	258.83 (141.50)
Internal Rotation (°/sec)	258.08 (221.76)	264.17 (171.40)

We did not measure the cutaneous or subcutaneous temperature of the shank and foot. We are therefore unable to quantify the precise amount of tissue cooling and were unable to find the critical temperature where intramuscular cooling began. We are only able to state that the effects of the cryotherapy are similar to the effects that would occur during a halftime, but cannot correlate the amount of change of joint motion to the amount of tissue cooling.

The subjects did not wear shoes during the testing because we did not want the various amounts of rearfoot control provided by different types of athletic footwear to influence the subject's gait. Because of budgetary constraints, we were not able to provide a single type of footwear for use by all participants. In order to maintain consistency of footwear, we required each subject to perform the sidestep cut while barefoot. The subtalar/ankle joint kinematics may have been altered because of this barefoot condition.

In the future, more extensive research should be done to investigate the effects of cryotherapy on lower extremity movement during sidestep cutting. Future studies should quantify the amount of tissue cooling, as well as any change in cutaneous sensation and joint proprioception. Further research should also be conducted to determine if longer cooling periods have a greater effect on ankle instability, muscle contractions and nerve conduction velocity. Because this study did not include EMG, future research should be conducted to explore muscle activity during a sidestep cutting maneuver during the pre and post stages of ice therapy. This will help researchers understand specific muscle twitch and contraction and relaxation phase changes.

CONCLUSIONS

Due to the current research findings, it is concluded that athletic trainers and team doctors should continue the use of cryotherapy as a method of treatment for ankle injuries during half time.

REFERENCES

Denys, E.H. (1991) The influence of temperature in clinical neurophysiology. *Muscle and Nerve* **14**, 795-811.

Halar, E. M., DeLisa, J. A. and Brozovich, F.V. (1980) Nerve conduction velocity: relationship of skin, subcutaneous and intramuscular temperatures. *Archives of Physical Medicine and Rehabilitation* **61**, 199-203.

Hopper, D., Whittington, D. J., Davies, J. and Chartier, J. D. (1997) Does immersion influence ankle joint position? *Physiotherapy Residents Internationsl* **2**, 223-236.

Lephart, S.M., Pincivero, D.M., Giraldo, J.L. and Fu, F.H. (1997) The role of proprioception in the management and rehabilitation of athletic injuries. *American Journal of Sports Medicine* **25**, 130-137.

Lephart, S.M., Pincivero, D.M. and Rozzi, S.L. (1998) Proprioception of the ankle and knee. *Sports Medicine* **25**, 149-155.

McLean, S.G., Neal, R.J., Myers, P.T. and Walters, M.R. (1999) Knee joint kinematics during the sidestep cutting maneuver: potential for injury in women. *Medicine and Science in Sports and Exercise* **31**, 959-968.

Meeusen, R. and Lievens, P. (1986) The use of cryotherapy in sport injuries. *Sports Medicine* **3**, 398-414.

NCAA, (1991). NCAA Injury Surveillance System. 6201 College Boulevard, Overland Park, KS, National Collegiate Athletic Association.

Neptune, R.R., Wright, I.C.,and van den Bogert, A. (1999) Muscle coordination and function during cutting movements. *Medicine and Science in Sports and Exercise* **31**, 294-302.

Palmer, M. L. and Epler, M. E. (1998). Chapter 14: Foot and ankle. In: *Fundamentals of musculoskeletal assessment techniques.* Philadelphia, PA, Lippincott, Williams, and Wilkins. 341-373.

Schieppati, M. and Nardone, A. (1997) Medium latency stretch reflexes of foot and leg muscles analyzed by cooling the lower limb in standing humans. *Journal of Physiology* **503**, 691-698.

Simpson, K., J., Sravens, S., Higbie, E., Theodorou, C. and DelRey, P. (1999) A comparison of the Sport Stirrup, Malleoloc, and Swede-O ankle orthoses for the foot-ankle kinematics of a rapid lateral movement. *International Journal of Sports Medicine* **20**, 396-402.

Stacoff, A., Steger, J., Stussi, E. and Reinschmidt, C. (1996) Lateral stability in sideward cutting movements. *Medicine and Science in Sports and Exercise* **28**, 350-358.

Swenson, C., Sward, L. and Karlsson, J. (1996) Cryotherapy in sports medicine. *Scandinavian Journal of Medicine and Science in Sports* **6,** 193-200.

Wojtys, E.M., Huston, L.J., Taylor, P.D. and Bastian, S.D. (1996) Neuromuscular adaptation in isokinetic, isotonic, and agility training programs. *American Journal of Sports Medicine* **24**, 187-188.

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KEY POINTS

- Cryotherapy does not affect ankle/subtalar joint movement.
- Subjects utilize two different landing patterns: sagittal plane or frontal plane dominant.

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