ELEVATION: RETARDING EDEMA FORMATION IN THE ACUTE LATERAL ANKLE SPRAIN

Jason Hageman

Advisor: Dr. Merrick

PROBLEM STATEMENT

Acute musculoskeletal injuries are typically managed using the combination of ice, compression, and elevation. There is reasonable body of research describing the effects of ice and a smaller body describing compression, however there is very little research describing the role of elevation. Elevation is typically used in an attempt to retard edema formation. However, the effects of elevation in retarding edema formation following acute phase injury are non-existent. In fact, the small body of research describing the effects of elevation on edema have largely used non-injured subjects. It is unclear whether elevation plays any important role in acute injury management. This has international importance due to the widespread and common use of elevation in the acute management of lateral ankle sprains.

RELATED RESEARCH

Introduction

Therapeutic modalities are used in managing injuries in order to achieve a specific set of clinical goals. Limiting the total quantity of tissue damage associated with the injury is one of the most important goals of using therapeutic modalities.[1,2] The quantity of tissue damaged partly affects the time needed for tissues to heal. So, a quicker repair and faster return to activity would be possible when a smaller amount of damaged tissue exists.[3]

Primary and Secondary Injury

The immediate tissue damage associated with an injury is known as primary injury.[1,2,4,5,6] Primary injury occurs immediately with the trauma and may involve disruption of a variety of structures such as ligamentous, tendinous, muscular, vascular, nervous, and bony tissues. Immobilizing the injured area to prevent further tearing of partially torn tissues is the only means of limiting the amount and severity of this primary tissue damage.[3] Furthermore, the primary injury causes a pathophysiological response that can lead to secondary injury, which is damage to originally uninjured tissues.[1,2,4,5,6] One of the leading causes of secondary injury is ischemia, which is the interruption of bloodflow due to trauma to the vascular tissues that supplies the otherwise uninjured tissues. Secondary injury, unlike primary injury, may be limited by the use of therapeutic modalities and other acute interventions. This results in a decreased amount of time required to repair the tissue damage and a faster return to activity.[3]

The acute use of therapeutic modalities can limit the magnitude of the sequelae of the inflammatory response. The five signs of inflammation- redness, warmth, pain, edema, and loss of function- can be expected to occur to some extent since every injury to perfused tissue results in acute inflammation.[3,7] Return to function and activity can occur sooner when these signs of inflammation, especially the pain and edema, are limited.[3]

Cryotherapy

The acronym R.I.C.E., which refers to Rest, Ice, Compression, and Elevation, describes the treatments for the traditional management of acute injuries.[8,9,10] The most commonly used and probably the most effective therapeutic modality for managing acute musculoskeletal injuries is the therapeutic application of cold, or cryotherapy.[4,5,6] Cryotherapy often involves using an ice bag, however, in clinical practice, there are many forms of cold that may be utilized such as ice massage, cold-water immersion, and frozen gel packs. From a scientific perspective, the most understood modality, yet still very limited, is cryotherapy.[3]

The therapeutic use of cold produces many physiological effects. Cryotherapy is commonly accepted as the standard treatment in the management of acute injuries in order to inhibit inflammation.[4,5,6] However, inflammation is a complex set of events that only becomes more complex when looking at the specific effects of cold on inflammation.[3] Inflammation can be described by its vascular events, chemical events, and cellular events since acute cryotherapy affects all three of these.[6,8,9,10] Vasoconstriction due to cold therapy counteracts the vascular events of inflammation, specifically vasodilation. Cryotherapy also affects the release of over 100 chemicals that mediate the inflammatory process through the chemical events of inflammation. Despite the effects of cold not being researched for most of these inflammatory chemicals, the release or activity of several of the key inflammatory chemicals is known to be inhibited as a result of cryotherapy.[3] The cellular events of inflammation involve the early activity of neutrophils that gradually over several hours allow the activity of macrophages to take over.[7,11] The activities of all of these cells are decreased by a cold-induced reduction in metabolism. In the early phases of inflammation, this is thought to be beneficial when neutrophils are the majority but less useful later on when the macrophages are actively cleaning up inflammatory debris in preparation for tissue repair. Neutrophils primarily function to fight a bacterial infection by phagocitizing the bacteria and releasing a variety of damaging chemicals which kill additional bacteria. Additionally, neutrophils magnify the immune response by releasing an variety of chemical messengers. Since open wounds and infection mostly do not occur with musculoskeletal athletic injuries, the activity of neutrophils with these injuries is generally greater than is necessary and can lead to unnecessary secondary damage to otherwise uninjured tissues.[2,12]

Cryotherapy also plays a significant physiological role due to its ability to retard the formation of edema/effusion by its primary effect on Starling forces.[5,6,13] These Starling forces, also referred to as capillary filtration forces, control the movement of plasma through the walls of the capillaries from the vascular system into the extravascular space. In normal homeostatic conditions, there is a small amount of fluid that is constantly escaping the capillaries and being collected by the lymphatic system. The three forces that cause fluid to migrate from the capillary into the extravascular space are the capillary hydrostatic, tissue hydrostatic, and tissue osmotic. The opposing force, capillary osmotic force, resists the extravascular movement of fluid.[7,11] A slight imbalance in the Starling forces indicates the "out" forces causing fluid loss from the capillary are slightly larger than the "in" forces which results in an overall loss of fluid from the vascular system.[3]

Following an injury, the tissue osmotic pressure, one of the outward forces, is thought to increase significantly because of the release of free proteins and other molecules from the damaged tissue and into the interstitial space. The balance of forces would shift further in the direction of fluid loss and result in edema formation. In injured tissue, there are two forces causing fluid to escape from the capillaries and two forces attempting to retain fluid in the capillaries. There is a dramatic increase in the outward forces since the plasma osmotic pressure decreases and the interstitial osmotic pressure increases. These changes in pressures are the result of the loss of plasma proteins into the surrounding tissues and damaged cells releasing free-proteins. The increase in the tissue osmotic pressure can be limited by using cryotherapy to reduce the quantity of tissue damaged and thereby hinder the release of free proteins. Using cryotherapy to decrease bloodflow by causing vasoconstriction will result in a decrease in the other escape force, capillary hydrostatic pressure. The formation of edema is decreased, but not entirely stopped, when both escape forces are reduced.[3]

Compression

Compression, the application of external pressure, is often used concurrently with cryotherapy but also has usefulness on its own. Compression involves applying an external pressure to an injured area in either a circumferential or focal manner. The application of circumferential compression involves using an elasticized bandage, elastic tape, or another compression device.[14] Focal compression can be applied by using a foam pad to apply pressure to a specific area.

Several physiologic effects of using compression can be used to explain its effectiveness. Compression is valuable in managing acute injuries in the following three primary ways.[6] First, compression enhances the cooling efficiency of cryotherapy.[15,16] The next two mechanisms for compression involve resisting the formation of edema by altering the Starling forces and by decreasing the bleeding from vessels damaged during the injury.[13,17]

Starling forces, the forces governing transcapillary fluid movement, are often used to describe the effects of compression on retarding the formation of edema.[6, 7,11] Reducing the magnitude of the edema-promoting pressure gradient by using external compression is thought to cause an increase in the tissue hydrostatic pressure. By decreasing this gradient, the fluid loss from the vascular system would diminish and therefore retard the formation of edema. Even with the use of external compression, some edema can be expected to form.[3]

Following an injury, the plasma fluid and protein that leaks through the intact capillary walls are not the only components of edema or effusion. Blood vessels damaged in the injury can lose blood to the interstitial space where it accumulates as a significant portion of the edema or effusion. The effective management of this blood loss is to the use of compression for several reasons. First, compression decreases bloodflow which limits the volume of blood that is available to leave the damaged vessels. Secondly, compression slows the rate of bloodflow which allows for quicker development of the fibrin scaffolding that eventually forms a clot to stop the blood loss.[7,11]

Elevation

The last part of R.IC.E., elevation, also is the least studied in the group of ice, compression, and elevation. However, it is widely used in the management of acute injuries. Elevation involves placing the injured body part above the rest of the body by any one of a variety of means. This may involve using specially designed treatment tables; propping ones injured area up against a wall; or placing a solid object, like an equipment bag, under the injured body part.[3]

It is presumed that elevation will limit the amount of blood delivered to the injured area due to the effects of gravity. This decreased bloodflow to the acutely injured area is thought to have three benefits. First, it would limit the formation of a hematoma and edema by assisting in controlling the bleeding from damaged vessels. Secondly, capillary hydrostatic pressure, one of the main forces causing fluid to move into the extravascular space from a vessel, would decrease. Thus, the transcapillary Starling forces in the injured area would change and aid in retarding edema formation. Also, the reduced bloodflow and reduced capillary hydrostatic pressure would limit the amount of neutrophils that are transported to the injured area. Since neutrophils are the most abundant leukocyte and important in the early intensification of the inflammatory process, they are probably responsible for causing secondary injury. The amount of tissue damage and inflammation that would have to be resolved before repair could take place could be reduced by limiting the amount of neutrophils and other pro-inflammatory agents that are transported to the injured area.[3]

Conclusion

Ankle sprains are one of the most common musculoskeletal injuries among athletes. One million people are estimated to report to emergency rooms, acute care clinics, physicians' offices, and sports medicine clinics each year for the treatment of acute ankle injuries. In the acute management of an ankle sprain, it is common practice to apply the principles of RICE: rest, ice, compression, and elevation.[18,19] Sometimes the acronym is modified to PRICE to include protection of the injured body part.[20] To control pain and edema in the acute phase, the widely accepted treatments are ice, compression, and elevation.[21] However, there is a lack of evidence indicating the effectiveness of elevation in retarding the formation of edema in the acute phase following a lateral ankle sprain.

Several investigators have studied the effects of elevation in reducing the volumetric measurement of an ankle. Sims[22] demonstrated that elevation of the uninjured leg resulted in a decreased ankle volume, whereas, an increase in ankle volume was observed in the seated patient. McCulloch et al[23] determined that ankle volume in the uninjured ankle decreased while in a supine position and increased when in a gravity-dependent position. Tsang et al[24] measured the change in ankle volume due to one elevation treatment in the postacute ankle sprain. They found that the volume of the ankle decreased but the effects lasted less than five minutes once the ankle was placed into a gravity-dependent position. None of the above studies examined injured ankles in the acute phase and therefore it is unclear whether these findings apply to injured patients. Because there is no data describing the efficacy of the elevation part of typical acute injury management, practitioners are forced to use this treatment based on the hope of benefit when it may not be useful at all.

Therefore, the purpose of this study is to determine the effects of elevation in retarding the formation of edema in the acute phase following a lateral ankle sprain.

OBJECTIVES

In this study we will attempt to determine whether elevation of sprained ankles immediately following injury is useful in retarding edema formation. In this limited clinical trial, we will specifically compare edema between injured ankles treated the conventional way (ice, compression, elevation) to those treated without elevation (i.e. ice + compression only). We hypothesize that the amount of edema formation will be similar in both the control group and experimental group. That is, we hypothesize that elevation will not cause a statistically significant reduction in edema formation in the acute phase following a lateral ankle sprain.

METHODS

Subjects

Subjects will include both male and female varsity athletes from The Ohio State University who have sustained a lateral ankle sprain within the past hour that will result in a loss of participation time. All subjects will provide written informed consent prior to treatment and the procedures to be used will be approved by the Biomedical Sciences IRB prior to subject enrollment.

Because there are no direct clinical data upon which to base a power estimate, we have used effect sizes from the Tsang et al study and the McCulloch study to aid in our predictions.[23,24] Using this data in an *a priori* power estimate, we expect to need approximately 20 subjects (10 per group) to identify treatment v. no-treatment differences with power of 0.80.

Because this study is being conducted during a single year and injury rates vary, it is possible that we may not be able to collect enough data to have adequate statistical power. Nonetheless, this data is important and may form the beginning of an on-going study that may be built upon by future students.

Inclusion

Patients who sustain an ankle injury will be evaluated by the certified athletic trainer (ATC) from the Department of Athletics at Ohio State in the normal manner. As part of a normal ankle evaluation, a cloth tape-measure will be used to obtain a baseline figure of eight measurement according to the guidelines by Esterson.[25] The figure of eight method involves wrapping the tape measure around the proximal foot and talocrural joint while the foot maintains a neutral dorsiflexion position. Petersen and Tatro-Adams determined the figure of eight method to be highly reliable (ICC [Interclass correlation coefficient] = .98-.99) for both intrarater and interrater reliability.[26,27] Patients with a lateral ankle sprain that meet all of the inclusion criteria and none of the exclusion criteria will be given the opportunity to join the study. The inclusion criteria are the following: lateral ankle sprain; injury will result in a loss of time from activity; pain upon palpation of anterior talofibular ligament; and a positive anterior drawer. The patient will be excluded from the study if one or more of the following conditions exist: injury includes a fracture or dislocation; the injury requires surgery; cold hypersensitivity; compromised local circulation; Raynaud's or other vasospastic disease; cardiac or respiratory involvement; circulatory insufficiency; anesthetic skin; advanced diabetes; peripheral vascular disease; lupus; gangrene; insufficient blood pressure; deep vein thrombosis; history of lymphatic disorders; and peripheral nerve injury to injured ankle.

Assignment & Procedure

Once patients read and sign an informed consent form, they will be randomly assigned into one of two groups as determined by the toss of a coin. Blinding is not possible in this study. The control group will consist of the standard treatment protocol involving an ice bag, compression, and elevation. Elevation treatment will consist of elevating the injured ankle during treatments of ice so that an angle of forty-five degrees or more is created from parallel to the table.[28] Furthermore, subjects in the control group will be instructed to elevate the injured ankle as much as possible during the seventy-two hours post injury. The experimental treatment will consist of the same treatment protocol with the exception of elevation. Subjects in the experimental group will be instructed to remain supine with legs parallel to table during treatments with ice and to not elevate the injured ankle above parallel to table while at home. Treatment will be initiated immediately according to the above protocols and continued for the seventy-two hours following injury.

Measurements

For all subjects, figure of eight measurements will be repeated at twenty-four, forty-eight, and seventy-two hours post injury. At all times during the study, the ATC will exercise professional judgment in determining if the subject may benefit more from a different form of cryotherapy or some other treatment option. Data analysis of the treatment provided to each subject will exclude any subject that received at least one of the following treatments within the seventy-two hours post injury: injection of medication; electrical stimulation; ultrasound; any warm modalities; or any form of cryotherapy besides an ice bag

Analysis

Figure eight measurement data will be analyzed using an independent t-test to determine if between group differences exist. Further, effect sizes and confidence intervals will be calculated to aid in determining if any treatment differences are clinically meaningful.

FACILITIES AND/OR RESOURCES AND EQUIPMENT NEEDED

Certified athletic trainers working for the Department of Athletics at The Ohio State University will assist in data collection that will occur within various athletic training rooms at The Ohio State University. Since the subjects would be receiving similar treatment if they were not in the study, supplies already located in the athletic training rooms will be used to care for the subjects. This includes, but is not limited to, the use of treatment tables, ice bags, elastic compression wraps, and ice from an ice machine. Additionally, Dr. Merrick will provide statistical support for the analysis of the data.

RESULTS

Since obtaining IRB approval, there have been no injuries that met the inclusion criteria or were brought to the attention of investigators despite a potential subject pool of nearly 1100 Ohio State University varsity student-athletes.

DISCUSSION

Factors Contributing to Inability to Collect Data

This research study is an evidence-based clinical trial that attempted to determine the efficacy of elevation in retarding edema formation in the acute lateral ankle sprain. We have identified four main explanations for our lack of qualifying incidence of injury: specific population, short time period, rigorous inclusion criteria of injury, and possible cultural hesitance of practitioners to enroll their patients.

First, we were limited to a specific subject pool that included approximately 1100 male and female student-athletes competing on over thirty varsity athletic teams at The Ohio State University. We limited our population in order to ensure that subjects in each group would be similar in comparison. Our population included athletes of similar ages in the competitive environment of Division One Collegiate Athletics.

Second, this clinical research trial was conducted over a very short period of time in comparison to many clinical trials that last several years. Due to the varying rates of injury, there are times of increased, decreased, and average occurrences of injuries. We were unfortunate to be conducting this study at a time when there was a less than normal occurrence of lateral ankle sprains. It is nearly impossible to recruit enough subjects with lateral ankle sprains when there were very few lateral ankle sprains reported by athletes and that occurred. A clinical trial conducted over a longer period of time, such as several years, would likely yield enough subjects and data.

Third, the rigor of our inclusion criteria of injury may have excluded possible subjects. Our rigorous inclusion criteria were used to limit the amount of extraneous variables that could contribute to alternative explanations for the results of our data. Possible subjects were excluded before enrollment in the study due to a previous history of a lateral ankle sprain, a sprain with concurrent fracture, and the athlete reporting the injury to the athletic trainer at more than two hours past the time of injury. However, we believe that the inclusion criteria are necessary as a means of excluding minor ankle sprains with little if any edema formation and for severe ankle injuries with excessive edema formation. Our inclusion criteria serve as a control in order to limit the variability in the severity of lateral ankle sprains and to account for the differences in the physiological responses of individuals to injury.

Lastly, cultural hesitance of athletic trainers to enroll their patients in the clinical trial may have been contributed to the lack of subjects. Two possible explanations have been identified. The first explanation is that the clinical trial is a time commitment and hassle for the athletic trainer. Some lateral ankle sprains occurred at inopportune times for the athletic trainer, and thus, subject recruitment and data collection became too difficult to accomplish. Two specific problematical times were home and away competitions. This is likely due to the importance the athletic trainer places on other necessary tasks that need to be completed at these critical times during and immediately following a competition. The athletic trainer does not appear to highly value the need for determining the effectiveness of athletic training services and for conducting clinical research that would guide clinical practice in the future.

The second explanation is that the athletic trainer perceives the need to treat injuries by all means available in order to return the patient to competition as soon as possible. This occurs despite the lack of evidence on the effectiveness of these treatments. Athletic trainers believe in the importance of elevation as a treatment in the acute phase of an injury and are reluctant to randomly assign any patient to the non-elevation group for fear of delaying the patient's return to activity. There is an increased reluctance on the part of the athletic trainer when the patient is a starting athlete or one of the better athletes on the team due to the possibility of the clinical research negatively impacting team performance.

<u>Clinical Research Philosophy in Athletic Training</u>

Evidence-based medicine has philosophical roots going back into the middle of the 19th century in Paris and earlier.[29] However, in 1992 the term "Evidence-based Medicine" or EBM was coined[30] to represent the "conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients."[29] The main goal of EBM is to improve the quality of health care delivered to our patients by integrating individual clinical expertise with the best available research evidence.[29,31,32] The best available research evidence involves current clinically relevant research derived from both basic sciences and patient-centered clinical research.[29,32] In EBM, scientific data is held to rigorous standards and evaluated on the basis of merit and applicability.[29] Meta-analyses, systemic reviews, and randomized controlled trials are the hallmark of EBM.[30,31,33] Individual clinical expertise, such as proficiency and judgment, is developed through a clinician's clinical experiences and practice.[29,32]

Many medical journals have incorporated special sections about EBM and clinical research into their journals. The first such journal, *ACP Journal Club*, began publication in 1991 by the American College of Physicians. In 1995 the journal *Evidence-Based Medicine* began as a joint venture between the American College of Physicians and the British Medical Journal Publications Group. Both of these journals published synopses of comprehensive reviews that were published in other journals.[31,32] Other journals such as *Physical Therapy* have provided sections of systemic reviews in selected issues for more than five years and have had a regularly-occurring section entitled "Evidence in Practice" for the past four years. As for the *Journal of Athletic Training*, a new section called "Evidence-Based Practice" was begun in 2004 in order to answer clinically relevant questions with a summary of published research and a succinct commentary. Additionally, articles on topics related to EBM will be included in future issues.[34] Other allied health professions have integrated EBM into journals sooner than athletic training and thus have a larger resource of clinical research to serve as scientific evidence on the effectiveness of treatments and interventions within their fields. Conversely, athletic training has recently begun including EBM into journals but still lags behind other allied health professionals in publishing evidence on the effectiveness of treatments and interventions used in clinical practice.[31,35] The athletic training profession will gain more support scientifically by demonstrating the efficacy of athletic training methods through an increased focus on clinical research.[31]

An essential component to obtaining financial reimbursement for athletic training services involves providing scientific evidence for the effectiveness of the specific athletic training treatments and interventions. Reimbursement from third-party payers for services provided by athletic trainers may become more difficult without scientific evidence showing that a treatment or intervention is effective.[31] As the amount of money available for health care services decreases and competition for those dollars increases, it is pertinent that athletic trainers be able to demonstrate the value of their services and be fairly compensated. By linking third-party reimbursement with EBM, the athletic trainer is held accountable for services rendered to patients.[36]

The athletic training profession needs to strive to gain professional recognition from other allied health professionals and physicians by embracing the concept of EBM like other health care professions such as physicians and physical therapists have done. Otherwise, we could potentially be regarded as not placing as high a value as other health care professions on evidence of effectiveness and critical thinking. Ultimately, this reputation could affect patients' decisions on who to provide health care services.[31]

Implementing EBM into clinical athletic training practice is a slow, evolving process that ideally should begin in undergraduate athletic training educational programs. However, EBM skills need to be developed through interactive seminars and workshops in current ATCs, especially approved clinical instructors who will be responsible for teaching athletic training students (ATSs).[31] Educators should ensure that undergraduate and graduate athletic training curricula include teaching clinical research skills and methods of practicing EBM. ATSs need to develop the skills necessary to consume, analyze, summarize, and apply research findings so that they may become “capable lifelong learners."[36] These students will be able to use their new research to refine their clinical skills and become better clinicians. The last component of education stresses the importance of athletic trainers in obtaining continuing education throughout their career.[36]

ATCs and ATSs should “learn to seek evidence to support their practice decisions.”[35] Sackett et al proposed the following five steps for integrating EBM into clinical practice: define clinically relevant questions, search for the best evidence, critically appraise the evidence, apply the evidence, and evaluate the performance of EBM.[29,32] Additionally, athletic trainers can be proactive by assisting researchers in conducting athletic training clinical research.

CONCLUSION

This purpose of this study was to determine the effectiveness of elevation in limiting edema formation in the acute phase of a lateral ankle sprain. No student-athletes were enrolled in this study as subjects for various reasons. Investigators identified several factors that contributed to the inability to conduct this clinical trial. The contributing factors included the following: limited potential subject pool; short duration of the study; rigorous inclusion criteria; perceived excessive time commitment by the athletic trainer collecting the data; reluctance of the athletic trainer to not treat an injury by all means available despite a lack of efficacy of the treatment; and the current cultural philosophy regarding clinical research that prevails among many athletic trainers. These factors will need to be taken into consideration when conducting a similar future study that examines the effectiveness of elevation and other clinical trials in the field of athletic training.

Clinical research trials, such as this study, are critical to the development of the athletic training profession and to serve the best interests of the patient. However, the athletic training professions lags behind other allied medical professions in conducting clinical research.[35] Evidence-based medicine will allow the athletic training profession to seek financial reimbursement for athletic training services and will enhance our reputation among other allied medical professions.[31] Despite the difficulty in conducting clinical research trials, it is important that athletic trainers continue to attempt these studies aimed at obtaining valuable clinical evidence on the day-to-day practice of patient care.

---

[1] Knight KL. Effects of hypothermia on inflammation and swelling. *J Athl Train*. 11:7-10, 1976.
[2] Merrick M. Secondary injury after musculoskeletal trauma: a review and update. *J Athl Train*. 37:209-217, 2002.
[3] Merrick MA. Therapeutic Modalities as and Adjunct to Rehabilitation. In Andrews G, Harrelson G, Wilk K, eds. *Physical Rehabilitation of the Injured Athlete,* 3rd ed. Philadelphia: W.B. Saunders; 2003. pp. 51 – 98.
[4] Knight, KL, Brucker JB, Stoneman PD, Rubley MD. Muscle injury management with cryotherapy. *Athletic Therapy Today*. 5:26-30, 32-23, 64, 2000.
[5] Knight, KL. *Cryotherapy : theory, technique, and physiology*. 1st ed. Chattanooga, TN: Chattanooga Corp. Education Division, 1985, ix, 188.
[6] Knight, KL. *Cryotherapy in sport injury management*. Champaign, IL: Human Kinetics, 1995, x, 301.
[7] Majno G, Joris I. *Cells, Tissues, and Disease: Principles of General Pathology*. Cambridge, Massachusetts: Blackwell Scientific, 1996.
[8] Denegar C. *Therapeutic Modalities for Athletic Injuries*. Champaign IL: Human Kinetics, 2000.
[9] Prentice W. *Therapeutic Modalities in Sports Medicine*. 4th ed. Boston: WCB McGraw-Hill, 1999.
[10] Starkey C. *Therapeutic Modalities*. 2nd ed. Philadelphia: F.A. Davis Co., 1999, 397.
[11] Guyton AC. *Textbook of Medical Physiology*. 8th ed. Philadelphia: W.B. Saunders, 1991, 149-203.
[12] Matthews J, Fisher B, Magee D, Knight K. Lipid peroxidation and protein turnover after trauma and cold treatment in skeletal muscle of exercise-trained rats. *Journal of Physical Therapy Science*. 13:21-26, 2001.
[13] Meeusen R, Van der Veen P, Joos E, Roeykens J, Bossuyt A, De Meirleir K. The influence of cold and compression on lymph flow at the ankle. *Clin. J. Sports Med.* 8:266-271, 1998.
[14] Whitelaw G, DeMuth K, Demos H, Schepsis A, Jacques E. The cryo/cuff versus ice and elastic wrap: postoperative care of knee arthroscopy patients... reprinted with permission from The American Journal of Knee Surgery. 1995; 8:28-31. *Today's OR Nurse*. 18:31-34, 1996.
[15] Barlas D, Homan C, Thode HJ. In vivo tissue temperature comparison of cryotherapy with and without external compression. *Annals of Emergency Medicine*. 28:436-439, 1996.
[16] Merrick M, Knight K, Ingersoll C, Potteiger J. The effects of ice and compression wraps on intramuscular temperatures at various depths. *J Athl Train*. 28:236-245, 1993.
[17] Mayrovitz H, Delgado M, Smith J. Compression bandaging effects on lower extremity peripheral and sub-bandage skin blood perfusion. *Wounds: A Compendium of Clinical Research and Practice*. 9:146-152, 1997.
[18] Wilkerson GB, Horn-Kingery HM. Treatment of the inversion ankle sprain: comparison of different modes of compression and cryotherapy. *J Orthop Sports Phys Ther.* 1993; 17:240-246.
[19] Weinstein ML. An ankle protocol for second-degree ankle sprains. *Mil Med.* 1993; 158:771-774.

[20] George FJ. Primary Care of the injured athlete, part 1. *Clin Sports Med.* 1997; 16(3):361-374.
[21] Nowig JA. Edema control and the acutely inverted ankle sprain. *Athletic Therapy Today.* 1997; 40-41.
[22] Sims D. Effects of Positioning on Ankle Edema. *J Orthop Sports Phys Ther.* 1986; 8(1):30-33.
[23] McCulloch J, Boyd VB. The effects of whirlpool and the dependent position on lower extremity volume. *J Orthop Sports Phys Ther.* 1992; 16:169-173.
[24] Tsang KKW, Hertel J, Denegart CR. Volume decreases after elevation and intermittent compression of postacute ankle sprains are negated by gravity-dependent positioning. *J Athl Train.* 2003; 38(4):320-324.
[25] Esterson PS. Measurement of ankle joint swelling using a figure-of-eight. *J Orthop Sports Phys Ther.* 1979; 1(1):51-52.
[26] Petersen EJ, Irish SM, Lyons Cl, et al. Reliability of water volumetry and figure-of-eight method on subjects with ankle joint swelling. *J Orthop Sports Phys Ther.* 1999; 29:609-615.
[27] Tatro-Adams D, McGann SF, Carbone W. Reliability of the figure-of-eight method of ankle measurement. *J Orthop Sports Phys Ther.* 1995; 22:161-163.
[28] Rucinski TJ, Hooker DN, Prentice WE, et al. The effects of intermittent compression on edema in postacute ankle sprains. *J Orthop Sports Phys Ther.* 1991; 14(2):65-69.
[29] Sackett DL, Rosenberg WMC, Gray JAM, Haynes RB, Richardson WS. Evidence based medicine: what it is and what it isn't. *BMJ.* 1996; 312:71-72.
[30] EBM Working Group. Evidence-based medicine. *JAMA* 1992; 268:2420-2425.
[31] Steves R., Hootman JM. Evidence-based medicine: what is it and how does it apply to athletic training? *J Athl Train.* 2004; 39(1):83-87.
[32] Sackett DL, et al. Evidence-based medicine How to practice & teach EBM. New York, NY: Churchill Livingstone, 1997, 1-19.
[33] Kulkarni AV. The challenges of evidence-based medicine: a philosophical perspective. *Medicine, Health Care and Philosophy.* 2005; 8:255-260.
[34] Hootman JM. New section in *JAT*: evidence-based practice. *J Athl Train.* 2004; 39(1):9.
[35] Denegar CR, Hertel J. Clinical education reform and evidence-based clinical practice guidelines. *J Athl Train.* 2002; 37(2):127-128.
[36] Hertel J. Research training for clinicians: the crucial link between evidence-based practice and third-party reimbursement. *J Athl Train.* 2005; 40(2):69-70.