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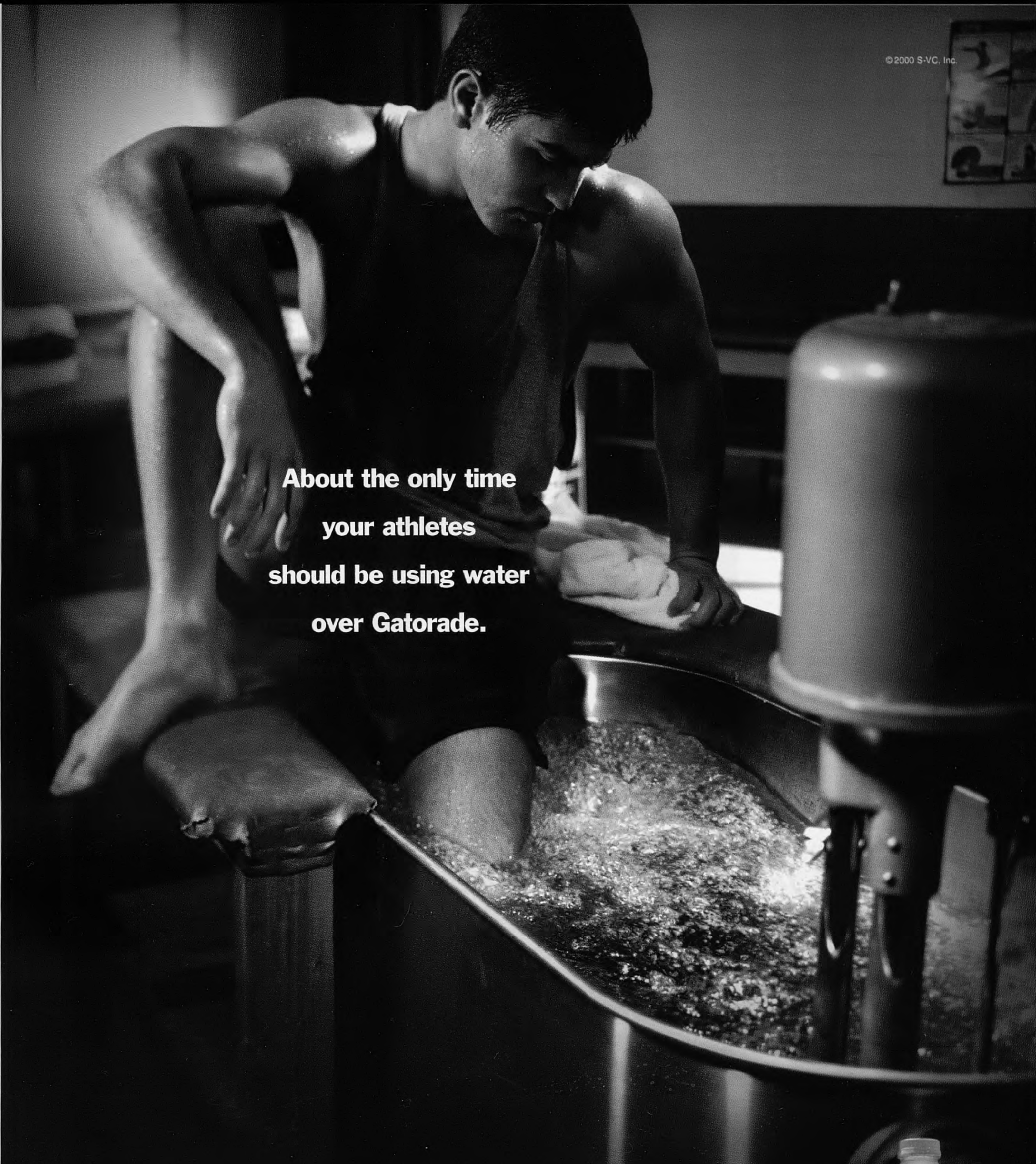
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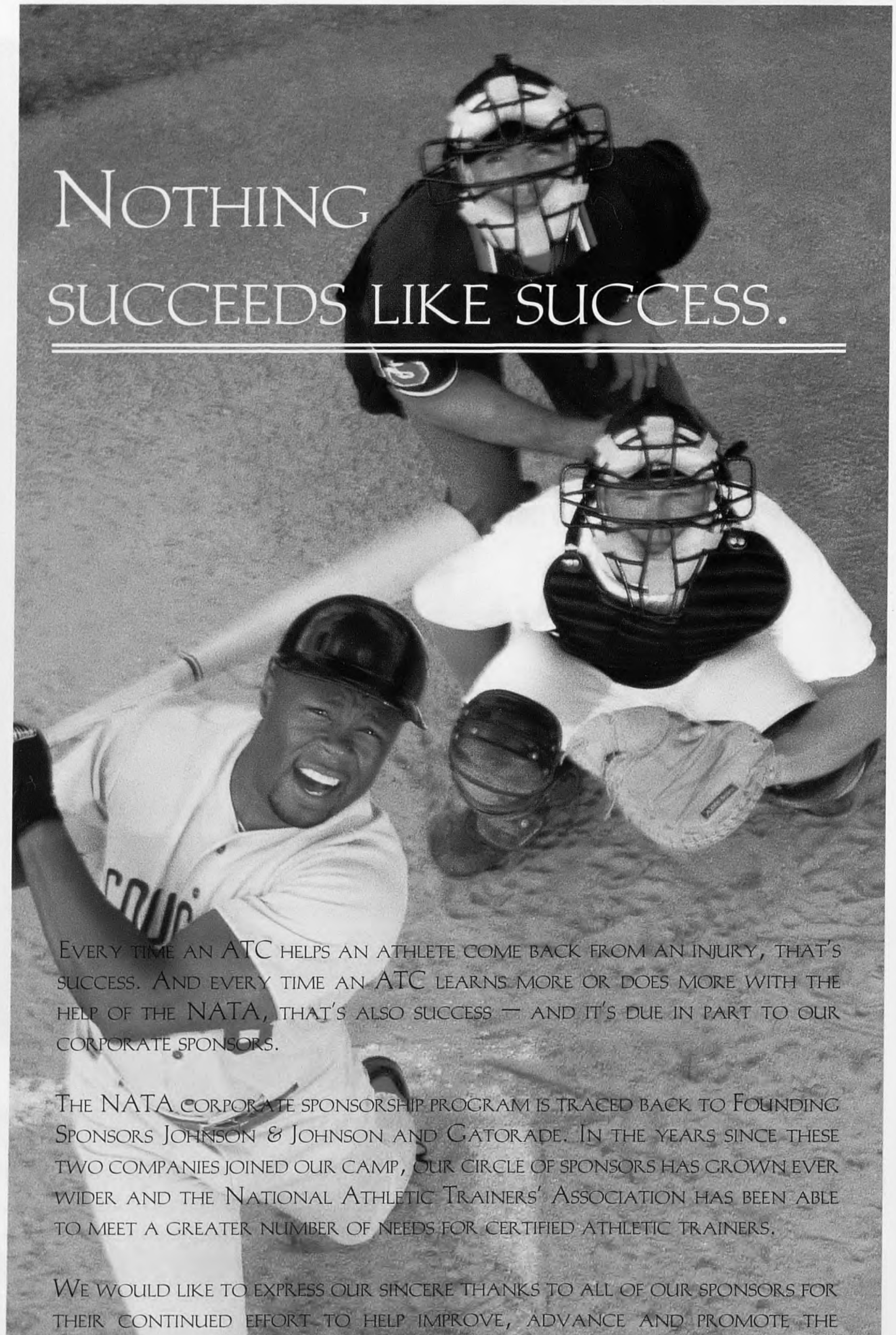

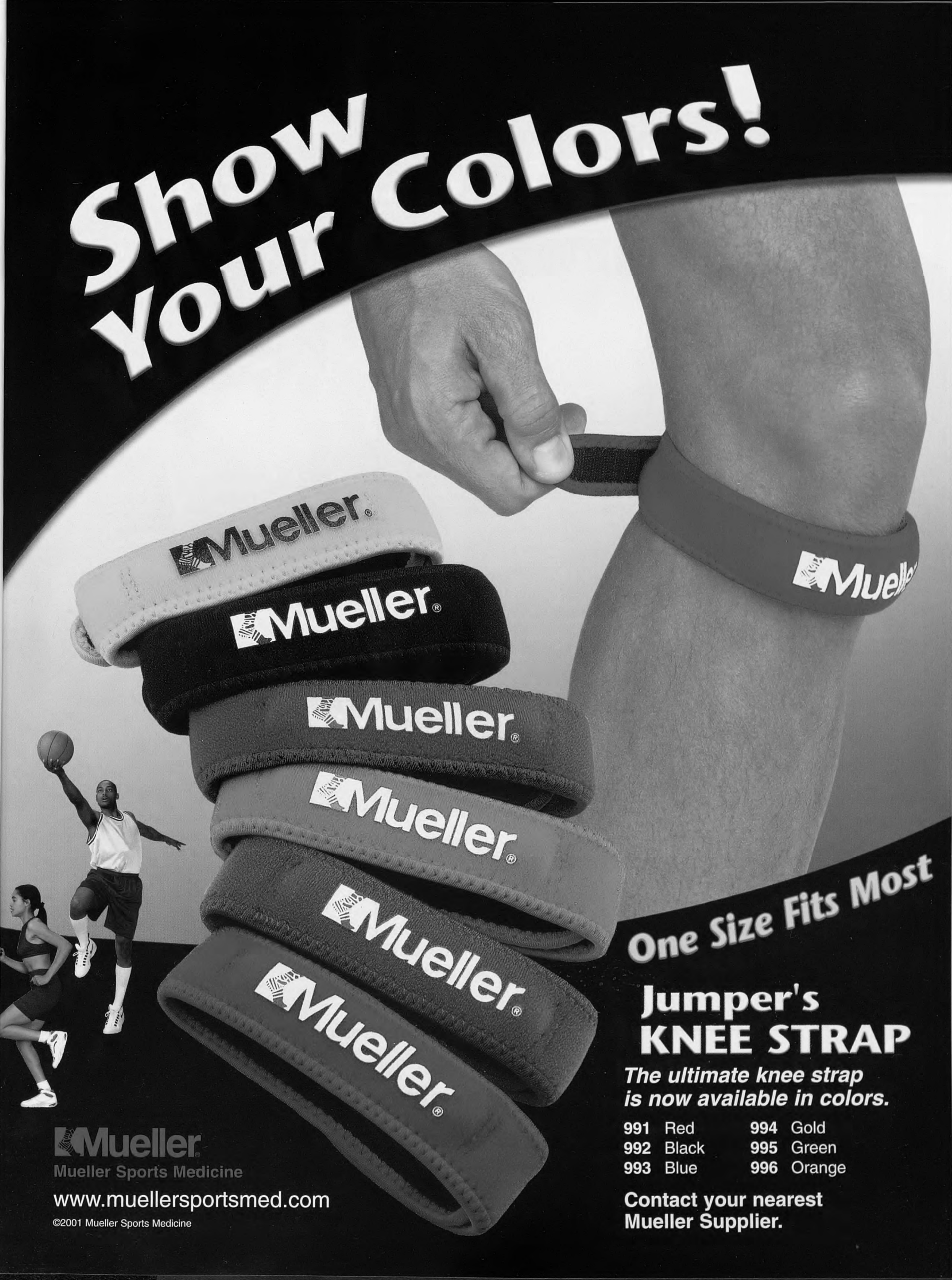

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David Perrin, PhD, ATC
University of North Carolina Greensboro
400-A HHP Building, P O Box 26169
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Letters to the Editor

In our recently published article (Potteiger JA, Randall JC, Schroeder C, Magee LM, Hulver MW. Elevated anterior compartment pressure in the leg after creatine supplementation: a controlled case report. *J Athl Train.* 2001; 36:85–88), my coauthors and I incorrectly credited the National Athletic Trainers' Association with funding the research. The correct funding entity was the National Athletic Trainers' Association Research and Education Foundation, grant 399 A004. We apologize for this error.

Jeffrey A. Potteiger, PhD, FACSM
University of Kansas
Lawrence, KS

I wish to comment on the article by Ransone et al entitled "The Efficacy of the Rapid Form Cervical Vacuum Immobilizer in Cervical Spine Immobilization of the Equipped Football Player" (*J Athl Train.* 2000;35:65–69). I commend the authors on their investigation of this new product. I wish to address one major point in their work. There are major clinical implications of their conclusions, and I ask the authors to explain the rationale of their stated position.

The authors state in the conclusions that "immobilization of the cervical spine is enhanced when the face mask is left in place." Two references[1,2] were given to support that statement. The study design in Prinsen et al[1] would not allow one to make this assumption from the data, and neither paper presents any discussion to support this assumption. In a recent review of cervical spine injuries in helmeted football players, no articles that would support leaving the face mask in place during transport were found.[3,4] Sports medicine texts state clearly that the face mask should be removed before patient transport, regardless of current respiratory status.[5]

The design in the study by these authors used helmeted subjects with face mask removed to allow each subject full movement of the cervical spine. With this study design, it would be difficult to extrapolate any data to support increased stability of cervical spine immobilization with the face mask left in place. I know of no published study that supports a biomechanical advantage to cervical spine stabilization by leaving a face mask in place during transport. One would not want to use the face mask to stabilize the helmet in place, because this might inhibit easy access to the face mask in the event that removal and airway management become issues. It would be better to remove the face mask in a controlled environment before transport in preparation for the necessity of airway management.

The face masks can be safely removed during transport.[3] This allows easy access to the airway if management becomes an issue during transport. Professionals working with football teams should be well trained in the methods of face-mask removal, and the proper equipment to remove the face mask must be readily available. Prehospital and sports medicine teams need to formulate a plan in advance to prepare for unexpected clinical scenarios such as cervical spine injuries, and skills such as face-mask and helmet removal, if necessary, should be practiced. Clinical policies need to be based on well-designed studies or clinical consensus. One must be careful extrapolating face-mask and helmet management to other helmet designs without further studies in this area.[6]

Thank you for your consideration of these points.

Kevin Waninger, MD, MS
St. Luke's Hospital
Bethlehem, PA

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Authors' Response

Thank you to Dr Waninger for his letter concerning our article entitled "The Efficacy of the Rapid Form Cervical Immobilizer in Cervical Spine Immobilization of the Equipped Football Player."

The purpose of our study was to measure the effectiveness of the Rapid Form Cervical Vacuum Immobilizer in controlling cervical forward flexion, extension, and lateral movements of an equipped football player. In 10 healthy subjects, we demonstrated that when a player is wearing a football helmet and shoulder pads, a properly placed cervical vacuum immobilizer does indeed restrict cervical movement radiographically compared with a similarly equipped person without the vacuum immobilizer in place. We were pleased to note that our study was referenced in the Inter-Association Task Force for the Appropriate Care of the Spine-Injured Athlete document.[1]

The position of the National Athletic Trainers' Association (NATA) is that face masks should be removed, regardless of the respiratory status of a spine-injured football player. Our 1999 study demonstrated the effectiveness of the cervical vacuum splint applied without the face mask in place, as the new protocol dictates. Furthermore, the guidelines of the American Orthopaedic Society for Sports Medicine,[2] NATA,[1] and other well-documented research papers clearly call for keeping the helmet and shoulder pads on in a spine-injured athlete unless there is cardiac cessation, because these equipment pieces work together to maintain cervical alignment. Our study provided data to support these findings and allowed for ease of application, flexibility in use, and the ability to take an x-ray film through the splint. We did not test subjects with a face mask on; therefore, we could draw no conclusions regarding the face mask. We do agree that further exploration is warranted in this area, but we stand by the cervical vacuum immobilizer as an excellent tool to preclude cervical movement in an equipped football player.

Katie Walsh, EdD, ATC-L
East Carolina University
Greenville, NC
Jack Ransone, PhD, ATC
Oklahoma State University
Stillwater, OK
Robert Kersey, PhD, ATC
California State University
Fullerton, CA

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Serial Testing of Postural Control After Acute Lateral Ankle Sprain

Jay Hertel; W. E. Buckley; Craig R. Denegar

Pennsylvania State University, University Park, PA

Jay Hertel, PhD, ATC, contributed to conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article. W. E. Buckley, PhD, ATC, and Craig R. Denegar, PhD, ATC, PT, contributed to conception and design; analysis and interpretation of the data; and critical revision and final approval of the article.

Address correspondence to Jay Hertel, PhD, ATC, Pennsylvania State University, 269 Recreation Building, University Park, PA 16802. Address e-mail to jnh3@psu.edu.

Objective: To identify subjects' changes in postural control during single-leg stance in the 4 weeks after acute lateral ankle sprain.

Design and Setting: We used a 2 × 2 × 3 (side-by-plane-by-session) within-subjects design with repeated measures on all 3 factors. All tests were performed in a university laboratory.

Subjects: Seventeen young adults (9 men, 8 women; age, 21.8 ± 5.9 years; mass, 74.9 ± 10.5 kg; height, 176.9 ± 7.1 cm) who had sustained unilateral acute mild or moderate lateral ankle sprains.

Measurements: Measures of center-of-pressure excursion length, root mean square velocity of center-of-pressure excursions (VEL), and range of center-of-pressure excursions (RANGE) were calculated separately in the frontal and sagittal planes during 5-second trials of static single-leg stance.

Results: We noted significant side-by-plane-by-session interactions for magnitude of center-of-pressure excursions in a given trial (PSL) ($P = .004$), VEL ($P = .011$), and RANGE ($P = .009$). Both PSL and VEL in the frontal plane were greater in the injured limbs compared with the uninjured limbs on day 1 and during week 2 but not during week 4, whereas sagittal-plane differences existed during all 3 testing sessions. Injured-limb, frontal-plane RANGE scores were greater than uninjured values at day 1 but not during weeks 2 or 4. No significant differences in sagittal-plane RANGE scores were seen.

Conclusions: Postural control was significantly impaired in the injured limbs at day 1 and during week 2 after lateral ankle sprain but not during week 4. Consistent improvement in postural control measures on both injured and uninjured limbs was seen throughout the 4 weeks after ankle sprain.

Key Words: balance, stabilometry, functional testing

Lateral ankle sprains (LASs) remain one of the most frequent injuries in sports.[1] The recurrence rate after LAS has been estimated to be as high as 80%.[2,3] Functional instability of the ankle has been hypothesized to be a potential cause of recurrent ankle sprains, and deficits in postural control after LAS have been postulated as one manifestation of functional instability.[4] Investigators have examined objective postural control measures in injured subjects after acute LAS,[5–10] but routine follow-up testing to track changes in postural control after acute injury has been conducted in only a few studies.[9,10]

Leanderson et al[9] performed a prospective study of 53 professional dancers, 6 of whom experienced moderate or severe LAS. Injured subjects had increased measures of center-of-pressure (COP) excursion amplitude and area from 0 to 12 weeks after injury compared with the uninjured dancers; however, testing was not performed at the same intervals in all subjects, and inferential statistics were not used to analyze the data. The postural control variables used were not calculated separately for the frontal and sagittal planes. Gradual improvements were seen with rehabilitation, and all injured subjects eventually returned to near preinjury levels.[9]

In a study of 92 subjects with ankle sprain, Holme et al[10] demonstrated initial increases in COP excursion length (LEN) 6 weeks after acute injury, but a return to normal values was seen within 4 months regardless of whether or not subjects completed a supervised rehabilitation program. The postural control measure was not calculated separately for the frontal and sagittal planes. No measurements of postural control were assessed between the occurrence of injury and the ensuing 6-week assessment. Additionally, it is unclear if the structured rehabilitation sessions were begun immediately or 6 weeks after injury.[10]

The amplitude and velocity of frontal-plane COP excursions are significantly impaired in injured limbs compared with uninjured limbs within 8 days of acute LAS.[5] To our knowledge, LEN, root mean square velocity of COP excursions (VEL), and range of COP excursions (RANGE) in both the frontal and sagittal planes at regular intervals within the first several weeks after acute LAS have not been quantified. An understanding of the typical pattern of changes in postural control in the first few weeks after LAS may serve as a useful guide to clinicians when making decisions to progress rehabilitation. Therefore, the purpose of our study was to serially assess these postural control variables between injured and uninjured ankles across the frontal and sagittal planes 1 day, 2 weeks, and 4 weeks after acute LAS.

METHODS

Subjects

Seventeen young adults (9 men, 8 women; age, 21.8 ± 5.9 years; mass, 74.9 ± 10.5 kg; height, 176.9 ± 7.1 cm) experienced acute mild or moderate LASs. All subjects were assessed by the same certified athletic trainer (J.H.). Mild sprains were classified as injury to 1 of the lateral ligaments, and moderate sprains were classified as injury to 2 of the lateral ligaments. Thirteen subjects sustained mild sprains, whereas 4 sustained moderate injuries. Nine sprains were to the right ankle, and 8 were to the left. All subjects were free of concomitant fractures or syndesmosis injuries. Subjects read and signed an informed consent form approved by the university's institutional review board (which also approved the study) before participating. We instructed all subjects in a graduated functional rehabilitation program that emphasized pain and swelling control; range-of-motion, strengthening, and balance exercises; and a gradual return to functional activities. Each subject progressed through the rehabilitation program under the guidance of either a certified athletic trainer or a licensed physical therapist.

Instrumentation

A 60 by 90-cm forceplate (Bertec Inc, Columbus, OH) measured translational forces (Fx, Fy, Fz) and moments of force (Mx, My, Mz), and COP trajectories were calculated using a custom computer program. Raw forceplate signals were amplified at 100 dB (model 4060S, Bertec), converted from analog to digital signals at 50 Hz, and filtered with a fourth-order, zero-lag, low-pass filter with a cutoff frequency of 8 Hz. We then calculated COP values using Labview software (National Instruments Inc, Austin, TX). The COP values could be resolved to an accuracy of 1 mm and were generated for both the frontal and sagittal planes.

Protocol

Subjects were asked to maintain a single-leg stance while standing barefoot on the forceplate and to stand as motionless as possible. The nonstance leg was held in approximately 30° of hip flexion and 45° of knee flexion and was not allowed to touch the stance leg during testing. Arms were folded across the chest, and testing was performed with eyes open to allow visual feedback during the maintenance of balance. If a touchdown (the nonstance leg touching the ground during data acquisition) occurred or the subject touched the nonstance leg to the stance leg, the trial was terminated and repeated. No trends were seen in terms of more repeated trials being necessary with the injured-limb stance versus the uninjured-limb stance.

The length of each trial was 5 seconds and was modeled after the methods previously reported by Goldie et al,[11–13] which have been shown to be reliable and valid. Subjects performed 3 trials on each leg with a rest period of 30 seconds between trials. The order of leg testing was counterbalanced among all subjects to avoid a learning effect. Subject 1 performed all 3 left leg trials first, followed by all 3 right leg trials, whereas subject 2 had the right leg tested first and so on. All trials were conducted by the same investigator.

Subjects performed identical testing procedures on 3 occasions. Subjects were tested within 1 day of return to full weight bearing after the acute injury. All subjects performed day 1 testing within 5 days of the injury. Testing was repeated 2 weeks and 4 weeks after day 1 testing.

Dependent Measures

We calculated measures of LEN, VEL, and RANGE separately in the frontal and sagittal planes for each trial using Matlab 5.3 software (The MathWorks Inc, Natick, MA). We determined LEN by calculating the length of the path of the COP in the frontal and sagittal planes, respectively, throughout the entire 250-data point trial using the following equation:

$$\text{LEN} = \sum |(\text{COP}_i - \text{COP}_{i-1})|$$

The VEL of frontal and sagittal COP excursions was determined independently by dividing the length between adjacent measurements by 0.02 seconds for all 250 data points. Because the velocity could be expressed as either a positive or negative value, the VEL was calculated using the following formula:

$$\text{VEL}_{i=250} = \sqrt{\frac{\sum \left(\frac{\text{COP}_i - \text{COP}_{i-1}}{0.020}\right)^2}{250}}$$

where VEL represents the magnitude of COP displacement over time and has been previously shown to be a highly reliable and valid measure of postural control.[14]

Frontal-plane and sagittal-plane RANGE scores were calculated by subtracting the minimum COP value from the maximum COP value in both respective planes. The maximum and minimum values are the single highest and lowest COP values recorded in a given trial. The RANGE scores represent the distance in which COP excursions occur throughout a trial.

Statistical Analysis

We used a 2 × 2 × 3 (side-by-plane-by-session) within-subjects design with repeated measures on all 3 factors. Three separate, 3-factor repeated-measures analyses of variance were performed on LEN, VEL, and RANGE. For each of the 3 dependent measures, the means for the injured and uninjured limbs were calculated by averaging the 3 trials for each of the 3 testing sessions. Independent variables were side (injured, uninjured), plane (frontal, sagittal), and session (day 1, week 2, week 4). Post hoc testing was performed using univariate analyses of variance and the Tukey post hoc procedure to identify specific differences. The level of significance was set at .05 for all procedures. SPSS 8.0 for Windows (SPSS Inc, Chicago, IL) was used for the statistical calculations.

RESULTS

Significant side-by-plane-by-session interactions were identified for LEN ($F_{2,32} = 6.56$, $P = .004$), VEL ($F_{2,32} = 5.21$, $P = .011$), and RANGE ($F_{2,32} = 5.50$, $P = .009$) (Table). The interaction for LEN is explained by greater differences existing between injured and uninjured frontal-plane LEN scores at day 1 compared with sagittal-plane LEN scores (Figure 1). The LEN scores in both planes were significantly greater in injured limbs than uninjured limbs on day 1 and during week 2 ($P < .05$), but during week 4, only sagittal LEN was significantly different. The LEN measures gradually improved on both sides across the 3 testing sessions. The VEL scores responded very similarly to LEN scores (Figure 2). The explanation of the 3-way interaction for VEL is identical to that

Center-of-Pressure Excursion Length (LEN), Root Mean Square Velocity (VEL), and Excursion Range (RANGE) in the Frontal (X) and Sagittal (Y) Planes

	LEN X, cm	LEN Y, cm	VEL X, cm/s	VEL Y, cm/s	RANGE X, cm	RANGE Y, cm
Day 1						
Injured limb	15.4 (±3.6)*	15.4 (±3.1)*	4.1 (±1.0)*	4.2 (±0.8)*	3.3 (±1.2)*	2.5 (±0.3)
Uninjured limb	13.1 (±2.7)	14.4 (±2.6)	3.5 (±0.7)	3.9 (±0.7)	2.6 (±0.6)	2.1 (±0.3)
Week 2						
Injured limb	13.4 (±3.8)*†	14.6 (±3.8)*	3.6 (±1.0)*†	4.0 (±1.0)*	2.9 (±1.1)	2.3 (±0.4)
Uninjured limb	12.0 (±3.6)	13.1 (±3.1)	3.1 (±0.7)	3.5 (±0.9)	2.6 (±0.6)	2.2 (±0.5)
Week 4						
Injured limb	11.0 (±2.4)†‡	12.9 (±2.9)*†‡	2.9 (±0.7)†‡	3.4 (±0.8)*†‡	2.5 (±0.6)†	2.1 (±0.4)
Uninjured limb	10.9 (±2.3)†	11.1 (±2.3)†	2.9 (±0.6)†	3.0 (±0.6)†	2.9 (±0.8)	2.0 (±0.3)

*Significantly greater in injured versus uninjured limbs.
†Significantly less than day 1 measures ($P < .05$, n = 17).
‡Significantly less than week 2 measures ($P < .05$, n = 17).

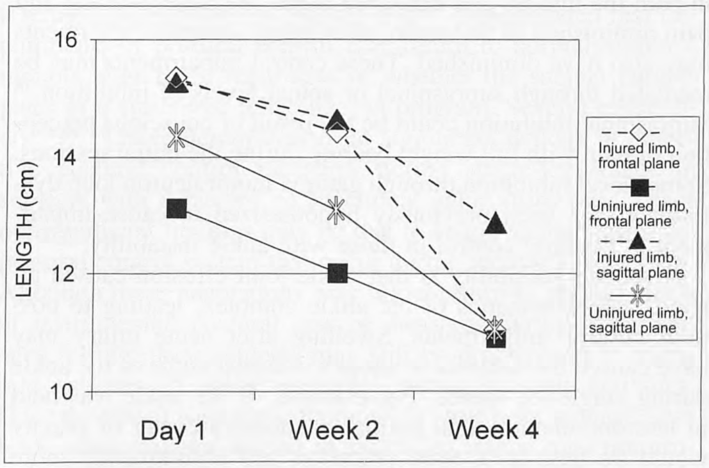

Figure 1. For center-of-pressure excursion length measures (LEN), the significant side-by-plane-by-session interaction was due to the gradual reduction in all measures except that of the injured limb in the sagittal plane.

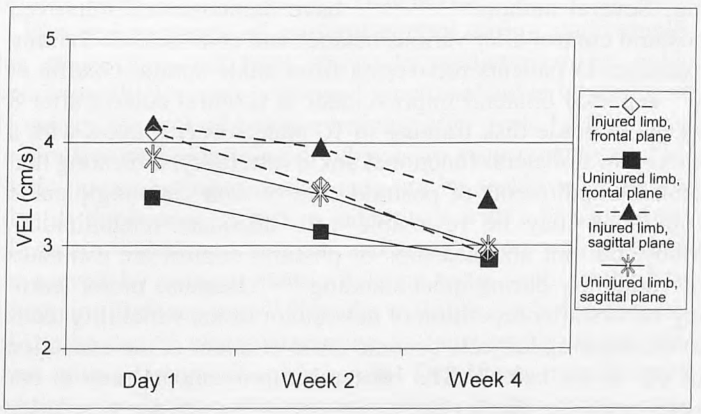

Figure 2. For center-of-pressure root mean square velocity measures (VEL), the significant side-by-plane-by-session interaction was due to the gradual reduction in all measures except that of the injured limb in the sagittal plane.

of LEN. The interaction for RANGE is explained by injured-limb, frontal-plane RANGE scores being significantly greater than uninjured values at day 1 ($P < .05$) but not during weeks 2 or 4 ($P > .05$) (Figure 3). Sagittal-plane RANGE scores were greater in the injured limbs compared with the uninjured limbs during all 3 sessions but not at statistically significant levels. Significant improvements were seen between sessions

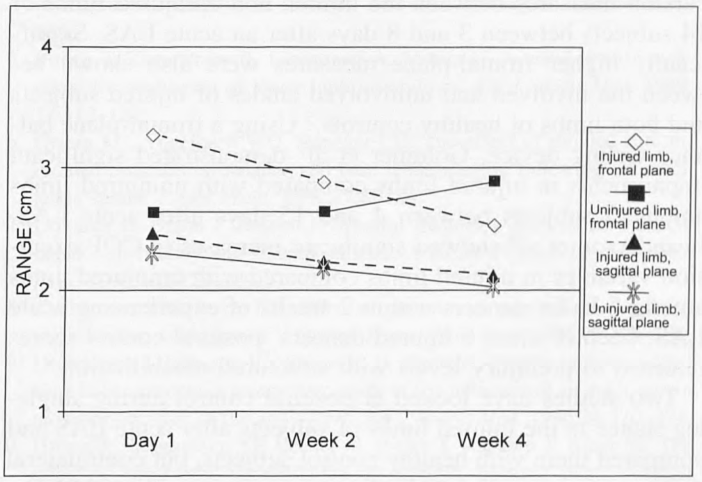

Figure 3. For center-of-pressure excursion range measures (RANGE), the significant side-by-plane-by-session interaction was due to the lack of significant differences except for the frontal-plane measures on day 1.

for VEL and LEN in both planes in the injured and uninjured limbs and for frontal-plane RANGE in the injured limbs.

DISCUSSION

Our results demonstrate a significant impairment in postural control within the first 2 weeks after LAS. Measurements of LEN and VEL were significantly elevated in injured limbs versus uninjured limbs at day 1 and during week 2 in the frontal plane and at day 1 and during weeks 2 and 4 in the sagittal plane. Measurements of RANGE were significantly increased in the frontal plane only at day 1 after injury. A close examination of our dependent variables may help to explain why the results were not identical for all of the measures.

The LEN results represent the sum of all COP excursions in each plane during a given trial. Individuals with impaired postural control are likely to have larger COP excursions and, thus, a larger sum of excursions throughout a trial. The VEL results represent the rate of COP excursions. Individuals with impaired balance are likely to have larger and faster COP excursions than those who are not impaired. As the velocity of COP excursions increases, it becomes more difficult, or even impossible, for the body to adequately compensate for the excursions and keep the COP within the base of support. The LEN and VEL results were very similar in our study because both reflect the magnitude of individual COP excursions during a trial. The RANGE results represent the limits of COP excursions during a trial and are constrained by the dimensions of an individual's foot. To maintain balance, COP must remain within the limits of the base of stability. If single-leg stance is maintained, measures of RANGE are limited within the finite breadth of the dimensions of the foot, whereas the measures of LEN and VEL are not constrained in a similar manner. The only significant difference in RANGE between limbs was in the frontal plane on day 1. This may be due to the limited variation possible in RANGE measures when single-leg stance is maintained throughout a trial.

Our results are consistent with previous findings[5,7,9] of increases in various objective measures of postural control in injured limbs versus contralateral uninjured limbs after acute LAS. Friden et al[5] reported increased frontal-plane COP excursion measures between the injured and uninjured limbs of 14 subjects between 3 and 8 days after an acute LAS. Significantly higher frontal-plane measures were also shown between the involved and uninvolved ankles of injured subjects and both limbs of healthy controls.[5] Using a frontal-plane balance testing device, Golomer et al[7] demonstrated significant impairments in injured limbs compared with uninjured limbs among 5 subjects between 4 and 15 days after acute LAS. Leanderson et al[9] showed significant increases in COP excursion variables in injured limbs compared with uninjured limbs among 6 ballet dancers within 2 weeks of experiencing acute LAS. Each of these 6 injured dancers' postural control scores returned to preinjury levels with structured rehabilitation.[9]

Two studies have looked at postural control during single-leg stance in the injured limbs of subjects after acute LAS and compared them with healthy control subjects, but contralateral differences among injured subjects were not evaluated.[6,8] Orteza et al[6] demonstrated impaired balance on a testing device similar to that of Golomer et al[7] among subjects within 6 weeks of an acute LAS compared with a group of healthy controls. Guskiewicz and Perrin[8] demonstrated impaired postural control within 21 days of an acute ankle sprain among injured limbs compared with the limbs of healthy controls.

Deficits in postural control after ankle sprain may be due to several factors. Freeman et al[4] originally hypothesized that balance impairments after ankle sprain were the result of impaired proprioception due to damage to joint mechanoreceptors and afferent nerve fibers, which occurs in conjunction with ligamentous damage during hyperinversion. Impaired proprioception may cause diminished or delayed response of the muscles that provide dynamic stability to the ankle joint and, thus, result in inadequate corrections to postural perturbations.[15–18] Impaired postural control may also be due to altered proximal muscle activity in response to ankle injury. Subjects with ankle injuries have been shown to shift from the typical ankle strategy of balance maintenance during single-leg stance to the less efficient hip strategy of balance.[19,20] Bullock-Saxton[21] also demonstrated impaired ipsilateral gluteus maximus electromyographic activity in patients with a history of severe LAS, suggesting that distal injury may cause proximal changes in neuromuscular activity.

Another potential cause of impaired postural control after LAS is that lateral ligamentous injury may result in mechanical instability of the subtalar and talocrural joints and allow greater ranges of pronation and supination to occur during single-leg stance, thus resulting in greater magnitude and velocity of COP excursions.[5,7–8] Interestingly, proprioceptive deficits have been reported as greatest near terminal ranges of motion.[22] In the presence of excessive range of motion due to pathologic joint laxity, proprioceptive deficits may be accentuated, thus contributing to impaired postural control.

Our results show improvements in postural control measures during the first month after injury in both injured and uninjured limbs. Three plausible explanations are possible. Friden et al[5] demonstrated bilateral impairments in several measures of frontal-plane postural control in subjects with acute LAS. Additionally, researchers[23–27] have reported bilateral proprioceptive and neuromuscular deficits after injuries to the anterior cruciate ligament, supporting the hypothesis of a central mechanism for proprioception, neuromuscular control, and postural control. It is possible that in our sample, swelling and pain associated with the acute injury may have caused central impairments of postural control and resulted in elevated measures in both the injured and uninjured limbs. Because swelling and pain diminished in the weeks after injury, central impairments may also have diminished. These central impairments may be mediated through supraspinal or spinal levels of inhibition.[28] Supraspinal inhibition could be the result of conscious perception of pain with full weight bearing during the initial sessions. Spinal-level inhibition through gamma motor neuron loop dysfunction has been previously hypothesized to cause impairment of postural control in those with ankle instability.[29]

A second possibility is that ankle joint effusion caused altered arthrokinematics of the ankle complex, leading to postural control impairments. Swelling after acute injury may have caused the subjects to adopt a different angle of the ankle during single-leg stance. For example, if the ankle was held in less dorsiflexion than normal, a subject's center of gravity would be held in a more posterior, and consequently more unstable, position and thus lead to elevated measures of COP excursions. Research is needed to validate this hypothesis.

The third possibility is that postural control improved bilaterally as a result of learning effects with repeated trials of balance exercises during rehabilitation and experimental testing. Several authors[9,13,20,30–32] have demonstrated improved postural control after various balance and coordination training exercises in patients recovering from ankle sprain. Gauffin et al[31] reported bilateral improvement in postural control after 8 weeks of ankle disk training in 10 male soccer players with a history of unilateral functional ankle instability, indicating that central impairments of postural control with pathologic ankle conditions may be reversible with adequate rehabilitation. Many, but not all, measures of postural control are estimates of variability during quiet standing.[33,34] Because motor learning occurs after repetition of new motor tasks, variability tends to decrease as subjects become more efficient at the execution of the motor tasks.[35] The bilateral improvements seen in our study may be due to decreased variability during single-leg stance with repetitive trials of balance exercises and tests.

It is not possible for us to unconditionally attribute the bilateral improvements seen in our study to reduction in central impairments of postural control, changes in ankle biomechanics, or motor learning in the 4 weeks after acute LAS. Most likely, a combination of all 3 contributed to improved postural control during recovery from ankle sprain. In future studies, the use of a control group may help to elucidate these issues.

Postural control measures have been used as an assessment modality to quantify functional improvement after rehabilitation of acute LAS[9–10,13] and residual functional ankle instability.[19,27–29,32] Significant reductions in measures of postural control have been identified in rehabilitation programs ranging from 6 to 16 weeks in length.[9,20,30–32,36] Holme et al[10] demonstrated reductions in COP excursion magnitude from 6 weeks to 4 months after ankle sprain in both a group of patients who completed a functional rehabilitation program and a group of patients who did not undergo supervised rehabilitation. However, subjects not undergoing supervised rehabilitation were 4 times more likely to experience a recurrent sprain within 1 year of initial injury than the group that undertook formal rehabilitation.[10] Similarly, Wester et al[37] reported a 2-fold reduction in recurrent ankle sprains in a group of ankle sprain–injured subjects undergoing a 12-week ankle disk–training program compared with a group not pursuing balance training.

Our results demonstrate that improvements in postural control may occur within 4 weeks of LAS when patients complete a rehabilitation program. Holme et al[10] demonstrated that impairments of postural control may return to normal within 4 months after LAS, regardless of whether the subject participates in a structured rehabilitation program. Several researchers[30,38–40] have demonstrated no significant deficits in objective postural control measures during single-leg stance in subjects with a history of functional ankle instability. These nonsignificant findings may be due to adaptive changes in the postural control system that occur during recovery from LAS. Although these adaptations may allow return to normal levels of instrumented postural control measures during static balance testing, these athletes may still be predisposed to recurrent episodes of ankle instability during dynamic activities. Once the initial pain and inflammation have been reduced after LAS, static balance testing in single-leg stance may not provide adequate challenge to the postural control and neuromuscular control systems to detect functional deficits. Hence, athletes who truly have functional ankle instability and may be at risk of recurrent sprain may not have significant differences in static postural-sway scores between their injured and uninjured limbs.

Elevated measures of postural control during static single-leg stance have not been shown to predict recurrent ankle sprain in athletes with prolonged functional ankle instability.[38] However, the lack of balance training after acute LAS appears to predispose ankle-injured subjects to recurrent sprain.[10,37] Static postural control testing may not be sensitive enough to identify functional deficits in individuals with a history of ankle sprain.[10] Perhaps clinicians and investigators would be better served by using dynamic balance tests, such as the Star Excursion Balance tests[41,42] or the multiple single-leg hop stabilization test,[43] when attempting to functionally assess athletes with a history of ankle sprain. These tests may be more sensitive in detecting functional deficits in the entire lower extremity during dynamic activities and may be more useful in predicting the risk of individual athletes for recurrent ankle sprains. Further research in this area is warranted.

In conclusion, we demonstrated initial impairment in postural control in the first 2 weeks after acute LAS. However, almost all measures of postural control returned to normal within 4 weeks of injury. We also identified bilateral improvements in postural control as athletes recovered from their ankle sprains. These bilateral improvements may be due to either training effects or the reduced central impairment of postural control after ankle injury. Future research is needed to identify quantifiable factors that may help to predict which athletes are predisposed to developing long-standing functional instability after acute LAS.

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The Effects of Sex, Joint Angle, and the Gastrocnemius Muscle on Passive Ankle Joint Complex Stiffness

Bryan L. Riemann; Richard G. DeMont; Keeho Ryu; Scott M. Lephart

Neuromuscular Research Laboratory, University of Pittsburgh, Pittsburgh, PA

Bryan L. Riemann, PhD, ATC, Richard G. DeMont, PhD, CAT(C), Keeho Ryu, MD, and Scott M. Lephart, PhD, ATC, contributed to conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article.

Address correspondence to Bryan L. Riemann, PhD, ATC, Georgia Southern University, PO Box 8076, Statesboro, GA 30460–8076. Address e-mail to briemann@gasou.edu.

Objective: To assess the effects of sex, joint angle, and the gastrocnemius muscle on passive ankle joint complex stiffness (JCS).

Design and Setting: A repeated-measures design was employed using sex as a between-subjects factor and joint angle and inclusion of the gastrocnemius muscle as within-subject factors. All testing was conducted in a neuromuscular research laboratory.

Subjects: Twelve female and 12 male healthy, physically active subjects between the ages of 18 and 30 years volunteered for participation in this study. The dominant leg was used for testing. No subjects had a history of lower extremity musculoskeletal injury or circulatory or neurologic disorders.

Measurements: We determined passive ankle JCS by measuring resistance to passive dorsiflexion ($5° \cdot s^{-1}$) from 23° plantar flexion (PF) to 13° dorsiflexion (DF). Angular position and torque data were collected from a dynamometer under 2 conditions designed to include or reduce the contribution of the gastrocnemius muscle. Separate fourth-order polynomial equations relating angular position and torque were constructed for each trial. Stiffness values ($Nm \cdot degree^{-1}$) were calculated at 10° PF, neutral (NE), and 10° DF using the slope of the line at each respective position.

Results: Significant condition-by-position and sex-by-position interactions and significant main effects for sex, position, and condition were revealed by a 3-way (sex-by-position, condition-by-position) analysis of variance. Post hoc analyses of the condition-by-position interaction revealed significantly higher stiffness values under the knee-straight condition compared with the knee-bent condition at both ankle NE and 10° DF. Within each condition, stiffness values at each position were significantly higher as the ankle moved into DF. Post hoc analysis of the sex-by-position interaction revealed significantly higher stiffness values at 10° DF in the male subjects. Post hoc analysis of the position main effect revealed that as the ankle moved into dorsiflexion, the stiffness at each position became significantly higher than at the previous position.

Conclusions: The gastrocnemius contributes significantly to passive ankle JCS, thereby providing a scientific basis for clinicians incorporating stretching regimens into rehabilitation programs. Further research is warranted considering the cause and application of the sex-by-position interaction.

Key Words: muscle, pathology, rehabilitation, range of motion, flexibility

Functional joint stability (FJS), the quality of possessing adequate joint stability to enable normal performance of a joint during functional activity, arises from complementary relationships existing between static and dynamic components.[1] Collectively, both components serve to maintain FJS throughout the physiologic range of motion by resisting potentially destabilizing forces.[1] An enhanced ability to diffuse destabilizing forces results in augmented FJS.[2–4] *Stiffness* is the mechanical property that determines how effectively external forces delivered to the skeletal system are absorbed or transmitted (or both) by the articular soft tissues.[5,6] In contrast to *muscle stiffness*, which describes the stiffness properties specifically exhibited by the tenomuscular tissues, *joint stiffness* encompasses contributions from all structures located within and over the joint (muscles, tendons, skin, subcutaneous tissue, fascia, ligaments, joint capsule, and cartilage).[1,7,8] Because dynamic restraints are included in addition to static restraints, joint stiffness becomes a function of not only the passive factors (ie, viscoelasticity) associated with each structure but also the level of neural influence over each articular muscle.[2,5,6,8–11] Neural influences can be considered to exist intrinsically, represented by the level of muscle activation (number of actin-myosin crossbridges) existing at an instant,[2,5,10,12–15] and extrinsically, represented by the arrival of a reflexive activation in response to a sensory stimuli.[2,10,16] Superimposed on these neural influences are the factors of single muscle fibers (ie, sarcomere length-tension and force-velocity relationships) as well as whole muscles (ie, arrangement of muscle fibers within a muscle and precise location of insertional sites).[9]

From an engineering perspective, stiffness may be defined in terms of elasticity, viscosity, friction, inertia, and plasticity.[7,8] In normal finger and knee joints measured with passive arthrography, elastic stiffness has been credited as the largest stiffness component (more than half).[8] Comprising ligaments, tendons, and muscle are varying concentrations of collagen, proteoglycans, water, and elastin.[17–20] These structural components determine each tissue's characteristic viscoelastic be-

Table 1. Subject Demographics (Mean ± SD)*

	Men (n = 12)	Women (n = 12)
Age (y)	22.0 ± 3.3	19.6 ± 1.3
Height (cm)	177.9 ± 6.82	165.5 ± 7.9
Weight (kg)	77.5 ± 16.5	64.8 ± 16.5

*SD indicates standard deviation, and n, number of subjects.

havior during passive lengthening[15,21] and the elastic and viscous stiffness properties.

A joint stability perspective suggests that increased joint stiffness is a desirable characteristic. Stiffer joints, arising from increased muscle stiffness, are theorized to have a heightened ability to absorb energy contained in destabilizing forces.[2–4,22,23] Although destabilizing forces may not be countered entirely, many could potentially be lessened in magnitude, thereby reducing the incidence of joint subluxation or dislocation. In contrast, stiffer joints are also theorized to increase the risk for injuries[5,23] or exacerbate the signs and symptoms associated with antagonistic muscle syndromes.[24,25] For example, increased extensor muscular stiffness requires higher contractile forces to be developed by the flexor muscles for a given movement. Secondary to the requirement for higher force production are increased stresses to the bone-tendon interfaces and abnormal muscle hypertrophy. Over time, these alterations may potentially increase the predisposition for development of insertional tendinitis and compartment syndromes, respectively.

Quantifying the influence of the gastrocnemius on passive ankle joint complex stiffness (JCS) would provide practitioners with a scientific rationale for selecting clinically advocated rehabilitation and intervention strategies. Such strategies include common clinical techniques such as stretching and strengthening the lower leg musculature. In the one study conducted on the influence of the gastrocnemius muscle on passive ankle JCS,[25] researchers focused solely on sedentary women older than 21 years. Additionally, while sex differences in stiffness have been shown at the knee and elbow joints,[7,26–28] no investigators have considered the existence of sex differences relative to passive ankle JCS. Therefore, our purpose was to determine the effects of sex, ankle and knee joint angles, and the gastrocnemius muscle on passive ankle JCS.

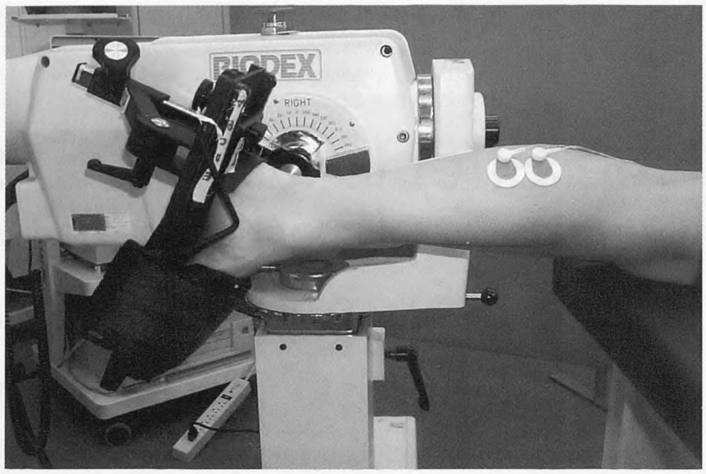
METHODS

Subjects

Twenty-four physically active subjects participated in this investigation (Table 1). The dominant leg, defined as the preferred leg for kicking a ball, was used for all data collection. Physically active was operationally defined as participation in physical activity for a minimum of 20 minutes, 3 times per week. None of the subjects had sustained a lower extremity musculoskeletal injury in their dominant leg or had a history of circulatory or neurologic disorders that could have potentially affected their JCS. Informed consent was obtained from all subjects in accordance with the university's institutional review board, which also approved the study.

Procedures

We determined passive ankle JCS by measuring the resistance to passive movement[7,8,21,24,25,28–30] from 23° plantar



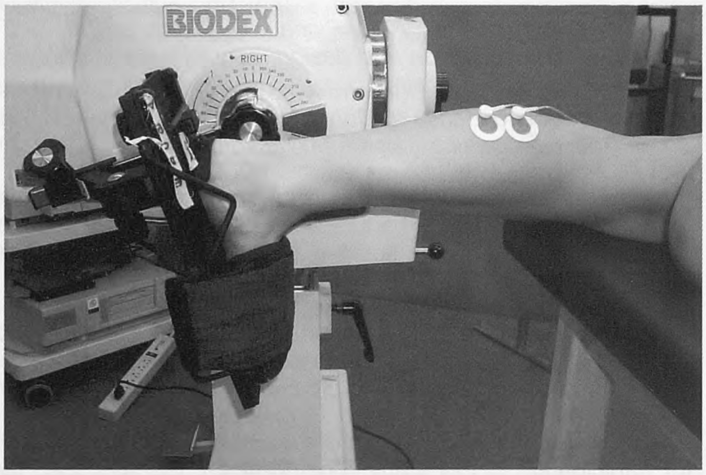


Figure 1. During each trial, the ankle was moved from a starting position of 23° plantar flexion (top) to an ending position of 13° dorsiflexion (bottom).

flexion (PF) into 13° dorsiflexion (DF) (Figure 1). Passive movements at an angular velocity of $5°\cdot s^{-1}$ were delivered[14,21] using the Biodex System 2 Isokinetic Dynameter (Biodex Inc, Shirley, NY) in a passive mode. The extra 3° ensured that constant velocity was achieved and maintained throughout the target range of 20° PF to 10° DF, thereby eliminating confounding changes in inertia. We used 2 straps (forefoot and midfoot) to fix the foot to the footplate once the axis of rotation was aligned with the lateral malleolus. During all testing, the ambient air temperature was maintained between 20.6°C and 21.7°C.

Trials were completed under 2 conditions designed to include or reduce the contribution of the gastrocnemius muscle. The first condition involved the subject in a prone position with the knee at 0° flexion, while the second condition involved the subject's maintaining a kneeling position with the knee held at 90° flexion. The order of the conditions was counterbalanced among subjects. During testing, we instructed subjects to relax all muscles in the lower leg and to not interfere with the passive movements. Before data collection, we gave each subject several familiarization trials under each condition. In addition to allowing the subjects to become familiar with the testing procedures, the familiarization trials decreased thixotropy[31] and the stress relaxation phenomena described by Taylor et al.[32]

Analogue data concerning angular position and torque from the potentiometer and load cell contained within the dyna-

Table 2. Reliability Analyses*

Condition	ICC	ICC 95% Confidence Intervals Lower Limit	Upper Limit	SEM
Knee straight				
10° PF	.44	.07	.77	.03
NE	.75	.47	.92	.05
10° DF	.88	.71	.96	.08
Knee bent				
10° PF	.54	.18	.83	.02
NE	.87	.69	.96	.02
10° DF	.94	.83	.98	.05

*ICC indicates intraclass correlation coefficients; SEM, standard error of measurement; PF, plantar-flexed position; NE, ankle-neutral position; and DF, dorsiflexed position.

Table 3. Stiffness Values (degrees) by Sex (Mean ± SD)*

Condition	Men	Women
Knee straight		
10° PF	.0028 ± .058	−.0041 ± .034
NE	.4115 ± .127	.3162 ± .081
10° DF	1.3162 ± .305	.9724 ± .217
Knee bent		
10° PF	−.0691 ± .050	−.0670 ± .035
NE	.2833 ± .096	.1911 ± .064
10° DF	1.1176 ± .470	.7726 ± .256

*SD indicates standard deviation; PF, plantar-flexed position; NE, ankle-neutral position; and DF, dorsiflexed position.

mometer head were collected at 100 Hz via an analogue-to-digital converter (Keithley Metrabyte DAS1402, Keithley Instruments Inc, Tauton, MA) and stored on a personal computer for later analysis. Additionally, to ensure that reflexive or voluntary muscle activity was not being elicited during the passive movements, we monitored the activity of the soleus, medial and lateral heads of the gastrocnemius, and medial and lateral hamstring muscles using the Noraxon Telemyo Electromyography System (Noraxon USA Inc, Scottsdale, AZ). Signals from the muscles were collected using self-adhesive silver-silver chloride bipolar surface electrodes (Multi Bio Sensors Inc, El Paso, TX) and passed through a single-ended amplifier (gain 500) to an 8-channel FM transmitter worn by the subject. A receiver then filtered and further amplified the signals (gain 500, Butterworth 15-Hz low-pass and 500-Hz high-pass filters, common mode-rejection ratio of 130 db) before conveying the data to the analogue-to-digital card.

Data Reduction

Although 6 trials of data were recorded under each experimental condition, only the first 3 trials that matched the selection criteria were used in the subsequent analyses. The selection criteria included no muscle activity or alterations in the torque curves through visual inspection of the raw data. We developed customized software to complete all data reduction procedures. First, torque and angular position data were smoothed using a median 5 filter. Gravity corrections for each torque data point were then completed using the corresponding angular position. Factored into the gravity corrections were the mass of the footplate, mass of the foot,[33] and lever arm length. Separate fourth-order polynomial equations relating angular position and torque were then constructed for each trial ($Y = ax^4 + bx^3 + cx^2 + dx + e$, where Y is the gravity corrected torque, x is the angular position, and a through e are constants). Stiffness values were calculated at 10° PF, neutral (NE), and 10° DF by using the first derivative (slope) of the equation ($dy/dx = 4ax^3 + 3bx^2 + 2c^2 + d$, where dy/dx is the stiffness) at each of the respective positions. This method of stiffness measurement, using the slope of the line relating torque and angular position during passive movement, has been previously described[30] and used.[24,25,29] The stiffness represented by taking the slope of the line has been attributed to elastic stiffness at that point in the range of motion.[25,34]

Reliability

We conducted a pilot study in conjunction with the current study to establish the reliability for our exact methods. Twelve subjects (8 men, 4 women, mean height = 176.6 cm, mean weight = 80.2 kg) participated in 3 repeated testing sessions. Twelve subjects were chosen based on an a priori power analysis.[35] All subjects conformed to the previously discussed inclusion and exclusion criteria. Intraclass correlation coefficients[36] (ICC) (2, K) ranged from .44 to .93 (Table 2). In addition, we established the confidence intervals and standard error of measurement associated with each ICC. Standard error of measurement ranged from .02 to .08, supporting the absolute reliability of the methods. These results are comparable with those previously reported using similar methods at the ankle.[37]

Data Analysis

The stiffness values across the 3 trials under each condition were averaged and analyzed using a 3-factor, repeated-measures analysis of variance with sex as a between-subjects factor and condition and position as within-subjects factors. Statistical significance of $P < .05$ was set a priori for all analyses.

In an attempt to probe the cause of the significant sex effects, we conducted several post facto analyses. First, we performed Pearson bivariate correlational analyses between the stiffness values (each position and condition) and subject height, weight, and ponderal index (calculated by dividing height by the cube root of weight[38]) across all subjects. Additionally, independent *t* tests were conducted on the height, weight, and ponderal index variables between the sexes. To reduce the Type I error rate, statistical significance for the *t* tests was adjusted to $\alpha < .01$. Last, we repeated the 3-factor analysis of variance using any of the demographic variables (height, weight, ponderal index) determined to be significantly related to stiffness and significantly different between the sexes as a covariate.

RESULTS

The data of 1 subject had to be disregarded for technical reasons. An example of the torque versus position data from 1 acceptable trial, as well as the constructed equation, is presented in Figure 2. Means and standard deviations are provided in Table 3. The results of the statistical analysis on the remaining subjects revealed significant condition-by-position ($F_{2,42} = 6.39$, $P = .004$) and sex-by-position ($F_{2,42} = 7.40$, $P = .002$) interactions, as well as significant main effects for

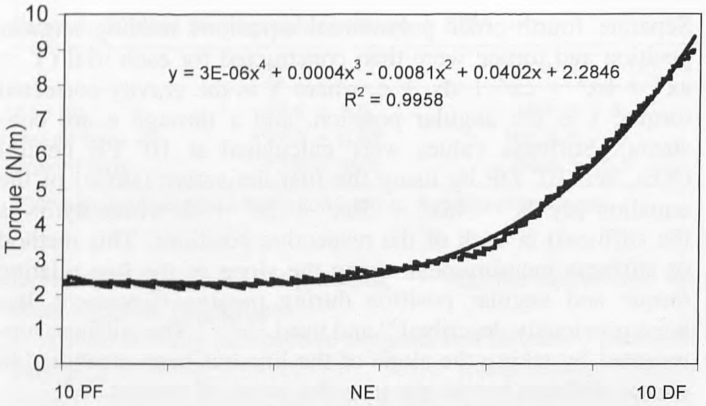


Figure 2. Separate fourth-order polynomial equations were constructed relating the angular position and torque data for each trial. Pictured are the original data (rough line) and line of the equation (solid).

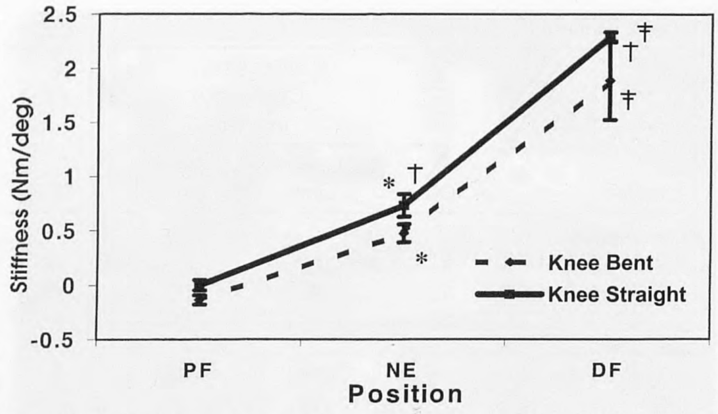


Figure 3. Position stiffness mean (±SD) for each condition illustrating the condition-by position interaction.

sex ($F_{1,21}$ = 6.22, P = .021), position ($F_{2,42}$ = 288.00, $P <$ .000), and condition ($F_{1,21}$=73.90, $P <$ .000). Tukey post hoc analyses of the condition-by-position interaction revealed significantly higher stiffness values under the knee-straight condition compared with the knee-bent condition at both ankle NE and 10° DF (Figure 3). Within each condition, stiffness values across positions were significantly higher as the ankle moved into DF (10° PF < NE < 10° DF). Tukey post hoc analysis of the sex-by-position interaction revealed significantly higher stiffness values at 10° DF in men (Figure 4). Lastly, Tukey post hoc analysis of the position main effect revealed that, as the ankle moved into dorsiflexion, the stiffness at each position became significantly higher than at the previous position (10° PF < NE < 10° DF).

Results of the post facto correlational analyses revealed significant relationships ($P <$ .05) between height and the stiffness values at the NE and DF positions under both conditions (Table 4). The independent t tests revealed only height to be statistically different between the sexes (t_{21} = 4.01, P = .00). The results of the analysis of covariance using height as the covariate were identical to the analysis of variance except that the main effect for sex was nonsignificant.

DISCUSSION

The purpose of our investigation was to determine the effects of sex, joint angle, and the gastrocnemius muscle on passive ankle JCS. The most significant aspect of our study was the quantification of the gastrocnemius' influence on passive ankle JCS. Collapsed across sex, our results suggest that the gastrocnemius significantly increased passive ankle JCS moving into DF as early as ankle NE. Clinically, this implies that the contribution of the gastrocnemius represents an important consideration during rehabilitation programs involving the lower extremity. Additionally, collapsed across condition, our results demonstrate significant sex differences in stiffness at 10° DF. The clinical significance and cause of this result warrant further investigation.

The speed with which we induced the passive displacements, $5° \cdot s^{-1}$, was chosen to avoid eliciting stretch reflexes.[14] Further, resistance to passive ankle displacement at this speed has been demonstrated as unchanged under ischemic conditions that block the Ia afferent fibers from the muscle spindles.[14] By asking subjects to not intervene with the passive movements,[5,6,10,21,23,27,29] we took advantage of the ability to abolish muscle activity through conscious relaxation,[39] thereby eliminating conscious muscle activation as a confounding factor. The relatively few trials in which increased electric activity occurred in our study, coupled with the ability to easily identify and eliminate these instances, support this presumption. Thus, it is reasonable to attribute the resistance measured in response to passive ankle joint displacement into DF to the intrinsic mechanical properties of the joint complex. The potential contributory sources, in addition to the gastrocnemius, include any of the structures spanning the joint: skin, ligaments, joint capsule, and anterior and posterior surrounding compartment muscles. After sequential resections of the tissues crossing the wrist joint, Johns and Wright[40] reported that resistance to passive movement arose primarily from the joint capsule (47%) and the muscles (41%). The remainder of the resistance was provided by tendons (10%) and skin (2%). With

Table 4. Correlational Analyses Among Demographic Variables and Stiffness Values (n = 23)*

	Knee Bent			Knee Straight		
	10° PF	Condition NE	10° DF	10° PF	Condition NE	10° DF
Height	r = −.219	r = .429	r = .501	r = .086	r = .494	r = .648
	P = .316	P = .041	P = .015	P = .696	P = .017	P = .001
Weight	r = −.394	r = .289	r = .373	r = −.108	r = .408	r = .569
	P = .063	P = .181	P = .080	P = .015	P = .054	P = .005
Ponderal	r = .287	r = .044	r = −.018	r = .250	r = −.076	r = −.143
index	P = .184	P = .841	P = .937	P = .251	P = .731	P = .516

*n indicates number of subjects; PF, plantar-flexed position; NE, ankle-neutral position; DF, dorsiflexed position; r, bivariate correlation coefficient; and P, P value.

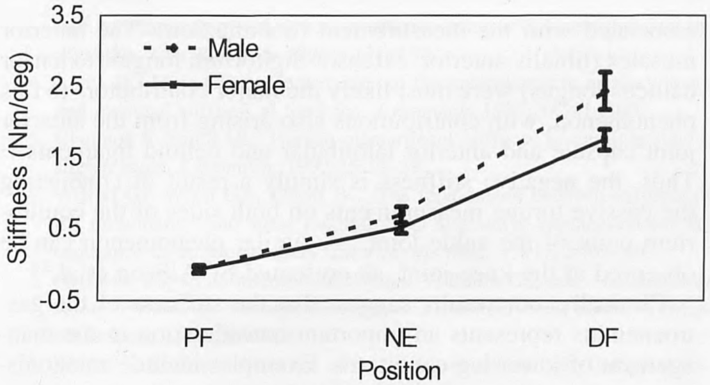


Figure 4. Position stiffness mean (±SD) for each sex illustrating the sex-by-position interaction.

respect to the elbow joint, Chleboun et al[28] noted that muscle volume accounted for 84% of the variance in elbow stiffness. Considered collectively, these studies suggest that the degree of contribution from each articular structure may be unique to a particular joint.[7] We were unable to find similar studies comparing contributions of the various articular structures at the ankle joint, leaving some of the etiologic interpretation of our results to limited degrees of speculation.

Our experimental design took advantage of the biarticular span of the gastrocnemius muscle. Because the proximal attachment of the gastrocnemius resides above the posterior femoral condyles, flexing the knee to 90° shortens the distance between the distal and proximal attachment sites, thereby decreasing the potential passive resistance. A similar method has been used to determine the contribution of the gastrocnemius to maximal voluntary ankle torque production.[41] Thus, comparing the stiffness values attained during the knee-bent condition with those attained during the knee-straight condition provided a means by which we could determine the relative influence of the gastrocnemius. Although changes in the tension offered by skin and associated connective tissues could have accompanied the change in knee position, we feel that it is reasonable to disregard such effects as minimal in light of the paper by Johns and Wright.[40]

Both testing conditions included the resistance offered by the uniarticular muscles crossing the axis of the ankle joint, posterior ankle joint capsule, and ligaments. Measurement of ankle ligament force values in various degrees of DF and PF using isolated cadaveric specimens has been conducted.[42] The anterior talofibular ligament comes under tension as the ankle moves into PF, while the calcaneofibular ligament comes under maximal tension in 15° of PF and DF. The deltoid ligament displays a pattern similar to that of the anterior talofibular ligament, coming under increased tension as the ankle moves into plantar flexion. The relevance of these results in resisting passive motion in vivo, with other articular structures intact, remains unknown. With respect to individual uniarticular muscle contributions, Gareis et al,[43] in establishing the active length-tension curves and passive force characteristics of 9 lower extremity muscles, demonstrated that the passive tension provided throughout the full range of elongation by the soleus muscle was more pronounced than that of the peroneus longus, tibialis posterior, and flexor digitorum longus muscles.

Our results of a significant condition-by-position interaction and a significant main effect for condition demonstrate that the gastrocnemius has substantial influence on passive ankle JCS. These results are in contrast with those reported by Chesworth and Vandervoort.[25,37] We find this discrepancy quite surprising and difficult to explain considering the identical methods in the 2 studies. The largest difference between the 2 studies involved the subjects. While we studied physically active men and women between 18 and 30 years old, Chesworth and Vandervoort[25,37] studied only women between 21 and 80 years old.

Table 5. Gastrocnemius Muscle Length Relative to Reference Position Length* Associated with the Knee And Ankle Angular Positions†‡

Condition	10° PF	NE	10° DF
Knee bent	−1.81%	0%	3.76%
Knee straight	4.48%	6.46%	10.05%

*The length of the gastrocnemius with 90° ankle and 90° knee flexion.
†Derived from equations established by Grieve et al.[44]
‡PF indicates plantar-flexed position; NE, ankle-neutral position; and DF, dorsiflexed position.

Several studies considering the effects of ankle and knee joint angle on the gastrocnemius support our significant condition results. Grieve et al[44] established a technique to estimate the length of the gastrocnemius muscle from knee and ankle angular measurements. Using the equations provided by their report, the knee-straight condition would have increased the length of the gastrocnemius in our subjects by approximately 6.5% in comparison with the reference length (the length of the gastrocnemius with 90° ankle and 90° knee flexion) at each of the respective ankle angular positions (Table 5). Sale et al[41] confirmed through a radiologic series that femoral condyle rotation accompanying knee extension causes considerable lengthening of the gastrocnemius independent of foot position. Although length and stiffness are not synonymous terms, temporarily increasing the length of the muscle-tendon unit with changes in joint position shifts the passive resistance-position curve to the left, resulting in increased stiffness at each ankle angle.

The post hoc analysis of the condition-by-position interaction revealed significant differences between conditions, beginning at the ankle neutral position. Further research should focus on further isolating the angular position where the significant difference begins. Given the differences in the passive length-force curves between the lateral and medial gastrocnemius[43] and differences in recruitment patterns,[15] we recommend further research to consider the influence of each head independently.

In light of several other studies reporting sex differences in stiffness,[7,26–28] our results of a significant sex-by-position interaction and significant main effect for sex are not surprising. The lack of significant sex-by-condition and sex-by-condition-by-position interactions, however, suggests that there was no difference in the stiffness of the gastrocnemius muscle between the sexes. The origin of the significant differences revealed could be related to dissimilarities in structural or physical characteristics. Potential structural characteristics include such factors as tissue elastic and collagen content variations. Komi and Karlsson[45,46] suggested the lower rates of force development and elastic energy storage exhibited by women could be related to differences in elastic tissue content within the muscle. Resistance to passive motion in the absence of muscle activation has been attributed to the parallel elastic components of muscle.[45,47,48] Different concentrations of elastic tissue between the sexes, as Komi and Karlsson[45,46] suggested, could therefore potentially explain the revealed sex differences in stiffness.

Pertinent physical characteristics include such factors as tissue cross-sectional areas, flexibility, and mechanical advantage differences. Several studies have demonstrated differences in muscle mass between the sexes.[28,49,50] Additionally, relationships have been shown to exist between cross-sectional areas and stiffness.[26,28,29] Thus, it could be that differences in muscle mass existed within our subjects between sexes, thereby accounting for the significant sex differences. However, within the limits of the relationships existing among muscle mass, body weight and ponderal index, this does not appear to be a factor in our study. The number of nonsignificant relationships revealed among stiffness, body weight, and ponderal index provides support for this statement. Interestingly, Chleboun et al[28] failed to reveal a significant relationship between muscle size and elbow stiffness at the end-range position, the location in the range where we revealed significant sex differences.

Much to our surprise were the significant, moderate-magnitude relationships revealed between the stiffness values and height. The results of the analysis of covariance, using height as the covariant, demonstrated that height could account for some of the previously revealed sex differences. This provides support for the ideas of structural or mechanical advantage (or both) differences existing between the sexes. Further research is needed to quantify the mechanism by which height influences stiffness.

We are not unique in finding significant position differences in stiffness at the ankle.[11,13,14,16,25,34] Toft et al[34] suggested that as the joint reaches end range, more parallel tissue elements become loaded, giving rise to the exponential increases in resistive forces required to passively move the ankle into further DF. The curves presented by Gareis et al[43] illustrate the exponential increases in passive tension resulting from muscle lengthening. The technique provided by Grieve et al[44] provides us with a method of quantifying the approximate length changes the gastrocnemius undergoes as the ankle moves into DF under each condition (Table 4).

It is also interesting to note the negative mean stiffness values at the 10° PF position under the knee-bent condition (both sexes) and under the knee-straight condition (women). We are not the first authors to report negative stiffness values.[51–53] Such expression, however, does not comply with the traditional concept of the physical characteristic stiffness. As Latash and Zatsiorsky[51] described, stiffness assessments reflect both features of the system and the method of testing. Because negative stiffness of biological tissues and structures is a clear impossibility, the negative stiffness values can be attributed to our particular assessment approach. Our method involved measuring the stiffness of the entire ankle joint complex under a passive state with respect to movement into dorsiflexion. During our measurements, throughout the entire range of motion, all components acting on the ankle joint, both anterior and posterior to the ankle joint axis, imposed their respective influences on our measurements. The negative stiffness value indicates that the net resistance measured while moving into DF from the 10° PF position was acting in the opposite direction (pulling the ankle into DF). In other words, in the plantarflexed position, the posterior musculoskeletal structures did not impose sufficient passive torque to overcome the passive torque being imposed by the anterior musculoskeletal structures, so negative values resulted. These negative values indicate the opposite of stiffness, or compliance, in the direction associated with the measurement (dorsiflexion). The anterior muscles (tibialis anterior, extensor digitorium longus, extensor hallicus longus) were most likely the major contributors to this phenomenon, with contributions also arising from the anterior joint capsule and anterior talofibular and deltoid ligaments.[42] Thus, the negative stiffness is simply a result of conducting the passive torque measurements on both sides of the equilibrium point of the ankle joint.[7] A similar phenomenon can be observed at the knee joint, as presented by Allison et al.[24]

Clinically, our results suggest that the stiffness of the gastrocnemius represents an important consideration in the management of lower leg conditions. Examples include antagonistic muscle syndromes such as anterior compartment syndrome and insertional tendinitis. Activities of daily living, including normal gait,[54,55] involve the ankle's moving repetitively into flexion positions greater than neutral by action of the anterior ankle muscles. If either of the previously mentioned antagonistic muscle syndromes is present, our results suggest that the work performed by the anterior muscles could be lessened through a reduction in the stiffness of the gastrocnemius. In other words, this investigation provides scientific rationale for addressing the gastrocnemius during clinical management strategies involving the lower limb. Further research should address the acute and chronic effectiveness of various intervention strategies on altering the passive stiffness of the ankle.

Most often, only flexibility (length) is taken into account during clinical assessments. Although stiffness and flexibility are interrelated,[6] they are largely separate physical characteristics. Flexibility is best defined as the angle beyond which no further displacement is possible,[34] providing limited information regarding the behavior of muscle-tendon units in response to stretch,[21,56] especially at muscle lengths used during daily activities.[34] In contrast, stiffness represents the amount of deformation proportional to the load applied.[21] Thus, from a clinical perspective, measuring passive stiffness to imposed dorsiflexion may provide additional insight into the cause of such pathologic conditions.

CONCLUSIONS

The results of this investigation are applicable to all clinicians treating lower extremity conditions and provide a scientific basis for clinicians incorporating gastrocnemius-stretching regimens into rehabilitation programs. The cause and application of the significant sex-by-position interaction requires further study. Further research is also warranted regarding the influence of the gastrocnemius during various levels of muscle activation and knee positions. The effectiveness of short-term and long-term intervention strategies in altering passive ankle JCS remains largely unknown.

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COMMENTARY

Kevin P. Granata

Kevin P. Granata, PhD, is the Research Director of the Motion Analysis and Motor Performance Laboratory, Departments of Orthopaedic Surgery and Biomedical Engineering, at the University of Virginia, Charlottesville, VA.

Musculoskeletal stiffness of the ankle joint is recognized as a significant factor contributing to postural stability, locomotion, and ankle joint stability. The clinical community is increasingly focusing on musculoskeletal joint stability for the prevention and treatment of injury. Although stiffness is not the lone determinant of stability, it is one of the major contributing factors. Hence, the authors provide much needed and timely data toward the understanding of ankle joint stiffness and stability. The purpose of this study was to identify the influences of ankle angle, knee angle (ie, gastrocnemius length), and sex on ankle joint complex stiffness (JCS). The results demonstrate a significant effect of all 3 factors on JCS.

Measurement and interpretation of musculoskeletal stiffness is a nontrivial effort. The authors provide a great service in pointing out that flexibility and stiffness are separate and distinct biomechanical concepts, each contributing in a unique manner to functional performance, injury, and pathology. An elegant method of computing stiffness was performed by computing the first spatial derivative of a best-fit analytic function to the measured force-by-angle data recorded during passive ankle dorsiflexion. Although the accuracy of the curve fit was not reported, example data in Figure 2 suggest excellent performance, indicating reliability when computing the slope, or JCS. However, the results and discussion illustrate the need for improved characterization of stiffness. Stiffness is not merely the ratio of joint moment divided by joint angle. It is defined as the partial derivative of force by length, or equivalently, rotational stiffness is the partial derivative of moment by angle. The authors employed the ordinary derivative to compute stiffness, thereby making the assumption that angle is the sole factor contributing to joint moment. This ignores changes in muscle activation and gravitational, inertial, and viscous contributions to joint moment among other factors. Focusing specifically on passive behavior controlled muscle activation. Examining the behavior during slow, isokinetic movement reduced inertial and viscous components. Gravitational confounding remained in the data and was noted by the authors (eg, negative stiffness values were explained as a gravitational artifact in combination with anterior muscle behavior). It is agreed that these effects caused this negative relationship between moment and angle, so it should not be confused with stiffness. Instead, it is simply the passive moment-by-angle relationship influenced by many factors. In fact, in this paradigm, negative stiffness would represent a source of free energy generation, thereby violating multiple laws of physics. Anatomical and physiologic stiffness elements that are part of the musculoskeletal system remain an excellent means for energy storage in the propagation of locomotion,[1,2] but the stiffness elements cannot generate energy. Hence, the values of negative stiffness reported in the results illustrate a source of error and the need for rigorous definitions and characterization of biomechanical stiffness. In an otherwise well-controlled effort, the results demonstrate potential pitfalls when interpreting stiffness data and warrant caution when interpreting the results.

The study identifies dorsiflexion angle, gastrocnemius length, and sex as factors that influence ankle JCS. Results from this study support previously published data illustrating that passive ankle JCS increases as the joint is moved toward the end range of motion.[3] Joint complex stiffness during the knee-flexed posture was reduced compared with the knee-straight condition, presumably identifying the contribution of the gastrocnemius stiffness characteristics. Results indicating sex differences in JCS are particularly interesting when considered from the clinical perspective of sex biases in musculoskeletal injury rates. Analyses suggest sex differences in JCS at the end range of motion may have been related to population differences in standing height and weight. These results are logical from a biomechanical perspective, as stiffness is related to material geometry, analogous to anthropometric trends in muscle cross-sectional area and length associated with height and weight.

The results describe passive characteristics of the ankle joint in unloaded conditions. One wonders to what extent these passive components contribute to functional performance or injury risk. During walking, a healthy adult readily exceeds 150 Nm of external dorsiflexion moment about the ankle.[4] The joint moment measured in this study attributed merely 9 Nm of external dorsiflexion moment to the JCS. Moreover, the data in the current study were measured with the ankle joint unloaded (ie, the subject was either kneeling or lying prone). Recent evidence[5] indicates that passive musculoskeletal stiffness may be influenced by the compressive load achieved in standing postures. Total JCS is also influenced by the contribution of active muscle stiffness[6] generated during weight-bearing activity. Passive, unloaded stiffness data are necessary to understand ankle joint performance and injury prevention but require further research efforts to fully characterize ankle stability.

In general, this study presents some very insightful information when considered from a clinical perspective. I encourage future researchers, based upon these efforts, to improve the characterization of musculoskeletal stiffness and to advance the paradigm to permit insight into stiffness behavior during functionally loaded conditions, including passive and active muscle contributions to joint stability.

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AUTHORS' RESPONSE

We thank Dr Granata for his commentary concerning our manuscript and appreciate the opportunity to respond. Dr Granata provides some excellent insights and raises an important question regarding the measurement of musculoskeletal stiffness: How should musculoskeletal stiffness be assessed? In light of the recent increased interest in the potential role that stiffness may play in functional joint stability, it is important that researchers work under universally accepted operational definitions and methods to promote synthesis of information across investigations. To date, however, there has been little consistency throughout the literature in either the definitions or methods of stiffness used. Thus, we completely agree with Dr Granata's recommendation for future research to improve our understanding of musculoskeletal stiffness and its importance in joint stability.

However, in contrast to regarding stiffness from a joint stability perspective, our current research was aimed at beginning to evaluate stiffness as a potential contributor to pathologic musculoskeletal conditions. Specifically, our purpose was simply to provide athletic trainers with a scientific rationale regarding several intervention strategies involving the gastrocnemius. To this end, we chose a passive measurement approach, and to remain consistent with several previously published investigations (references 7,8,21,24,25,28–30), we opted for the approach used. As Dr Granata indicates, stiffness is the partial derivative of the force-length relationship (or moment-angle relationship in angular systems), and therefore, all other factors (ie, muscle activation, gravitational, inertial, viscosity, thixotropy, etc) confounding this relationship must be either controlled or reduced. Our methods involved a slow, isokinetic displacement in the absence of muscle activation, thereby controlling the issues associated with inertia, viscosity, and muscle activity. The confounding effects of gravity were reduced during data reduction by correcting for the mass of the footplate and foot and lever arm length, while thixotropy and stress relaxation effects were reduced through use of familiarization trials.

The apprehension that Dr Granata expresses concerning the negative stiffness values revealed in the 10° plantar-flexed position is valid. His interpretation of this phenomenon appears to be that residual confounding stiffness influences resulted from limitations in the measurement technique selected. The point concerning negative stiffness representing free energy generation is well taken; however, we propose that energy was not generated but rather released from storage as a result of forcing the ankle into a 20° plantar-flexed position. In this position, the anterior ankle musculature was stretched, and, as the ankle displaced into dorsiflexion, the anterior ankle musculature strain energy was recovered. Accompanying the changing ankle position would be alterations in the moment arms of the anterior ankle musculature, thus potentially explaining the negative stiffness values. Regardless, we agree with Dr Granata that caution must be exercised in interpreting stiffness data.

While we agree that our measurement method was not perfect and may account for the above discrepancies, we maintain our position that it was appropriate to answer our specific clinical research question: What is the role of the gastrocnemius in passive ankle joint complex stiffness? It is important to recognize that all structures about the ankle joint influenced our measurements, and thus, the final resistance measured by the load cell was the net torque acting at the ankle joint to the imposed dorsiflexion displacement. The fact that the negative stiffness values were revealed only under the knee-bent position for the men further supports our conclusion that the gastrocnemius potently influences passive ankle joint complex stiffness. In other words, under reduced gastrocnemius influence, the ankle joint demonstrated compliance to the imposed dorsiflexion displacement in the 10° plantar-flexed position.

We want to emphasize that our results are valid only under specific circumstances: an unloaded joint without muscle activity. As Dr Granata indicates, these results cannot be directly applied to many acute injury mechanisms that involve the joint's being loaded with varying degrees of muscle activation. The results are applicable, however, to specific circumstances within activities of daily living, such as the anterior musculature working to dorsiflex the ankle during the swing phase of gait.

Again, we thank Dr Granata for his excellent commentary. We also thank the anonymous reviewers and editorial staff for their assistance in helping to improve the quality of this manuscript.

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Isokinetic Hamstrings:Quadriceps Ratios in Intercollegiate Athletes

John M. Rosene*; Tracey D. Fogarty†; Brian L. Mahaffey‡

*University of Hawaii at Manoa, Honolulu, HI; †Castleton State College, Castleton, VT; ‡Smith Glynn Callaway Clinic, Springfield, MO

John M. Rosene, DPE, ATC, contributed to conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article. Tracey D. Fogarty, DPE, and Brian L. Mahaffey, MD, MSPH, contributed to analysis and interpretation of the data and drafting, critical revision, and final approval of the article.

Address correspondence to John M. Rosene, DPE, ATC, Department of Kinesiology and Leisure Science, University of Hawaii at Manoa, 1337 Lower Campus Road, PE/A Complex, Room 231, Honolulu, HI 96822. Address e-mail to rosene@hawaii.edu.

Objective: To compare the differences in the concentric hamstrings:quadriceps (H:Q) ratio among athletes in different sports at 3 velocities.

Design and Setting: We measured the H:Q ratio of both knees using the Biodex Pro Isokinetic Device.

Subjects: Eighty-one male and female collegiate athletes.

Measurements: We performed analyses for sport, velocity, and side of body for each sex. To compare the means of the concentric H:Q ratios for mean peak torque and mean total work, a 2 × 3 × 4 mixed-factorial analysis of variance was computed for women and a 2 × 2 × 3 mixed-factorial analysis of variance was computed for men.

Results: We observed no significant interactions for men and women for the concentric H:Q ratio for mean peak torque. There was a significant mean difference among velocity conditions and a significant difference for men with respect to velocity. No significant differences were found for side of body or sport.

Conclusions: The H:Q ratio increased as velocity increased. No differences existed for the H:Q ratio for sport or side of body.

Key Words: knee, sex, concentric, eccentric

Isokinetic assessment can be used to measure torque values at several joints in the body; the knee is perhaps the joint most commonly tested. This assessment typically involves comparing the involved joint with the uninvolved joint.[1] Isokinetic testing can be used to evaluate quadriceps and hamstrings muscle strength, providing a determination of the magnitude of torque generated, and subsequently, the hamstrings to quadriceps (H:Q) strength ratio.[2]

The H:Q ratio has been used to examine the similarity between hamstrings and quadriceps moment-velocity patterns and to assess knee functional ability and muscle balance.[1,3,4] This ratio has conventionally been expressed as concentric hamstrings to quadriceps strength[5,6] and recently as eccentric hamstrings to concentric quadriceps strength.[7] Researchers have examined this ratio in both sexes and in different age groups and rehabilitation settings.[1,6,8–21] The H:Q ratio is velocity and position dependent[7] and may reflect predisposition to injury.[22,23] This predisposition may result from decreased antagonist hamstrings coactivation during extension loads.[24]

Baratta et al[24] examined antagonist musculature assisting in knee joint stability. Athletes who did not regularly exercise their hamstrings had a significant decrease in hamstrings activation compared with normal healthy subjects and athletes who regularly exercised the hamstrings during knee flexion-extension movements. Inhibiting antagonist coactivation activity allows for increased torque and efficiency during extension. It has been suggested that a highly developed quadriceps muscle contributes to decreased antagonist hamstrings coactivation, thereby increasing susceptibility to anterior cruciate ligament (ACL) injury.[24]

Although it is difficult to generalize, the normal H:Q ratio is considered to be 50% to 80% as averaged through the full range of knee motion, with a higher ratio at faster speeds.[2,8,23] As the ratio approaches 100%, the hamstrings have an increased functional capacity for providing stability to the knee.[10] This increased knee stability may reduce the possibility of an anterolateral subluxation of the tibia.[4]

To date, investigations have focused on evaluation of the H:Q ratio in the ACL-deficient knee.[10,25,26] Although the H:Q ratio has been studied in athletes with healthy knees, many of the populations studied have been professional athletes.[5,19,23,27,28] Few researchers have investigated the collegiate athletic population.[16] Therefore, our purpose was to compare the differences in concentric H:Q ratio for mean peak torque (MPT) and mean total work (MTW) among athletes in different sports and right versus left limbs at 60, 120, and $180°\cdot s^{-1}$. The velocities were chosen based on similar velocities used in previous investigations.[1,3,4,10,16,22,23]

METHODS

The subjects tested were 81 (26 men, 55 women) collegiate athletes with a mean age of 19.3 ± 1.32 years; mean height, 172.16 ± 1.00 cm; mean weight, 70.79 ± 11.34 kg; and mean body fat percentage, 18.65 ± 8.79%. Each subject was currently active with an intercollegiate varsity athletic team and volunteered for the study. The sports represented were men's volleyball (n = 9), women's volleyball (n = 12), men's soccer (n = 17), women's soccer (n = 10), women's basketball (n = 10), and women's softball (n = 23). A subject was disqualified for any documented history of knee ligament or meniscal damage or current injury to the thigh musculature. All procedures were approved by the Institutional Review Board at the University of Missouri-Columbia, and all subjects gave written informed consent to participate in athletics and medical screenings.

To measure the H:Q ratio, we used the Biodex Pro Isokinetic Device (Biodex Medical Systems, Shirley, NY) to perform knee concentric flexion and extension movements. We assessed MPT and MTW among men and women involved in various sports and between right and left limbs. Measurements were taken at 60, 120, and 180°·s^{-1}.

For the testing session, subjects were seated with the powerhead orientation, powerhead tilt, and seat orientation set at 0°. The seatback tilt was set at 15°. Knee axis of rotation was determined by a line drawn in the sagittal plane through the femoral condyles. The subject was restrained when seated in the chair by 2 straps across the torso in a criss-cross fashion and by a strap placed across the thigh midway between the anterior superior iliac spine and superior border of the patella. The standard knee-attachment device was secured to the leg so that the inferior border of the pad was placed on the superior border of the medial malleolus.

Once the subject was secured in the chair, the range-of-motion limits were determined via goniometry and set. The starting position was 90° of knee flexion, and the endpoint was 0° of full knee extension. Gravity correction was performed for each limb before testing in order to reduce the risk of inaccurate data. Failure to correct for the effects of gravity when measuring the H:Q ratio may result in an overestimation of the ratio. This overestimation is due to a perceived increase in the strength of the hamstrings relative to the quadriceps.[29] Once the subject was seated and secured, he or she performed 5 repetitions at 60°·s^{-1}, 10 repetitions at 120°·s^{-1}, and 15 repetitions at 180°·s^{-1}. Before the isokinetic test, subjects performed 5 repetitions at 60°·s^{-1} as a warm-up. A 1-minute rest period was provided between velocities, and at the conclusion of the 180°·s^{-1} set, the opposite leg was tested. Before the testing sessions, subjects were allowed to practice by performing several light contractions until they demonstrated proper technique.[27,30]

Statistical Analysis

Analyses were performed for sport, velocity, and side of body for each sex. For women, a 2 × 3 × 4 mixed-factorial analysis of variance (ANOVA) was computed to compare the means of the concentric H:Q ratios for MPT and MTW. The 3 independent variables included 2 within-subjects factors (side of body [right or left] and velocity [60, 120, or 180°·s^{-1}]) and a between-subjects factor of sport (volleyball, soccer, softball, or basketball). For men, a 2 × 2 × 3 mixed-factorial ANOVA was computed with 2 within-subjects factors, side of body and velocity, and the between-subjects factor of sport (volleyball or soccer). We used the generalized least squares procedure from the Statistical Package for Social Sciences[31] (version 8.0 for Windows, SPSS Inc, Chicago, IL) to calculate the ANOVAs. For all analyses, the alpha level was set at $P = .05$.

To test for basic assumptions, the Mauchly test of sphericity was computed for the within-subjects factors of velocity and side of body. We used this test to analyze the similarity of the treatment differences across the 3 velocity conditions for all subjects.

Table 1. H:Q Ratio of Right and Left Legs for Mean Peak Torque by Sport and Velocity (°·s^{-1}) in Women

Velocity (°·s^{-1})	n	Right Side	Left Side
Soccer athletes	10		
60		52.53 ± 8.41	47.16 ± 6.18
120		62.20 ± 29.22	53.54 ± 9.14
180		58.31 ± 13.12	57.96 ± 10.11
Softball athletes	23		
60		46.60 ± 6.15	46.59 ± 6.62
120		51.22 ± 7.02	52.29 ± 8.70
180		59.23 ± 10.55	61.00 ± 12.10
Volleyball athletes	12		
60		50.84 ± 5.53	52.36 ± 9.73
120		53.46 ± 7.28	54.00 ± 10.32
180		56.93 ± 9.94	53.52 ± 7.37
Basketball athletes	10		
60		55.03 ± 9.65	51.20 ± 4.73
120		66.26 ± 36.37	55.88 ± 4.37
180		63.85 ± 10.58	60.27 ± 4.65
Total	55		
60		50.14 ± 7.74	48.79 ± 7.32
120		56.44 ± 20.76	53.54 ± 8.45
180		59.40 ± 10.86	58.68 ± 10.37

Results

The descriptive statistics for side of body across the 3 velocities and sport are presented in Tables 1 through 4 for women and men. For the Mauchly test of sphericity, the concentric H:Q ratios for MPT for women for velocity and velocity × side of body conditions were significantly different ($P < .05$) (Mauchly $W_{speed} = 831$; Mauchly $W_{speed \times side} = .571$). For men, the concentric H:Q ratios for MPT and MTW were significantly different for velocity (MPT, Mauchly $W_{speed} = .717$; MTW, Mauchly $W_{speed} = 16.014$). We used the Greenhouse-Geiser statistic to adjust for the degrees of freedom.

For men and women, no significant interactions were found for concentric H:Q ratio for MPT. The analysis of the main effects revealed only a significant mean difference among velocity conditions (women: $F_{1.71,87.22} = 20.962$, $P = .000$; men: $F_{1.56,37.43} = 15.314$, $P = .000$). Pairwise comparisons for both groups indicated that 180°·s^{-1} was associated with significantly higher MPT values than 120 and 60°·s^{-1}, and 120°·s^{-1} was associated with significantly higher MPT values than 60°·s^{-1} (Figures 1 and 2). No significant differences were found for side of body or sport. Additionally, we noted no significant interactions or main effects for concentric H:Q ratio for MTW for women. However, a significant difference was found for men with respect to velocity ($F_{1.56,37.43} = 15.314$, $P = .000$). Analysis of the pairwise comparisons indicated that 120°·s^{-1} was associated with significantly higher MTW values than 180°·s^{-1} (Figure 3).

DISCUSSION

Isokinetic testing of the H:Q ratio provides a quantitative measurement of torque from agonist and antagonist muscle contraction surrounding the knee joint.[15] This ratio has also been examined as a possible screening tool for predisposition to injury.[23] When the knee is injured, the H:Q ratio is often

Table 2. H:Q Ratio of Right and Left Legs for Mean Total Work by Sport and Velocity (°·s⁻¹) in Women

Velocity (°·s⁻¹)	n	Right Side	Left Side
Soccer athletes	10		
60		54.02 ± 19.69	53.75 ± 7.52
120		57.99 ± 15.22	57.60 ± 11.69
180		54.10 ± 15.15	56.37 ± 11.54
Softball athletes	23		
60		56.31 ± 9.67	54.85 ± 10.41
120		54.23 ± 11.95	58.23 ± 22.69
180		53.53 ± 13.04	54.07 ± 13.54
Volleyball athletes	12		
60		58.53 ± 7.14	60.83 ± 10.52
120		55.87 ± 5.65	59.31 ± 9.66
180		56.04 ± 6.63	54.48 ± 7.33
Basketball athletes	10		
60		64.64 ± 12.01	61.61 ± 7.23
120		62.63 ± 10.42	62.72 ± 8.03
180		60.10 ± 10.22	60.76 ± 9.26
Total	55		
60		57.89 ± 12.23	57.19 ± 9.79
120		56.80 ± 11.44	59.17 ± 16.29
180		55.37 ± 11.82	55.80 ± 11.33

Table 3. H:Q Ratio of Right and Left Legs for Mean Peak Torque by Sport and Velocity (°·s⁻¹) in Men

Velocity (°·s⁻¹)	n	Right Side	Left Side
Soccer athletes	17		
60		50.82 ± 11.04	50.18 ± 13.29
120		56.87 ± 13.42	56.34 ± 15.39
180		60.77 ± 14.55	58.31 ± 13.13
Volleyball athletes	9		
60		50.94 ± 12.29	47.09 ± 6.98
120		50.02 ± 7.99	51.30 ± 6.68
180		57.71 ± 12.93	57.56 ± 8.65
Total	26		
60		50.86 ± 11.24	49.11 ± 11.44
120		54.50 ± 12.12	54.60 ± 13.11
180		59.71 ± 13.82	58.05 ± 11.60

Table 4. H:Q Ratio of Right and Left Legs for Mean Total Work by Sport and Velocity (°·s⁻¹) for Men

Velocity (°·s⁻¹)	n	Right Side	Left Side
Soccer athletes	17		
60		57.88 ± 15.68	59.26 ± 17.34
120		59.32 ± 15.08	59.51 ± 14.89
180		52.41 ± 16.69	56.45 ± 13.63
Volleyball athletes	9		
60		53.81 ± 18.77	53.55 ± 12.14
120		50.33 ± 15.00	56.85 ± 9.85
180		47.50 ± 14.16	48.41 ± 11.22
Total	26		
60		56.47 ± 16.55	57.28 ± 15.72
120		56.20 ± 15.38	58.59 ± 13.21
180		50.71 ± 15.75	53.67 ± 13.21

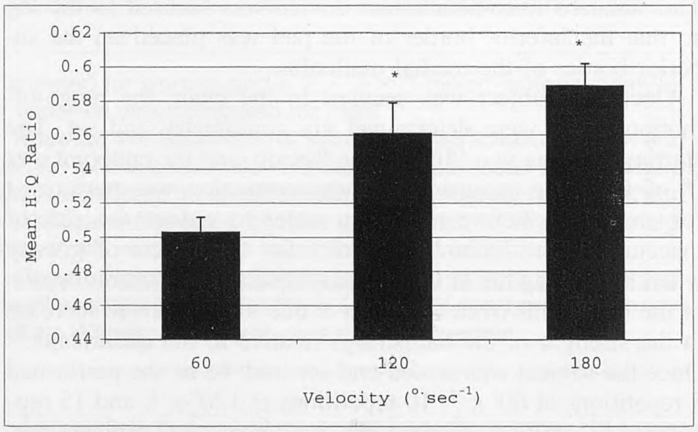

Figure 1. Women's mean peak torque H:Q ratios. Values were significantly higher at 180°·s⁻¹ than at 120 and 60°·s⁻¹ and significantly higher at 120°·s⁻¹ than at 60°·s⁻¹.

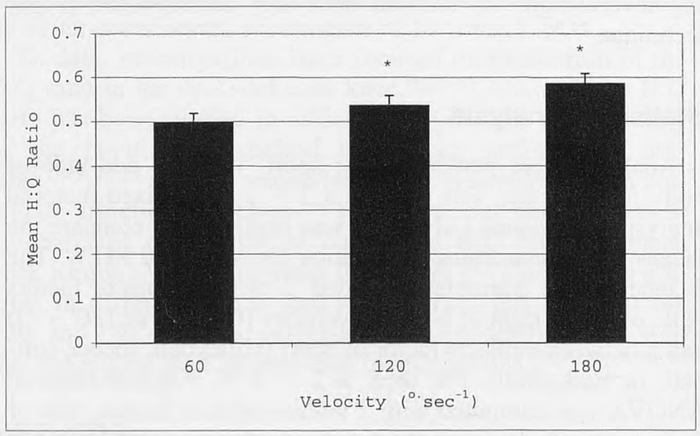

Figure 2. Men's mean peak torque H:Q ratios. Values were significantly higher at 180°·s⁻¹ than at 120 and 60°·s⁻¹ and significantly higher at 120°·s⁻¹ than at 60°·s⁻¹.

used as a rehabilitative goal due to the importance of the flexor-extensor strength balance in overall knee stabilization.[16] Reduced function of the antagonist hamstrings due to activities that emphasize loads on the knee extensors may result in muscular imbalances between the hamstrings and quadriceps, thereby possibly predisposing athletes to injury. This predisposition may be due to the surrounding ligamentous structures supporting most of the imposed load and decreased antagonist hamstrings coactivation during extension loads.[24,32]

Several investigators have examined the H:Q ratio after ACL injury, using different test velocities and examining the consequences of proprioception relative to the H:Q ratio after ACL injury.[4,6,10,25,33] In a comparision of injured versus noninjured knees at 2 test velocities, Lund-Hanssen et al[6] reported a higher H:Q ratio in injured knees at the higher velocity (240°·s⁻¹) compared with uninjured knees. However, at the lower velocity (60°·s⁻¹), no difference was noted between groups. This difference at the higher test velocity was attributed to a decrease in quadriceps muscle strength in the injured group due to rehabilitation; fast-twitch muscle fiber atrophy may have been caused due to alterations in exercise patterns during rehabilitation.[6] Kannus[25] also reported a higher H:Q ratio in injured knees at higher speeds (180°·s⁻¹). This

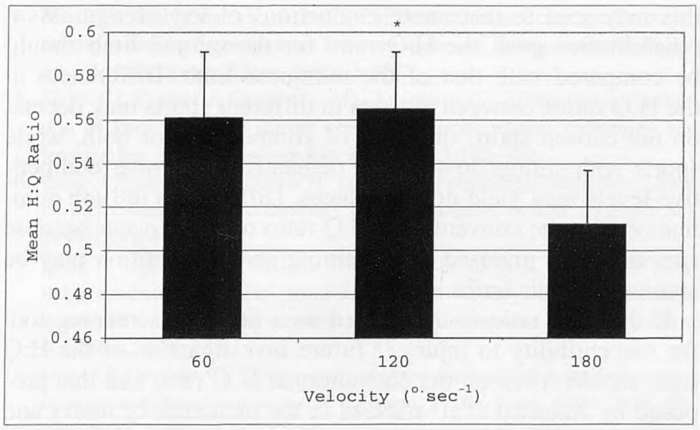

Figure 3. Men's mean total work H:Q ratios. Values were significantly higher at 120°·s^{-1} than at 180°·s^{-1}.

led to the conclusions that, in injured knees, the H:Q ratio increases at higher speeds, in part due to quadriceps femoris muscle weakness, and H:Q ratios of the opposite limb should be used as rehabilitative goals. However, the opposite limb ratio should only be used if that limb is not injured. An injured opposite limb may result in misleading H:Q ratios.[25]

Corrigan et al[33] examined proprioception in the ACL-deficient knee, including correlating the position sense of the knee with the H:Q ratio. No correlations were found between position sense and H:Q ratios for the control (non-ACL-deficient) group. However, in the study group, the ACL-deficient knee did significantly correlate with the H:Q ratio for both threshold of perception of movement (joint angle is slowly altered less than 0.5°·s^{-1}) and position sense (ability to reproduce the angle in which the joint had been placed before being moved). No such correlations were found for the non-ACL-deficient knee in the study group.[33]

In the ACL-deficient knee, hamstrings dominance can aid in stabilization by acting as a synergist to the normal ACL. This stability is of particular importance during high-speed activity because, it has been suggested, instability at slow speeds is well compensated for, while compensation decreases as speeds increase. Posterior stabilization about the knee through proper hamstrings conditioning may assist in the reduction of anterolateral translation and, thereby, reduce the incidence of ACL injury or reinjury.[33] However, rehabilitative goals should focus on obtaining an optimal H:Q ratio, not deemphasizing quadriceps strength in knee function.

In our investigation using healthy knees, as velocity increased, the H:Q ratio increased. The increased H:Q ratio with increased velocity is consistent with the findings of Kannus[25] in injured knees and with those of Croce et al,[22] who reported increases in the H:Q ratio from 61.0 ± 14.3% at 60°·s^{-1} to 62.0 ± 14.7% at 90°·s^{-1} in nondisabled, sedentary controls. Comparatively, our subjects had H:Q ratios of 49.8% at 60°·s^{-1}, 53.6% at 120°·s^{-1}, and 58.6% at 180°·s^{-1} for men and 50.3% at 60°·s^{-1}, 56.1% at 120°·s^{-1}, and 58.9% at 180°·s^{-1} for women. These ratios are lower than those reported by Bennell et al[23] at 60°·s^{-1} and 180°·s^{-1}, yet similar to those of Aagaard et al[3] at 120°·s^{-1}. Table 5 presents selected normative values for the H:Q ratio at similar velocities.[29]

We found no differences in the H:Q ratio between athletes in different sports. Zakas et al[28] reported no significant differences in H:Q ratio among different divisions of basketball and soccer players at 60°·s^{-1} and 180°·s^{-1}. However, Read and Bellamy[19] noted differences in the H:Q ratios among tennis, squash, and track athletes. In each case, the authors attributed

Table 5. Selected Normative Values for the H:Q Ratio at Velocities of 60°, 120°, and 180°·s^{-1}*

Study and Population	Sex	Age (y)	Dominant Flexion-Extension Ratio	Nondominant Flexion-Extension Ratio
60°·s^{-1}				
Berg et al (1985)†				
College basketball players	F	20	.63	.67
Fillyaw et al (1986)‡	F	19	.67	
University soccer players			.54‖	
120°·s^{-1}				
Berg et al (1985)†				
College basketball players (dominant = right-side values, nondominant = left-side values)	F	20	.67	.71
180°·s^{-1}				
Berg et al (1985)†				
College basketball players (dominant = right-side values, nondominant = left-side values)	F	20	.72	.74
Oberg et al (1986)§				
Soccer players‖	M	24–26	.75	
Nonsoccer players‖	M	21	.62	

*Adapted with permission from David H. Perrin, 1993, *Isokinetic Exercise and Assessment* (Champaign, IL, Human Kinetics), 153–158.[31]
†Berg K, Blanke D, Miller M. Muscular fitness profile of female college basketball players. *J Orthop Sport Phys Ther.* 1985;7:59–64.
‡Fillyaw M, Bevins T, Fernandez L. Importance of correcting isokinetic peak torque for the effect of gravity when calculating knee flexor to extensor muscle ratios. *Phys Ther.* 1986;66:23–31.
§Oberg B, Moller M, Gillquist J, Ekstrand J. Isokinetic torque levels for knee extensors and knee flexors in soccer players. *Int J Sports Med.* 1986; 7:50–53.
‖Gravity corrected.

the findings to training adaptations acquired by the subjects for their respective sports. The finding of no differences in the H:Q ratios among athletes in different sports in our study may be associated with training adaptations and level of competition.

Zakas et al[28] suggested that the strength and flexibility associated with game demands in sport, specifically basketball and soccer, may result in specific training adaptations that produce similar H:Q ratios among these 2 sports. Bennell et al,[23] in their study of Australian rules footballers, suggested that differences in H:Q ratios may be due to level of competition. The sports represented in our study (volleyball, soccer, basketball, and softball) all require similar movements (running, jumping, cutting, deceleration, and acceleration) to adequately perform the chosen activity. In addition, each subject participated in a collegiate setting, with each sport in the same division. These factors of training adaptations and level of competition may be responsible for the lack of differences in the H:Q ratios among the sports examined. However, coaches, strength and conditioning professionals, and athletic trainers should exercise caution when incorporating training and conditioning programs for similar sports at any level. Attention must be given to proper muscle balance between agonist and antagonist muscle groups due to a possible increased risk of injury as a result of muscular imbalance.[24]

Muscular imbalance has been shown to affect injury patterns in female athletes. Before training, female athletes exhibit imbalances between hamstrings and quadriceps muscle strength. When comparing the incidence of knee injury in male athletes, untrained female athletes were 4.8 to 5.8 times more likely and trained female athletes were 1.3 to 2.4 times more likely to suffer a knee injury than male athletes.[32] Through neuromuscular training, a reduction in knee ligament injuries may be possible because of biomechanical effects (decreased landing forces and adduction-abduction moments) and physiologic effects (decreased estrogen levels and increased H:Q strength ratios).[32]

Female athletes tend to be quadriceps dominant, contracting the quadriceps muscles in response to anterior tibial translation, versus nonathletes, who tend to contract the hamstrings. If the hamstrings are ignored during training, quadriceps dominance in the trained female athlete influences the H:Q ratio when compared with the nonathlete. To reduce the incidence of knee injury in female athletes, conditioning should include measures to increase the H:Q ratio and decrease abduction-adduction moments.[32]

Side-to-side differences in muscle strength typically are expressed as differences between dominant and nondominant sides,[1,27,34] particularly in uninjured subjects. We found no differences between right and left or dominant and nondominant limbs. These findings are in agreement with those of Holmes and Alderink,[1] Gur et al,[27] and Calmels et al.[34] Leg dominance has been defined as the preferred versus nonpreferred leg[34] or the leg preferred for kicking.[22,27,35] It is possible that specific loads placed on the lower extremities in these athletes involved in different sports were sufficient to maintain similar strength on both sides.

The H:Q ratio can be used to examine similarities between quadriceps and hamstrings moment-velocity patterns with isokinetic testing. This ratio, however, is velocity dependent, as evidenced by the increase in the H:Q ratio as velocity increases. When using this ratio as an evaluative tool, the velocity-dependent changes in the H:Q ratio must not be ignored as this may lead to inaccurate evaluations of leg strength. As a rehabilitative goal, the H:Q ratio for the injured limb should be compared with that of the uninjured limb. Differences in the H:Q ratios between athletes in different sports may depend on the chosen sport, the level of competition, or both, while sports with similar lower limb demands and similar competitive levels may yield no differences. Differences in limb dominance with the conventional H:Q ratio may not occur because specific loads imposed with training and competition may be similar for both limbs.

If the H:Q ratio is to be used as a possible screening tool for susceptibility to injury,[23] future investigations of the H:Q ratio should focus on the conventional H:Q ratio and that proposed by Aagaard et al[7] relating to the incidence of injury and recovery from injury. Preseason assessments should include a baseline evaluation of the H:Q ratio with the subsequent tracking of injuries to the lower extremities.

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Knee Extensor Electromyographic Activity-to-Work Ratio is Greater With Isotonic Than Isokinetic Contractions

Randy J. Schmitz; Kevin C. Westwood

University of North Carolina at Greensboro, Greensboro, NC

Randy J. Schmitz, PhD, ATC, contributed to conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article. Kevin C. Westwood, MS, ATC, contributed to conception and design; acquisition of the data; and critical revision and final approval of the article.

Address correspondence to Randy J. Schmitz, PhD, ATC, 250 HHP, Applied Neuromechanics Research Laboratory, University of North Carolina at Greensboro, Greensboro, NC 27402. Address e-mail to rjschmit@uncg.edu.

Objective: To determine whether isotonic or isokinetic contractions produced greater electromyographic (EMG) activity per unit of work during isotonic and isokinetic knee-extension exercise.

Design and Setting: Subjects performed three 3-second maximal voluntary isometric contractions of the dominant knee extensors for EMG normalization. Exercise testing performed on the Biodex System 3 Dynamometer involved 10 isokinetic contractions at $180° \cdot s^{-1}$ and 10 isotonic contractions with the resistance set at 50% of the previously recorded maximal voluntary isometric contraction.

Subjects: Recreationally active college students (10 men and 11 women).

Measurements: Surface EMG signals were collected from the vastus medialis and lateralis muscles and then integrated (IEMG) over the concentric phase of each repetition for both exercises. The IEMG was divided by the total work performed during the concentric phase for each exercise (IEMG/W).

Results: We analyzed the IEMG/W data using a 1-between (sex), 2-within (exercise and muscle) repeated-measures analysis of variance. There was a significant main effect for exercise, with the isotonic IEMG/W value being significantly greater than the isokinetic IEMG/W value. Additionally, the IEMG/W relationship did not appear to be affected by sex or individual muscle tested.

Conclusions: Per unit of work performed, the isotonic contractions resulted in greater motor unit recruitment or an increased rate of firing, or both. This finding may have implications for the early phase of rehabilitation, when goals include complete motor unit recruitment of injured or atrophied muscles.

Key Words: rehabilitation, IEMG, dynamometry

Two common types of active resistance exercise are reported in the sports medicine literature: isotonic (constant load) and isokinetic (constant velocity or accommodating). Force-production capability of muscle can be increased by either method of resistance, provided the normal stimulation patterns of the muscle are exceeded.[1] With the advent of the isokinetic method of muscle resistance came the natural comparisons with the more common methods of isotonic resistance training. With either method, training regimens of the past and the present are most often based on the number of sets and repetitions completed.[2]

Work is performed when the muscle shortens and a limb is moved through space. Isokinetics are an accommodating type of exercise that theoretically allows the muscle to perform more work over the same range of motion compared with isotonic exercise.[3,4] This allows the exercising muscle to generate its maximal mechanical output at all angles throughout the range of motion, which allows for changes in the musculoskeletal lever system. With isotonic resistance, the muscle must simply overcome inertia to move the limb through space.[5] It has been speculated that isotonic resistance may not be entirely efficient for loading the muscle throughout the physiologic range of motion.[3] Efficiency in this context occurs when the type of resistance matches the maximal muscle-joint complex torque output throughout the entire range of motion.[3]

The effectiveness of isotonic versus isokinetic contractions in the development and assessment of muscle strength has long been investigated.[3,6] The superiority of both isotonics[7] and isokinetics[8] has been demonstrated. Kovaleski et al[7] showed that an equal number of sets and repetitions for isotonic and isokinetic training groups resulted in greater strength gains for the isotonic group. In contrast, Wojtys et al[8] reported that isokinetics were superior to isotonics in training groups that completed an equal number of sets and repetitions during a 6-week training protocol. However, Wojtys et al[8] did not account for specificity of contraction type and testing.

To increase the force-generating capacity of muscle, one must increase normal activation levels.[1] Activation levels can be increased by increasing the number of stimulated muscle fibers or increasing the rate at which the muscle fibers are recruited, or both. Surface electromyography (EMG) is a tool that may be useful in the indexing of such phenomena because it can measure the voltage associated with recruitment of motor units. Integrated EMG (IEMG) has been described as a measurement for estimating the number of motor units firing and the firing frequency of motor units.[1]

As described previously, isotonics and isokinetics are 2 dynamic methods used to improve muscle strength. Because the goal of both training methods is to increase the number of motor units being recruited or the frequency at which they are recruited (during maximal contractions), surface EMG could be used to measure motor unit activation during each type of contraction. Previous researchers have investigated differences in activation levels of maximal isotonic and maximal isokinetic contractions. No differences were noted between the IEMG of the 2 contraction types of the biceps brachii.[5]

The previously described information provides insight into the differences between isokinetic and isotonic contractions. To correctly determine which type of resistance may be best suited to recruit more motor units or increase the frequency at which motor units fire, we can investigate the relative activation level of the motor units per unit of work performed. If muscle activation level is normalized to the amount of work done, the contraction type that provides for optimal recruitment of the muscle could be determined. This may be of importance in the early phase of rehabilitation, when completeness of central drive rather than intensity (force level) is important.[9] Therefore, our purpose was to determine whether isotonic or isokinetic contractions produced greater EMG activity per unit of work during knee-extension exercise.

METHODS

Subjects

Twenty-one volunteers (10 men, 11 women; age, 20.3 ± 1.6 years; height, 175.9 ± 10.5 cm; mass, 74.4 ± 15.6 kg) were recruited from the general college population. All subjects gave informed consent as approved by the university institutional review board before participating in the study. The board also approved the study.

Instrumentation

All muscle testing was performed on the Biodex System 3 Dynamometer (Biodex Medical Systems, Shirley, NY). Torque, velocity, and position analog data were collected from the Biodex during all muscle performance measures and digitized for storage and later analysis. Simultaneously, the surface EMG signal from the vastus lateralis and vastus medialis muscles was collected with the Therapeutics Unlimited Model 544 System (Therapeutics Unlimited Inc, Iowa City, IA) (input resistance, 15 MΩ at 100 Hz; common mode-rejection ratio, 87 dB at 60 Hz; sampling frequency bandwidth, 20 to 4000 Hz) using preamplified electrodes (Therapeutics Unlimited; preamplification gain, 35; interelectrode distance, 22 mm; electrode diameter, 8 mm) and subsequently recorded at a frequency of 1000 Hz on a Pentium-based microcomputer. The EMG activity from both muscles was collected to ensure that we obtained the valid signal from the muscles, because EMG and force contribution should be equal from the respective muscles during knee extension.[10,11] Therefore, any EMG differences between the vastus lateralis and vastus medialis would alert us to problems with the EMG data collection. All data extraction was performed with custom LabVIEW Software programming (National Instruments Corp, Austin, TX).

Setup Procedures

To prepare each subject for EMG surface-electrode placement, the skin was shaved at each electrode location, followed by abrasion and alcohol cleansing to help reduce skin impedance. Preamplified electrodes were placed midway between the muscle belly and the distal tendinous insertion of the vastus lateralis and medialis muscles and were left in place until the completion of the experiment. A reference surface electrode was placed over the contralateral lateral malleolus. After a 5-minute warm-up on a cycle ergometer, the subject was seated in the chair of the dynamometer. All testing was performed on the dominant knee. Knee dominance was determined by asking the subject which leg would be used to kick a ball. The anatomical axis of the knee was aligned with the axis of the dynamometer, and the distal aspect of the arm of the dynamometer was placed 4 cm proximal to the medial malleolus. The dynamometer seat back was placed at 100°. The ankle was fastened to the dynamometer arm, and the chest, thigh, and waist were fastened to the dynamometer seat with hook-and-loop tape stabilization straps to minimize extraneous movements.

Experimental Protocol

Subjects underwent isotonic and isokinetic exercise protocols on the same day, separated by 5 minutes. Testing order was stratified by sex, then randomly assigned. Total work was calculated from the concentric knee extension data for each exercise.

Exercise Session

Each subject performed 3 submaximal voluntary isometric contractions for isometric familiarization purposes. This was followed by three 3-second maximal voluntary isometric contractions (MVICs) of the quadriceps muscle. Isometric testing was performed with the knee in 90° of flexion.[12]

For all exercise testing, the subject performed concentric knee extension from 90° to 0° of knee extension.[13] For isokinetic testing, the dynamometer's resistance was set at $180^\circ \cdot s^{-1}$. This velocity was based on clinical practice and a previous investigation using $180^\circ \cdot s^{-1}$ to compare isokinetic with isotonic knee extension.[14] The subject performed 5 to 10 isokinetic concentric warm-up repetitions at submaximal and maximal effort for familiarization. For data inclusion, the subject then performed 10 maximal concentric knee extensions. The subject was instructed to kick out "as fast and hard as possible" and then allow the dynamometer to passively return the limb to the starting position (90°) before beginning the next contraction.

For isotonic testing, the resistance of the dynamometer was set at 50% of the peak torque previously recorded during the MVICs. We used this 50% value because it was the highest resistance at which subjects (those not included in the study) could completely extend their knees to 0° in pilot testing. The subjects performed 5 to 10 warm-up repetitions at this resistance. For all isotonic contractions, the subjects were instructed to complete the 90° motion in approximately 1 second. This method is based on anecdotal information to mimic exercise commonly performed in the athletic training rehabilitation setting. We instructed the subjects to allow the dynamometer to passively return the leg to the starting position. For data inclusion, the subjects then performed 10 continuous concentric knee extensions.

Mechanical Data Extraction

Peak torque was obtained from 1 of the 3 isometric contractions with the highest torque produced during that isometric contraction. Work (joules) was defined as the product of the average torque and displacement in units of radians. Total work was calculated from the isokinetic (W_{isok}) and isotonic (W_{isot}) exercise.

EMG Data Extraction

The EMG data were forward and backward low-pass filtered at 500 Hz using a second-order Butterworth filter. Data were then full-wave rectified and normalized to the mean amplitude of a 1-second interval that encompassed the MVIC. For each exercise, the EMG data from the concentric portion of the knee extension were integrated over the 10 repetitions and subsequently normalized to the work performed isokinetically (IEMG/W_{isok}) and isotonically (IEMG/W_{isot}).

Statistical Analysis

We performed a 1-between (sex = male or female), 2-within (exercise = isokinetic or isotonic, muscle = vastus medialis or vastus lateralis) repeated-measures analysis of variance on the dependent variable of IEMG/W calculated following each exercise. The α level for all statistical tests was set at $P <$ .05.

RESULTS

We found a significant main effect for type of exercise, with IEMG/W_{isot} being greater than IEMG/W_{isok} (isotonic, 1156.2 $\pm$ 347.3 $mV \cdot s \cdot J^{-1}$; isokinetic, 629.1 $\pm$ 334.5 $mV \cdot s \cdot J^{-1}$; $F_{1,19} = 33.6$; $P < .001$). Main effects for sex ($F_{1,19} = 0.21$, $P = .391$) and muscle ($F_{1,19} = 0.054$, $P = .819$) were not significant. There were no significant interactions for exercise by muscle ($F_{1,19} = 0.015$, $P = .904$), exercise by sex ($F_{1,19} = 0.048$, $P = .829$), or sex by exercise by muscle ($F_{1,19} = 0.713$, $P = .409$).

DISCUSSION

Our current data are evidence that, per unit of work performed, motor unit activation is greater during isotonic exercise than during isokinetic exercise. Our novel method of normalizing IEMG to total work makes comparisons with previous studies difficult. Previous researchers have attempted to determine which contraction type (isotonic or isokinetic) can best recruit motor units as measured through surface EMG activity.[5,13] In both studies, maximal isotonic and isokinetic contractions of the knee extensors were used, and no significant difference in IEMG activity was reported. These investigators attempted to determine the more effective way to strengthen muscle, but no consideration was given to the amount of work performed during the contractions.

A limitation to our study is that we compared the EMG amplitude from a maximal contraction (isokinetic) with the EMG amplitude from a submaximal contraction (isotonic). We studied these contraction types to better understand differences in motor unit recruitment between isokinetic and isotonic resistance. These findings support the use of isotonic resistance training in the early stage of rehabilitation when central drive to the muscle (motor unit recruitment) may be more important than absolute muscle force production.[9]

The relationship between EMG and muscle force production in the quadriceps muscle must be considered because we are operating under the assumption that as EMG increases, force also increases linearly.[15] Previous research has supported the concept that IEMG does not have a fixed relationship to quadriceps force production at specific points in the range of motion.[16] However, we were interested in the EMG across the entire range of motion. As joint angles and muscle lengths change, they may change the EMG-force relationship, making the relationship nonlinear.[17] By including the entire range of motion and calculating the IEMG for the entire contraction, we believe that the concerns about EMG and force being nonlinearly related throughout the range of motion are allayed.

Muscle force production is a combination of central factors (such as stimuli to the higher motor centers and motor neuron excitability[18]) and peripheral factors (such as muscle pH[19] and phosphocreatine depletion[20]). Thus, the ability of muscle to perform work should also be investigated at the peripheral level, because central command may not completely explain the resultant force of muscle contraction.[21] We were able to locate one investigation in which isometric contractions were reported to perform more work using fewer energy resources at the peripheral level than concentric isokinetic contractions, using measures of metabolic strain and adenosine triphosphate turnover.[22] However, no comparison was made between isotonic and isokinetic contractions.

In our study, isotonic contractions resulted in greater motor unit activation per unit of work performed as measured by our IEMG/W ratio. During the early stages of rehabilitation, it may be more important to maximize the neural drive (ie, increase IEMG) than to increase absolute force levels.[9] Increased forces may result in detrimental forces being placed on the recovering injury, such as increased quadriceps force increasing shear forces across the tibiofemoral joint.[23]

Although we found no differences between men and women, we thought it important to examine any differences between the sexes that would differentiate the use of specific contraction types. In the clinical setting, previous researchers have demonstrated that specific training regimens may decrease incidence of injury around the knee.[24] Various training regimens may include isotonics or isokinetics or both; thus, we need to determine differences that would facilitate the rehabilitative process. Our results show that optimal motor unit activation during isotonic and isokinetic resistance exercise appears to be independent of sex. Therefore, the type of resistance may not be important during resistance training for men and women.

CONCLUSION

The development of strength is a complex phenomenon, regardless of the type of exercise performed. Based on our results, we recommend that clinicians incorporate isotonic exercise early in the rehabilitation process, when motor unit recruitment is of primary importance. With greater motor unit activity per unit of work performed by the muscle-joint system, the potential benefits of less stress placed on the musculoskeletal lesion and more complete or more rapid (or both) motor unit recruitment could serve to enhance the early phase of rehabilitation.

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Self-Perceived Continuing Education Needs of Certified Athletic Trainers

Marchell M. Cuppett

School of Health, Physical Education and Recreation, University of Nebraska at Omaha, Omaha, NE

Marchell Cuppett, EdD, ATC, provided conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article.

Address correspondence to Marchell Cuppett, EdD, ATC, School of HPER, University of Nebraska at Omaha, 6001 Dodge Street, Omaha, NE 68182-0216. Address e-mail to maustin@mail.unomaha.edu.

Objective: To determine the self-perceived continuing education needs of current certified athletic trainers and the factors that affect those needs.

Design and Setting: Self-reporting surveys using a Likert-type scale were sent to 2000 certified athletic trainers.

Subjects: All subjects were certified athletic trainers working in the United States.

Measurements: A 3-part survey of continuing education participation, continuing education needs, and demographic data was developed. Continuing education items were based on the domains of athletic training as defined by the Athletic Training *Role Delineation Study,* 3rd edition.

Results: The response rate was 52% (1040/2000). Athletic trainers in this study perceived "some to moderate need" for continuing education within each of the domains. Rehabilitation of Athletic Injuries (domain 3) was the area in which athletic trainers saw the most need for continuing education. The back and neck were specific anatomical areas perceived by the athletic trainers as needing the highest level of continuing education. Sex was a significant factor in the perceived importance of continuing education within all but domain 5, Professional Development and Responsibility. Other factors included employment setting and years of experience.

Conclusions: Athletic trainers in this study perceived each of the tasks within the domains to be at least "somewhat important," with rehabilitation and specific continuing education programs for the back and neck being the most important. Sex, employment setting, and years of experience may influence what athletic trainers think is important. Therefore, continuing education providers should attempt to vary programs and tailor them to various audiences.

Key Words: continuing education, professional development, adult learning

Continuing education has historically been a part of the profession of athletic training. Mandatory continuing education requirements were originally established by the National Athletic Trainers' Association (NATA) in 1973 to encourage attendance at the national meeting. Two continuing education units (CEUs), equaling 20 hours of contact time, were provided for attendance at the national meeting, which equaled the 20 CEUs per year necessary for continued certification (Paul Grace, oral communication, March 30, 1996). When the initial requirements for continuing education were set, athletic trainers were required to have 60 contact hours in a 3-year period. As the profession of athletic training progressed, mandatory continuing education made a gradual switch from service-based continuing education to health care–based continuing education, consistent with the maturation of a profession. As the profession sought accreditation and recognition, continuing education credit for serving on committees was replaced by more content-oriented practices as required by the various accrediting agencies for the NATA and later the NATA Board of Certification (NATABOC) (NATABOC, unpublished data, 2000). The number of hours was also changed several times since the inception of mandatory continuing education in 1974 and continues to be evaluated at the end of each 3-year reporting period. Currently, the NATABOC requires that at the end of each cycle certified athletic trainers (ATCs) must have met recertification requirements, including the completion of 80 CEUs, which are equivalent to 80 clock hours.[1]

Mandatory continuing education is not unique to the field of athletic training. The mandatory continuing education movement arose out of the perception that professionals need to be committed to lifelong learning to maintain and improve their competence. According to Cervero,[2] the impetus for mandatory continuing education came from federal and state governments, especially state licensing boards, professional associations, and consumer groups. State governmental involvement in mandatory continuing education resulted in part because of awareness of professional support for lifelong practitioner learning and partly through the stimulus of the malpractice crisis.[3] Professional associations have been at the forefront of encouraging mandatory continuing education and, as Little[3] suggested, were known to proclaim its value before the states began to apply their regulatory actions.

Benefits for patients and clients are some of the main thrusts behind mandatory continuing education policies put forth by consumer groups. Such policies assume that secondary beneficiaries—consumers of professional services, professional associations, institutional providers of services, and the public in general—have a vested interest in continuing professional education.[4]

Even though continuing education for many professions is mandatory, that does not seem to be the primary motivating factor for professionals who attend continuing education programs. Several authors[4,5] indicated that professionals' primary motivation to learn arises from problems or issues in their daily practice and that these interest areas are part of a well-rounded program of learning.

Large group instruction for continuing education is the norm in many allied health professions (athletic training, nursing, physical therapy, occupational therapy, physician assistant). Typically, professionals gather for topic-centered symposiums usually consisting of 1-hour lectures by experts on the topics. The topics are generally chosen by the continuing education provider using feedback from the previous year's symposium, trends, technology issues, or simply the availability of certain experts for the scheduled date.

The number of approved continuing education providers for athletic trainers (currently 850) has never been higher.[6] Numerous programs are available to the ATC for use in obtaining the required CEUs. However, much discrepancy exists among the programs in terms of length, quality, depth of information offered, and value to the ATC.

The need for ATCs to maintain competence through systematic acquisition of new knowledge and skills as part of a lifelong learning process has never been greater. Factors that contribute to this increased need are the more rapidly changing nature of knowledge in the field, increasing diversity of employment settings in athletic training, restructuring of the professional preparation requirements, the influence of technology on assessment and treatment procedures, and the changing health care system. Growing diversity in professional roles dictates that continuing education opportunities be broadened to meet the needs of the entire profession.

Research is lacking on continuing education in athletic training. A review of the current literature shows little evidence that continuing education opportunities are offered systematically. Additionally, little research has been done to assess the self-perceived or expressed needs of ATCs for continuing education or if those needs differ for various employment settings or with years of experience in the profession. In focus group research, Weidner[7] found that ATCs across employment settings felt that their needs were not being met by continuing education opportunities at district meetings. Subjects in his study indicated a preference for less traditional topics and a more thematic approach to presentations.

Weidner's[7] research indicated that ATCs may have many educational needs in various settings that are going unmet. Many factors can influence what the ATC needs to maintain continued competence in the field. Questions also exist as to whether simply attending a continuing education course equates to immediate or long-term competence. Debate continues on the value of certain types of continuing education. With the focus of the NATA and the NATABOC on reform of all aspects of athletic training education, a formal needs assessment in the area of continuing education is timely to determine what ATCs perceive they need. The purpose of my article is to report the findings on self-perceived continuing education needs of ATCs and factors that affect those needs.

METHODS

Subjects

Subjects included a random sample of 2000 ATCs chosen to coincide with the sample numbers used by the NATABOC in the validation of the *Role Delineation Study*.[8] The sample was stratified by NATA districts. Names in each district were randomly selected, with the count per district determined by the district's percentage of the total NATABOC ATCs.

Instrument

I developed the questionnaire by analyzing and adapting other needs assessment instruments used in several disciplines, including adult education, medicine, engineering, allied health, and leisure services. Specific instruments used in the development of the questionnaire for this study included Kerlin's Continuing Education Needs Assessment for Nursing Home Surveyors[9] and Escovitz and Augsburger's survey instrument of the continuing education needs of Ohio optometrists.[10] The questionnaire for this research was created through consultation with athletic training experts and the adaptation of questions from the above-mentioned surveys to the specific profession of athletic training. The NATABOC *Role Delineation Study*[8] was the basis for structuring the survey of ATCs. Content validity was established through review by the NATABOC Board of Directors and was pilot tested with 30 randomly selected ATCs. Minor changes to clarify wording were made after the pilot testing. The survey instrument consisted of 3 parts.

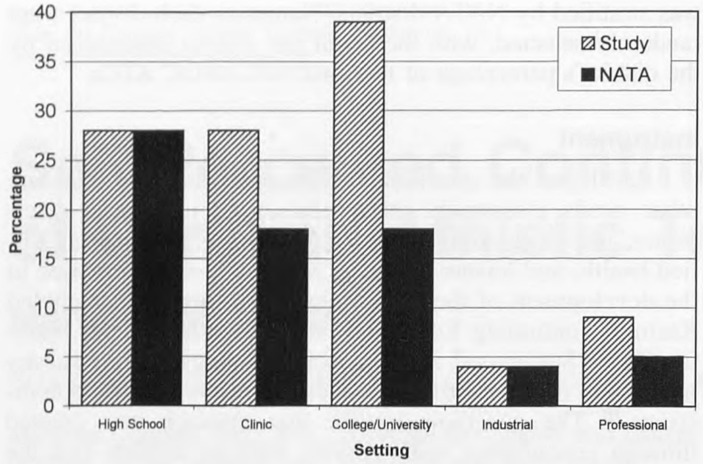
Part 1: Continuing Education Participation. The first part of the survey asked about the respondents' participation in continuing education activities during the last 3-year reporting period. Information was gathered about the importance of factors that determined attendance at continuing education activities, employers' support of continuing education participation, preferred format for continuing education (specifically, respondents' preferences for conferences, workshops, college courses, research, and home study audio and video programs, among others), and various factors that affect the participant's decision to attend or not attend continuing education activities. Attendance factors and preferred format will be discussed in a future article.

Part 2: Continuing Education Needs. This section contained ordinal-scale items that addressed topics or professional areas of perceived needs and interest in continuing education. The *Role Delineation Study*[8] was used as a framework for developing the questions, which paralleled the tasks listed within each of the domains identified in the study. To determine the level of interest for each task within each domain, a 5-point Likert-type scale was used, with A signifying substantial need; B, moderate need; C, some need; D, little need; and E, no need. Space for other areas of need or interest was provided in the form of open-ended questions.

Part 3: Demographics. Thirteen variables were measured on nominal and ordinal measurement scales to obtain the ATC's educational and work experience profiles, including employment setting, years of experience, educational degrees, sex, ethnicity, age, salary, marital status, dependent children at home, NATA district, number of ATCs they are in contact with daily, other health professionals they are involved with on a daily basis, and environment (eg, city, urban, rural).

Procedures

After institutional review board approval and pilot testing of the instrument, questionnaires, answer sheets, and accompanying letters were sent to all ATCs identified in the sample. Each questionnaire was numerically coded to assist with follow-up notices on unreturned questionnaires. Three weeks af-



Employment settings of certified athletic trainers.

ter the mailings were sent, a total of 760 surveys (38% return rate) was received. A follow-up postcard reminder was then mailed to all individuals who had not responded. Statistical analysis involved descriptive statistics and multiple regression analysis using the Statistical Package for the Social Sciences for Windows (version 8.0, SPSS, Inc, Chicago, IL).

RESULTS

A total of 1040 ATCs responded, for a return rate of 52%. Distribution of respondents by employment setting is seen in the Figure. The proportion of college or university ATCs who responded to the study was higher than the NATA membership figures for the same period. This may have been due to the willingness of college and university ATCs to return the study or may have been a result of the randomization process.

Most respondents (657, 63%) worked in a city or urban environment. Another 297 (29%) worked in a small community, with 64 (6%) working in a rural environment. Of all respondents, 551 (53%) held a master's degree. Ninety-four (9%) were currently pursuing an additional degree.

When viewed as a whole, 322 (31%) of the respondents did not have daily contact with other ATCs, and 218 (21%) had daily contact with only 1 other ATC. When analyzed by environment, 634 (61%) of rural athletic trainers worked with 0 to 1 other ATC, compared with 551 (53%) of the small-community and 510 (49%) of the urban ATCs. A total of 541 (52%) of the rural ATCs worked with 0 to 1 other health professional, whereas 458 (44%) of small-community ATCs and 343 (33%) of the urban athletic trainers worked with 0 or 1 other health care professional. As would be expected, a larger number of urban ATCs (499, 48%) worked with more than 3 other health care professionals, whereas 406 (39%) of the small-community ATCs did the same. Of the rural ATCs, 343 (33%) worked with more than 3 other health care professionals.

Reported Continuing Education Participation

Most ATCs (624, 60%) obtained between 90 and 130 contact hours during the previous 3 years. This is expected, since the minimum requirement for CEUs in a 3-year period is 80 contact hours. In addition, ATCs indicated strong attendance at the NATA Annual Meeting and Clinical Symposia. More than 473 (45%) of respondents obtained more than 3 CEUs (30 contact hours) from the annual meeting, and 226 (22%) obtained more than 6 CEUs (60 hours) from that source. District meetings and conferences offered through NATA-approved providers also were popular choices among ATCs in this study; 317 (30%) of respondents received more than 3 CEUs from those activities. College courses, publications, and home study were the least popular methods of attaining CEUs.

Table 1. Perceived Continuing Education Needs Within Each Domain

Domain	Mean (SD)
1. Prevention of athletic injuries	3.67 (0.82)
2. Recognition, evaluation, and immediate care	3.88 (1.06)
3. Rehabilitation and reconditioning of athletic injuries	4.15 (0.90)
4. Health care administration	3.60 (0.98)
5. Professional development and responsibility	3.58 (0.88)

Table 2. Self-Perceived Need for Prevention of Athletic Injuries (Domain 1)

Task	Mean (SD)
Identification of physical conditions predisposing the athlete to increased risk of injury or illness (task 1)	3.96 (1.06)
Information on conditioning programs and testing (task 2)	3.84 (0.88)
Construction of protective devices (task 5)	3.81 (1.03)
Fitting of protective devices (task 7)	3.71 (1.10)
Education of parents and athletes about the risks associated with participation (task 8)	3.64 (1.07)
Environmental conditions and guidelines for safe participation (task 3)	3.62 (1.02)
Taping and wrapping techniques (task 6)	3.44 (1.27)
Facility inspection and maintenance records (task 4)	3.36 (1.08)

Self-Perceived Continuing Education Needs Among ATCs

Need was defined by using the domains and tasks identified by the NATABOC 1995 *Role Delineation Study*. The reader should note that this study was performed before the release of the 1999 *Role Delineation Study* (4th edition),[11] which included 6 domains instead of the 5 in the 3rd edition.

Respondents were asked to rate their perceived need in each task (ranging from 5 to 8 tasks per domain), indicating "no need" (1) through "substantial need" (5). Responses within each domain were rank ordered according to frequency of response. The level of concern was determined for each domain as a whole with an overall mean so that comparisons could be made across domains. The overall means for the 5 domains are presented in the following sections, with the overall mean for each domain presented in Table 1.

Prevention of Athletic Injuries (Domain 1)

The 8 tasks dealing with prevention of athletic injuries are included in the analysis of the first domain (Table 2). The mean level of self-perceived need for this domain was 3.67, reflecting a moderate level of concern. When tasks within prevention of athletic injuries (domain 1) were compared, identification of physical conditions predisposing the athlete or physically active individual to increased risk of injury or illness in athletic activity (task 1) was most frequently cited as

Table 3. Self-Perceived Need for Recognition, Evaluation, and Immediate Care (Domain 2)

Task	Mean (SD)
Special tests on involved area (task 4)	4.27 (0.94)
Determining appropriate course of action (task 5)	4.13 (1.08)
Selection and application of emergency equipment and techniques (task 7)	3.99 (1.16)
Administering first aid or immediate care techniques (task 6)	3.93 (1.23)
Palpation of the involved area (task 3)	3.83 (1.26)
Inspection of the involved area (task 2)	3.76 (1.30)
Obtaining history from the athlete (task 1)	3.63 (1.35)
Referral procedures (task 8)	3.53 (1.28)

a continuing education need. This task includes content areas such as preseason screening, nutrition, and normal anatomy and physiology. When the tasks were rank ordered by means, ATCs placed more importance on continuing education opportunities for tasks pertaining directly to patient or athlete care than on more administrative tasks. Tasks that the ATC does daily, such as taping and wrapping, were not deemed as important as others in this domain.

Recognition, Evaluation, and Immediate Care (Domain 2)

The mean level of self-perceived need for this domain was 3.88, reflecting a moderate level of concern for continuing education dealing with recognition, evaluation, and immediate care of athletic injuries. Respondents indicated that special tests on the injured area (task 4) was the most important task requiring need for continuing education (Table 3). The application of special tests was followed in level of need by the task concerned with determining the appropriate course of action (task 5) and selection and application of emergency equipment and techniques (task 7). Referral procedures (task 8) were the area with the least need in this domain. As in domain 1 (Prevention of Athletic Injuries), the rank order of self-perceived need for continuing education in this domain indicated that ATCs were more concerned with evaluating the injury via special tests than with any of the other tasks within this domain.

Although the NATA has identified specific tasks in which an ATC must be competent, it is also possible that ATCs' additional education needs may be greater for injuries to some parts of the body than others. In addition to the NATA-identified tasks, respondents were asked to indicate their need for continuing education for recognition, evaluation, and immediate care of various anatomical sites and conditions. Respondents indicated considerable perceived need on all listed anatomical areas or conditions (Table 4). Means for all listed anatomical areas and conditions were greater than 3.81, indicating moderate to substantial need in each area. Subjects indicated the most perceived need for continuing education within the listed anatomical areas as the back and neck, with the area of least concern being the lower leg, ankle, and foot. However, the mean for this area was 3.82, reflecting a higher level of self-perceived need for continuing education than any of the means for individual tasks within Health Care Administration (domain 4) and Professional Development and Responsibility (domain 5). The means for importance of continuing education indicated by the respondents for the anatomical areas were also higher than the overall means of domains 4 and 5.

Table 4. Self-Perceived Need for Continuing Education Units According to Anatomical Site or Condition

Anatomical Area or Condition	Mean (SD)
Neck	4.35 (0.94)
Back	4.31 (0.91)
Emergency procedures	4.26 (1.00)
Shoulder	4.15 (1.00)
Head	4.11 (1.01)
Systemic illness	4.08 (0.96)
Abdomen	4.01 (0.96)
Elbow, wrist, and hand	3.96 (1.02)
Hip	3.86 (1.03)
Knee	3.86 (1.15)
Lower leg, ankle, and foot	3.82 (1.15)

Table 5. Self-Perceived Need for Rehabilitation and Reconditioning of Athletic Injuries (Domain 3)

Task	Mean (SD)
Construction of rehabilitation programs (task 2)	4.19 (0.99)
Identifying injury status, functional tests, physiological response of the body to therapeutic modalities and exercise (task 1)	4.18 (0.99)
Selection of appropriate rehabilitation equipment (task 3)	4.16 (0.97)
Administering rehabilitation techniques and procedures (task 4)	4.15 (1.03)
Evaluation of readiness and functional status of the athlete (task 5)	4.07 (1.08)

Table 6. Self-Perceived Need for Health Care Administration (Domain 4)

Task	Mean (SD)
Developing an emergency plan, referral, and management of injuries or illnesses (task 6)	3.79 (1.23)
Establishing written protocols for injury management (task 4)	3.74 (1.07)
Maintenance of health care records, documentation (task 1)	3.71 (1.18)
Compliance with safety and sanitation standards (task 2)	3.64 (1.13)
Personnel management (task 3)	3.50 (1.12)
Purchasing practices, bid letting, and budgeting (task 5)	3.23 (1.16)

Rehabilitation and Reconditioning of Athletic Injuries (Domain 3)

This domain showed the highest overall level of self-perceived need (mean, 4.15) (Table 5). The task most frequently identified as having the highest level of need was construction of rehabilitation programs for the injured athlete (task 2), followed by identifying injury or illness status, functional tests and measurements (task 1), and selection of appropriate rehabilitation equipment, techniques, and modalities (task 3).

Health Care Administration (Domain 4)

Responses for this domain indicated less overall concern than for the first 3 domains (mean, 3.66) (Table 6). Developing

Table 7. Self-Perceived Need for Professional Development and Responsibility (Domain 5)

Task	Mean (SD)
Regulations regarding athletic training practices, ethical and legal parameters, insurance (task 3)	3.83 (1.04)
Obtaining current literature about sports medicine issues (task 1)	3.73 (1.16)
Developing interpersonal communication skills, motivational techniques (task 2)	3.61 (1.10)
Methods of informing the general public, public relations techniques (task 5)	3.46 (1.09)
How to conduct sports medicine research (task 4)	3.27 (1.08)

Table 8. Summary of Regression Analysis for Variables Predicting Importance of Tasks Within Prevention of Athletic Injuries (Domain 1)

Variable	R^2	b (SE)	β
Step 1	.005		
Sex		−0.12 (0.05)	−.07*
Step 2	.01		
Years of experience		−0.09 (0.04)	.06*
Sex		−0.13 (0.05)	−.08*
Step 3	.02		
Years of experience		0.09 (0.04)	−.07
Sex		−0.14 (0.05)	−.09
No. of certified athletic trainers in workplace		−0.03 (0.02)	−.06*

*$P < .05$.

a plan for emergencies, referral, and management of injuries or illnesses (task 6) was ranked first among this group in need, followed by establishing written protocols for injury management (task 4) and maintenance of health care records and documentation (task 1). Compliance with safety and sanitation standards (task 2), personnel management (task 3), and purchasing practices, bid letting, and budgeting (task 5) rounded out the domain.

Professional Development and Responsibility (Domain 5)

Domain 5 includes tasks regarding professional development, communication skills, research, and public relations. The respondents indicated the least concern of all domains for continuing education in the area of professional development and responsibility (mean, 3.58) (Table 7). This may be due in part to the fact that the tasks in this domain do not deal directly with the health care of the athlete. The tasks within this domain were rank ordered according to mean level of indicated need for continuing education. Obtaining information about state, local, and federal regulations regarding athletic training practices (task 3) ranked first in this domain, followed by obtaining current literature about sports medicine issues (task 1) and developing interpersonal communication skills (task 2). Tasks 4 and 5, learning to conduct sports medicine research and public relations, were seen as the areas within this domain with the least need for continuing education.

Other Indicated Needs for Continuing Education

After the questions within each domain, space was provided for subjects to identify other topics within the domain for which they needed continuing education. Very few responses were given for other needs within each domain. Domain 4, Health Care Administration, had the highest response, with areas of additional self-perceived continuing education needs listed as personnel management, business management, third-party providers, outcome studies, and legal issues. Other predominant themes were "specific conditions as opposed to general themes," indicated for domains 1 and 2 by many of the athletic trainers who chose to answer the open-ended questions. Open-ended responses for domain 2 also included eating disorders and dermatology. Respondents who chose to answer the open-ended questions within Professional Development and Responsibility (domain 5) gave tenure and promotion issues, public relations ideas, and sensitivity training as areas of interest. No other predominant themes or suggestions were given within any of the domains, but the open-ended questions elicited very few responses. Fewer than 300 respondents chose to write anything in the space available for open response to other topics of interest.

Factors That Affect Self-Perceived Continuing Education Needs

I used multiple regression analysis to determine the influence of each factor (employment setting, years of experience, environment, employer support, age, professional isolation, and education) on the perceived need for additional education in each of the domains of knowledge in athletic training.

Prevention of Athletic Injuries (Domain 1)

The variables indicated as predictors of the importance of continuing education in domain 1 were employment setting, years of experience, employee support, age, educational background, environment, and professional isolation. Stepwise multiple regression was used to analyze the contribution of the predictor values to the self-perceived educational needs in domain 1. Sex was a significant factor in predicting the importance of continuing education for the various tasks dealing with prevention of athletic injuries (Table 8). Female athletic trainers indicated greater need for continuing education within this domain. Years of experience also was a predictor, as was professional isolation ($b = -0.03$, SE of $b = 0.02$, $\beta = -.06$, $P < .05$).

Recognition, Evaluation, and Immediate Care of Athletic Injuries (Domain 2)

Sex was the only significant variable for domain 2 ($b = -0.32$, SE of $b = 0.067$, $\beta = -.15$, $P < .05$). As in domain 1, statistical significance was achieved; however, R^2 was only 0.02, thus indicating that sex accounted for only 2% of the variance in self-perceived need for continuing education in the knowledge of the tasks within domain 2. Women again felt more need for continuing education for skills in this domain.

Rehabilitation and Reconditioning of Athletic Injuries (Domain 3)

Female athletic trainers perceived more need for continuing education in the area of rehabilitation and reconditioning, and therefore, sex was again a significant contributor to the self-perceived continuing education needs of the ATCs in this study (b = −0.18, SE of b = 0.057, β = −.09, $P < .05$). Again, R^2 was low at 0.01. Employment setting entered the regression analysis on the second step, increasing the R^2 to 0.02 (b = −0.05, SE of b = 0.02, β = −.09, $P < .05$).

Health Care Administration (Domain 4)

Sex again was the only independent variable in this set to enter the multiple regression equation at the .05 level (b = −0.28, SE of b = 0.06, β = −.14). As in the above domains, although statistical significance was achieved, the R^2 was 0.02. Therefore, sex accounted for only 2% of the variance in responses within domain 4, with female ATCs perceiving more need for continuing education in this area.

Professional Development and Responsibility (Domain 5)

Employer support contributed significantly to the self-perceived need for continuing education in domain 5. Employer support was significant (b = −0.12, SE of b = 0.04, β = −.10, $P < .05$). R^2 for domain 5 was 0.01. The negative β indicates that those ATCs who received full or partial employer support for continuing education did not perceive this domain to be as critical as those who did not receive employer support.

DISCUSSION

Athletic trainers in this study perceive "some to moderate need" for continuing education within each of the defined areas of knowledge and skills expected of athletic trainers. Rehabilitation of athletic injuries (domain 3) was the area in which continuing education was seen by the respondents as having more need than the others, with a mean of 4.15. The other domains all had means between 3.62 and 3.88. In this study, the ATCs indicated greater need for continuing education when asked to identify need by anatomical area or condition. The back and neck were the areas perceived by the athletic trainers with the highest level of need for continuing education (mean, 4.3). High level of need was also indicated for information on emergency procedures, the shoulder, head, systemic illness, and abdominal injuries (mean, 4.0). Subjects in this study indicated the most perceived need for continuing education within the listed anatomical areas as the back and neck. The area of least concern was the lower leg, ankle, and foot. However, the mean for this area was 3.82, indicating a higher level of self-perceived need for continuing education than any of the means for individual tasks within Health Care Administration (domain 4) and Professional Development and Responsibility (domain 5). Thus, ATCs' level of concern for obtaining continuing education specific to the evaluation and treatment of certain injuries and illnesses was higher than that for health care administration, public relations skills, or legal or ethical parameters.

Tasks within each of the domains are general in nature and represent not so much what athletic trainers are doing but what skills and knowledge we as a profession expect our new graduates to possess. Sample tasks from the Recognition, Evaluation, and Immediate Care of Athletic Injuries (domain 2) included palpation of the involved area and performing special tests on the involved area. In this study, ATCs may have felt less need for these tasks because evaluation of injuries, regardless of anatomical area, follows general procedures that are taught throughout the athletic training education programs. However, when specific anatomical areas are considered, the procedures to assess an injury become more specific. This may have led the ATCs in this study to indicate that they perceive more need for continuing education when these anatomical areas are considered. This is consistent with other authors' findings[4,5,7] that professionals often are most interested in topics that are specific to problems they may see in their everyday practice. The desire for additional education on specific injuries, illnesses, and anatomical areas was also expressed in the open-ended questions. The respondents who chose to answer these questions stressed that specificity was important and that information was desired on new ways of testing specific body parts. They also wanted hands-on practice of specific evaluative tests and in-depth study of specific anatomical areas. These findings follow Weidner's[7] findings that athletic trainers desired more thematic approaches and more practical application workshops. The fact that the respondents' desire for knowledge and skill was not addressed in the 3rd edition of the NATABOC *Role Delineation Study,*[8] which was used to create this questionnaire, further illustrates the changing of the profession. Since the completion of this research, the 4th edition of the *Role Delineation Study*[11] has been released and includes many of the topics that were indicated as desired areas for continuing education.

Emergency procedures and information on systemic illness were also indicated by the respondents as areas of greater perceived need. This may be in part due to the potential seriousness of those injuries and the infrequency with which they occur in the normal athletic setting. If an ATC is not exposed to a potentially serious situation on a regular basis, he or she may feel greater need to seek practice situations or update procedures through continuing education.

Factors That Affect Self-Perceived Continuing Education Needs

I hypothesized that employment setting, years of experience, environment, employer support, age, professional isolation, and education contribute to the perception of need within each domain of athletic training. Sex was a significant factor in the importance of continuing education within each domain except for Professional Development and Responsibility (domain 5). Female ATCs in this study indicated a greater need for continuing education across most of the domains. Sex has rarely been investigated in the continuing education literature but appears to be of greater influence than other individual variables in the self-perceived need for continuing education within the domains of athletic training and in the reasons for attending continuing education activities. This finding is particularly interesting because little research has been conducted on differences in professional practice and professional career patterns by sex, although Cafferella and Olson[12] identified differences in more general career patterns for men and women. To date, I am unaware of any studies within athletic training that have addressed sex issues with regard to professional preparation and practice.

By contrast, I found that some individual variables seem to have less influence than expected. Although they achieved statistical significance, sex, years of experience, and professional isolation accounted for less than 2% of the variance in domain 1. This may have been due to several factors. First, because

Table 9. Mean (SD) Level of Need for Continuing Education for Each Domain by Employment Setting

Employment Setting	Domain 1	Domain 2	Domain 3	Domain 4	Domain 5
High school	3.85 (0.73)	3.96 (0.95)	4.24 (0.71)	3.68 (0.96)	3.52 (0.88)
College/University	3.52 (0.81)	3.67 (1.14)	4.29 (0.91)	3.55 (0.98)	3.60 (0.85)
Clinic	3.67 (0.82)	3.97 (1.03)	4.13 (1.0)	3.56 (0.98)	3.59 (0.87)
Industrial	3.50 (1.21)	4.06 (1.19)	4.40 (0.86)	3.65 (0.92)	3.65 (0.92)
Professional	3.79 (0.84)	4.15 (1.07)	4.26 (1.07)	3.65 (0.92)	3.59 (0.93)

of the large sample population, statistical significance was obtained but did not necessarily account for a large percentage of the variance. Second, variance within the domain itself across all subjects was minimal. The mean for domain 1 was 3.67, with an SD of 0.82. This small variance across all subjects may reflect the fact that CEUs are required by the NATA and are therefore deemed important or that these tasks are already defined by the NATA as being important.

The literature on professions, especially the writings of Slotnick et al,[13] emphasize the development of a career through several stages and the influence of this psychological development on attendance and preferences for continuing education. Yet, age and years of experience showed little influence on the self-perceived continuing education needs among the respondents in this study. The only domain in which years of experience was a significant factor was Prevention of Athletic Injuries (domain 1), where it, along with sex and professional isolation, proved to be a predictor for the importance of continuing education. However, within domain 1, sex, years of experience, and professional isolation together accounted for only 2% of the variance in self-perceived need.

The only other factors to enter the multiple regression analysis at the .05 level of significance were employment setting for Rehabilitation of Athletic Injuries (domain 3) and employer support for Professional Development and Responsibility (domain 5). When the means were examined in relation to the multiple regression results, ATCs working in the clinic setting, whether full time or in conjunction with another setting, saw less need for continuing education in rehabilitation techniques than did ATCs in the traditional settings of the high school or college (Table 9). Generally, ATCs in the clinic setting perform numerous and thorough rehabilitation programs with athletes for most of their work day. However, ATCs in other settings may perform a smaller number of rehabilitation programs in the course of their job.

The inability of the variables in this study to account for a larger percentage of the variance may be because all ATCs deemed the tasks within each domain to be important. This resulted in very little variance among the domains, so that when multiple regression analysis was run, mathematical significance was achieved because of the large sample size. The results may also reflect the fact that the *Role Delineation Study* does not necessarily represent what ATCs are doing in their professional practice but what the profession expects its entry-level candidates to know. Another possibility, as suggested by a number of researchers,[4,5,14] is that the selection of continuing education material by other health professionals is highly individual and may even be idiosyncratic. Also, attending a continuing education opportunity does not necessarily mean that an ATC has obtained competence in that skill. For example, ATCs may choose continuing education topics for reasons other than their perceived weaknesses, perhaps because they are interested in a topic (no matter how competent they already are) or for numerous other reasons. Other, possibly unmeasurable variables may affect the perception of need within the domains.

CONCLUSIONS

Overall, ATCs in this study perceived each of the tasks within the domains to be at least "somewhat important." The fact that the NATABOC has indicated that these are the tasks that athletic trainers should be able to perform and the knowledge that athletic trainers should possess may have affected the response to these questions and resulted in the small variance among the responses. Because of the small variance, however, the results substantiate the NATABOC's *Role Delineation Study* by showing that these ATCs perceived the tasks described by the study to be important, therefore reinforcing the validity of that instrument with regard to the importance of specific athletic training knowledge and skill.

Several areas not covered by the *Role Delineation Study* were determined by ATCs to be important areas for continuing education. Interest in tenure and promotion issues, research information, and public relations may be the result of more ATCs moving into faculty positions as program directors. Eating disorders and dermatology were also important areas for continuing education. Those ATCs working with specific athletic populations that are more susceptible to these conditions may feel a greater need than those ATCs who are not as closely associated with those groups.

Sex was a significant factor in the importance of continuing education within all but 1 domain. Female ATCs indicated a greater need for continuing education opportunities across most domains. Sex appeared to be of greater influence than other individual variables in the self-perceived need for several questions in this study. Male and female ATCs may inherently perceive need differently or may be influenced by other occupational factors. Further exploration of the differences in continuing education needs between male and female ATCs and for various employment settings and years of experience is needed.

Other predictors of perceived importance of continuing education included employment setting and years of experience. Continuing education providers should attempt to provide practical information that ATCs can apply in their daily practice. Many respondents in this study indicated that they attended continuing education activities to search for answers to daily problems they see in their own athletic training rooms. If continuing education is to improve or enhance performance, it must be related to practice. It has to build on previous education, address the professional's entire scope of practice, improve performance, and update knowledge. Regardless of the model used, the relationship between what professionals learn and the direct application of learning to daily practice is critical to the degree of participation and the success of the program. Professionals have specific and diverse educational needs, both because of individual differences and differences in practice due to settings and experiences.

The respondents' greatest need for continuing education in the area of rehabilitation and reconditioning should persuade continuing education providers to include more offerings in these areas. Information pertaining to the rehabilitation of the back and neck was deemed especially important. This may reflect the changing role of the ATC and the involvement of many ATCs in settings with more diverse patient populations.

Continuing education providers need to recognize and understand both the diversity and the changing status of the profession of athletic training and address these factors in educational planning.[15] Offering a broad set of topics throughout the year but focusing on thematic, in-depth topics within a given conference may help address this issue. The Annual Meeting and Clinical Symposia has been changed to include numerous breakout sessions and hands-on workshops to try to best meet the needs of most of the participants. The *Role Delineation Study* should be used as a basis for continuing education topics, but opportunities must exist beyond what the entry-level ATC needs to know to provide the practicing ATC the opportunity to expand his or her knowledge. As a profession, we must also address whether mere attendance at a continuing education opportunity equates to learning or competence. If not, we must consider vast changes in how our continuing education is offered and evaluated. The profession of athletic training is changing and continuing education must change with it. More research and insight are definitely needed in this area.

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Dilemmas of Program Directors: Then and Now

Sally A. Perkins*; Michael R. Judd†

*Marist College, Poughkeepsie, NY; †Southern Illinois University, Carbondale, IL

Sally A. Perkins, MSEd, ATC/L, and Michael R. Judd, PhD, contributed to conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article.

Address correspondence to Sally A. Perkins, MSEd, ATC/L, School of Science, Marist College, Poughkeepsie, NY 12601. Address e-mail to Sally.perkins@marist.edu.

Objective: To describe the current roles and responsibilities of program directors of athletic training education programs accredited by the Commission on Accreditation of Allied Health Education Programs (CAAHEP) and to address the dilemmas of program directors' credibility with student athletic trainers, tenure and promotion, and clinical involvement in athletics.

Design and Setting: We sent a survey to all program directors who direct CAAHEP athletic training education programs.

Subjects: Eighty-three of 113 program directors of undergraduate programs participated in the study—a response rate of 73.4%.

Measurements: The survey consisted of demographic data: degree, age, major, years of experience as program director, and route to certification and questions concerning title, job responsibilities, expectations, and academic appointment.

Results: Most respondents (72%) indicated that their title was program director, and they had a median of 9 years of experience. Sixty-two percent had been certified as an athletic trainer for a median of 18.5 years. Forty-three percent had doctoral degrees and held the rank of assistant professor. Ninety-six percent indicated teaching was the primary duty and expectation of their program director's position.

Conclusions: The dilemmas of tenure and promotion, decreased clinical involvement, and student athletic trainers' perceptions of program directors remain problematic. The dilemmas still exist as they did 12 years ago and are becoming more involved due to educational reform. Program directors must be able to communicate their roles and responsibilities to their administrators.

Key Words: curriculum director, CAAHEP, athletic training

As early as 1981, program directors (PDs) of athletic training education programs in colleges and universities were described as both clinicians and educators.[1–3] Their clinical work was predominately the care of student-athletes in intercollegiate athletics, and the education portion involved teaching classes and providing hands-on instruction in the athletic training room. Leard et al[2] described the PD position not only as a clinician and educator but also as a faculty member, recruiter of students, supervisor of clinical assignments, coordinator of educational experience, and liaison between the athletic training curriculum and the accrediting agency. In 1988, Perrin and Lephart[3] perceived that PDs were facing several dilemmas. These dilemmas were possibly forcing PDs to make choices between traditional roles as clinicians and the emerging roles of educators. The dilemmas the PDs faced included classroom credibility with student athletic trainers (SATs) when they were actually spending less time in the intercollegiate athletics clinical setting. This dilemma in turn produced a quandary of "career frustration," wherein the PDs' love and concern for student-athletes, which was the primary reason for becoming an athletic trainer, now was thwarted by limited contact with student-athletes.[2,3] Also, how would clinical instruction be evaluated with regard to tenure and promotion? Was it service or teaching, or could it be viewed as research?

In the past 20 years, the PD position has undergone significant changes in administrative responsibilities and institutional expectations. Since the National Athletic Trainers' Association (NATA) approval process began in the early 1970s to the current Commission on Accreditation of Allied Health Education Programs (CAAHEP) process, the standard for the PD is described as "a member of the teaching faculty and 3 years of experience as an NATA-certified athletic trainer."[4,5] (The terms *Program Director* and *Curriculum Director* are used interchangeably. However, *Program Director* is the proper title to reflect the terminology in the CAAHEP standards.) According to Staurowsky and Scriber,[6] the PD position has become a "time-intensive occupation." Furthermore, "PDs are set apart from their faculty colleagues in other disciplines by virtue of the diverse nature of their appointments."[6]

With the growth of athletic training education programs in colleges and universities, the demand for a highly qualified faculty member to serve as PD and fill the multiple roles and responsibilities of the position is important and yet problematic. The problem is that the position of PD has been evolving for years, and it has become an occupation within higher education carrying multiple roles and responsibilities. The position is difficult to define because of its complexity. It is important to "explore the distinctions among PDs" to further understand, explain, and justify the professional role in higher education.[6] A literature review since 1980 produced only a few studies that documented and described the changing roles, responsibilities, and distinctions among PDs.[1,3,6,7] Our purpose was to investigate and describe the current status of the PDs' roles and dilemmas first described by Perrin and Lephart in 1988.

Table 1. Program Directors' Demographics Compared with Perrin and Lephart (1988)[3]

Demographic	2000*	1988†
Total number athletic training education programs	114	64
Highest degree earned (PhD/EdD)	43%	25.6%
Years of experience as a certified athletic trainer	18.5 years (median)	13.6 years‡
Years of experience as a program director	9 years (median)	7.5 years‡
Presently clinically active as an athletic trainer?	42%	80%
If you have a shared appointment with an academic unit and athletics, what is the percentage assignment for each?		
Academics	66.5%	77.4%
Athletics	33.5%	22.6%

*2000 data based on Commission on Accreditation of Allied Health Education Programs training education programs.
†1988 data based on National Athletic Trainers' Association athletic training education programs.
‡Indicates the mean of a combined sample of undergraduate and graduate program directors.

METHODS

In the fall of 1999, we conducted a literature review to investigate workload and position-related issues of the PDs of athletic training education programs. The literature review guided the conceptual formulation of the survey instrument. For this project, we extracted data from the survey instrument in order to address and compare the roles and dilemmas as described by Perrin and Lephart[3] in 1988. The entire survey was constructed to elicit responses in the areas of (1) demographics (ie, age, experience, sex, ethnicity, major, and avenue to certification); (2) professional appointment (ie, title, roles, assignment); (3) PD position (ie, duties and responsibilities, institutional expectations); (4) reasons for becoming a PD; (5) reasons for leaving the PD position; (6) most beneficial and most satisfying aspects of the position; (7) least beneficial and least satisfying aspects of the position; and (8) general issues not addressed in previous questions.

The survey included closed-ended demographic questions. To elicit responses in the areas of (2) professional appointment and (3) PD position, subjects were asked to check all that applied. Subjects were asked to provide 2 responses for each of the open-ended questions (reasons for becoming a PD, reason for leaving the position, most beneficial and most satisfying aspects of the position, least beneficial and least satisfying aspects of the position, and general issues not previously addressed).

A panel of experts consisting of 5 professionals from athletic training, health education, and sport management analyzed content validity. The panel reviewed the survey for content, clarity, whether questions would provide the needed data, length of the survey, question order, relevance, and ambiguity. The panel recommended minor editing and grammatic changes, which were incorporated into the survey instrument. The survey focused on collecting descriptive data and was determined sufficient to yield reliable and valid data; therefore, a pilot study was not conducted. The Human Subjects Committee at Southern Illinois University approved the survey instrument.

The PDs' names, addresses, and academic ranks were obtained from the NATA Web site in which program information is updated regularly, ensuring accuracy. The survey was mailed to all PDs of the 114 CAAHEP-accredited athletic training education programs at the time of this study. A coauthor of this article (S.A.P.) did not participate in the study; thus, the sample size was adjusted to 113.

Each PD was asked to complete the survey to the best of his or her ability and return the completed questionnaire in a self-addressed, stamped envelope that was provided in the initial mailing. Subjects who had not responded within a timely manner were sent a reminder through electronic mail.

Subjects

The subjects for this study were 83 PDs from CAAHEP-accredited undergraduate athletic training programs in the United States. The sample consisted of 51 men and 31 women; on one survey the question of sex was not answered.

Statistical Analysis

The data were analyzed using simple descriptive statistics: percentages and median distributions. Medians were reported to find the 50th percentile of the data set for age, years of experience as a certified athletic trainer, and years of experience as a PD. The statistical median best represented the data set by dividing the data into 2 equal halves.

RESULTS

Eighty-three of 113 PDs returned the survey, yielding a 73.4% response rate. After the initial mailing, 74 surveys were returned. An additional 9 surveys were received after we sent a follow-up reminder. The median age of the respondents was 42 years. The vast majority of the respondents, 90%, had been physical education or physical education and health education majors. Fifty-two percent pursued the accredited/approved route and 47% pursued the internship route to certification; 2 respondents did not answer this question. According to information found on the NATA Web site, 43% held doctorate degrees.[8] The median number of years of professional experience as a certified athletic trainer was 18.5 years, with a median of 9 years as a PD (Table 1). Seventy-seven percent shared an appointment with athletics. A total of 42% were clinically active in the athletic training room. Also, 17% of the PDs traveled with athletic teams as a duty. Ninety-six percent listed teaching and administrative tasks as a primary duty. As for the university's expectations of the PD, 92% indicated committee work and 72% indicated community service (Table 2). Fourteen percent of the PDs also held the position of head athletic trainer, while 27% were assistant athletic trainers.

Most of the respondents (72%) indicated that their title included PD. In addition to the PD title, 43% had the title and rank of assistant professor. Twenty-six percent had already received tenure (Table 3).

Table 2. Program Directors' Duties and Expectations Compared with Perrin and Lephart[3] by Rank

Our Study			Perrin and Lephart	
Rank	Duties*	Percentage	Rank	Criteria for Tenure†§
1 (tie)	Teaching	96	1	Teaching
1 (tie)	Administration	96	2	Research and publications
3	Committee work	92	3	Professional involvement
4	Advisement	85	4	Committee work
5	Professional involvement	79	5	Advisement
6	Community service	72	6	Athletic training service
7	Presentations	67	7	Administration
8	Research and publications	55	8	Community service

*Rank is based on frequency of responses for important duties and expectations.
†Rank of criteria important for tenure.
§Combined undergraduate and graduate programs.

Table 3. Nature of Program Directors' Academic Appointments Compared with Perrin and Lephart[3]

Academic Appointment	Our Study (%)	Perrin/Lephart[3] (%)
Assistant professor	43	28
Associate professor	20	25
Professor	12	13
Instructor	6	20.6
Tenure track	26	39
Tenured	26	22
Nontenured	20	38

DISCUSSION

Several dilemmas that faced PDs in 1988 are similar to the dilemmas that we have found in our research on PDs today[3]: tenure and promotion, student athletic trainers' perceptions of PDs, personal quandaries surrounding clinical involvement with student-athletes, and personal and family time.

Traditionally, athletic training education programs have been referred to as minors, concentrations, emphases, or specializations as part of the larger physical education program. The trend within athletic training education appears to be away from these traditional curriculums to the development of and emphasis on stand-alone majors according to the proposed CAAHEP standards. This emphasis, along with PDs' qualifications, may be the reasons that colleges and universities are hiring faculty on tenure-track appointments with both athletic training certification and a PhD, EdD, or equivalent. A content analysis of the NATA Position Vacancy Notice from November 1999 to June 2000[9] found 42 PD position announcements that indicated a doctoral degree was preferred. Of those positions, 14 were tenure-track appointments. With the possible trend in hiring PDs with terminal degrees on tenure-track appointments, it is even more important for PDs to understand the tenure and promotion (T&P) process. Perrin and Lephart[3] found that 25.6% of NATA-approved undergraduate PDs had doctoral degrees, as compared with 43% of CAAHEP-accredited undergraduate PDs in our study.

Perrin and Lephart[3] indicated that, depending on the size of the college and university, each of the T&P areas (teaching, research, and service) may be accorded different weights. Generally, each institution adheres to a T&P process that involves a probationary period. In a typical case scenario at University X, faculty are reviewed annually by the department chairperson or personnel committee and the dean of the college. They are directed in the preparation of a tenure dossier and are evaluated on the progress made in each of the 3 T&P areas. After the third year, the tenured faculty, chairperson, and dean of the college conduct a mock tenure review to assess the progress made in all 3 areas. In the sixth year, a tenure dossier is finalized and submitted for review at the department level and then forwarded to the faculty norms committee, dean, president, and board of trustees for the final decision on tenure.

Teaching at colleges and universities may be viewed as the most important of the 3 T&P areas, depending upon the institution. Perrin and Lephart[3] found that PDs ranked teaching as the most important criterion for tenure. In our study, 96% of all respondents were responsible for teaching athletic training courses (Table 2). Good to excellent ratings on courses taught by PDs are expected. Evaluation by SATs of clinical instruction is also necessary. Faculty "peer" evaluation of the PD's performance in the classroom and clinical setting should also be included to complete the teaching evaluation process.

Research appears to be an important area in the T&P process in many institutions. PDs are expected to make presentations and publish articles in peer-reviewed journals. The publication requirement may be one article per year or more, depending on the college or university T&P criteria. Presentations at local, state, district, or national meetings or workshops are also part of the research area. In our study, 55% of the respondents perceived publishing as a college or university expectation, and 67% listed presentations as a college or university expectation. Perrin and Lephart[3] ranked research and publication second and professional involvement third as expectations (Table 2).

There may also be an argument for clinical instruction as a viable research activity. If this is the case, clinical instruction techniques must be validated, presented, and published. One way to incorporate research into the PD's clinical instruction is through "systematic observation," which is used extensively in the teaching profession. The techniques of "observing and recording behavior" and competency evaluation have been used successfully in documenting teaching; thus, the reliability is well documented.[10] This method of objective evaluation can easily be incorporated and is useful in identifying problems that ultimately can change clinical instruction and practices. PDs may write scholarly papers on the uses and the effects of these methods in clinical education. Such papers can be presented at professional meetings or conferences and published in discipline-specific journals.

Service is an integral part of the T&P process but may be considered of less importance in relation to the teaching and research areas, depending on the institution. Our study found that PDs perceived professional involvement (79%) and community service (72%) as important college and university expectations (Table 2). Service can be further delineated into several areas, such as national, district, or state or university, college, department, or community. The PD must determine how service is viewed within the T&P process and should educate members of the T&P committee and administrators as to its importance. Finally, advising students may also be perceived by college and university administrators to be service. In our study, 85% of respondents regarded advising students as a responsibility. Whereas Perrin and Lephart's[3] study combined undergraduate and graduate programs' important criteria for tenure and promotion, respondents ranked advising fifth (Table 2). This is consistent with the finding of Staurowsky and Scriber[6] that their respondents had student advising responsibilities.

Initially, individuals assuming the PD position may have perceived that they would have an increase in discretionary time due to a reduction in their clinical role in athletics. However, such an increase may not have been realized because of an unexpected increase in the demands and responsibilities of the position as PD. The PD today is working less with student-athletes in a clinical setting.[2] In our study, 42% of respondents indicated they were clinically active, as compared with Perrin and Lephart,[3] who reported 80% were clinically active in the athletic training room. In addition, we found that 77% of the PDs responding to the question on multiple role appointment had a shared appointment with athletics, but only 33% of that shared appointment involved working in the athletic training room (Table 1). These data can be misleading, as the PD position may be funded by athletics with only academic responsibilities.

The love for athletics and concern for the health and welfare of the student-athlete are typical forces driving one into the athletic training profession.[3] However, changing roles may have created personal quandaries for the PD. Accepting the role of PD may have been perceived as an opportunity to decrease time spent traveling with athletic teams and, subsequently, an increase in personal and family time. We found that only 17% of the respondents had traveling responsibilities with athletics. This may also force the PD to make difficult choices among T&P requirements, involvement in clinical work, and personal and family time.

It has become increasingly difficult for PDs to keep up with clinical responsibilities in athletics as an athletic trainer. By limiting the clinical responsibilities and contact with student-athletes, the PD is not integrally involved in the daily operation of the athletic training room.[11] This may affect the SAT's opinion of the PD's abilities as an athletic trainer. Also, this may be a conflict for the PD who wishes to continue performing clinical work. Restricting or eliminating this contact with the student-athlete may be a source of career dissatisfaction.[3] Program directors may not feel they have the time to do everything that is required of them and are unsure how everything "fits in" with the overall priorities of the position. If left unsettled, this stressor could lead to job burnout and eventually more severe consequences, such as removing themselves from the athletic training profession completely.

RECOMMENDATIONS

Program directors must educate T&P faculty members, administrators, chairpersons, and deans on the responsibilities of their position. There may be some consideration given during a T&P decision if committee members are aware that the responsibilities of the PDs are much different than the traditional faculty member. Also, the aspect of clinical instruction needs to be addressed. In which area should clinical instruction be evaluated, and how?

The PD must understand the T&P process and be aware of how each of the 3 areas (teaching, research, and service) of the process are viewed and weighed at each respective institution. Do not assume that one area is weighted more than another. Find out from the most reliable source: the chairperson of the department or dean of the college. More time and effort should be spent on the areas of deficiency or areas viewed as more important by administrators. For example, if research is perceived by the university to be more important than service, then PDs need to make time in their schedule to concentrate on doing research, presenting research at scholarly meetings or conferences, and publishing research in refereed journals. As Perrin and Lephart[3] indicated, areas such as teaching and student advising may suffer because of the "publish or perish" requirement.

When dealing with students' perceptions, the PD may need to spend more time with SATs when they are treating student-athletes or stop by and visit their practice sites. This is an important element of clinical experience and should be incorporated into the evaluation process. Injuries can be discussed and questions from the SAT can be answered. This makes the PD one of the "practicing athletic trainers" who has discussed their student-athletes' injuries. Also, attend workshops and demonstrate new techniques to SATs. This shows that the athletic training skills of PDs are no different than the skills of athletic trainers employed in athletics or other settings.

There is a question as to where clinical instruction belongs in the T&P process. Does it belong under teaching, research, or service? If clinical instruction is going to be evaluated in the area of teaching, then goals and objectives should be designed for clinical instruction. In addition, instructor and peer evaluations should be administered to assess the effectiveness of this form of teaching. Clinical instruction that is considered service should be logged or documented (including the number of hours spent on clinical instruction and a site evaluation) to show its importance. For clinical instruction to be considered research, there must be a well-thought-out plan, which may include validation of clinical techniques, presentation of quantitative or qualitative findings at regional and national conferences, and publication in appropriate peer-reviewed journals.

An athletic trainer should be designated as the clinical coordinator. The responsibilities of the clinical coordinator are to ensure that information taught in the classroom is practiced in the clinical setting. This is very helpful for the PD who has no clinical instructor or athletic responsibilities. It also lessens students' confusion when they are taught one technique in the classroom, only to be told to perform a different technique in the clinical setting.

CONCLUSIONS

The position of PD in an athletic training education program is continuing to evolve. Many of the expectations of the PD regarding tenure are the same today as they were more than a decade ago. It also appears that the profile of the PD is changing athletically, with fewer clinical activities involving student-athletes, and educationally with more terminal degrees.

Even though expectations have remained the same, roles and responsibilities have been increasing, thus creating a greater workload for the PD. Finally, the dilemmas described by Perrin and Lephart[3] still exist today and may have become more complex because of educational reform and promotion and tenure requirements. Our study confirms that ongoing evaluation of the PD position is necessary.

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Life-Stress Sources and Symptoms of Collegiate Student Athletic Trainers Over the Course of an Academic Year

Vincent G. Stilger*; Edward F. Etzel*; Christopher D. Lantz†

*West Virginia University, Morgantown, WV; †Truman State University, Kirksville, MO

Vincent G. Stilger, HSD, ATC, Edward F. Etzel, EdD, and Christopher D. Lantz, EdD, contributed to conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article.

Address correspondence to Vincent G. Stilger, HSD, ATC, PO Box 6116-Coliseum, West Virginia University, Morgantown, WV 26506. Address e-mail to vstilger@wvu.edu.

Objective: To examine the impact of life-stress sources that student athletic trainers encountered over the course of an academic year, to investigate the existence of sex differences in stress source symptoms, and to provide athletic training staffs with suggestions on ways to assist student athletic trainers.

Design and Setting: In a classroom setting, the 25-item Quick Stress Questionnaire (QSQ) was administered to all subjects at the beginning of each month during an academic year. The QSQ, which can be completed in approximately 5 minutes, uses a 9-point Likert scale ranging from 1 (little stress) to 9 (extreme stress) to measure sources of stress and stress-related symptoms.

Subjects: The sample consisted of 11 male and 9 female student athletic trainers enrolled in a Commission on Accreditation of Allied Health Education Programs (CAAHEP)-accredited undergraduate program at a mid-Atlantic university.

Measurements: We computed descriptive statistics for the stress items and symptoms (ie, cognitive, somatic, and behavioral) and graphed them according to sex. Separate sex × time analyses of variance were performed to investigate changes in cognitive, somatic, and behavioral stress over the course of the study and to determine if these changes were different for male and female student athletic trainers.

Results: Academic and financial concerns represented the greatest sources of stress for student athletic trainers. Repeated-measures analyses of variance indicated that stress levels fluctuated significantly during the academic year, with peak stress levels experienced during midterm and at the end of the spring semester. Although female student athletic trainers consistently reported higher levels of stress than their male counterparts, these differences were not statistically significant.

Conclusions: Student athletic trainers exhibited fluctuations in their stress levels throughout an academic calendar. Academic and financial concerns were the most common stressors. Certified athletic trainers should take an interest in their student athletic trainers and be willing to provide assistance in times of need. Additional research is needed regarding student athletic trainers and stress.

Key Words: burnout, college students, coping, stress

Life stress, in particular chronic distress, has an undesirable effect on physical and mental health.[1–7] Capel[8] investigated burnout among athletic trainers and identified various sources of life stress, such as extensive time commitment, low salary, limited opportunity for career advancement, poor working conditions, job dissatisfaction, and conflicts with coworkers.

Capel[8,9] further observed that the rate of burnout among athletic trainers was relatively low when compared with that of other allied health professionals.[10–12] Campbell et al[13] reported that approximately 40% of all athletic trainers they surveyed were suffering from stress and burnout. Psychological aspects of rehabilitation from sport injury[14–21] and the potential influences of stress on injury[22–28] have received considerable scholarly attention, as has the topic of stress and certified athletic trainers.[8,9,13,29] However, no research has addressed the psychological stresses of student athletic trainers.

Thousands of student athletic trainers provide care to student-athletes on a daily basis in various athletic training curriculum and internship sites across the United States. Recent data indicated that more than 1000 students were enrolled in 121 National Athletic Trainers' Association-approved or Commission on Accreditation of Allied Health Education Programs (CAAHEP)-accredited undergraduate curriculums and hundreds more in nonaccredited programs.[30] Under the direct supervision of a certified athletic trainer (ATC), student athletic trainers must often provide coverage for a specific intercollegiate team or to an entire school's sport program (eg, when assigned to a high school). Such commitment requires the regular investment of considerable time and energy, in addition to the demands of the academic program.

Many researchers have investigated the demands and stressors faced by college students.[2,31–33] This population regularly reports experiencing numerous stressful academic, health-related, and personal-social challenges, such as the pressures to perform well in the classroom, excessive time demands, relationship issues, family pressures, and financial concerns.[2,31–33]

Much like the collegiate student-athletes they serve, student athletic trainers are confronted with multiple, often stressful, life demands.[34] Typically high-achieving student athletic trainers must balance the roles of student, helping professional in the making, and perhaps most challenging of all, developing young person. First and foremost, student athletic trainers are young people in transition. Like their peers, they must work through the so-called "developmental tasks" of college students, such as establishing one's life purpose, solidifying a set of personal values and standards, establishing meaningful and lasting relationships, developing feelings of competence, and establishing one's independence.[35–37] The stress associated with these tasks creates the developmental undercurrents that influence the daily functioning, growth, achievement, and satisfaction of student athletic trainers—factors that deserve attention and study.

A review of the literature revealed limited information regarding student athletic trainers and stress. Therefore, the 3 purposes of our study were to (1) identify the sources of stress that student athletic trainers face regularly and the types of stress symptoms they experience over the course of an academic year, (2) investigate the existence of possible sex differences between stress sources and symptoms, and (3) provide suggestions for athletic training staffs and helping professionals on how to assist this population.

METHODS

Subjects

Forty-three student athletic trainers at a mid-Atlantic National Collegiate Athletic Association Division I institution with an accredited undergraduate CAAHEP athletic training curriculum volunteered to participate in the study. Only 20 of 43 subjects (47%; 11 men, 9 women; age, 22 ± 4.6 years) provided data suitable for analysis due to missing stress questionnaires, missing items, or both. Thus, 23 of the original 43 subjects dropped out of the study for various reasons. The length of the study (8 months) may have contributed to the high attrition rate due to students' dropping the class, or they may have simply lost interest in participating. The University's Institutional Review Board for the Protection of Human Subjects approved this study. All participants provided informed consent.

Instrument

The Quick Stress Questionnaire (QSQ) is a 25-item, self-report inventory designed to measure sources of stress and stress-related symptoms in college students along a 9-point Likert scale (1 = little stress, 9 = extreme stress).[38] The QSQ provides a cost-effective, psychometrically sound measure of stress sources and symptoms. Respondents rate the severity of 8 potential areas of stress (academic, social/personal, family, financial, self-image, health, sexual, day-to-day hassles) on their lives and identify the types and degrees to which they experience various stress-related symptoms. Individual stress symptoms can be classified as cognitive (eg, anxiety), somatic (eg, headaches), or behavioral (eg, procrastination). Adding items according to the factor loading reported by Otani,[38] one can derive stress symptom factors (Table). Support for the QSQ's construct validity has been established through maximum likelihood factor analysis,[38] which revealed that the 9 stress source items loaded (loading reflects the extent of a relationship between each observed variable and each factor)[39] on a single stress source factor. Maximum likelihood factor analysis also identified 3 symptom factors that were labeled cognitive, somatic, and behavioral. Omega coefficient estimates of internal reliability for the cognitive, somatic, and behavioral factors were observed to be .89, .83, and .79, respectively.[38]

Quick Stress Questionnaire (QSQ) Items and Item Loadings for Cognitive, Somatic, and Behavioral Factors

Item	Item Loadings
1	Academic (or work) concerns
2	Social/personal relationships
3	Family concerns
4	Financial concerns
5	Self-image
6	Health concerns
7	Sexual concerns
8	Day-to-day hassles
9	Other (optional question not included in this study)
10	Feelings of depression, hopelessness, powerlessness, and/or poor self-esteem
11	Anger, hostility, irritability, and resentment
12	Apprehension, fears, and worrying
13	Muscle tension, headaches, backaches, and muscle aches
14	Indigestion, stomach ache, diarrhea, ulcer attacks, constipation, and colitis
15	Tics, tremors, and muscle spasms
16	Sleeping disturbances, insomnia, oversleeping, night awakening, and troublesome dreams
17	Eating disorders, overeating, and undereating
18	Excessive drinking and/or use of drugs (including nicotine and caffeine)
19	Forgetfulness, mental inefficiency, inability to study, and lack of motivation
20	Hypertension (high blood pressure)
21	Acne, eczema, hives, breaking out, and skin blotching and skin blanching
22	Avoidance behavior (eg, procrastination, escapism, TV watching, excessive partying, class cutting, absenteeism)
23	Overall level of stress and anxiety at this time
24	Overall stressors (eg, studies, job) this year in comparison with those of last year
25	Your level of stress when you first sought counseling or treatment (ignore if not applicable)

*QSQ items 1–9 represent sources of stress. QSQ items 10–23 represent expressions of stress. Cognitive factor includes items 10–12 and 23. Somatic factor includes items 13–17. Behavioral factor includes items 18, 19, and 22.

Survey Administration

Student athletic trainers enrolled in 3 different athletic training theory classes completed the QSQ within the first week of each month during the academic year (ie, September to April), for a total of 8 administrations. Students who missed class were asked to complete the QSQ within 24 hours of the in-class administration of the instrument. The QSQ was administered by a research assistant, who discouraged students from discussing their answers while completing the questionnaire, advised students that their responses would remain confidential, and encouraged them to respond honestly to all items. Only the data provided by the subjects who responded to all QSQ items were retained for data analysis.

Statistical Analysis

We calculated means and standard deviations for each stress source and for the cognitive, somatic, and behavioral symptoms of stress. Separate sex × time analyses of variance (ANOVAs) were performed to investigate changes in the severity of stress from each of the 8 stress sources. Also, separate sex × time repeated-measures ANOVAs were performed to examine if the cognitive, somatic, or behavioral expression of stress changed significantly over the course of the study. Significant main effects were analyzed via post hoc testing. In addition, all statistical analyses were based on an alpha level of .05 and were conducted using the SPSS statistical package (version 7.0, SPSS Inc, Chicago, IL).

RESULTS

Means and standard deviations for the 8 stress-source items and the 15 stress-symptom items, partitioned by sex, were calculated separately for each month. Academics (men, 5.36 ± 1.55; women, 6.39 ± 1.46) and financial concerns (men, 5.51 ± 1.90; women, 6.63 ± 1.87) were the primary sources of stress for both male and female student athletic trainers. The means and standard deviations for all other stress source items were 3.01 ± 1.65 for men and 4.36 ± 2.24 for women.

Fluctuations in the severity of stress associated with each of the 8 stress-source items (ie, items 1–8) over the course of the academic year were assessed using separate sex × time ANOVAs. The stress levels associated with all but one of the stress sources (family concerns) fluctuated significantly over the course of the study ($F_{7,15} = 1.80$, $P = .093$). However, in no case did men and women differ in the amount of stress they reported.

In order to examine changes in the cognitive, somatic, and behavioral expression of stress over the course of the study, responses to individual symptom items (ie, items 10–22) were added according to the factor loadings reported by Otani.[38] Separate sex × time repeated-measures ANOVAs revealed no significant interactions relative to changes in the cognitive ($F_{7,126} = 1.90$, $P = .074$), somatic ($F_{7,126} = .65$, $P = .711$), or behavioral ($F_{7,126} = .48$, $P = .870$) symptoms of stress. In addition, there was no main effect for sex with regard to the somatic expression of stress ($F_{1,18} = 2.58$, $P = .126$). However, significant main effects for sex relative to the cognitive ($F_{1,18} = 5.99$, $P = .001$) and somatic expressions of stress ($F_{1,18} = 2.50$, $P = .019$) were noted. In both cases, women reported greater stress symptoms than did men. Significant time main effects were found for behavioral ($F_{7,15} = 2.50$, $P = .019$), cognitive ($F_{7,15} = 5.99$, $P = .001$), and somatic ($F_{7,15} = 4.18$, $P = .001$) symptoms of stress. Changes from month to month with regard to behavioral, cognitive, and somatic symptoms of stress are presented in Figures 1–3.

Relative to cognitive stress, both male and female student athletic trainers tended to report apprehension, fear, and worry. Men reported thoughts of anger and hostility as well. Somatic stress was experienced by both men and women through sleep disturbances, insomnia, and troublesome dreams. Men also reported excess muscle tension and headaches. Behavioral manifestations of stress were expressed through forgetfulness, mental inefficiency, and amotivation. Women reported excessive alcohol consumption and avoidance behaviors such as procrastination and escapism.

Finally, in order to assess the overall stress levels experienced by student athletic trainers over the course of an academic year, a repeated-measures ANOVA was conducted on item 23 of the QSQ (overall stress at this time). The results of this analysis revealed no significant interaction ($F_{7,126} = .58$, $P > .05$) but did reveal significant main effects for sex ($F_{1,18} = 14.38$, $P < .001$) and time ($F_{7,126} = 4.20$, $P < .001$). This indicates that women reported greater overall stress during the academic year than men. Additionally, the overall levels of stress fluctuated in a similar fashion for both male and female student athletic trainers (Figure 4).

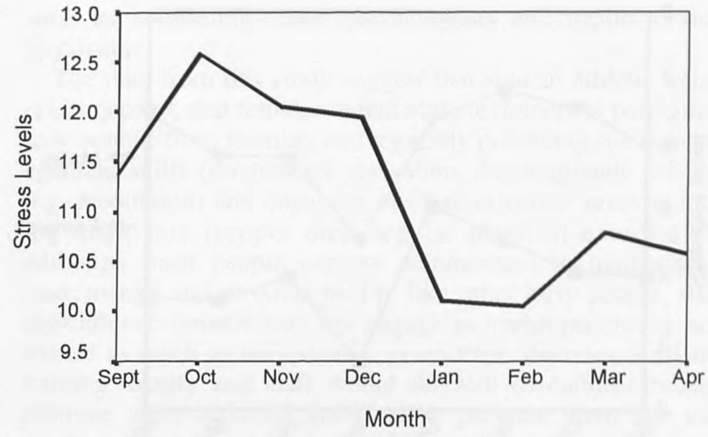

Figure 1. Fluctuations in behavioral stress.

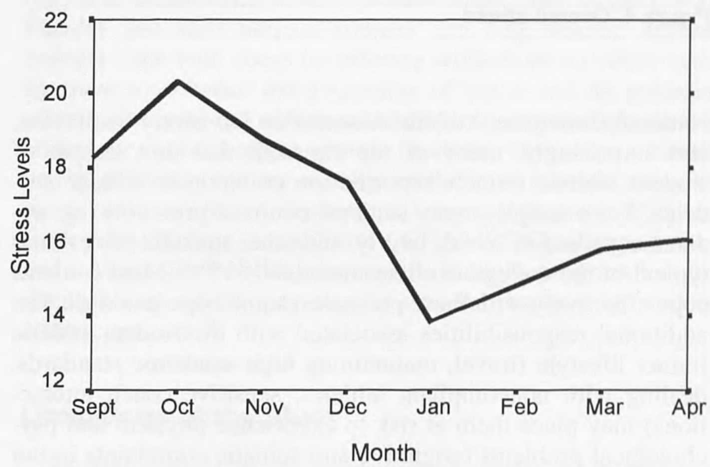

Figure 2. Fluctuations in cognitive stress.

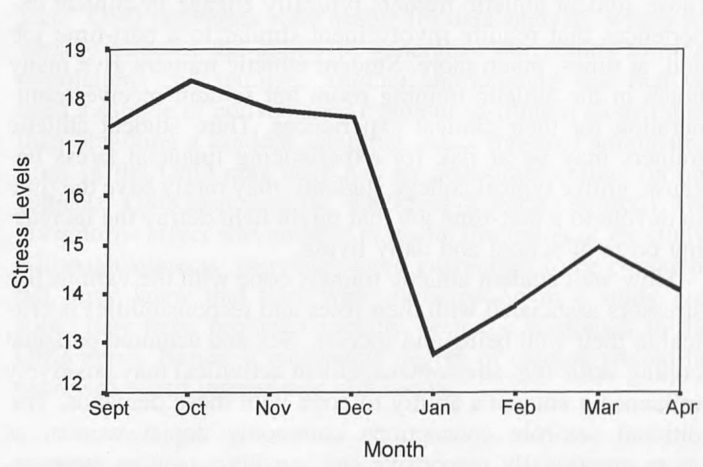

Figure 3. Fluctuations in somatic stress.

DISCUSSION

Although gleaned from a small sample of convenience, our findings provide unique preliminary insights into the life stresses and stress symptoms of student athletic trainers at a

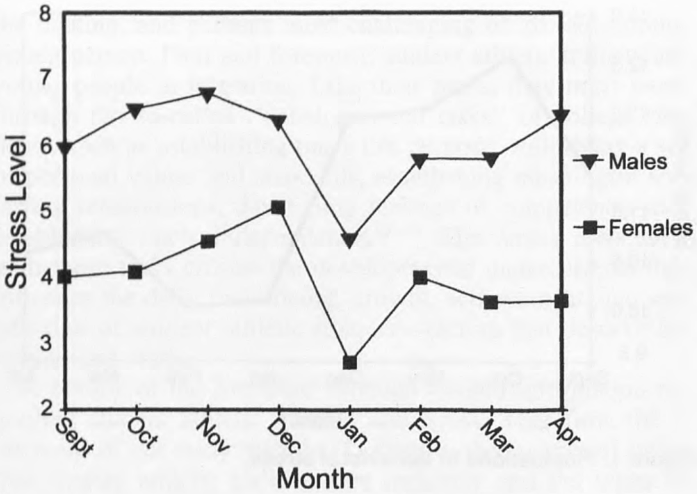

Figure 4. Overall stress.

National Collegiate Athletic Association Division I institution. Not surprisingly, many of the stressors that this sample of student athletic trainers reported are common to college students. For example, many students confront pressures (eg, academic, financial, social, family, and other stressful life events) typical of the collegiate environment.[2,31,34,40,41] Most students cope effectively with these pressures; some cope less well. The additional responsibilities associated with the student athletic trainer lifestyle (travel, maintaining high academic standards, dealing with noncompliant athletes, sensitive coach interactions) may place them at risk to experience physical and psychological problems (cognitive and somatic complaints in our sample). Perhaps these lifestyle demands are unavoidable, because student athletic trainers typically engage in clinical experiences that require involvement similar to a part-time job and, at times, much more. Student athletic trainers give many hours in the athletic training room but seldom receive remuneration for their clinical experiences. Thus, student athletic trainers may be at risk for experiencing financial stress because, unlike typical college students, they rarely have the time to devote to a part-time job that might help defray the increasing costs of school and daily living.

How well student athletic trainers cope with the various life stressors associated with their roles and responsibilities is critical to their well being and success. Sex and acquired personal coping skills (eg, stress-management activities) may positively influence a student's ability to cope with these demands. Traditional sex-role conceptions commonly depict women as more emotionally responsive and sensitive, men as more analytic and task oriented.[42–44] Thus, men may tend to work through their difficulties on their own and use personal problem-solving strategies to cope with stress, whereas women often reach out to others and rely on emotion-focused coping strategies.[43]

Heilburn and Chefitz[45] reported that general irritability, unstable emotions, inability to concentrate, easy fatigability, emotional tenseness, and loss of appetite are common stress symptoms among college students. Female students are more susceptible to psychosomatic symptoms, physical illness, psychological disorders, and anxiety and report greater depressive mood symptoms than male students.[46,47] Sigmon et al[48] found that women rated stressful situations as more unpleasant than men, whereas men perceived themselves as having more control and viewed stressful events as more of a challenge than a threat.

Men and women in this study tended to differ on how they managed time and stress. Macan et al[49] found that women scored higher than men when dealing with time-management behaviors. Women reported a higher frequency of engaging in time-management practices such as making lists, planning, and scheduling; however, they felt no more in control of time as a result of these behaviors.[49] A National Collegiate Athletic Association report on intercollegiate athletes noted that female athletes spent more time preparing for class than male athletes and less time in social activities and relaxing alone.[50,51]

Our results suggest that academics may be a major source of stress to student athletic trainers. This is particularly evident in the months of October, December, and March due to midterm and final examinations. However, less stress is reported during March than in October, and this may be attributed to spring break, which often serves as a source of stress relief.

Effective time-management and study skills appear to be essential facilitators of academic success in the classroom. In fact, students who are academically challenged are often less able to manage and control their time.[49] How male and female student athletic trainers manage their time and studies may have significant positive or negative effects, both in and out of the classroom. With the stringent demands associated with the responsibilities of student athletic trainer programs, faculty and staff should encourage students to participate in time-management and study-skill seminars or to obtain individual assistance from on-campus professionals for these needs.

Students face many stresses associated with college, such as moving away from home and family, adapting to a new environment, establishing new friendships, and managing a challenging academic environment.[52,53] Student athletic trainers face additional pressures similar to those of college student-athletes, such as increased travel demands, high performance expectations, team expectations and rules, and financial pressures.[52] Thus, student athletic trainers' involvement with athletics at the collegiate level places them in the role of nonathletes participating in an extracurricular activity as they strive to be successful in both the classroom and their athletic training clinical responsibilities. In comparison with their more high-profile athlete peers, they strive to be accepted by their fellow student athletic trainers, to be recognized by staff athletic trainers based on their clinical performance, and to provide quality health care for the athletes and coaches they interact with on a daily basis.

Providing Support and Assistance to Student Athletic Trainers

Our data suggest that student athletic trainers are young people at risk for experiencing stress in various ways. Their many responsibilities make their lifestyles uniquely demanding. They should be viewed much like student-athletes, first as developing young people in an academic community, and second as people who are actively involved in a very challenging extracurricular activity—college athletics.[54]

Certified athletic trainers who work with student athletic trainers can have a significant effect on the daily functioning and development of these future professionals. Helping student athletic trainers to understand our efforts in the athletic training room with an athlete's treatment and rehabilitation is often given the utmost attention and concern. Nevertheless, attending to a student athletic trainer's health and welfare should also be a very high priority for all faculty and staff athletic trainers in the collegiate setting.

Athletic training professionals should learn to be effective listeners and be sensitive to the concerns of student athletic trainers. According to Bolton,[55] we spend more time listening than anything else we do during our waking hours. Clearly our ability to listen directly influences our friendships, relationships, and effectiveness at work. Often, a faculty or staff athletic trainer may not need to intervene formally but can simply provide an empathetic ear to a struggling young person.

The physical and mental health of student athletic trainers may be facilitated by regularly engaging in a few simple professional practices. Always have an open-door policy for student athletic trainers. Student athletic trainers should believe they can approach any staff or faculty athletic trainer with problems (eg, class demands, peer conflicts, family matters) should the need arise. Encourage student athletic trainers to check in with the athletic training faculty or staff on a regular basis, even if the contact is brief. Be willing to spend time with them when they visit. Demonstrate a genuine interest in them and their concerns by giving them undivided attention. Get to know them on an ethically appropriate personal level rather than just through the superficial daily interactions in the clinical or classroom setting. Ask them questions regarding their daily life interactions:

- How are things at home?
- How are they and their roommates or classmates getting along?
- How are their classes going?
- Are they traveling out of town this week with their respective teams?
- What's new and exciting in their life?
- How is their health these days?

These types of questions show genuine interest and concern for student athletic trainers as people and not merely students. Professionals can inquire about these and other issues without losing sight of what needs to be accomplished every day in the classroom and athletic training room. Indeed, providing such social support facilitates the student's coping with stress and promotes overall health.[21,56]

Because of their involvement in and commitment to the athletic training program, academics, and personal lives, student athletic trainers may be vulnerable to physical and mental breakdown, especially around certain demanding times. Our data suggest that they may be especially vulnerable to stress during midterm examinations (ie, October and March), when academic pressures are common and team-related responsibilities are often heavy. Faculty and staff athletic trainers should be sensitive to these vulnerable times to better recognize when students may encounter problems and to be aware of unusual stress responses. Unusual stress responses might include feelings of depression, apprehension, anger, hostility, sleep disturbances, muscle tension, headaches, forgetfulness, and avoidance behavior. Faculty and staff athletic trainers need to monitor stressful responses among student athletic trainers and show care and concern without being intrusive. Perhaps a day off to deal with their stressful plight (academics, family, or personal) may be all the student athletic trainer needs. If further intervention is needed, athletic training professionals need to be aware of on-campus resources so they can make appropriate and timely referrals to qualified helping professionals, such as counseling-center psychologists and health-service physicians.

The data from this study suggest that student athletic trainers in general, and female student athletic trainers in particular, may benefit from learning and regularly practicing stress-management skills (progressive relaxation, diaphragmatic breathing, meditation) and engaging in other effective stress-reducing behaviors (proper diet, regular physical exercise).[57] Although most people express commitment to maintaining peak mental and physical health, like other busy people, student athletic trainers may not engage in health-promoting activities as much as they should, given their lifestyles. Athletic training faculty and staff would do well to enthusiastically promote these activities and even to program them into the weekly schedules of student athletic trainers. It can be quite helpful to make available mechanisms to monitor life stress (eg, brief instruments to self-monitor stress, such as the QSQ). Faculty and staff athletic trainers can help student athletic trainers cope with stress by offering workshops on stress management to enhance the awareness of stress and its potential effects. Students can obtain emotional support through student athletic trainers' support groups or clubs. On-campus mental health professionals are usually available to provide many of these services. Many institutions have adopted the National Collegiate Athletic Association's CHAMPS(Challenging Athletes' Minds for Personal Success)/Life Skills program for student-athletes, which may also be a useful resource for student athletic trainers.[58]

Limitations of the Study

Several aspects of the investigation should be considered when interpreting the findings of our study. Only 47% of subjects' QSQ responses were usable for data analysis, which adversely affected the ability to generalize our results to other populations and settings. Another shortcoming was that we used a sample of convenience from our institution alone rather than obtaining a random sampling. Also, repeated administrations of the QSQ may have had an undesirable effect on our subjects' QSQ responses (ie, the threat of testing existed). The Hawthorne effect was another potential limitation of the study. Although subjects' responses were guaranteed to be confidential, they knew that they were participating in a study and some may have provided socially desirable responses to the QSQ items. Hence, a reasonable degree of caution should be exercised when interpreting our results.

CONCLUSIONS

Student athletic trainers appear to lead stressful and demanding lives, much like those of college student-athletes. The time demands placed upon student athletic trainers in combination with daily life stressors confronting them as college students (eg, academic pressures, financial concerns) may lead to considerable distress that can affect health and functioning. Certified athletic trainers should promote primary prevention strategies that help student athletic trainers cope effectively with anticipated life stress and should provide a holistic approach to assisting student athletic trainers in times of need. Future studies should involve random selection, using a control group, and include other programs accredited by the Commission on Accreditation of Allied Health Education Programs to better understand the stress experienced by student athletic trainers at the collegiate level.

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A Survey of Athletic Training Employers' Hiring Criteria

Leamor Kahanov*; Lanna Andrews†

*San Jose State University, San Jose, CA; †University of San Francisco, San Francisco, CA

Leamor Kahanov, EdD, ATC, and Lanna Andrews, EdD, contributed to conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article.

Address correspondence to Leamor Kahanov, EdD, ATC, San Jose State University, One Washington Square, San Jose, CA 95192-0054. Address e-mail to leamor@email.sjsu.edu.

Objective: To identify athletic training employers' hiring criteria and to determine if the importance of individual hiring criteria vary by setting.

Design and Setting: The Athletic Training Employer Needs Assessment Survey was mailed to athletic training employers advertising in the National Athletic Trainers' Association (NATA) placement vacancy notice between October 1996 and October 1998.

Subjects: A total of 111 athletic training employers in NATA Districts 7, 8, and 10 were surveyed.

Measurements: Employers rated the importance of hiring criteria on a 7-point Likert scale. Means and standard deviations were calculated for each criterion and compared these values to ascertain the importance of individual criteria. A principal component analysis was done to determine the underlying factors.

Results: Hiring characteristics can be divided into 4 factors that include highly related criteria: (1) personal characteristics, (2) educational experience, (3) professional experience, and (4) work-related attributes. In addition, the hiring characteristics desired by employers varied among athletic training settings.

Conclusions: When interviewing and presenting themselves for entry-level positions, athletic trainers should pay particular attention to the attributes within the 4 hiring criteria factors. Also, the desired hiring criteria of athletic training employers differed by setting. Applicants need to pay particular attention to these hiring criteria differences when constructing résumés, cover letters, and professional correspondence and when interviewing with prospective employers.

Key Words: hiring characteristics, employment, self-marketing, hiring attributes

Researchers who have studied athletic training employment have primarily reported employment statistics in the job market and examined the extent to which employers desire athletic trainers.[1–5] The recent literature on athletic training employment has primarily focused on salary ranges and marketability. The prevailing criterion predicting employment and salary is the educational status of the applicant.[3,6–8] Most job marketability studies have pertained to athletic training employment in the public schools, for kindergarten through 12th grade.[1–3,5,6,9]

The National Athletic Trainers' Association (NATA) routinely reports statistics on athletic training employment rates in 5 work settings: (1) clinic, (2) college, (3) high school, (4) industrial, other, and (5) professional sports[4]; however, there is no empiric evidence to explain the hiring criteria used by employers. Few researchers have examined employers' hiring criteria in the selection of athletic trainers. The purposes of our study were to identify athletic training employers' hiring criteria and to determine if hiring criteria vary by setting.

METHODS

We used a descriptive research design. Data were collected and analyzed from athletic training employers in 5 athletic training settings to describe employers' hiring criteria. The population for this study consisted of athletic training employers with employment positions available in Districts 7, 8, and 10 of the NATA. We identified employers by their placement of advertisements in the NATA placement vacancy notice between October 1996 and October 1998. With the exception of graduate assistantships, all employment positions advertised in the NATA placement vacancy notice were included in this study. The University of San Francisco Institutional Review Board approved a Human Subjects Review for the protection of human subjects.

Survey Instrument

The Athletic Training Employer Needs Assessment Survey (ATENAS) used in this study was a modification of the original Hiring Criteria Survey (HCS).[10] The HCS was introduced by Gaedeke et al,[10] who surveyed more than 170 companies hiring graduates to fill entry-level business positions. A total of 33 hiring criteria characteristics were identified. Related studies verified the validity and reliability of the 33 hiring characteristics.[10,11] The HCS has 33 items and is based on a 7-point Likert scale ranging from 1 (extremely important) to 7 (not important at all). The ATENAS was designed for athletic training employers by adopting the Likert-based assessment of 33 hiring criteria and adding demographic information specific to the population of this study.

A pilot study was conducted to test the ATENAS with 12 athletic training employers from various athletic training settings. Respondents to the pilot study indicated only minor formatting errors, which were used to refine the survey instrument. The survey instrument was designed to follow the

Dillman Total Design Method.[7] Two weeks after the survey was mailed, reminder postcards were mailed, followed by another mailed survey to individuals who had yet to respond.

The ATENAS was mailed to 111 athletic training employers. Employers were identified as the individuals responsible for recruitment and hiring recommendations. Codes were randomly assigned to each participant to maintain anonymity and placed on each envelope to identify respondents. A cover letter describing the importance of participation in the study, who should complete the ATENAS, and confidentiality issues was included in the survey packet. Surveyed employers received a reminder postcard 1 week after the survey was mailed. Three weeks after the initial mailing, nonrespondents received a second cover letter and a second copy of the questionnaire.

Data Collection and Analysis

Each respondent completed the ATENAS by rating each item on a scale of 1 to 7, with 1 being most important and 7 being not important at all. The data were collected to assess the hiring criteria used by athletic training employers. The data were analyzed for a description of hiring criteria by athletic training employers and in employment settings. We used the Statistical Package for Social Sciences (version 8.0, SPSS Inc, Chicago, IL) to calculate means, standard deviations, and a factor analysis. A principal component analysis was done to determine underlying factors.

RESULTS

We identified 111 athletic training employers in NATA Districts 7, 8, and 10 for this study. Eighty-two of the 111 employers (74%) responded to the survey. More than three quarters of respondents to the ATENAS were in clinical (n = 29; 35.8%) or collegiate or university (n = 33; 39.9%) settings. High school setting employers constituted 23% (n = 19), the third largest subgroup of respondents. The remaining subgroups included 5 respondents in the industrial setting (6.2%) and 3 respondents in the professional sports setting (3.7%). The respondents' work experience ranged from less than 1 year to more than 20 years, with most respondents having fewer than 10 years of experience (n = 57; 70%). Forty-eight percent (n = 39) of the athletic training employers were noncertified athletic trainers, including athletic directors, physical therapists, and other administrative professionals, and 52% (n = 43) were certified athletic trainers in employer positions.

Hiring Criteria Importance Across Factors

Hiring criteria data from the ATENAS were factor analyzed and collapsed in order to reduce the 33 hiring criteria into a smaller number of components (factors) to reveal patterns among the variation of characteristics. The 33 hiring characteristics of the ATENAS fell into 7 factors, which accounted for 70% of the variance. Four of the 7 factors accounted for 64% of the variance. The remaining factors loaded on several categories, with small coefficients of α indicating weak relationships. These factors consisted of 7 hiring characteristics: ability to acknowledge limitations, computer skills, master's degree, professional membership, quantitative skills, related work experience, and applicant's salary requirements. The 3 weak factors were subsequently eliminated from this study. The 4 most salient factors were personal characteristics, educational experience, professional experience, and work-related attributes.

Personal characteristics (factor 1) accounted for 25% of the variance in employers' hiring criteria (Table 1); these characteristics included self-confidence, maturity, interpersonal skills, assertiveness, enthusiasm, technical skills, ability to articulate goals, oral communication skills, leadership skills, initiative, ambition, problem-solving skills, and writing skills. These items had a coefficient of α (r = .90) that indicated a high relationship among these variables.

Educational experience (factor 2) accounted for 14.6% of the variance and included college minor, grade point average, membership in a fraternity, and college reputation (Table 1). The coefficient of α (r = .82) indicated a high relationship among these characteristics.

Professional experience (factor 3) included a master's degree and military service. The coefficient of α (r = .30) indicated that these were weak hiring criteria.

Work-related attributes (factor 4) included related work experience, entrepreneurialism, willingness to relocate, or membership in a professional organization (Table 1). The coefficient of α (r = .40) indicated a weak relationship among attributes.

Hiring Criteria Across Athletic Training Employment Settings

Mean hiring ratings for the 33 criteria are presented in Table 2. On average, personal characteristics were rated an important hiring criterion in all work settings, including the ability to articulate goals, assertiveness, writing skills, quantitative skills, personal appearance, a bachelor's degree, and interpersonal skills. Technical skills were rated important across all settings except the industrial setting (mean, 3.40). The ability to acknowledge limitations and problem-solving skills were rated as important across all work settings with the exception of professional sports; in this setting, these skills were rated as less important (means, 3.67 and 3.00, respectively). Entrepreneurialism was the only personal characteristic rated less important in all work settings, except in the industrial setting, in which it was rated of slightly greater importance.

A bachelor's degree was rated very important across all settings, whereas a master's degree was rated less important in the clinical (mean, 3.24), high school (mean, 2.75), and industrial (mean, 4.60) settings. In the college and university (mean, 1.67) and professional sports (mean, 2.00) settings, a master's degree was viewed as very important.

Employers in clinical settings regarded professional membership as unimportant (mean, 5.08). Willingness to relocate was an important hiring criterion in all settings except the industrial setting (mean, 4.40). Related work experience was rated very important in the high school (mean, 1.84) and professional (mean, 2.00) settings and less important for clinical (mean, 3.04), collegiate and university (mean, 2.58), and industrial (mean, 2.60) settings. Supporting experiences such as civic, church, and social work rated low in importance, and membership in fraternal groups and military service were rated as unimportant across all athletic training work settings.

DISCUSSION

Four hiring criteria factors emerged as desirable characteristics for athletic training employers: personal characteristics,

Table 1. Factor Analysis Component Matrix of Athletic Training Hiring Criteria*

Hiring Criterion	Personal Characteristics (Factor 1)	Educational Experience (Factor 2)	Professional Experience (Factor 3)	Work-Related Attributes (Factor 4)
Self-confidence	.76	NA	NA	NA
Maturity	.73	NA	NA	NA
Interpersonal skills	.73	NA	NA	NA
Assertiveness	.71	NA	NA	NA
Enthusiasm/motivation	.70	NA	NA	NA
Technical skills	.69	NA	NA	NA
Ability to articulate goals	.69	NA	NA	NA
Oral communication skills	.67	NA	NA	NA
Leadership skills	.66	NA	NA	NA
Initiative	.65	NA	NA	NA
Ambition	.64	NA	NA	NA
Problem-solving skills	.63	NA	NA	NA
Writing skills	.58	NA	NA	NA
References	.53	NA	NA	NA
Bachelor's degree	.52	NA	NA	NA
Personal appearance	.49	NA	NA	NA
College minor	NA	.77	NA	NA
Grade point average	NA	.76	NA	NA
Membership in fraternal group	NA	.73	NA	NA
Reputation of college	NA	.70	NA	NA
Civic, church, and social work	NA	.68	NA	NA
Honors and awards	NA	.66	NA	NA
Nonrelated work experience	NA	.61	NA	NA
Master's degree	NA	NA	.52	NA
Military service	NA	NA	.52	NA
Related work experience	NA	NA	NA	−.46
Entrepreneurialism	NA	NA	NA	.44
Willingness to relocate	NA	NA	NA	.42
Membership in professional organization	NA	NA	NA	.33

*Data were extracted by principal component analysis. NA indicates not applicable.

educational experience, professional experience, and work-related (professional) attributes. Each of the 4 factors consisted of interrelated hiring criteria or attributes that should be viewed as a whole unit or pattern of related hiring criteria. Although we recognize that personal characteristics, such as appearance, by law should not be used as criteria for employment, it is clear that employers rate these criteria as important, suggesting that such characteristics should be taken into consideration. It should also be noted that personal characteristics accounted for 25% of the variance in employer hiring criteria and were an important component in selecting employees.

In general, the hiring criteria related to personal characteristics (eg, ability to articulate goals, ambition, assertiveness, a bachelor's degree, oral and written communication skills, enthusiasm, initiative, interpersonal skills, leadership skills, maturity, personal appearance, problem-solving skills, references, self-confidence, and technical skills) were rated highest by all athletic training employers. Since employers rate personal characteristics as the most important hiring criteria, a practical review and discussion of the hiring process for graduating students may be warranted. Athletic trainers matriculating from undergraduate programs should be aware of the importance of personal characteristics, such as professional demeanor during an interview, and should learn how to write a résumé, cover letter, and professional correspondence to enhance their chances of being hired.

Personal characteristics, educational experience, and professional experience were clearly hiring criteria considered by employers during the hiring process. Undergraduate athletic trainers may not understand the significant hiring criteria used in various settings and, therefore, may not prepare themselves well for the interview and hiring process. Defining and discussing the 4 most significant hiring criteria at some point during the athletic training curriculum may enhance the students' abilities to successfully market themselves after graduation.

Hiring Criteria Across Work Settings

With the exception of personal characteristics, the importance of hiring criteria to employers varied with the work setting. One possible explanation may be that 48% of the employers were not athletic trainers and may have valued a different set of skills compared with the 52% of employers who were athletic trainers.

Hiring criteria across work settings indicated that employers had similar preferences with regard to personal characteristics. These personal characteristics become evident during an interview and, thus, the findings of Arnold et al[12] that interview performance is highly important in securing employment may be supported. The only personal characteristic that was not rated important by employers in all work settings was entrepreneurialism.

The importance of a bachelor's or master's degree varied by employers in different work settings. Previous research supports the extreme importance of a bachelor's degree in all settings as a hiring criterion.[12–14] Employers may rate a bachelor's degree higher because it meets the minimum acceptable

Table 2. Importance of Hiring Criteria to Athletic Training Employers (n = 82) in 5 Work Settings*

	Athletic Training Work Setting									
	Clinic		College and University		High School		Industrial, Other		Professional Sports	
Criterion	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ability to acknowledge limitations	2.08	1.31	2.21	0.92	2.16	0.76	3.00	0.54	3.33	1.15
Ability to articulate goals	2.32	0.92	2.52	0.57	2.37	0.70	2.20	0.44	3.00	0.00
Ambition	2.24	1.33	2.28	0.77	1.68	0.70	2.40	1.30	2.00	1.15
Assertiveness	2.54	1.10	2.03	0.73	1.74	0.74	2.60	0.83	2.00	1.15
Bachelor's degree	2.40	1.51	1.25	1.38	1.58	0.81	2.20	0.89	1.33	2.64
Civic, church, and social work	4.84	1.12	5.38	0.92	4.16	0.82	5.20	1.14	5.33	1.00
College minor	4.80	1.56	5.50	0.96	3.16	1.30	5.40	0.54	5.33	1.52
Computer skills	4.04	1.09	3.14	0.57	3.11	0.31	2.80	0.44	4.33	1.15
Enthusiasm/motivation	1.83	1.39	1.93	0.99	1.63	0.69	1.40	1.22	1.67	0.57
Entrepreneurialism	3.16	1.37	3.86	1.02	3.00	0.89	2.60	1.30	4.00	2.00
Grade point average	4.00	1.31	4.14	0.98	3.37	0.65	4.40	1.14	3.67	1.00
Honors and awards	4.12	1.22	4.34	0.77	8.74	0.69	5.40	0.44	4.33	3.46
Initiative	1.84	0.94	1.55	1.05	1.68	0.85	1.80	1.14	1.67	1.00
Interpersonal skills	1.88	1.26	1.48	1.18	1.11	1.04	1.20	0.83	1.67	1.52
Leadership skills	2.76	1.54	2.24	1.45	2.11	0.83	2.20	0.89	3.67	1.00
Master's degree	3.24	1.24	1.69	1.12	2.79	0.73	4.60	0.70	2.00	1.52
Maturity	1.96	1.10	1.93	1.85	1.42	0.70	2.00	0.95	1.33	2.08
Membership in fraternal group	6.12	1.07	6.31	0.72	5.05	0.83	6.60	1.22	6.00	1.15
Membership in professional organization	5.08	1.31	3.00	0.99	2.68	0.76	3.00	1.34	3.33	1.00
Military service	5.88	1.33	6.07	0.74	5.68	0.99	5.80	1.30	4.67	1.15
Nonrelated work experience	4.48	1.15	5.17	1.40	3.68	0.68	5.40	1.14	4.33	0.57
Oral communication skills	1.58	1.24	1.48	1.62	1.55	1.00	1.20	2.00	1.00	1.52
Personal appearance	2.68	1.70	2.45	1.33	2.11	1.34	2.00	0.83	2.33	1.00
Problem-solving skills	1.80	1.21	1.62	1.39	1.58	1.06	1.20	1.22	3.00	0.57
Quantitative skills	2.79	1.36	3.50	1.44	2.56	5.02	3.75	1.51	2.67	0.57
References	2.36	1.38	2.04	0.92	1.79	0.22	2.40	1.14	3.00	1.00
Related work experience	3.04	1.68	2.55	1.31	1.84	0.32	2.60	1.34	2.00	1.52
Reputation of college	4.08	1.85	4.00	1.56	3.53	0.23	4.80	1.34	4.00	1.52
Salary	3.42	1.59	3.43	1.49	2.53	0.33	4.00	2.16	2.33	1.15
Self-confidence	2.04	1.42	1.62	1.03	1.42	0.33	2.20	0.54	1.67	1.00
Technical skills	2.32	1.56	2.28	1.57	1.60	1.52	3.40	1.30	2.00	1.20
Willingness to relocate	3.24	1.82	2.69	0.84	2.47	1.01	4.40	1.09	2.33	0.33
Writing skills	2.68	1.69	2.45	1.00	2.79	1.54	2.40	1.14	3.00	0.57

*Criteria were rated on a scale of 1 (very important) to 7 (not important at all).

educational standards for their open positions. However, employers in the collegiate setting rated the possession of a master's degree more important than did employers in other work settings, which supports the opinion of Arnold et al[13] that a relationship exists between highest degree attained and employment setting.

The results of this study further support the findings of Arnold et al[12] regarding job characteristics that employers deem important, but contrary to previous findings, the reputation of the applicant's college was an unimportant hiring criterion in all settings. In addition, nonrelated work experience was consistently rated as unimportant in all settings other than the high school setting. The fact that nonrelated work experience was rated more important in the high school setting again emphasizes the need for prospective applicants to market themselves specifically to each work setting. Thus, when entry-level athletic trainers seek employment in the high school, they may need to highlight their nonrelated work experience.

With few exceptions, the hiring criteria deemed important across all athletic training work settings were fairly consistent; however, it may be that attention to slight differences in the importance of certain skills within various athletic training settings improves the likelihood of obtaining an athletic training position in that setting. Athletic trainers seeking employment should target their employment inquiries and applications to reflect the desired hiring characteristics in those settings.

CONCLUSIONS

Data from this study suggest that employers, regardless of work setting, rate personal characteristics and the achievement of a bachelor's degree as highly important. During the job-application process, athletic trainers should pay particular attention to personal characteristics (ie, communication skills, enthusiasm, initiative, interpersonal skills, maturity, self-confidence, ability to articulate one's goals, ambition, and problem-solving skills). In particular, a master's degree was rated highly important in collegiate and university settings compared with other work settings. Athletic trainers may be unaware of employers' hiring criteria and the relationship among the criteria, which may explain the difficulty some prospective employees have in marketing themselves.

RECOMMENDATIONS

Future Research

Our study surveyed athletic training employers from the western continental United States, Alaska, and Hawaii. A future study should be conducted with employers across the United States, which will increase the generalizability of the findings. We used hiring criteria validated for the business field. A separate assessment to determine hiring criteria in the athletic training field may uncover characteristics not addressed by this study. The hiring criteria used for this study define the attributes that employers seek during the hiring process for athletic trainers; however, a review of hiring criteria across related allied health care fields may help clarify why such a high proportion of matriculating undergraduate athletic trainers are unable to find athletic training employment. Few researchers have attempted to describe the preparation necessary for employment in athletic training education programs; therefore, further investigation into the description of current practices should be addressed.[13] In addition, research into athletic training employers' understanding of the athletic training profession and athletic training domains should be addressed.

Professional Practice

A comparison of our results and those found in the literature regarding hiring criteria practice makes it clear that students should be introduced to employment practices during their educational preparation.[15] As noted by Meador and Tsuchiya,[16] athletic training educators spend a minimal amount of educational time on employment practices and procedures. The data cited throughout this study suggest new ways to consider athletic training education and employment. We propose that a better understanding of employer hiring criteria may increase athletic trainers' ability to market themselves. Perhaps awareness of employers' hiring practices, including the specific emphasis in different work settings on individual and professional characteristics, will make entry-level athletic trainers more successful in completing the interviewing and hiring process.

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A Review of Articular Cartilage Pathology and the Use of Glucosamine Sulfate

Carey-Beth James*; Timothy L. Uhl†

*University of Hartford, Hartford, CT; †University of Kentucky, Lexington, KY

Carey-Beth James, MS, ATC, contributed to conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article. Timothy L. Uhl, PhD, ATC, PT, contributed to conception and design; analysis and interpretation of the data; and drafting, critical revision, and final approval of the article.

Address correspondence to Timothy L. Uhl, PhD, ATC, PT, Division of Athletic Training, University of Kentucky, CAHP Building, Room 205, 121 Washington Street, Lexington, KY 40536-0003. Address e-mail to tluhl2@uky.edu.

Objective: To refresh the athletic trainer's knowledge of articular cartilage biomechanics, physiology, and structure and explore the role of glucosamine sulfate in treating articular cartilage pathologic conditions, including supplementation methods and clinical outcomes.

Data Sources: We searched MEDLINE from 1989 through 2000 and SPORT Discus from 1975 through 2000 using the following key words: *glucosamine sulfate, articular cartilage, osteoarthritis,* and *proteoglycans.*

Data Synthesis: Articular cartilage functions as a wear-resistant, smooth, nearly frictionless, load-bearing surface. Glucosamine sulfate can be thought of as a building block that helps restore the proteoglycan-rich extracellular matrix and thus balance articular cartilage catabolism and anabolism. Beneficial clinical effects of glucosamine sulfate in the osteoarthritic population have been documented. However, the use of glucosamine sulfate for athletic articular cartilage injuries is unproved.

Conclusions/Recommendations: Clinical studies indicate that glucosamine sulfate has been shown to be a safe and relatively effective treatment for osteoarthritis. However, no evidence to date supports or refutes a carryover effect to the athletic population and the injuries that occur in sport.

Key Words: osteoarthritis, proteoglycans, outcomes, treatment, supplements

Glucosamine sulfate is being extensively marketed as a treatment for osteoarthritis. Glucosamine is an endogenous aminomonosaccharide synthesized from glucose.[1–3] It is used in the biosynthesis of proteoglycans and glycosaminoglycans (GAGs) as a proposed substrate for the synthesis of these important cartilage components and perhaps a direct stimulator of their synthesis.[1–3] Glucosamine can be thought of as a building block that helps restore the proteoglycan-rich matrix and thus balance cartilage catabolism and anabolism.[1–3] Glucosamine is also proposed to protect damaged cartilage from metabolic impairment.[4,5]

Osteoarthritis is a gradual disease characterized by a continual wearing of the articular cartilage, resulting in changes in the underlying subchondral bone.[5] Management of osteoarthritis currently includes weight reduction, physical therapy, occupational therapy, and the use of nonsteroidal anti-inflammatory drugs (NSAIDs).[4] NSAIDs have been shown to have both positive and negative effects on cartilage metabolism, but neither NSAIDs nor acetaminophen has been shown to reverse the degenerative process of osteoarthritis.[4]

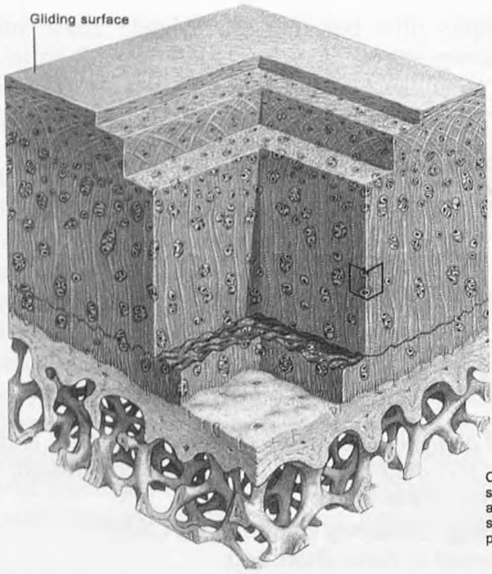
The anatomic, physiologic, and biomechanical properties of articular cartilage should be considered in treating articular cartilage pathologic conditions. Understanding these articular cartilage properties allows the athletic trainer to better appreciate how glucosamine sulfate may affect articular cartilage. The purpose of our review was to explore the relationship between articular cartilage pathology and glucosamine sulfate.

THE ROLE OF HUMAN ARTICULAR CARTILAGE

Articular cartilage functions to distribute the load, minimize peak stresses on subchondral bone, and provide a friction-reducing, weight-bearing surface. Articular cartilage can be deformed and regain its original shape, because it is remarkably elastic. In comparison with other soft tissues, articular cartilage has a low level of metabolic activity and lacks blood vessels, lymphatic vessels, and nerves. Essentially, articular cartilage functions and stands alone. The simple homogeneous appearance of cartilage hides its highly ordered complex structure. This structure apparently remains unchanged unless affected by disease or injury.[6]

COMPOSITION AND STRUCTURE OF ARTICULAR CARTILAGE

Articular cartilage is typically depicted in 4 zones (Figure). Each zone has its own distinct matrix region. The superficial zone includes the gliding surface of the joint. This layer of cell-free matrix contains fine fibrils with few polysaccharides and adjoins a layer of elongated chondrocytes organized parallel to the articular surface. The cells in this zone are almost inactive but contain endoplasmic reticulum, Golgi membranes, and mitochondria. The next layer is the transitional zone, which includes active chondrocytes containing endoplasmic reticulum, Golgi membranes, mitochondria, glycogen, and intracytoplasmic filaments. The collagen fibrils of this zone are larger than those of the superficial zone. In this layer, collagen fiber orientation transitions from parallel to columnar. The



The 4 zones of articular cartilage. Copyright 1995. Reprinted with permission from Havas MediMedia, illustrated by Drs. John A. Craig and Carlos Machado. *Clin Symp.* 1995;47(2). All rights reserved.

deep zone contains chondrocytes that are similar to those of the transitional zone but are organized in a columnar pattern perpendicular to the joint surface. These cells hold large amounts of intermediate filaments and glycogen granules. Furthermore, the largest collagen fibrils of articular cartilage and the highest content of proteoglycans are also contained here. As the number of proteoglycans increases, the amount of water decreases from the superficial to the deep zone. The deepest zone of calcified cartilage divides the softer cartilage from subchondral bone. The cells from the deep zone bore directly into the calcified cartilage. These chondrocytes contain little cytoplasm and almost no endoplasmic reticulum but connect the articular cartilage to the underlying bone.[6]

A chondrocyte cell membrane adheres directly to the pericellular matrix, which contains proteoglycans, noncollagenous proteins, and glycoproteins. A layer of territorial matrix encompasses the pericellular matrix. This matrix surrounds individual cells or pairs or clusters of chondrocytes. The interterritorial matrix forms the majority of articular cartilage and accounts for its mechanical characteristics.[6]

Chondrocytes provide 10% or less of the total volume of cartilage; consequently, the functional properties of cartilage, including stiffness, durability, and distribution of load, rely on the extracellular matrix. Overall, tissue fluid contributes 60% to 80% of the wet weight of cartilage and contains water with dissolved gases, small proteins, and metabolites. The structural macromolecules contribute 20% to 40% of the wet weight[7] and include collagens, proteoglycans, and glycoproteins. The chondrocytes and matrix depend on each other. The material properties of articular cartilage depend on its extracellular matrix, but the existence and maintenance of the matrix depend on the chondrocytes.[6]

BIOMECHANICAL PROPERTIES OF ARTICULAR CARTILAGE

Articular cartilage functions as a wear-resistant, smooth, nearly frictionless, load-bearing surface. The composition and physicochemical properties of articular cartilage, the fundamental organization of the collagen network, and the molecular organization of collagen and proteoglycans all have profound effects on the intrinsic mechanical properties of the extracellular matrix and the fluid transport and diffusional properties of the cartilage. These characteristics provide articular cartilage with its normal function, lubrication, wear, and load-bearing features.[8]

When an external load is placed on the cartilage surface, immediate deformation is produced primarily by a change in the proteoglycan molecular domain. This external load can also make the interstitial fluid pressure in the porous solid matrix exceed the osmotic swelling pressure; therefore, the interstitial fluid begins to flow and exudation occurs. After exudation occurs and the load is removed, GAGs function hydrophilically, pulling the fluid back into the cartilage, similar to the action of a sponge soaking up water, in preparation for the next load. With a decrease in the interstitial fluid, the proteoglycan concentration within the solid matrix increases, which in turn increases the osmotic swelling pressure, charge-charge repulsive force, and bulk compressive stress until they are balanced with the applied external load. In this manner, the physicochemical characteristics of the proteoglycan gel trapped within the collagen meshwork enable cartilage to resist compression. This mechanism supplements the role played by collagen fibers, which are strong in tension but can easily fold under compression.[8]

Articular cartilage demonstrates a viscoelastic response when placed under loads and deformation.[7–10] It creeps under a constant applied load and stress relaxes under a constant applied deformation.[7–10] This viscoelastic response of articular cartilage relies on 2 essentially different physical mechanisms: (1) the intrinsic viscoelastic properties of the macromolecules that form the organic solid matrix[9] and (2) the frictional drag from the flow of the interstitial fluid through the permeable solid matrix.[7–9] Each mechanism promotes the overall viscoelastic response of cartilage under tension, compression, and shear.[8] Additionally, the rate at which a load is applied to articular cartilage affects its viscoelastic response. Under a slow, sustained force, articular cartilage is able to respond accordingly and accommodate this load. However, under a concentrated force, articular cartilage is unable to react to the load, and therefore, the tissue is vulnerable to injury.

Alterations associated with injuries, osteoarthritis, and other degenerative processes vary normal structure-function relationships that exist within the articular cartilage. Particular compositional, molecular, and structural changes detected in degenerated tissues include decreased proteoglycan and increased water content,[11] collagen fibril network disorganization, and proteoglycan separation. These changes may alter the intrinsic mechanical properties of articular cartilage and produce swelling.[8] The organizational structure of collagen and proteoglycans in conjunction with water normally determines the mechanical properties of articular cartilage. This structural relationship among collagen, proteoglycans, and water does not exist for healing articular cartilage or osteoarthritic cartilage.[12]

ARTICULAR CARTILAGE DAMAGE AND REPAIR

Acute injuries to articular cartilage can be categorized into 2 broad groups: (1) the loss of matrix macromolecules without mechanical damage to the chondrocytes or the collagen fibril meshwork (ie, prolonged joint immobilization) and (2) mechanical disruption of the chondrocytes and the extracellular matrix (ie, impact-load injury). Progressive loss of matrix macromolecules leads to mechanical disruption of the articular cartilage surface, and mechanical disruption may result in factors that stimulate matrix degeneration. Thus, the 2 groups may overlap.[12]

Cartilage exposure to an injurious agent can stimulate degeneration of proteoglycans or suppress proteoglycan synthesis. These insults may also have effects on the matrix and the chondrocytes, but the loss of matrix proteoglycans is the most obvious initial change. Immediate cessation of the process responsible for the loss of matrix proteoglycans allows the chondrocytes to restore the lost matrix components, perhaps allowing the articular cartilage to regain its normal composition and function. However, if this process continues, damage sustained by the articular cartilage may become irreversible.[12]

Blunt trauma, penetrating injuries, frictional injuries, and concentrations of weight-bearing forces destroy chondrocytes and disrupt the extracellular matrix. Physiologic levels of impact loading do not seem to cause articular cartilage damage. Blunt trauma to articular cartilage occurs often, even in the absence of fractures, and may be the cause of significant long-term joint dysfunction. The severity of acute, blunt trauma can be categorized as greater than normal loading but less than that necessary to fracture bone or cartilage or sufficient to fracture bone and cartilage. The effect of a penetrating injury depends on whether the defect is confined to the substance of the articular cartilage or extends into the subchondral bone.[12]

The response of articular cartilage to an injury is determined by numerous factors: the type of injury, the extent and severity of the injury, the state of the cartilage and the joint at the time of the injury, the age of the individual, and the structure, composition, function, and durability of the repair tissue. For repaired tissue to fulfill the demands of a joint surface, it must return normal, pain-free motion to the joint for an extended period and prohibit further degeneration of the joint. An abundance of methods for promoting cartilage repair have been researched. These include cartilage shaving,[13–16] abrasion of subchondral bone,[17–20] change in the loading of the injured articular surface,[21] passive motion,[22–24] resurfacing with periosteum or perichondrium,[25–32] digestion or extraction of matrix proteoglycans, laser stimulation of chondrocytes,[33] implantation of immature chondrocytes,[34] implantation of gels,[34–36] pulsed electromagnetic fields,[37,38] and chondrogenesis-stimulating factors.[12,39,40] Conservative measures for treating articular cartilage injury include the use of NSAIDs and chondroprotective supplements, such as glucosamine sulfate.

NATURAL PRODUCTION AND ABSORPTION OF GLUCOSAMINE SULFATE

Glucosamine is a building block for articular cartilage's extracellular matrix. Specifically, it is used to produce GAGs and proteoglycans.[4,5,41–44] Glucosamine is synthesized by chondrocytes from glucose to produce GAGs,[43] and the production of GAGs stimulates proteoglycan production.[44] The lack of proteoglycans can lead to degeneration of articular cartilage.[16] Glucosamine is present in meat, fish, poultry,[45] and almost all human tissue and has a special positive attraction for cartilaginous tissue.

Glucosamine sulfate was rapidly absorbed into the bloodstream regardless of the route of administration.[46] Approximately 90% of orally administered glucosamine sulfate was absorbed through the digestive tract.[1] However, only 26% of this oral dose of glucosamine was available for processing by the body's tissues.[47] Glucosamine concentrates in the liver, where it is combined with plasma proteins, reduced into smaller molecules, or used for other biologic processes.[1,4] The highest concentrations are found in liver, kidney, and articular cartilage.[4,43,46] Glucosamine is used in GAG synthesis.[4]

ACTION OF GLUCOSAMINE SULFATE

Glucosamine sulfate is the salt of D-glucosamine with sulfuric acid. In solution, glucosamine sulfate separates into the D-glucosamine ion and the sulfate ion.[48,49] Glucosamine ions are used to synthesize GAGs, which are combined with proteins to form proteoglycans, critical components of articular cartilage ground substance. Researchers[48] believe that the glucosamine ion is the active element, but some evidence indicates that a benefit of the glucosamine sulfate is related to sulfur residues, because sulfur is an essential nutrient for the stabilization of the connective tissue matrix. Glucosamine sulfate stimulates the uptake of sulfate ions,[50] which can be used as an indicator of GAG synthesis by the chondrocytes.[50–55] Sulfate is also an important component of proteoglycans.[50–52] Glucosamine sulfate, which provides both glucosamine and sulfate ions, facilitates GAG production and synthesis of proteoglycans as a whole.[49] Glucosamine also hinders hyaluronidase, the tissue-damaging enzyme, and helps to rebuild the damaged articular cartilage. In addition, glucosamine sulfate improves the lubricant properties of synovial fluid.[46]

THE ROLE OF GLUCOSAMINE SULFATE

Glucosamine sulfate is proposed to be a safe and effective treatment of osteoarthritis.[56] Glucosamine supposedly plays a part in the repair and maintenance of joint cartilage, stimulating cartilage cells to produce GAGs and proteoglycans.[57] Investigators have compared glucosamine sulfate with placebos[41,49,50,58–62] and with common NSAIDs (ie, ibuprofen).[42,63–66] Glucosamine sulfate has been described as a slow-acting drug in osteoarthritis by the International League Against Rheumatism.[44,49,63] However, the Arthritis Foundation does not recognize glucosamine sulfate as a treatment for osteoarthritis or any other form of arthritis.[3,5] The National Collegiate Athletic Association has classified glucosamine sulfate as a nonpermissible supplement for institutions to provide to their athletes.[67]

SUPPLEMENTATION METHODS

Various methods have been used to provide glucosamine supplementation to subjects (Table). These methods included oral supplements,[42,46,50,58–61,63–66] intravenous injections,[50] intramuscular injections,[50,58] and intra-articular injections.[46,62] However, oral supplementation has been deemed the most effective because of the mode of delivery and is the most commonly used method.[51] The current recommended dosage is 1500 mg of glucosamine sulfate daily. This typical 1500-mg dosage is generally divided into 3 doses (500 mg each) per day.

A concern with oral supplementation of glucosamine sulfate is that it does not require Food and Drug Administration approval. "The Dietary Supplement Health and Education Act

Summary of Glucosamine Sulfate (GS) Clinical Trials

Source, y	Efficacy Evaluation of Subjects	Supplementation Methods and Dosage	Outcome
Crolle and D'Este,[58] 1980	30 Inpatients (8 men, 22 women) • Evaluated pain at rest and during active and passive range of motion • Evaluated restricted function • Walking time for 20 m	• Group 1 (15 subjects): 1 intramuscular (IM) injection of 400 mg of glucosamine sulfate (GS) daily for 7 days, then 14 days of 1.5 g of oral GS • Group 2 (15 subjects): IM injection of 100 mg of piperazine/100 mg of chlorbutanol for 7 days, the 14 days of oral placebo	• No significant improvement was seen in either group from IM injections • During oral treatment, the GS group continued to improve over the placebo group
D'Ambrosio et al,[50] 1981	30 Inpatients (7 men, 23 women) • Semiquantitative scoring of pain at rest, pain during active and passive range of motion, and limitation of joint function	• Group 1 (15 subjects): 1 intravenous (IV) or IM injection of 400 mg of GS daily for 7 days, followed by 14 days of 1.5 g of oral GS • Group 2 (15 subjects): IM or IV injection of 100 mg of piperazine/100 mg of chlorbutanol for 7 days, followed by 14 days of oral placebo	• Significant overall symptom score decreased during injectable GS ($P < .05$) • Further significant decrease with GS oral therapy ($P < .01$) • Initial gains of group 2 lost during oral placebo treatment
Drovanti et al,[59] 1980	80 Inpatients • Evaluated joint pain, tenderness, swelling, active and passive range of motion • 2 patients had cartilage removed with subsequent electron microscopy	• Group 1: oral GS, 1.5 g, for 30 days • Group 2: oral lactose placebo	• Symptom intensity decreased significantly in both groups ($P < .05$) • GS group's symptoms decreased sooner • On scanning electron microscopy, the articular cartilage appeared normal after treatment
Leffler et al,[60] 1999	34 Male subjects • Subjective questionnaire (Lequesne Index or Roland) • Physician assessment of severity • Time to run 100 yd (91.44 m) and down 80 stairs • Pavelka physical examination	• Group 1: 1 capsule daily containing 1500 mg of GS, 1200 mg of chondroitin sulfate, and 228 mg of manganese ascorbate, followed by 8 weeks of placebo • Group 2: 1 placebo capsule daily, followed by 8 weeks of 1 daily capsule containing 1500 mg of GS, 1200 mg of chondroitin sulfate, and 228 mg of manganese ascorbate	• Significant improvement in the patient assessment of treatment and in the visual analog scale while on GS ($P = .02$) • No signs of significant improvement in other assessment areas
Noack et al,[49] 1994	252 Outpatients (100 men, 152 women) • Evaluated function by the Lequesne Index	• Group 1: 1.5 g of sugar-coated oral GS for 4 weeks • Group 2: 1.5 g of an oral placebo for 4 weeks	• Lequesne Index demonstrated a significant ($P < .05$) improvement in the GS group
Pujalte et al,[61] 1980	24 Outpatients • Physician assessment of articular pain, joint tenderness, swelling, and movement restriction • Subjective assessment	• Group 1: 1.5 g of oral GS daily for 6–8 weeks • Group 2: 1.5 g of oral lactose placebo capsules for 6–8 weeks	• GS group significantly improved in composite scores ($P < .01$) • GS group experienced earlier alleviation of symptoms ($P < .01$)
Reichelt et al,[41] 1994	155 Outpatients • Assessed using the Lequesne Index	• Group 1: 400 mg of GS IM 2 times per week for 6 weeks • Group 2: placebo IM 2 times per week for 6 weeks	• Significant improvement of pain and movement limitation in GS group throughout the 6 weeks ($P = .012$) • Improvement maintained through the 2-week follow-up
Tapadinhas et al,[65] 1982	1208 Patients (516 men, 692 women) • Physician objective and subjective assessment	All subjects received 1.5 g of oral GS for 6–8 weeks	• Objective assessment of therapeutic efficacy: 58.7% good, 36.0% sufficient, 5.3% insufficient • Concomitant illness affected GS effectiveness • Significant reduction in overall intensity of articular symptoms during treatment ($P < .001$)

Continued

Source, y	Efficacy Evaluation of Subjects	Supplementation Methods and Dosage	Outcome
Vajaradul,[62] 1981	54 Outpatients • Evaluated pain, active and passive range of motion, swelling	• Group 1: weekly intra-articular injection of solution of glucosamine salts for 5 weeks • Group 2: weekly intra-articular injection of 0.9% sodium chloride for 5 weeks	• Significantly decreased pain in GS group ($P < .001$) • Significantly improved flexion angle in GS group ($P < .02$) • Significantly improved active joint mobility in both groups ($P < .001$)
Vaz,[64] 1982	40 Outpatients • Evaluated articular pain and swelling	• Group 1: 1.5 g of oral GS daily for 8 weeks • Group 2: 1.2 g of oral ibuprofen daily for 8 weeks	• Significant decrease in pain scores in both groups ($P < .001$) • Significantly less pain in ibuprofen group at 1 week ($P < .001$) • Significantly less pain in GS group at 8 weeks ($P < .05$)

of 1994 provides for the use of various types of statements on the label of dietary supplements, although claims may not be made about the use of a dietary supplement to diagnose, prevent, mitigate, treat, or cure a specific disease (unless approved under the new drug provisions of the Federal Food, Drug, and Cosmetic Act)."[68] For any "dietary supplement," the consumer should investigate the quality of the product before supplementation.[5,56]

TOLERANCE

All studies reported low incidence of adverse effects with glucosamine supplementation. The few adverse effects that were reported, all mild to moderate in intensity, included abdominal pain,[42,65] epigastric pain or tenderness,[49,64] heartburn,[64] vomiting,[41] diarrhea,[49] nausea,[41,49,64] drowsiness,[42] headache,[49] and itching.[41,49] Increased insulin resistance has been reported after intravenous glucosamine doses in laboratory animals[69] and after a 12-week course of oral glucosamine supplementation in humans.[70] Insulin resistance decreases the ability of insulin receptors to transmit glucose into tissue's cells. Certainly, further investigation into this phenomenon is necessary; patients with diabetes may need to be followed closely during glucosamine treatment.

CLINICAL OUTCOMES

Bassleer et al[44] showed a stimulatory effect of glucosamine sulfate on the biosynthetic activity of human chondrocytes. Their findings agree with other reports that glucosamine exerts a protective action in animal models of experimental osteoarthritis.[71] Glucosamine counteracts the damage induced on chondrocytes by dexamethasone[49,72] and some NSAIDs,[49,55,73] and its effect in patients with osteoarthritis compares favorably with that of NSAIDs.[44,49,54,55,64,74,75] Glucosamine sulfate also displays a definite, although mild, anti-inflammatory activity in in vivo models of inflammation and arthritis.[49,63] Glucosamine did not show any inhibiting activities of prostaglandin biosynthesis; therefore, the mild anti-inflammatory activities described are most likely achieved through this prostaglandin-independent mechanism.[49,63] This may also explain its low toxicity and better therapeutic index when compared with NSAIDs.[49,63]

In one study,[64] NSAIDs reduced pain within 2 weeks; however, this action tended to fade away as treatment continued. Researchers concluded that treatment with glucosamine sulfate was slower to become effective, but it was consistent and progressive throughout the trial period and overall produced significantly better results than the NSAID. Additionally, the effects from treatment with glucosamine sulfate lasted longer, even after treatment was discontinued.[49]

Authors of recent reviews[4,76] noted that the studies conducted thus far have indicated improved pain and mobility. However, Barclay et al[4] reported that most of the studies have shown significant flaws in design or data analysis. Although glucosamine sulfate does not appear to have negative short-term side effects, long-term effects are unknown.[4,5] Rovati[51] explained that long-term studies are difficult to perform, whereas the short-term studies often have several methodologic problems. The most common problems associated with clinical trials of disease-modifying drugs in osteoarthritis can be summarized into the following categories: (1) number of patients, (2) experimental design, (3) diagnosis, (4) disease status, and (5) evaluation criteria and end points.[51]

One unique report has been published by Drovanti et al.[59] Like many other studies, these researchers administered 1500 mg of glucosamine sulfate or an identical placebo daily. Articular pain, joint tenderness and swelling, and restriction of active or passive motion, as well as other diagnostic tests, were assessed, with promising results. However, these authors, unlike any others, also used electron microscopy scanning to evaluate the integrity of the articular cartilage surface of 5 subjects. They examined 1 healthy subject with no articular cartilage damage, 2 subjects from the placebo treatment group, and 2 subjects from the glucosamine sulfate treatment group. Glucosamine sulfate supplementation appeared to help rebuild the articular cartilage of the 2 subjects who underwent that treatment.

Studies comparing glucosamine sulfate to placebos have demonstrated significant reduction in knee pain,[49,58,60–62] improved range of motion,[41,50,58,60–62] decreased swelling,[59,61] improved function,[58,60,62] and improved patient or physician (or both) qualitative assessment.[60,61] Glucosamine sulfate and NSAIDs both significantly decreased knee pain,[42,63,64] decreased swelling,[42] and improved patients' subjective assessments,[64] but glucosamine tended to elicit greater improvements in function.[42] In investigations without a control group,[46,65,66] glucosamine sulfate significantly decreased pain and range-of-motion limitation and increased function. No published studies have shown that supplementation of glucosamine sulfate is an effective prophylactic measure against osteoarthritis.

CONCLUSION

Glucosamine assists the body in providing the components necessary to synthesize proteoglycans, which are required for articular cartilage synthesis. It appears to slow the process of articular degeneration and facilitate the recovery of normal joint mobility. In osteoarthritis, changes occur in the articular cartilage (due to mechanical insult) and in its metabolism. Glucosamine sulfate appears to have a positive effect on the metabolism of articular cartilage. However, whether sports injuries result in the same articular cartilage changes found in osteoarthritis is unclear. Mechanical insults associated with sports are common, but no clinical trials on this population are currently available. Further research needs to be completed on the use of glucosamine sulfate in patients without osteoarthritis.

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Ephedra and Its Application to Sport Performance: Another Concern for the Athletic Trainer?

Michael E. Powers

University of Florida, Gainesville, FL

Michael E. Powers, PhD, ATC, CSCS, provided conception and design; analysis and interpretation of the data; and drafting, critical revision, and final approval of the article.

Address correspondence to Michael E. Powers, PhD, ATC, CSCS, 144 FL Gym, PO Box 118205, Gainesville, FL 32611–8205. Address e-mail to mpowers@hhp.ufl.edu.

Objective: The ma huang herb, otherwise known as ephedra, has gained widespread popularity as an ergogenic supplement. With the sympathomimetic alkaloid ephedrine as its primary active ingredient, ma huang is marketed to reduce fatigue; increase strength, power, and speed; decrease reaction time; and improve body composition. Although numerous side effects have been associated with the use of ma huang, its popularity in athletes continues to grow. This review provides rationale for the ergogenic claims regarding ma huang and compares and contrasts those claims with data from scientifically controlled investigations.

Data Sources: MEDLINE and SPORT Discus were searched from 1970 to 2000 using the key words *ma huang, ephedra,* and *ephedrine* in combination with *humans, exercise, performance,* and *side effects.*

Data Synthesis: Ephedrine has been used alone or in combination with other drugs as an effective weight-loss agent. The weight loss has been attributed to thermogenic and lipolytic effects which, in combination with the central nervous system stimulating effects, have also resulted in its use as an ergogenic aid. Most of the scientific data, however, do not support manufacturers' ergogenic claims, and numerous side effects have been associated with ephedrine use. Thus, the safety and efficacy of ma huang as an ergogenic supplement must be questioned.

Conclusions/Recommendations: It appears that the risks associated with the use of ma huang far outweigh any possible ergogenic benefits. Thus, it is extremely important that athletic trainers educate athletes on these issues so they can continue to perform at an optimum level in a safe and healthy manner.

Key Words: ma huang, ephedrine, ergogenic aid, performance enhancement

If you followed the 2000 Olympics in any way, you probably noticed a recurring headline. Regardless of the broken records and upset victories, the 2000 Olympics will always be known for the disqualifications and scandals surrounding the use of banned substances. One question that arose during the Games concerned the influence of nutritional supplement use on drug test results. The use of nutritional supplements for ergogenic benefit has gained increasing popularity over recent years and, in a report submitted after the Games, the World Anti-Doping Agency (WADA) concluded that there is widespread use, and possible abuse, of nutritional supplements in modern sport. Because they are considered natural and are available without a prescription, the misconception is that these supplements are all healthy and safe. Some of the more popular products are those marketed to either enhance energy or improve body composition. Many of these supplements contain the ma huang herb, otherwise known as ephedra (Table).

MA HUANG

Ephedrine

The plant species *Ephedra sinica, Ephedra equisetina,* and *Ephedra intermedia,* collectively known by their Chinese name ma huang, are indigenous to Pakistan, China, and northwestern India.[1] For centuries, the dried stems of these plants have been used as a remedy for numerous medical conditions. In 1923, scientists discovered that the ma huang plant has 2 primary active ingredients: ephedrine (2-methylamino-1-phenyl-1-propanol) and pseudoephedrine, the same drugs commonly used in many nasal decongestant medications.[1,2]

Ephedrine and pseudoephedrine are classified as sympathomimetic alkaloids because they directly stimulate the sympathetic, or "fight or flight," nervous system. These alkaloids are structurally similar to amphetamines and have direct alpha- and beta-agonistic properties and catecholamine-releasing actions.[2,3] The alpha- and beta-sympathetic receptors are cell membrane receptors sensitive to epinephrine (adrenaline) and norepinephrine (noradrenaline) and are found on most cells throughout the body, including the cells of the heart, lungs, and surrounding blood vessels. Ephedrine alkaloids also function as indirect adrenoreceptor agonists.[2] Thus, they augment the availability and action of the natural neurotransmitter norepinephrine in the brain and in the heart.[4] Unlike pseudoephedrine, ephedrine also mediates its effects via circulating epinephrine[4,5] and is a bronchial dilator that has been used in the treatment of asthma.

Nutritional Supplements Containing Ma Huang

Supplement	Manufacturer	Ma Huang Content† (mg)	Caffeine Content (mg)
Xenadrine*	Cytodyne Technologies	20	200
BetaLean	EAS, Inc	20	150
Diet Stack	Metaform	16	66
Metacuts	Metaform	16.5	150
Metadrene	Metaform	18	100
Hydroxycut	Muscletech Research & Develop.	20	200
Diet Fuel	Twin Laboratories, Inc	20	200
Metabolift Diet	Twin Laboratories, Inc	20	200
Ripped Fuel	Twin Laboratories, Inc	20	200

*Also contains 105 mg white willow bark extract (equivalent to 15 mg salicin) and 5 mg synephrine.
†Ephedrine alkaloid equivalent.

Pharmacokinetics

Ephedrine, pseudoephedrine, methylephedrine, norpseudoephedrine, and norephedrine have all been extracted from the ma huang plant. However, ephedrine and pseudoephedrine are the only 2 active components found consistently in ma huang products, with ephedrine being the predominant alkaloid.[1,6] The other alkaloids are usually found only in small or trace amounts. For example, capsules containing 375 mg of ma huang have been found to contain an average of 4.84 mg (range, 3.8 to 5.9 mg), 1.22 mg (range, 0.77 to 1.82 mg), and 0.31 mg (range, 0.19 to 0.46 mg) of ephedrine, pseudoephedrine, and methylephedrine, respectively.[1] The levels of ephedrine alkaloids can also vary depending on the product and the ephedra species used.[6,7] In an investigation of 9 commercially available supplements, Gurley et al[6] observed considerable variability in both the ephedrine (range, 1.08 to 13.54 mg) and pseudoephedrine (range, 0.52 to 9.46 mg) contents. Two of the products contained measurable quantities of ephedrine only, which led the authors to speculate whether the product actually contained ma huang (as claimed on the label) or was instead spiked with synthetic ephedrine. Unfortunately, ma huang product labels usually indicate how much of the ephedra herb is present, but few identify the ephedrine alkaloid content.

Synthetic ephedrine is easily absorbed after oral administration, with peak plasma levels occurring within an hour of ingestion.[8] Its plasma half-life is approximately 3 to 6 hours, which varies depending on urine pH.[2,9] After absorption, ephedrine is excreted, primarily unchanged, in the urine: less than 10% is excreted as norephedrine. When ephedrine is ingested in the form of ma huang, the elimination kinetics are similar to those for synthetic ephedrine.[1,7] Reports conflict, however, regarding absorption kinetics. Gurley et al[7] investigated 3 brands of ma huang and observed absorption kinetics similar to those following ingestion of a 25-mg synthetic ephedrine capsule. In contrast, White et al[1] observed that it took longer for the ephedrine to reach peak levels in the plasma (approximately 4 hours) when ingested in the form of ma huang.

Ergogenic Claims

Because ephedrine is a sympathomimetic and a central nervous system stimulant, it is commonly used as an energy enhancer. Ma huang-containing products are marketed and used to improve aerobic performance and endurance, reduce fatigue, increase alertness, improve reaction time, and even increase strength. These products are also marketed to body builders (and those simply concerned with cosmetic appearance) with the claim that they can improve body composition via thermogenic and lipolytic effects. The lipolytic effects have also led to the claim that ma huang can improve endurance via increased fat utilization and glycogen sparing during exercise. Because of this, it is very common to find ma huang products that also contain other thermogenic and lipolytic supplements, such as caffeine (usually found in the form of guarana).

Ephedrine and Caffeine

It has been suggested that the thermogenic effects of combining ephedrine and caffeine are synergistic (the effect of the 2 drugs combined is greater than their additive effects).[10–12] Similar to ephedrine, caffeine has been suggested to have stimulating effects on the central nervous system (CNS) and energy metabolism.[13] However, the primary reason for combining the 2 drugs is to potentiate the effects of the ephedrine.[5] Ephedrine exerts its thermogenic effects via catecholamine release. The increased catecholamine release after ephedrine ingestion is subjected to negative feedback systems, which then tend to inhibit catecholamine release and actions. These negative feedback systems include adenosine and prostaglandin release in the synaptic junction and elevated phosphodiesterase enzyme activity, which results in degradation of cyclic adenosine monophosphate (cAMP). Caffeine interferes with this negative feedback mechanism by inhibiting both adenosine and phosphodiesterase activity and preventing degradation of cAMP.[5] Aspirin has a similar effect via its inhibition of prostaglandin synthesis. Thus, it is conceivable that either of these mechanisms could potentiate the thermogenic effects of ephedrine. Because of this, some of the more popular weight-loss supplements on the market today combine ma huang (ephedrine), guarana (caffeine), and white willow bark extract (aspirin).

Effects on Performance

Many of the ergogenic claims associated with ephedrine originated from earlier studies investigating its anti-obesity and anoretic effects. Ephedrine and the combination of ephedrine and caffeine have been considered effective weight-loss agents,[11,14–16] although not all studies support this claim.[17–19] Originally, the observed weight loss was attributed solely to the appetite-suppressing effects of ephedrine[20]; however, other mechanisms have more recently been suggested.[14,17,19] In 3 weight-loss studies,[11,15,16] body weight (as opposed to body composition) was the only variable assessed. Thus, it is unknown whether the weight loss was due to a reduction in fat mass or a loss of lean tissue and water mass. However, each of the authors suggested that increased energy expenditure (and primarily fat metabolism) accounted for most of the weight loss.

Thermogenesis and Lipolysis

The measurement of oxygen consumption ($\dot{V}O_2$) is the primary index and documented evidence of a person's aerobic metabolism and energy expenditure. Thus, thermogenic claims associated with ephedrine have been supported, as increases in resting $\dot{V}O_2$ have been observed after both acute and chronic ephedrine ingestion.[14] Similarly, ephedrine and combined ephedrine and caffeine have been observed to partially prevent the usual fall in resting metabolic rate during a calorie-restricted diet.[17–19] However, the higher metabolic rates observed in these studies were not always associated with weight loss.[17,19] There is also support for lipolytic claims, as significant increases in both fat oxidation and fat loss have been observed when ephedrine is administered in combination with caffeine.[17] In contrast, however, ephedrine ingestion alone failed to produce such changes.[14] Only clinically obese individuals were used as subjects in these investigations; thus, it is likely that the subjects may have had deficient metabolic rates or fat metabolism or both. Unfortunately, it is common practice for supplement manufacturers to take results from deficiency studies and generalize them to young, healthy, athletic individuals when advertising their products. Those of us in the research community know that this cannot and should not be done.

Exercise Performance

While the research concerning ephedrine and performance in an athletic population is limited, most investigations do not support ergogenic claims.[21–25] As mentioned previously, $\dot{V}O_2$ is a primary measure of aerobic performance and, although ephedrine ingestion has been observed to increase resting $\dot{V}O_2$ and fat oxidation in healthy individuals,[26,27] these changes have not been observed during exercise.[12,22,24,28] Similar observations have been made after pseudoephedrine ingestion, as no differences in $\dot{V}O_2$ occurred in comparison with placebo conditions during exercise.[25,29] As with $\dot{V}O_2$ and fat oxidation, a number of other performance measures have been unaffected by supplementation.[23–25] Sidney and Lefcoe[24] administered 24 mg of ephedrine and found no improvements in muscle strength, endurance, or power; lung function; reaction time; hand-eye coordination; anaerobic capacity or speed; cardiorespiratory endurance; ratings of perceived exertion; or recovery. Similarly, Gillies et al[23] reported that a single 120-mg dose of pseudoephedrine had no effect on 40-km cycling time, maximal muscle force, or muscle endurance during repeated isometric contractions. More recently, Swain et al[25] administered pseudoephedrine (1 and 2 mg/kg) to trained cyclists and found no changes in ratings of perceived exertion or time to exhaustion.

One group of researchers, however, has observed performance changes when combining ephedrine with caffeine. Bell et al[12] observed that the combination significantly increased cycling time to exhaustion by 38% over a placebo condition, while ephedrine and caffeine given separately failed to provide such an effect. In another study, the combination of ephedrine and caffeine improved cycling time to exhaustion by 64% over a placebo condition.[28] In both studies, ratings of perceived exertion were significantly lower after supplementation, but heart rate was significantly elevated as well. The authors attributed the improvement to CNS stimulation, as no changes were observed for $\dot{V}O_2$, carbon dioxide production, or fat oxidation. It is important to note that one would have to double the serving size of typical sport supplements containing both ephedrine and caffeine (Table) to achieve the doses used in these 2 studies. More recently, Bell and Jacobs[30] administered 75 mg of ephedrine with 375 mg of caffeine and observed a slight (5%) but significant improvement in running time during a Canadian Forces Warrior Test (3.2 km run while wearing field gear). Unfortunately, the literature supporting the ergogenic claims associated with ephedrine in a healthy population appears to be limited to just one group of researchers. Negative side effects were commonly observed during these investigations and others involving both healthy and obese individuals.[7,11,12,14–18,21,25,26,28]

Side Effects

The spectrum of adverse health events associated with the use of ephedrine-containing products cannot be overlooked. The Food and Drug Administration (FDA) has received more than 1000 reports of adverse effects (including deaths) in persons ingesting nutritional supplements containing ephedrine and associated alkaloids.[31] These side effects vary and do not always depend on the dose consumed.[32] Although the occurrence of side effects was likely the result of misuse in many cases, such side effects have been regularly observed in subjects involved in clinical trials in which the dosages were controlled.[7,11,12,14–18,21,25,26,28]

Some of the minor side effects associated with ephedrine include tremors, palpitations, headache, restlessness, anxiety, and insomnia.[9,17,25,32] Because of its direct sympathomimetic effects, ephedrine can increase heart rate, contractility, cardiac output, and peripheral resistance. Thus, increases in both heart rate and blood pressure are common observations after ephedrine ingestion.[10,12,21,23–25,32] This is also true after ma huang ingestion, as significant increases in heart rate and blood pressure have been observed.[1,7] Although these effects are not serious in most users, the consequences can be severe in those with underlying heart disease, hypertension, or diabetes and those sensitive to ephedrine.[6] The more serious side effects include seizures, severe hypertension, arrhythmias, psychosis, hepatitis, stroke, myocardial injury, and intracranial hemorrhage.[3,32–38] The adverse effects do not always depend on the dose consumed, as serious problems can occur in susceptible persons with use of low dosages.[9,32] Furthermore, the toxicity of sympathomimetic agents is exacerbated by physical exercise, dehydration, and increases in body temperature,[22] which are all commonly experienced during athletic training.

Although few in number, cases of fatal intoxication after ephedrine ingestion have been reported.[8,32] In instances of ephedrine overdose, cardiovascular and CNS stimulant effects predominate. The most common causes of death are myocardial infarction and cerebrovascular accident.[32] The recent death of a young, apparently healthy male college student brought attention to the possible dangers associated with ma huang–containing products. The individual regularly consumed a product containing ephedrine and caffeine known as Ripped Fuel (Twin Laboratories Inc, Ronkonkoma, NY).[4] The official autopsy report and death certificate read "patchy myocardial necrosis associated with ephedrine toxicity from protein drink containing ma huang extract." The blood and urine ephedrine levels suggested that the death was not caused by an acute poisoning but was the result of prolonged use.

CONCLUSIONS

Over-the-counter availability and unrestrained self-medication with products containing ma huang create a heightened potential for serious side effects. Unfortunately, most companies that manufacture and sell nutritional supplements are prof-it driven and often use misleading advertising. One of the primary concerns is that manufacturers are not required to list the ingredients on the labels of natural supplements; thus, the consumer does not always know the true contents of the product. One product labeled "no side effects" was found to contain 45 mg of ephedrine and 20 mg of caffeine in a single tablet, despite the fact that it listed Chinese ginseng as the only ingredient.[32] The label also instructed users to take 5 tablets, which represents a total ephedrine dosage of approximately 11 times the usual recommended over-the-counter dosage.

Recent changes by the FDA regarding the definition of a nutritional supplement have allowed a wide variety of products to be considered as such, and, although the term *natural* implies it, they are not always healthy and safe. Because of widespread reports of adverse events associated with ma huang use, the FDA has proposed to limit the allowed dose of ephedrine to 8 mg per serving or 24 mg per day.[31] Furthermore, manufacturers would be required to state on the label that the product is not to be used for more than 7 days. At this time, however, these changes are still being assessed and no definitive decisions have been made. Both the International Olympic Committee and the National Collegiate Athletics Association have banned ephedrine and ephedrine alkaloids.

Whenever an athlete is considering using ma huang or any ergogenic supplement, two questions must be asked: is it safe and does it work? Ephedrine appears to be an effective CNS stimulant with thermogenic and lipolytic effects. However, its ergogenic advantages are highly debatable and the dangers associated with its immediate and prolonged use are well documented. Thus, it appears that the risks far outweigh the benefits. The key to performance is a healthy diet and a well-developed training program: there is no "quick fix" or "shortcut to success." As allied health professionals, athletic trainers must be able to educate athletes on these issues so they continue to perform at optimal levels in a safe and healthy manner.

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Herbal Supplements: Considerations for the Athletic Trainer

Andrew P. Winterstein; Cordial M. Storrs

University of Wisconsin-Madison, Madison, WI

Andrew P. Winterstein, PhD, ATC, and Cordial M. Storrs, MS, ATC, contributed to conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article.

Address correspondence to Andrew P. Winterstein, PhD, ATC, 1037 Unit II Gym/Nat, 2000 Observatory Drive, Madison, WI 53706. Address e-mail to winterstein@education.wisc.edu.

Objective: To examine common herbal supplements, explore potential risks associated with herbal use, and provide recommendations to the athletic trainer regarding patient care issues.

Data Sources: We searched MEDLINE, SPORT Discus, CINAHL, and Academic Search Elite databases 1990–2000 using the key words *herbals, regulation, supplements, toxicity,* and *adulteration.*

Data Synthesis: The use of herbal products continues to grow. While the origins of some medications and herbal supplements are similar, clinical testing and understanding of most herbal remedies is lacking. Some herbal products may prove useful in an athletic setting; however, current United States Food and Drug Administration (FDA) regulations do not ensure safe and effective products. A descriptive review focusing on specific considerations for the athletic trainer is provided.

Conclusions/Recommendations: Despite their increasing tendency to seek natural therapies, athletes need to be aware that "natural" does not equal "safe." Athletes are entitled to know that most herbs are not proven safe or effective under current FDA standards. The athletic trainer must be able to provide honest, unbiased information when educating athletes regarding herbal supplements.

Key Words: herbals, botanicals, toxicity, adulteration, regulation

Recent increases in the availability and popularity of herbal supplements and complementary health care products have created an environment of hyperbole and misinformation for patients and health care providers alike. Athletic trainers and other health care professionals must be able to distinguish fact from fiction and direct their patients to appropriate sources when trying to determine the efficacy and potential dangers of these products. Reports indicate that Americans spend in excess of $12 billion annually on vitamins, minerals, herbals, sports supplements, and specialty supplements.[1]

The prevalence of herbal use is largely unstudied.[2–4] It is estimated that 33% of patients have used at least 1 unconventional treatment in the past year.[3] Eisenberg et al[3] defined unconventional treatments as medical interventions not taught widely at United States (US) medical schools or generally available at US hospitals; examples include acupuncture, chiropractic, and massage therapy. In another study, Eliason et al[5] found that 52% of patients have taken 1 or more dietary supplements during the past year and that the media is their primary source of information about the supplements. Compounding this increase in availability and use are government regulations that limit the Food and Drug Administration's (FDA) ability to regulate any product labeled as a supplement. The 1994 Dietary Supplement and Health Education Act (DSHEA) allows companies to promote supplements with claims of improved "function and health" as long as they make no claims to affect disease.[6]

Athletes demonstrate a greater willingness to use supplement products when compared with their nonathlete counterparts.[7] The athletic trainer is often called upon to serve as an educational resource for athletes wishing to learn more about herbal supplements. Herbal products are vigorously marketed to both competitive and recreational athletes with claims of performance gains and improved health and wellness. This review examines the regulation of herbal supplements, explores potential risks associated with herbal use, and provides recommendations to the athletic trainer regarding patient care issues.

REGULATION

Food and Drug Administration

The regulation of herbal products has proven to be a confusing blend of public safety issues, varied international guidelines, advertising hyperbole, and partisan politics. In the US, the regulation of drugs, food, and cosmetics is the job of the FDA, which helps assure the public that drugs are safe and effective and have been subject to scientific scrutiny. In 1962, the FDA required that all drugs be evaluated for safety and efficacy.[8] To avoid the burden of proof associated with FDA approval, herbal manufacturers began to label herbs as "foods" and sell them in health food stores. The FDA maintains a list of products "Generally Recognized as Safe" (GRAS). Appoximately 250 herbs appear on this list, but these are herbs used for food flavoring and not for medicinal purposes. Currently, only a handful of herbs have been shown safe and effective based on a 1990 FDA review of over-the-counter drugs (Table 1).[9]

It is estimated that more than 1400 herbs are commonly sold and promoted for medicinal uses worldwide.[1,2,4] Historically,

Table 1. Common Herbs With FDA Approval[2]

Herbs*	Approved Use	Recommended Dosage[10]	Adverse Effects/Warnings/Comments
Aloe *Aloe barbadensis* (fresh gel, dried juice)	Laxative	20–30 mg/d Anhydrous aloin	Loss of electrolytes with chronic use; contraindicated if gastrointestinal obstruction is present; do not use if pregnant or lactating.
Capsicum or cayenne pepper *Capsicum* spp. (fruits)	Topical analgesic/counter irritant	50 mg Capsaicin in 100 mg neutral base; use beyond 2 days is not recommended	Avoid touching eyes or mucous membranes after applying product.
Cascara *Rhamnus purshiana* (dried bark)	Laxative	20–30 mg Tablet cascaroside/d	Loss of electrolytes with chronic use; contraindicated if gastrointestinal obstruction is present; do not use if pregnant or lactating.
Psyllium *Plantago psyllium, P. ovata, P.* spp (seed)	Laxative	Varies; 12–40 g/d; 1–3 teaspoons; 5–15 g soaked in water, taken with ample liquid (1–2 glasses of water)	Contraindicated if gastrointestinal obstruction is present; allergic reactions (rare).
Senna *Cassia* spp. (leaflets)	Laxative	Often taken as an infusion or tea; 0.5–2 g steeped in hot water for 10 minutes	Diarrhea, nausea; avoid chronic use.
Slippery elm *Ulmus fulva* (inner bark)	Oral demulcent/agent that forms a soothing, protective film on a mucous membrane surface	No specified dosage	No adverse warnings; available in throat lozenges and teas.
Witch hazel *Hamamelis virginiana* (leaves, bark)	Astringent	External – diluted 1:3 with water or 1:3 as steam distillate; ointment/gel: 5 g witch hazel in 100 g ointment base	Stomach irritation, liver damage if taken internally (rare).

*Common name, *scientific name*, (parts of plant used).

US manufacturers have had little incentive to seek FDA approval due to the costs associated with drug research. In turn, herbs reviewed by the FDA have only been examined within a very narrow definition of medicinal actions.[9] This left the public largely unaware of which products were safe, effective, or both safe and effective.

In 1993, the FDA distributed an advance notice of proposed rule making that addressed the herbal and supplement industry. The report discussed instances of herb-related deaths and concerns about toxicities. The consensus in Washington was that stricter regulation was on the way.[11] What resulted was an unanticipated public and political backlash from consumers who thought that their access to herbals and supplements would be taken away. At the urging of the supplement industry, Congress was deluged with millions of letters and faxes. The result was DSHEA,[6] a political compromise that has limited the FDA's influence on herbal products.

This legislation allows herbal products to be sold without any testing for efficacy. Companies cannot make claims on an herb's ability to cure a disease, but they may make claims about how a supplement affects the "structure" and "function" of the body. This nebulous language has not helped to clear the confusion surrounding the herbal industry. For example, an herb could not be claimed to cure inflammation but could be claimed to promote healthy joints (structure and function). Manufacturers can make structure and function claims as long as they provide a disclaimer stating that their products have not been reviewed by the FDA and are not intended to be used as drugs.[6] Under the current legislation, supplement makers do not have to prove a product is safe; the FDA has the burden of proving a product is unsafe. The FDA can only take action if a product is found to present a significant or unreasonable risk of illness or injury. Further confounding the herbal landscape are studies that show consumers tend to believe that products sold in a pill form have been reviewed for safety by the FDA, despite required label disclaimers.[11,12]

International Considerations

Given the limited number of herbs with FDA approval, considerable information on the use and dosage of herbals comes from European guidelines.[4] These guidelines vary considerably from one country to the next and often rely on the historical use of a product. Substances are often accepted under the doctrine of reasonable certainty because they have a long history of use. This philosophy is similar to the World Health Organization's Guidelines for the Assessment of Herbal Medicines, which state that a substance's historical use is a valid way to document safety and efficacy in the absence of scientific evidence to the contrary.[13] A long history of use may allow for safety information to be gathered; however, it may do little to assess efficacy.

The most often cited European guidelines are those of the German Commission E. Beginning in 1978, the German Commission E has reviewed clinical literature (including clinical trials and case studies) on more than 1400 herbal drugs.[2,4] The commission has produced more than 300 monographs on common herbal remedies. However, these monographs must be used with caution given their reliance on historical bibliographic information that may or may not include data gathered from clinical trials.

Athletic trainers must also be aware of the availability of Chinese herbal preparations and Ayurvedic herbal products. Ayurvedic herbs are used in the Ayurveda medical system that is common in India. Currently, about 300 herbs are used in general practice in traditional Chinese medicine. Often these herbs are sold in preparations that contain multiple herbs. For example, Chinese black balls contain up to 20 different herbs and are used to treat everything from arthritis to asthma.[14] Both Chinese and Ayurvedic products are largely unregulated, and some do not list ingredients in English. The concerns for athletes range from positive drug testing to the risk of toxicity due to unknown ingredients.

RISK FACTORS

Concentration and Purity

The risks associated with the use of herbal remedies and supplements can range from minor skin irritations to death. Determining the safety and efficacy of herbal products continues to be difficult because the FDA, herbal supplement manufacturers, and herbal experts disagree on how to interpret the varying evidence available for many types of herbal remedies.[15] Owing to the limited regulation of herbs, patients are often unable to tell how much of the herb or which part of the herb is contained within a given product.[1] Both the scientific literature and the media have reported concerns with herbal products. In 1995, *Consumer Reports*[1] tested 10 brands of ginseng and found substantial variations in concentration among brands. In March 1998, the Good Housekeeping Institute tested 9 brands of St. John's wort and found a significant variation in the amount of active ingredient. The *Los Angeles Times* also tested St. John's wort in 1998 and found that 7 of the 10 brands tested were low in the amount of purported active ingredient.[1] An herb's ability to create a physiologic response depends upon the availability of a specific chemical constituent. The variability of these active ingredients is of concern because the most profound risks of herbal product use are toxicity and adverse reactions, herb-drug interactions, and adulteration of herbal products.

Toxicities and Adverse Reactions

Numerous cases of toxicity have been linked to the use of herbal products.[16–47] The resulting problems range from minor adverse reactions to serious physical disabilities and death. Adverse reactions have been reported in athletic training settings. Myers et al[47] reported syncope and atypical chest pain in an intercollegiate wrestler after ingestion of an over-the-counter metabolic stimulant containing Chinese herbal extracts. This particular stimulant (Ripped Fuel, Twinlab Inc, Ronkonkoma, NY) contained ma huang (ephedrine) and caffeine. The stimulant effects were compounded by the athlete's aggressive weight-loss techniques. Winterstein (unpublished data, 2000) described a 19-year-old female soccer player with an episode of syncope and tachycardia after ingestion of an over-the-counter stimulant containing ma huang, guarana, and caffeine. This athlete had also been severely restricting calories to lose weight. These cases illustrate a common problem: athletes taking products that are marketed as "metabolism boosters" that contain "natural" herbal ingredients.

The herb ma huang and all ephedrine alkaloids have received considerable attention from the FDA. More than 15 deaths have been attributed to the use of ephedrine alkaloid products.[47] In 1996, the FDA issued a warning to consumers to avoid nutritional supplements containing ephedrine.[48] In 1997, the FDA proposed the use of warning labels addressing the adverse effects of ephedrine, banning products containing more than 8 mg per serving, and eliminating products containing combinations of ephedrine and caffeine.[49] The FDA received 14 775 public comments in response to the 1997 ephedrine alkaloids proposal. The Center for Food Safety and Applied Nutrition and the FDA's Center for Drug Evaluation and Research have examined hundreds of reports from consumers who have experienced adverse effects from supplements containing ephedrine. Despite the volume of adverse reactions, the FDA has yet to impose the 1997 proposed rule changes and continues to meet resistance and political pressure from herbal manufacturers.[50]

In addition to recent concerns over products containing ma huang and ephedrine alkaloids, the FDA has recently made public additional concerns over botanical products containing aristolochic acid. Aristolochic acid is a known carcinogen and nephrotoxin; side effects include interstitial renal fibrosis and renal failure. A recent FDA report[51] identified 76 botanicals known or suspected of containing aristolochic acid and 92 botanicals believed adulterated with aristolochic acid. Products containing a large amount of this substance may produce rapid-onset toxicity. However, the effects of long-term use are unknown. The first indication of adverse effects may be irreversible, such as renal failure.[51]

The toxicity and adverse effects of some common herbs that athletes may come in contact with or may already be using are outlined in Table 2. These are categorized as stimulants or energy boosters, weight-control agents, pain-control (ie, analgesics) and wound-healing agents, anti-inflammatories, antidepressants, and sleep aids.

Some herbal drugs on the market have been found to be relatively safe and free of serious adverse effects when taken in specific dosages (Table 3).[4] These herbs have undergone clinical trials, have been reviewed by German Commission E, or have a history of safe consumption.

Despite safety claims, patients and health care providers should be aware that abuse of dosages and problems with adulteration may render an otherwise safe herbal product dangerous. Ginseng, although considered by many sources to be relatively safe, had a high incidence of adverse effects in a 2-year study by Siegel.[56] The long-term use of ginseng has been associated with central nervous system excitation and arousal.[57] The long-term effects have been labeled ginseng abuse syndrome.[56,57]

Herb-Drug Interactions

Patients often neglect to mention herbs when asked by their health care providers about medications taken on a regular basis because they (1) assume that herbs are natural,[3] (2) are embarrassed by the reason they are taking the herb, or (3) feel their physician will not approve of their herbal use.[52,69] However, not informing health care providers about herbal use places patients at risk because of the possible interactions between drugs and herbs (Table 4). Owing to a lack of research showing which herb-drug combinations athletes are likely to consume, we have included examples from the literature of over-the-counter and prescription drugs that athletes may come in contact with or may already be using. The known effects of using prescription drugs and herbs in combination are that herbs can "mimic, magnify, or oppose the effect of the drugs."[69,70] Athletic trainers need to be sensitive, form a trusting relationship with athletes, and ask about the possible use of herbal products in a nonthreatening manner.

Product Adulteration

Despite attempts to improve manufacturing processes, reports on product adulteration, contamination, or both are com-

Table 2. Toxicity and Adverse Effects of Common Herbs

Herb Name	Common Use	Toxicity/Adverse Effects	Supplements Containing Suspect Herbs
Stimulants/energy boosters			
Asian ginseng[1,52]	Increase energy, improve mood, and improve resistance to infection	Insomnia, nervousness, irritability	
Ephedrine (ma huang)[1,52,54]	Stimulant, appetite suppressant, treatment of asthma, colds, flu, nasal congestion	Seizures, high blood pressure, cardiac arrhythmia and infarction, insomnia, psychosis, stroke, urine retention, uterine contractions	Metabolife (Metabolife International, Inc, San Diego, CA); Thermogenic Activator Plus (Rippedbody4less Corp, Marina Del Rey, CA); Ripped Fuel (Twinlab Inc, Ronkonkoma, NY).
Ginseng[55]	Stimulant	Sleeplessness, nervousness, hypertension, euphoria (GAS); hypertension together with nervousness, sleeplessness, skin eruptions, edema, morning diarrhea[56,57]	Metabolife
Khat[58]	Stimulant	Deterioration of psychosis, weight loss, abdominal pain	
Guarana[58]	Stimulant	Insomnia and agitation	Metabolife Thermogenic Activator Plus; Herbalife Products (Herbalife International Inc, Century City, CA); Diet Fuel (Twinlab)
Weight control			
Aristolochic acid[26–28]	Weight control	Interstitial renal fibrosis and renal failure	
Sauropus androgynus[25]	Weight control	Bronchiolitis obliterans	
Pain control/wound healing			
Comfrey[4]	Internal and external wound healing	Can cause carcinoma of the liver and veno-occlusive disease	
Feverfew[1,52,53,59]	Treatment of migraine headaches, anti-inflammatory	Increases heart rate, allergic reactions, mouth ulcers, headaches, gastric disturbances, postfeverfew syndrome (withdrawal symptoms of aches, pains, and joint and muscle stiffness)	
Germander[4,20,21]	Choleretic and antiseptic properties	Causes hepatotoxicity; more than 30 cases of acute liver failure, including 1 fatality	
Anti-inflammatories			
Evening primrose oil[59]	Anti-inflammatory, sedative, anticoagulant, astringent	Gastrointestinal disturbances	
Flax	Anti-inflammatory	Diarrhea, nausea, flatulence	
Lobelia[1]	Aid for asthma and bronchitis	Respiratory depression, rapid heart rate, coma, death	
Antidepressants			
St. John's wort[1,52,53,59,60]	Alleviates depression and anxiety	Restlessness, fatigue, photosensitivity, constipation, dizziness, dry mouth	
Sleep aids			
Kava kava[1,60]	Sedative, reduces stress	Gastrointestinal disturbance; temporary discoloration of skin, hair, and nails; metabolic abnormalities	
Valerian root[1,52]	Sleep aid	Decreases blood pressure, heart palpitations, upset stomach	

mon in the literature.[1,24,46,53,59,70,73–97] Adulteration cases often include Ayurvedic and Chinese herbal medicines with multiple ingredients; these products have been contaminated with lead, arsenic, and other highly toxic substances. The British National Poisons Information Service identified herbal preparations containing toxic levels of lead, zinc, mercury, arsenic, aluminum, and tin. The individuals who had ingested the herbals had blood concentrations of the heavy metals el-

Table 3. Potentially Beneficial Herbs

Herb Name	Safety/Efficacy*	Recommended Dosage[10]	Clinical Trials
Chamomile (*Matricaria chamomilla*)	Safe and effective†[4]	Infusion/tea: 3 g/150 mL water steeped for 10 minutes	In controlled trials, positive effects on wound healing, as a mild sedative, and in combination with other herbs as a treatment for infant colic.[59]
Echinacea (*Echinacea*)	Safe and effective†[4]	Varied; tincture: 30–60 drops, tid; pressed juice: 6–9 mL	Mixed results: beneficial in shortening duration of common colds but less effective in preventing colds.[61–64]
Feverfew (*Tanacetum parthenium*)	Safe and effective‡[9]	50 mg–1.2 g/day (leaf powder)	Mixed results, but clinical research tends to support feverfew as a prophylaxis agent for migraines.[59,65]
Garlic (*Allium sativum*)	Safe and effective†[4]	Varied preparations; 4 g fresh garlic/day; 8 mg essential oil/day	Mild beneficial effect on serum lipids and reducing serum cholesterol, serum triglycerides, and low-density lipoprotein cholesterol; modest antihypertensive effect.[59] Randomized, double-blind, placebo-controlled clinical trial: no change in cardiovascular risk factors compared with placebo in children who had familial hyperlipidemia.[59]
Ginger (*Zingiber officinale*)	Safe and effective†[4]	2–4 g taken with liquid	Mixed results: treatment of motion sickness and postsurgical nausea and vomiting; helpful in treating hyperemesis gravidarum (morning sickness).[59,63]
Ginkgo biloba (*Ginkgo*)	Safe and effective†[4]	120 mg dried extract bid to tid	Controlled trials: positive results in the treatment of chronic cerebral insufficiency. Double-blind, placebo-controlled trials of patients who have memory loss: some improvement in memory. Randomized, controlled studies: promise in treating memory loss and psychopathologic conditions in Alzheimer disease and dementia. Controlled studies on intermittent claudication: favorable results. No studies have been done on pulmonary problems or attention deficit hyperactivity disorder.[59,63,66]
Ginseng (*Panaxt ginseng*)	Generally deemed safe and effective†[4]	Varied preparations, average daily dose is 1–2 g root/day	Clinical trials: ginseng improved mood, cognitive performance, and physical performance.[67]
Saw palmetto (*Serenoa repens*)	Safe and effective†[4]	1–2 g/day	Randomized trials support the efficacy of saw palmetto in treating urinary flow in men with benign prostatic hyperplasia.[89]
Valerian (*Valeriana officinalis*)	Safe and effective†[4]	Varied preparations; 15 g/day; tea: 3–5 g/150 mL hot water, steeped for 10–15 minutes, bid or tid	Randomized, double-blind, placebo-controlled studies: decreased sleep latency and improved sleep quality.[59]

*Standardization and product manufacturing practices vary greatly for the herbs listed. Although the herbs are potentially beneficial, poor standardization and product quality may alter the desired effect of the herbal product.
†According to German Commission E.
‡According to Health Protection Branch, Health and Welfare of Canada.

evated by 2 to 10 times the upper limit of normal physiologic values.[83]

One report of herbal product adulteration showed more than 48 cases of renal poisoning when the patients thought they were taking fang ji. In actuality, patients were taking guang fang ji. The problem seems to lie in the similarity of the names in Chinese.[70] In another instance, a young woman suffering from lifelong eczema received an herbal cream from a Chinese practioner. She became suspicious after its effects resembled those of other corticosteroid creams she had used. She sent a sample to the Leicester Royal Infirmary for analysis and the presence of a corticosteroid, possibly fluocortolone or prednisolone, was confirmed.[92] In yet another case, FDA researchers determined that a large batch of plant material laced with digitalis was sold to several herbal companies in the US. Digitalis can cause nausea, vomiting, and irregular heartbeats.[73]

Many studies call into question the purity and content of herbal products. Bahrke and Morgan[55] reported on quantitative differences in individual and total ginsenosides within herbal products. The factors affecting these differences were species, growing environment, soil and fertility conditions, age of the roots, different parts of the plant, and extraction methods.[98] These aforementioned factors may also play a role in the physiologic effects of ginseng, which might explain the reported adverse effects.[55] Many of the problems associated with the adulteration, variable purity, and potency of herbs could be addressed with improved manufacturing and quality standards.

Table 4. Drug Interactions With Common Herbs

Drug Name	Common Use	Herbal Name	Common Use	Known Interactions
Anti-inflammatories				
Aspirin	Anti-inflammatory Analgesic Antipyretic Antirheumatic[71]	Ginkgo biloba	Increase circulation, increase short-term memory	Spontaneous hyphema[70]
Hydrocortisone	Anti-inflammatory	Licorice	Expectorant, antiulcer[4]	Glycyrrhetinic acid (an acid in topical anti-inflammatories) potentiates cutaneous vasoconstrictor response[70]
Oral and topical corticosteroids	Anti-inflammatory	Licorice	Expectorant, antiulcer[4]	Potentiates corticosteroids[70]
Oral contraceptives				
Combined oral contraceptive	Birth control	St. John's wort	Alleviate depression and anxiety	Breakthrough bleeding[70]
Oral contraceptives	Birth control	Licorice	Expectorant, antiulcer[4]	Hypertension, edema, hypokalemia[70]
Antidepressants				
Antidepressants	Antidepressant	Panax ginseng	Stimulant	Induces mania in depressed patients[70]
Lithium	Manic depression[71]	Psyllium	Reduce cholesterol[72]	Decreases lithium concentrations[70]
Paroxetine	Antidepressant[71]	St. John's wort	Alleviate depression and anxiety	Lethargy, incoherence[70]
Phenelzine	Monoamine oxidase inhibitor; antidepressant[71]	Ginseng	Stimulant	Headache, tremor, mania[70]
Serotonin-reuptake inhibitors	Antidepressant	St. John's wort	Alleviate depression and anxiety	Mild serotonin syndrome, decreased bioavailability of digoxin, theophylline, cyclosporin, phenprocoumon[70]
Trazodone, sertraline, and mefazodone	Antidepressant; obsessive/compulsive disorders[71]	St. John's wort	Alleviate depression and anxiety	Mild serotonin syndrome[70]
Bronchodilator				
Theophylline	Bronchodilator[71]	St. John's wort	Alleviate depression and anxiety	Decreased theophylline concentration[70]

Product Manufacturing

The DSHEA granted authority to the FDA to establish "good manufacturing practices" for herbal products.[6] These regulations would govern the preparation, packing, and holding of dietary supplements under conditions that assure their safety. These regulations are to be modeled under guidelines currently in effect for the food industry. To date, the FDA has not fully implemented manufacturing guidelines for the herbal industry.[99]

Good manufacturing practices to ensure purity and potency of products were a common theme during the June 1999 Dietary Supplement Stakeholder Meeting held by the FDA's Center for Food Safety and Applied Nutrition.[99] This meeting included participants from every aspect of the herbal industry. At the center of the manufacturing discussion is the idea of standardization. Setting standards for supplements would mean that a specified amount of a herb is detectable, measurable, and known to have a biological response in the body.[100] This desired consistency does not currently exist. Resolving this problem of standardizing and regulating herbal supplements is difficult. Differences in soil quality, percentage of herb utilized, harvest time, climate changes, growing seasons, and exposure to light are some factors that may affect herb quality.[100] While the need to improve manufacturing practices is widely accepted, lack of agreement on standards and rules for enforcement has slowed the bureaucratic rule-making process.[99]

The herbal industry has taken strides to police itself with regard to product quality. The National Nutritional Foods Association randomly tests products produced by its members. The Association also plans to begin certification of factories every 3 years using the same good manufacturing processes proposed by the FDA, although manufacturers are not obligated to belong to this organization. In addition to the National Nutritional Foods Association, the United States Phamacopeia (USP) sets standards for pharmaceuticals, vitamins, and minerals. The USP, a private, nonprofit organization, has begun to produce monographs about herbs that sum up evidence of effectiveness and detail standards for quality, strength, and purity of the final product.[1,99] Adoption of these standards is voluntary, and manufacturers claiming to meet them are not checked except in response to complaints.

CONCLUSIONS

Despite the increased tendency to seek natural therapies, athletes need to be aware that "natural" does not equal "safe." Herbs should not be touted as miraculous cure-alls but rather compounds that work through simple biochemistry. Specific compounds trigger a specific physiologic effect—an effect that can be exacerbated if too much of a product is used or if it is used in combination with other medications. Athletes are entitled to know that most herbs are not proven safe and effective under current FDA standards. In addition, athletes may be unaware that the hyperbolic advertising and advocacy literature surrounding herbal products often contains untested claims. If an athlete wishes to take an herbal supplement, he or she should use a standardized product. Products should have the scientific name and quantity of the botanical clearly identified on the label. The name and address of the manufacturer, lot number, and expiration date should be clearly marked.[4]

Given the risks of toxicity and drug interaction, questions regarding the use of herbal supplements are essential when a health care provider takes a complete history. Athletes should consult a physician about potential drug interactions (both over the counter and prescription) before taking an herbal supplement. They should be advised to stop taking the herb immediately if adverse effects occur. Athletic trainers and physicians must be aware that herb use is deeply rooted in specific cultures and a key component of folk medicine. Therefore, an appropriate level of cultural sensitivity must be used when discussing the use of these products with athletes. Being judgmental or dismissive when discussing herbal products can erode the athlete's trust. The sports medicine team must be able to provide honest, unbiased information to educate athletes regarding herbal supplements.

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Acute Subdural Hematoma in a High School Football Player After 2 Unreported Episodes of Head Trauma: A Case Report

Shannon M. Logan*; Gerald W. Bell*; James C. Leonard†

*University of Illinois, Champaign-Urbana, Urbana, IL; †Carle Sports Medicine, Urbana, IL

Shannon M. Logan, MS, ATC, contributed to conception and design; analysis and interpretation of the data; and drafting, critical revision, and final approval of the article. Gerald W. Bell, EdD, PT, ATC/L, contributed to conception and design and drafting, critical revision, and final approval of the article. James C. Leonard, MD, contributed to conception and design; analysis and interpretation of the data; and critical revision and final approval of the article.

Address correspondence to Shannon M. Logan, MS, ATC, 4434 Smokerise Drive, Stow, OH 44224. Address e-mail to Smlogan21@aol.com.

Objective: To discuss the association between 2 unreported episodes of head trauma and an acute subdural hematoma in a high school football player; to address the role of the sport health care team in secondary schools when caring for an athlete with head trauma; and to recognize the importance of educating athletes and coaches about this condition.

Background: A previously healthy athlete experienced 2 unreported episodes of head trauma during a single game. The athlete was conscious and oriented to person, time, and place, but he vomited and complained of severe headache, nausea, and vertigo. During transfer, the athlete appeared to have a seizure.

Differential Diagnosis: Subdural hematoma, epidural hematoma, intracerebral hemorrhage, second-impact syndrome, cervical spine injury, or epilepsy.

Treatment: Computed tomography scan indicated fluid over the left frontal temporal fossa. Conservative treatment was begun, and the fluid resolved without incident.

Uniqueness: A single episode of blunt trauma has been thought to cause an acute subdural hematoma. However, multiple concussions can also result in this condition.

Conclusion: Single or multiple episodes of head trauma can lead to an acute subdural hematoma. This case study reflects the importance of proper education in the recognition and care of head trauma and return-to-play guidelines for athletes and coaches. A sport health care team in all secondary schools can provide the immediate and appropriate intervention for such injuries.

Key Words: second-impact syndrome, head injury, concussion, seizure

In football alone, an estimated 1 in 5 high school athletes will experience a concussion each year. Overall, 250 000 concussions are observed in football, with head injuries being the leading cause of death in sports.[1] In 2000, the National Collegiate Athletic Association[2] reported a continuing increase in the concussion rate, which was significantly higher by 4.2% than previous averages. In a 3-year study of mild traumatic brain injury of 10 high school sports by Powell and Barber-Foss,[3] football accounted for the highest proportion of such injuries (63.4%).

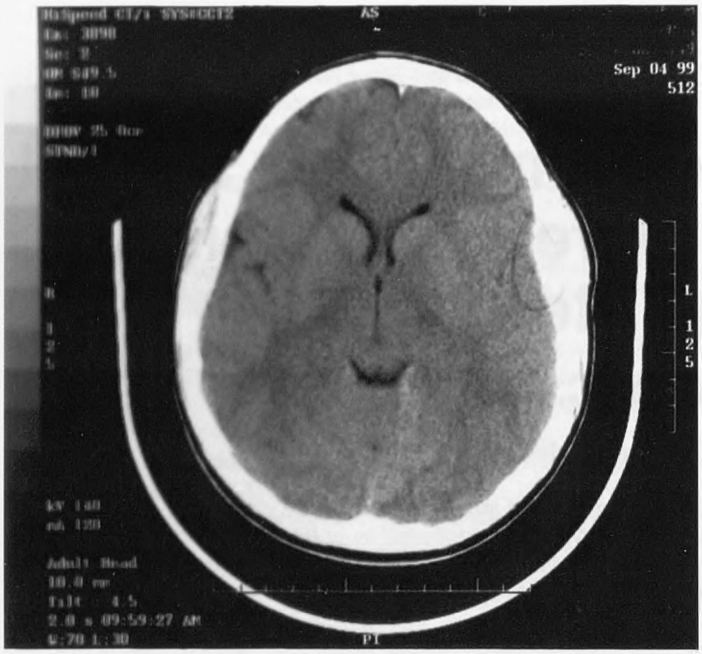
In general, a concussion can be defined as a traumatic alteration in mental status, commonly followed by confusion and amnesia.[4] Severe head impact occurs with a concussion, and an individual may develop or be predisposed to severe traumatic brain injury, such as a cerebral, epidural, or subdural hematoma, which is a medical emergency.[5] Second-impact syndrome, a subsequent and possibly fatal brain injury that can occur when a second head injury is received before the initial head injury has resolved, can be associated with a concussion. This syndrome is important because an athlete may present with a seemingly mild concussion; however, within seconds, the athlete may develop symptoms of second-impact syndrome. Second-impact syndrome has a mortality rate of up to 50%,[6] and therefore, it must be prevented whenever possible and recognized early when it occurs.

In 1984, Albright[7] reported 16 intracranial hematomas in high school football athletes, leading to 6 deaths. The most common cause of head injury death is a subdural hematoma, which results most often from a rupture of the veins in the subdural space, leading to slow venous bleeding between the dura and brain parenchyma. If the parenchyma is ruptured, arterial bleeding may also contribute to this pathologic condition.[8,9] Between 1984 and 1988, the National Center for Catastrophic Sports Injury Research[10] reported 18 incidences of subdural hematomas in athletes at various levels of football.

A football player who has received a minor head injury is 4 times as likely to sustain a subsequent head injury.[1] The following case study reveals how 2 unreported episodes of head trauma can lead to a subdural hematoma, a potentially life-threatening head injury.

CASE REPORT

The patient was an 18-year-old high school football player, with an unremarkable medical history, who was 181 cm tall and weighed 84 kg. While walking toward the sideline, the athlete took off his helmet and appeared confused. Falling to



CT scan suggesting left-temporal acute subdural hematoma measuring 1.2 cm with an equivalent left-to-right shift.

his knees, he began to vomit. However, the patient was oriented to time, person, and place. His immediate complaints included severe head pain, nausea, and vertigo. No neck pain or any lower or upper extremity paresthesias were present.

The specific head injury or head contact that precipitated this event could not be identified. However, the athlete recalled being hit on 2 separate occasions during the game, although he did not report the incidents to the coaching staff or certified athletic trainer. The patient stated that he had a headache and nausea, but he continued to participate in the game.

To prevent a catastrophic outcome, even though loss of consciousness was not witnessed, paramedics were summoned on the field for transfer because of the patient's 2 unreported episodes of head trauma and symptoms associated with a concussion. While he was being prepared for transfer, the patient's level of consciousness decreased, and he became less responsive. The neck was stabilized with a cervical collar to prevent further injury, although there was no cervical spine tenderness, and the patient appeared to have a mild seizure, becoming temporarily unresponsive to stimuli. In the ambulance during transport, the patient had a witnessed seizure and was incontinent of urine. Attempts to intubate him were unsuccessful due to his resistance.

On arrival at the emergency department, the athlete was oriented to time, person, and place. He complained of severe headache, nausea, and retching. He denied any neck or back pain or paresthesias. Mannitol, 80 g, was given to reduce intracranial pressure. The neurologic examination revealed a Glasgow coma scale score of 15. Pupils were equal, round, and reactive to light. No nystagmus or periorbital or retroauricular ecchymosis existed, and extraocular function was intact. Reflexes and sensation were normal. Cervical, thoracic, and lumbosacral x-ray films were normal. An immediate computed tomographic (CT) scan suggested a left frontal-temporal acute subdural hematoma that measured 1.2 cm, with an equivalent left-to-right shift (Figure), although the images were not particularly remarkable.

The patient was given phenytoin (dosage was not stated in the patient's record) for prophylaxis of seizures, which were thought to be a possible result of the subdural bleeding. He was admitted to the surgical intensive care unit for monitoring of his neurologic status and for an additional CT scan, if his condition worsened during the night, to assess the need for neurosurgical intervention. Additional CT scans and examinations throughout the night did not indicate the need for surgical intervention. Approximately 24 hours later, the CT scan revealed a significantly smaller amount of blood than on the previous examination, with no additional subdural collections or mass effects. The athlete was released under his parents' care. He complained of a headache and inability to recall specific events involving his transport to the emergency department (anterograde amnesia). The parents were instructed not to let the patient participate in any activities, such as school or sports, until he was cleared by the physician and follow-up CT scan.

One week later, the patient returned for a follow-up CT scan and electroencephalography. The CT scan revealed that the subdural hematoma had resolved. The athlete complained of severe headache and nausea, not uncommon after such an injury. Acetaminophen was prescribed for pain and headache and trimethobenzamide for nausea (medication dosages were not stated in the patient's chart). The electroencephalogram revealed abnormal sharp waves, consistent with seizure activity, and therefore, phenytoin was prescribed for 6 months. The patient was instructed not to participate in football for the remainder of the season or drive for 6 months and was withheld from school for 2 weeks.

Twelve days after the initial head injury, the patient complained of continued headaches and nocturnal neck pain. Clinical examination by the physician revealed an area of marked tenderness that measured 1 to 2 cm in diameter beneath the left occipital protuberance and increased pain when the patient turned his head to the right. No cervical spine radiographs were taken during the evaluation. The clinical impression was a cervical ligament strain from the previous injury. A prescription for ketorolac, 10 mg/d, was given in conjunction with diazepam, 5 to 10 mg/d.

One month later, the patient was progressing well and able to increase daily activities. The nocturnal neck pain from the cervical ligament sprain had ceased. The athlete was restricted from physical education class until fully asymptomatic and cleared by the physician. He was able to complete a full day at school but still had mild headaches at the end of the day or after walking to classes and excessive activity in class. The patient's restrictions included no contact sports, such as football, for at least 1 year. However, depending on recovery, he might be able to participate in the upcoming high school baseball season with the use of special protective equipment at all times, such as a helmet, and clearance from the physician. Nonetheless, the sport health care team must make a careful decision in allowing the athlete to participate in the baseball season. Although a protective helmet would be used, requirements for participation would include sprinting, base running, and sliding, all of which could result in contact or collision.

DISCUSSION

Cantu and Mueller[11] reported the number of catastrophic and fatal injuries in high school football, including head injuries, had decreased dramatically between 1982 and 1996. The authors noted 1.76 fatalities per 100 000 high school football participants, with a low of 0 in 1990.[11] However, to prevent possible catastrophic outcomes, health care professionals

Table 1. Concussion Grading Scales

Scale	Severity of Concussion		
	Mild	Moderate	Severe
American Academy of Neurology[4]	Confusion: transient Loss of consciousness: no Posttraumatic amnesia: no Symptoms resolve within 15 min	Confusion: transient Loss of consciousness: no Symptoms last longer than 15 min	Loss of consciousness: brief or prolonged
Bruno et al[23]	Confusion: yes Loss of consciousness: none	Loss of consciousness: no Posttraumatic amnesia: delayed	Loss of consciousness: yes Posttraumatic amnesia: immediate
Colorado Medical Society[24]	Confusion: yes Loss of consciousness: no Posttraumatic amnesia: no	Loss of consciousness: no Confusion: yes Posttraumatic amnesia: yes	Loss of consciousness: yes
Cantu[25]	Loss of consciousness: no Posttraumatic amnesia: less than 30 min	Loss of consciousness: less than 5 min Posttraumatic amnesia: 30 min or more but less than 24 h	Loss of consciousness: 5 min or more Posttraumatic amnesia: 24 h or more

must immediately recognize, evaluate, and manage athletes with head injuries. First, to successfully care for head injuries, both players and coaches need to understand the risks of multiple head injuries and how return-to-play guidelines guide decision making. Players often decide to return to play after a head injury without seeking medical attention. This action is at times motivated by the fear of ridicule from the coaching staff and fellow players. Also, players often are ignorant of the possible life-threatening consequences of returning to play without proper medical attention.[1]

Second, according to Ransone and Dunn-Bennett,[12] coaches alone did not meet adequate first-aid standards in dealing with injuries and may make decisions that exceed their training. To date, sport first-aid and safety training for high school coaches is only required in 28 states.[13] Certified athletic trainers can not only provide proper recognition and care of athletic injuries but also play an important liaison role among the team physician, coaches, and athletes.[14]

Concussions

The Centers for Disease Control and Prevention[15] recently reported that approximately 300 000 general sports concussions occur per year in the United States. Although no universally accepted definition of a concussion exists, this condition was previously defined as "a clinical syndrome characterized by immediate or transient posttraumatic impairment of neural function, such as alteration of consciousness and disturbance of vision or equilibrium, due to brainstem involvement."[16] However, in 1997, Kelly and Rosenberg[17] concisely defined a concussion as "an alteration in mental status due to biomechanical forces that affect the brain that may or may not cause the loss of consciousness." The hallmarks of a concussion are confusion and amnesia, although signs and symptoms vary with each individual.[4] A recent study by Collins et al[18] revealed that most sport-related concussions do not result in loss of consciousness. However, we must remember that loss of consciousness may be transient or missed.[19]

Acute Subdural Hematoma

According to Powell and Barber-Foss,[3] 4 cases of subdural hematomas in high school football were identified during a 3-year period. The individual with a subdural hematoma typically presents with loss of consciousness. Focal neurologic findings include pupillary asymmetry. Individuals need immediate medical attention and transport for a CT scan.[20]

Subdural hematoma, the most common cause of head injury death,[7] can be divided into 2 categories. A simple subdural hematoma presents without cerebral contusion or edema. The mortality rate for a simple subdural hematoma is approximately 20%. The second category consists of brain contusion with hemispheric swelling or bleeding. The mortality rate for this subdural hematoma is 50%.[21] Severe damage is caused by swelling or bleeding, typically due to venous rupture, which results in herniation of brain tissue and cerebral ischemia, potentially causing death.[9] Although a subdural hematoma may be caused by a single incident, there are patients in whom this severe head injury resulted from repeated head injuries.[9,22]

Concussion Grading Scales and Return-to-Play Guidelines

Various grading and guidelines exist (Table 1),[4,23–25] and confusion or miscommunication among the physician, athletic trainer, coaches, and players may occur as to when the athlete can safely return to competition.

Our patient presented with no loss of consciousness, symptoms lasting for more than 15 minutes, confusion, and delayed posttraumatic amnesia. Interestingly, according to Cantu[25] and the Colorado Medical Society,[24] our patient would have been classified as having a grade I (mild) concussion. However, the American Academy of Neurology[4] and Bruno et al[23] would have classified him as having a grade II (moderate) concussion. Although each of these classifications is correct according to the patient's presentation, these variances reiterate the importance of establishing communication and guidelines among the sport health care team regarding recognition, evaluation, and treatment of head injuries and concussions.

In conjunction with the various concussion grading guidelines, athletes and the sport health care team must understand and comply with return-to-play guidelines[4,24,25] adopted by the physician, athletic trainer, coaching staff, and athletes (Table 2). For this patient, the physician conservatively decided on no contact sports for at least 1 year. However, the patient might be able to participate in the upcoming baseball season with clearance and wearing protective equipment, such as a helmet, at all times. Nevertheless, the final decision as to when the patient may return to play is a clinical judgment by the patient's physician.[4] If surgical intervention is required, such as in removal of a blood clot or posttraumatic hydrocephalus, the athlete should not be allowed to return to contact sports.[25]

Table 2. Return-to-Play (RTP) Guidelines

Guidelines	Severity of Concussion		
	Mild	Moderate	Severe
American Academy of Neurology[4]	RTP if no symptoms in 15 min	RTP in 1 wk if asymptomatic	RTP in 1 wk if loss of consciousness was brief, 2 wk if loss of consciousness was prolonged
Colorado Medical Society[24]	RTP if asymptomatic (no posttraumatic amnesia) after at least 20 min	RTP in 1 wk if asymptomatic	RTP not before 1 mo and then only if asymptomatic for at least 2 wk
Cantu[25]			
First	RTP if asymptomatic for 1 wk	RTP in 2 wk if asymptomatic for 1 wk	Terminate season; may RTP next season if asymptomatic
Second	RTP if asymptomatic for 1 wk	RTP not before 1 mo and then only if asymptomatic for 1 wk	Terminate season; may RTP next season if asymptomatic
Third	RTP not before 1 mo and then only if asymptomatic for 1 wk	Terminate season; may RTP next season if asymptomatic	

CONCLUSION

This case report reveals how 2 unreported episodes of head trauma can be associated with an acute subdural hematoma, a potentially life-threatening condition. Although an athlete who has been unconscious may, in some instances, be able to return to play safely, an athlete who has remained conscious may, in fact, be developing a subdural hematoma or other severe traumatic brain injury.[26] Loss of consciousness is used in all the current guidelines; however, Collins et al,[27] using neuropsychological measures, demonstrated that the presence or absence of consciousness does not predict severity of injury.[27] Although our patient sustained no distinct loss of consciousness, his severe head injury needed to be recognized and evaluated to prevent a catastrophic outcome.

Appropriate education and training for players and coaches regarding the care of head injuries is needed to prevent potentially catastrophic events. According to a recent report from the Scientific Affairs Council of the American Medical Association,[14] certified athletic trainers are proposed to be present in secondary schools to provide proper recognition, care, and management of athletic injuries in conjunction with the team physician. Finally, within the sport health care team, agreement is needed before the season on which concussion grading and return-to-play guidelines will be used. Also, there should be agreement that the sport health care team will make all on-field and off-field decisions on the evaluation and treatment of head injuries. Compliance by the team physician, athletic trainer, coaching staff, and players is needed at all times to prevent catastrophic outcomes.

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Osteitis Pubis Syndrome in the Professional Soccer Athlete: A Case Report

Cristina Rodriguez*; Antonio Miguel*; Horacio Lima*; Kristinn Heinrichs†

*Club Universidad Nacional AC, Coyoacan, Mexico; †Armstrong Atlantic State University, Savannah, GA

Cristina Rodriguez, MD, contributed to conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article. Antonio Miguel, MD, contributed to conception and design; analysis and interpretation of the data; and drafting, critical revision, and final approval of the article. Horacio Lima, PT, contributed to conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article. Kristinn Heinrichs, PhD, PT, SCS, ATC, CSCS, contributed to analysis and interpretation of the data and critical revision and final approval of the article.

Address correspondence to Cristina Rodriguez, MD, Insurgentes Sur #4425–36, Col. La Joya C.P. 14430 Mexico D.F. Address e-mail to crisger@prodigy.net.mx.

Objective: To describe the pathomechanics, diagnostic procedures, classification, and conservative management of the osteitis pubis syndrome in the elite soccer athlete.

Background: Groin injuries can be the most difficult sport injuries to accurately diagnose and treat. Osteitis pubis is a painful, chronic syndrome that affects the symphysis pubis, adductor and abdominal muscles, and surrounding fascia. If misdiagnosed or mismanaged, osteitis pubis can run a prolonged and disabling course. The abdominal and adductor muscles have attachments to the symphysis pubis but act antagonistically to each other, predisposing the symphysis pubis to mechanical traction microtrauma and resulting in osteitis pubis. These antagonistic forces are most prevalent in kicking sports, such as soccer or football.

Description: We provide a retrospective review of the demographics, diagnostic criteria and procedures, and conservative management of osteitis pubis in a professional soccer team. Osteitis pubis represented 3% to 5% of all injuries sustained by our professional soccer team between 1989 and 1997; 71.4% of those presenting with osteitis pubis were classified as having stage I disease, with a mean recovery time of 26.7 days. Midfielders were most affected by the syndrome (42.8%), whereas defenders and forwards exhibited equal incidences (25.7%) of osteitis pubis. Conservative management included nonsteroidal anti-inflammatory medication, electric stimulation, ultrasound, laser, cryomassage, and a progressive rehabilitation program.

Clinical Advantages: Athletes who participated in this conservative management program appeared to return to full sport participation earlier and with fewer restrictions than the current literature seems to suggest. A 4-stage diagnostic criteria system was helpful in determining the course of treatment.

Key Words: groin pain, soccer injuries, pubic symphysis, rehabilitation, diagnosis

Osteitis pubis is a painful inflammatory condition of the symphysis pubis and surrounding muscle fascia caused by repeated traumatic or exertional stresses on the fascia and the joint, resulting in a traction microtrauma.[1] First described by Beer in 1924,[2] who presented 5 cases of osteitis pubis, and later by Spinelli in 1932[1] as a rectus abdominis adductoris syndrome, osteitis pubis has been recognized as one of the most chronic and debilitating syndromes to affect athletes. Although this condition has been reported as affecting basketball players and distance runners,[3–5] most literature describes osteitis pubis as affecting athletes participating in kicking sports, such as soccer or football.[3–5] Despite the low incidence of osteitis pubis (0.5% to 7%)[5–7] in the general athletic population, it may run a prolonged and disabling course if misdiagnosed or mismanaged. Because groin injuries have been recognized as some of the most difficult sport injuries to diagnose and treat accurately, the practicing athletic trainer should understand the pathomechanics and clinical features of the osteitis pubis syndrome. The purpose of this article is to describe the diagnostic procedures, classification, and conservative management of osteitis pubis.

ANATOMY AND PATHOMECHANICS

The symphysis pubis is a fibrocartilaginous joint between the pubic rami. In addition, the abdominal muscles (rectus abdominis and external and internal oblique muscles) attach distally to the inguinal ligament, conjoined tendon, and pubic symphysis, whereas the adductor muscles (pectineus, adductor longus, adductor brevis, adductor magnus, gracilis) arise from the superior and inferior rami of the pubis. The obturator and femoral nerves with their cutaneous branches have been suggested as etiologic factors in groin pain.[8] Thus, dysfunctions that affect the pubic symphysis can affect either joint mobility or the musculotendinous attachments of the abdominal or adductor muscles.

Muscle imbalances between the abdominal and hip adductor muscles have been suggested as an etiologic factor in osteitis pubis.[3] Because of their attachments to the thoracic cage proximally and the pubis distally, the abdominal muscles act synergistically with the posterior paravertebral muscles to stabilize the symphysis, allowing single-leg stance while maintaining balance and contributing to the power and precision of the kicking leg.[3] The adductors, because they stabilize the sym-

Table 1. Demographic Data: Club Universidad Nacional, AC Soccer Players Presenting With Osteitis Pubis, 1989–1997

Variable	Data
Age, y (n = 35)	18.97 ± 2.89 (range, 1–27)
Position, %	
Midfielders (n = 15)	42.8
Defenders (n = 9)	25.7
Forwards (n = 9)	25.7
Goalkeepers (n = 2)	5.7
Disease classification, %	
Stage I (n = 25)	71.4
Stage II (n = 9)	25.7
Stage III (n = 1)	2.8
Recovery period, d	
Stage I	26.7 ± 17.84 (range, 3–65)
Stage II	47.3 ± 22.04 (range, 9–83)
Stage III	72

physis by bringing the lower extremity closer to the pelvis, are antagonists to the abdominal muscles. In addition, the adductor muscle group transmits mechanical traction forces toward the symphysis pubis during its activity as a prime mover in the soccer push pass, tackling, and directing the soccer ball. Imbalances between abdominal and adductor muscle groups disrupt the equilibrium of forces around the symphysis pubis, predisposing the athlete to a subacute periostitis caused by chronic microtrauma. This microtrauma exceeds the dynamic capacity of tissue for hypertrophic remodeling, resulting in tissue degeneration.[9,10] Shear stress at the symphysis pubis can also cause sacroiliac dysfunction in osteitis pubis if hip internal rotation is limited in either flexion or extension. This shear stress is transmitted to the symphysis pubis, resulting in either anteroposterior movement of one half of the pelvis in relationship to the other in extension or proximal-distal movement in flexion.[11]

DEMOGRAPHICS

Jumping, twisting, or turning motions in sprinting, cutting, and kicking activities common to soccer and football have been implicated in the pathogenesis of osteitis pubis. The incidence of this syndrome in the general athletic population has been reported as 0.5% to 6.4%. Our demographic data collected between September 1989 and March 1997 reflect an incidence of 3% to 5% of all injuries affecting our soccer team,[12] more consistent with the higher incidence of 2.5% to 7%[6,7] found in the kicking sports compared with the general athletic population. Table 1 presents the demographic data for position, disease classification, and recovery period for 35 male elite soccer athletes who presented with osteitis pubis between 1989 and 1997. Although 44 athletes originally presented with osteitis pubis, 9 patients with stage IV osteitis pubis required surgical intervention, leaving 35 athletes (age, 18.97 ± 2.89 years) with stage I through III disease to undergo conservative management. Most athletes presented with stage I disease (71.4%). Not surprisingly, midfielders (42.8%) demonstrated the highest incidence, defenders and forwards were affected equally (25.7%), and goalkeepers had the lowest incidence (5.7%). These injury demographics are consistent with the pathomechanics of injury.

Table 2. Differential Diagnosis of Groin Pain in Athletes

Structure	Mechanism of Injury
Adductor strain	Violent eccentric (eg, "the splits") or concentric load on adductors; localized tenderness, usually at musculotendinous junction; weakness of resisted adduction, ecchymosis, pain
Iliopsoas strain	Deep groin pain after forceful hip flexion, as in kicking the ball; lower abdominal pain lateral to rectus abdominis and above inguinal ligament; weakness in hip flexion; mechanism: maximal hip flexion, then forced into eccentric muscle action; positive Ludloff sign: in prolonged sitting, elevation of heels causes pain
Conjoined tendon weakness	"Footballer's hernia"; pain (and/or slight bulging) with coughing or sit-ups; incipient hernia: episodes of pain above the pubic tubercle with tenderness around pectineal eminence; does not respond well to nonsteroidal anti-inflammatory drugs or conservative physical therapy
Hernias	Direct inguinal hernia; femoral hernia
Sacroiliac dysfunction	Pubic pain with ascending or descending stairs, asymmetric movements, hip extension; sensation of clicking
Fractures	Adolescents with open epiphyses present with a higher risk of avulsion fractures; pubic bone and/or femoral neck: suspect in severe trauma
Stress fractures	Inferior pubic ramus: uncommon; femoral neck: occurs in long-distance runners logging high mileage; generally refers pain to hip; limited flexion and internal rotation
Nerve entrapment	Obturator (L2-3) or femoral (L3-4) nerve
Spine (referred to groin)	Dermatome levels for T12-L4/5
Hip joint injury or disease	Osteoarthritis, osteochondritis dissecans, chondral injuries referring pain to the groin

DIAGNOSIS

The clinical diagnosis of osteitis pubis was based on the history, physical examination, and radiographic (x-ray examination and bone scan) findings. Because the origin of groin pain is often difficult to elucidate, the sport medicine team must consider several differential diagnoses[5,8,13–15] (Table 2); thus, the players were examined by the team's sports medicine specialist and orthopaedic surgeon and a general surgeon to eliminate inguinal hernia, urologic pathologic conditions, muscular injury, or other orthopaedic problems. Symptoms of osteitis pubis include pain when kicking or advancing the leg forward during the swing phase of gait, localized pain in the symphysis pubis, and pain in the lower portion of the abdominal muscle groups. The adductor muscles are evaluated bilaterally for pain and tenderness and increased muscle guarding in the muscle belly and at the musculotendinous attachments. Standard passive flexibility and resisted muscle tests of the adductor and abdominal muscle groups were performed to reproduce the painful symptoms.

We determined tissue reactivity and stability of the pubic

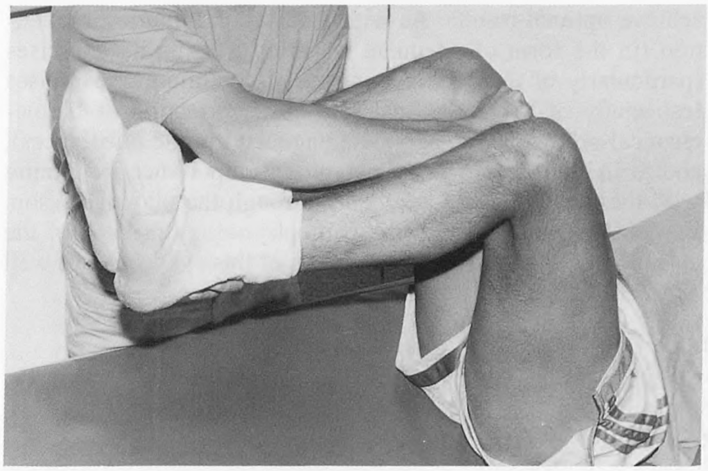

Figure 1. Pubic symphysis gap test with isometric adductor contraction.

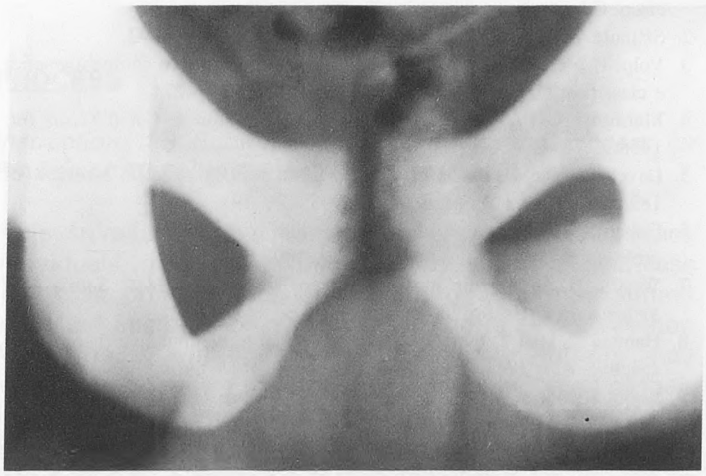

Figure 2. Radiograph of the symphysis pubis demonstrating increased space between the symphyses.

symphysis by the symphysis gap test (Figure 1). The athlete is in a 90°-90° hip- and knee-flexion position with the legs supported by the examiner. The athlete then performs an isometric adductor muscle contraction against the examiner's fist; painful isometric muscle action was considered a positive test result.

Magnified pubic radiographs (Figure 2) were taken, using a flamingo view in double- and single-leg stance positions on the right and left legs to detect pubic subluxation (>2 mm) with weight bearing and irregular borders over the symphysis and pubic rami. Technetium Tc 99m pubic bone scans were also taken to detect increased uptake in the area of the pubic symphysis (Figure 3).

Athletes with osteitis pubis were classified into 4 stages based on their presenting clinical diagnostic features. Stage I includes unilateral symptoms involving the kicking leg and inguinal pain in the adductor muscles. The pain subsides after warm-up but recurs after the training session. Stage II consists of bilateral symptoms with inguinal pain involving the adductor muscles. The pain increases after the training session. Stage III comprises bilateral inguinal pain involving the adductor muscles and abdominal symptoms. The athlete complains of pain when kicking the ball, sprinting with rhythm or directional changes, changing positions from sitting to standing, and walking long distances. The athlete is unable to continue

Figure 3. Technetium Tc 99m bone scan image showing increased uptake in the pubic symphysis characteristic of osteitis pubis.

sport participation. Stage IV describes pain in the adductor and abdominal muscles referred to the pelvic girdle and lumbar spine with defecation, sneezing, and walking on uneven terrain. The athlete is unable to perform activities of daily living.

CONSERVATIVE MANAGEMENT

Conservative management of osteitis pubis for all athletes included pharmacologic management consisting of oral ibuprofen, 800 mg 3 times a day for 14 days; daily application of therapeutic modalities (cryomassage, laser, ultrasound, or electric stimulation) for 14 days; and a progressive rehabilitation program (Table 3). Ultrasound was not applied to athletes younger than 18 years because of concern for damage to the epiphyseal plates; alternatively, they received electric stimulation treatment.

CONCLUSIONS

Our protocol has been used successfully to return athletes to a high level of sport performance. The mean time to symptom remission for the stage II group was nearly double that for the stage I group (6.7 weeks and 3.8 weeks, respectively). The sole athlete in the stage III group required 10 weeks for full recovery. These demographics suggest that early diagnosis and prompt treatment are of utmost importance to prevent this condition from becoming chronic. We have found our classification scheme helpful in improving our diagnostic accuracy and our ability to predict the course of recovery.

In addition to our approach to the conservative management of osteitis pubis, other authors[1,16] have suggested nonsteroidal anti-inflammatory infiltration of the symphysis pubis. However, they do not mention the severity of the disease at the time of injection. This treatment plan, if initiated early in the syndrome, has demonstrated positive results in as little as 3 to 8 weeks in our population (compared with a range of 1 to 96 months[17]) without the need for invasive techniques or the athlete to modify or discontinue sport participation.

Because the symphysis pubis serves as the anterior axis for innominate rotation during normal walking[18] and is also subjected to superior shear forces during single-leg stance, it seems reasonable to hypothesize this as the mechanism for osteitis pubis in the kicking athlete. Greenman[18] further noted the importance of the abdominal muscles from above acting

Table 3. Therapeutic Modalities and Rehabilitation Protocols for Osteitis Pubis

Electric stimulation (used in athletes younger than 18 years)
SysStim 207 muscle stimulator (Mettler Electronics, Anaheim, CA)
Alternating current
Bipolar techniques: active (−) over painful region and dispersive (+) adjacent to the involved adductor muscle group
8-minute treatment
Submotor amplitude
Rate: 8 pps
14 daily sessions
Ultrasound (used in athletes younger than 18 years)
Continuous wave over pubic bone
5-minute treatment at 1.5 W/cm², 1 MHz, 10-cm² effective radiating area
Cryomassage
10 minutes over painful area
GaAs laser
Infrared GaAs pulsed (180-nanosecond) laser (904 nM)
10-W output power
2 minutes per painful spot using grid technique with 2-cm distance between treatment points
4 to 5 treatment sites total
10 sessions
Progressive rehabilitation (exercises were added as the athlete progressed through each rehabilitation phase without discomfort)
1. Flexibility exercises emphasizing the adductors
2. Strengthening exercises of abductor and adductor muscle groups using an elastic band
3. Cardiovascular endurance: cycling or swimming
4. Walk-jog program progressing to full jogging program
5. Exercises on a 50-m incline plane with a 10% slope. All exercises were performed on the incline, and jogging was performed on the decline.
Line jogging
15-m sprint
Jogging with knees high
Jogging with knees high plus a jump
Jogging with left- and right-side hops, keeping both feet together
Jogging with buttocks kicks
Carioca: walk and jog
Squat running
Frog leaps
6. Abdominal exercise
7. Progressive kicking exercises
Short, medium, long distance
Increasing velocity and kick intensity

in a synergistic manner with the hip adductor muscles from below in maintaining joint integrity. Painful isometric hip adduction that occurs with the pubic symphysis gap maneuver[19] is only one of a series of physical findings present in the clinical scenario of osteitis pubis. In severe cases, reflexogenic symptoms may extend to the thoracolumbar paraspinal muscles, the muscles of the pelvis and abdomen, and the anterior thigh muscles and tensor fascia latae.[20]

Osteitis pubis syndrome, because it is a chronic, painful syndrome that significantly impairs athletic performance, should be recognized and treated as early as possible to achieve optimal results. As with many sports injuries, prevention (in the form of adequate warm-up), flexibility exercises (particularly of the adductor muscles), conditioning exercises (especially of the abdominal muscles), correction of biomechanical problems (eg, agonist-antagonist muscle imbalances), and technique factors are of paramount importance, beginning with the preseason and extending through the playing season. Further investigation into the pathophysiology of each of the stages, causes, and triggering factors of this syndrome, as well as treatment outcomes, is warranted.

ACKNOWLEDGMENTS

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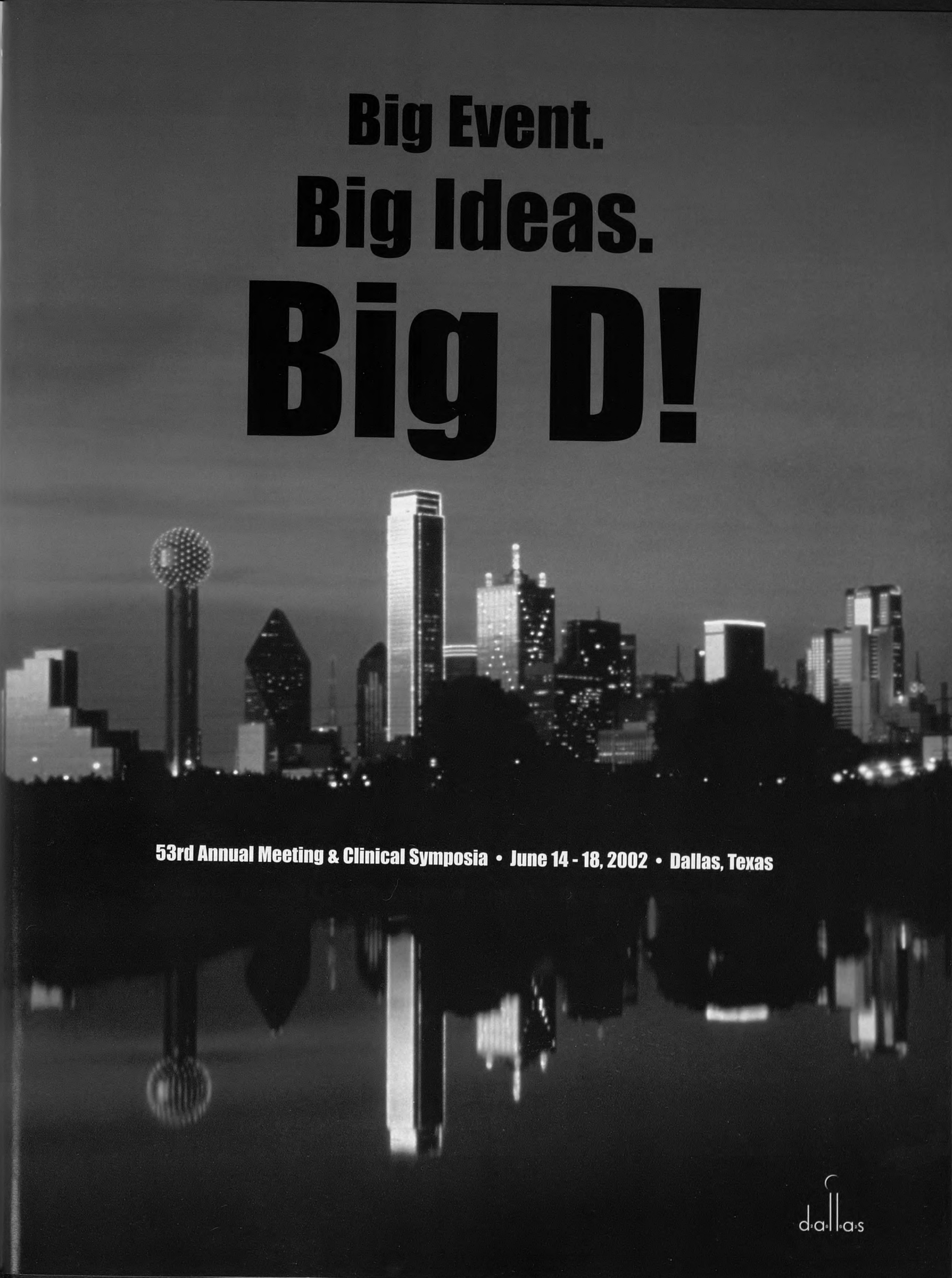
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    c. Abstract and Key Words (first numbered page)
    d. Text (body of manuscript)
    e. References
    f. Tables (each on a separate page)
    g. Legends to figures
    h. Figures
13. Begin numbering the pages of your manuscript with the abstract page as #1; then, consecutively number all successive pages.
14. Units of measurement shall be recorded as SI units, as specified in the *AMA Manual of Style*, except for angular displacement, which should be measured in degrees rather than radians. Examples include mass in kilograms (kg), height in centimeters (cm), velocity in meters per second ($m \cdot s^{-1}$ or m/s), angular velocity in degrees per second ($° \cdot s^{-1}$), force in Newtons (N), and complex rates (mL/kg per minute).
15. Titles should be brief within descriptive limits (a 16-word maximum is recommended). If a disability is the relevant factor in an article, the name of the disability should be included in the title. If a technique is the principal reason for the report, it should be in the title. Often both should appear.
16. The title page should also include the name, title, and affiliation of each author, and the name, address, phone number, fax number, and e-mail address of the author to whom correspondence is to be directed. No more than 3 credentials should be listed for each author.
17. A structured abstract of no more than 250 words must accompany all manuscripts. Type the complete title (but not the authors' names) at the top, skip 2 lines, and begin the abstract. Items that are needed differ by type of article. **Literature Reviews**: Objective, Data Sources, Data Synthesis, Conclusions/Recommendations, and Key Words; **Original Research** articles: Objective, Design and Setting, Subjects, Measurements, Results, Conclusions, and Key Words; **Case Reports**: Objective, Background, Differential Diagnosis, Treatment, Uniqueness, Conclusions, and Key Words; **Clinical Techniques**: Objective, Background, Description, Clinical Advantages, and Key Words. For the Key Words entry, use 3 to 5 words that do not appear in the title.
18. Begin the text of the manuscript with an introductory paragraph or two in which the purpose or hypothesis of the article is clearly stated and developed. Tell why the study needed to be done or the article written and end with a statement of the problem (or controversy). Highlights of the most prominent works of others as related to your subject are often appropriate for the introduction, but a detailed review of the literature should be reserved for the discussion section. In a 1- to 2-paragraph review of the literature, identify and develop the magnitude and significance of the controversy, pointing out differences among others' results, conclusions, and/or opinions. The introduction is not the place for great detail; state the facts in *brief*, specific statements and reference them. The detail belongs in the discussion. Also, an overview of the manuscript is part of the abstract, not the introduction. Writing should be in the active voice (for example, instead of "Subjects were selected," use "We selected subjects") and in the first person (for example, instead of "The results of this study showed," use "Our results showed").
19. The body or main part of the manuscript varies

Authors' Guide

according to the type of article (examples follow); however, the body should include a discussion section in which the importance of the material presented is discussed and related to other pertinent literature. When appropriate, a discussion subheading on the clinical relevance of the findings is recommended. Liberal use of headings and subheadings, charts, graphs, and figures is recommended.

a. The body of an **Original Research** article consists of a methods section, a presentation of the results, and a discussion of the results. The methods section should contain sufficient detail concerning the methods, procedures, and apparatus employed so that others can reproduce the results. The results should be summarized using descriptive and inferential statistics and a few well-planned and carefully constructed illustrations.
b. The body of a **Literature Review** article should be organized into subsections in which related thoughts of others are presented, summarized, and referenced. Each subsection should have a heading and brief summary, possibly one sentence. Sections must be arranged so that they progressively focus on the problem or question posed in the introduction.
c. The body of a **Case Report** should include the following components: personal data (age, sex, race, marital status, and occupation when relevant—not name), chief complaint, history of present complaint (including symptoms), results of physical examination (example: "Physical findings relevant to the rehabilitation program were . . . "), medical history (surgery, laboratory results, examination, etc), diagnosis, treatment and clinical course (rehabilitation until and after return to competition), criteria for return to competition, and deviation from expectations (what makes this case unique).
d. The body of a **Clinical Techniques** article should include both the *how* and *why* of the technique: a step-by-step explanation of how to perform the technique, supplemented by photographs or illustrations, and an explanation of why the technique should be used. The discussion concerning the *why* of the technique should review similar techniques, point out how the new technique differs, and explain the advantages and disadvantages of the technique in comparison with other techniques.

20. Percentages should be accompanied by the numbers used to calculate them. When reporting nonsignificant results, a power analysis should be provided.
21. **Communications** articles, including official Position Statements and Policy Statements from the NATA Pronouncements Committee; technical notes on such topics as research design and statistics; and articles on other professional issues of interest to the readership are solicited by the *Journal*. An author who has a suggestion for such a paper is advised to contact the Editorial Office for instructions.
22. The manuscript should not have a separate summary section—the abstract serves as a summary. It is appropriate, however, to tie the article together with a summary paragraph or list of conclusions at the end of the discussion section.
23. References should be numbered consecutively, using superscripted arabic numerals, in the order in which they are cited in the text. References should be used liberally. It is unethical to present others' ideas as your own. Also, use references so that readers who desire further information on the topic can benefit from your scholarship.
24. References to articles or books, published or accepted for publication, or to papers presented at professional meetings are listed in numerical order at the end of the manuscript. Journal title abbreviations conform to *Index Medicus* style. Examples of references are illustrated below. See the *AMA Manual of Style* for other examples.

    Journals:
    1. van Dyke JR III, Von Trapp JT Jr, Smith BC Sr. Arthroscopic management of postoperative arthrofibrosis of the knee joint: indication, technique, and results. *J Bone Joint Surg Br.* 1995;19:517–525.
    2. Council on Scientific Affairs. Scientific issues in drug testing. *JAMA.*1987;257:3110–3114.

    Books:
    1. Fischer DH, Jones RT. *Growing Old in America.* New York, NY: Oxford University Press Inc; 1977:210–216.
    2. Spencer JT, Brown QC. Immunology of influenza. In: Kilbourne ED, Gray JB, eds. *The Influenza Viruses and Influenza.* 3rd ed. Orlando, FL: Academic Press Inc; 1975:373–393.

    Presentations:
    1. Stone JA. Swiss ball rehabilitation exercises. Presented at: 47th Annual Meeting and Clinical Symposia of the National Athletic Trainers' Association; June 12, 1996; Orlando, FL.

    Internet Sources:
    1. Knight KL, Ingersoll CD. Structure of a scholarly manuscript: 66 tips for what goes where. Available at http://www.journalofathletictraining.org/jat/66tips.html. Accessed January 1, 1999.
    2. National Athletic Trainers' Association. NATA blood borne pathogens guidelines for athletic trainers. Available at http://www.journalofathletictraining.org. Accessed January 1, 1999.
25. Table Style: 1) Title is bold; body and column headings are roman type; 2) units are set above rules in parentheses; 3) numbers are aligned in columns by decimal; 4) footnotes are indicated by symbols (order of symbols: *, †, ‡, §, ||, ¶); 5) capitalize the first letter of each major word in titles; for each column or row entry, capitalize the first word only. See a current issue of the *Journal* for examples.
26. All black-and-white line art should be submitted in camera-ready form. Line art should be of good quality; should be clearly presented on white paper with black ink, sans serif typeface, and no box; and should be printed on a laser printer—no dot matrix. Figures that require reduction for publication must remain readable at their final size (either 1 column or 2 columns wide). Photographs should be glossy black and white prints. Do not use paper clips, write on photographs, or attach photographs to sheets of paper. On the reverse of each figure attach a write-on label with the figure number, name of the author, and an arrow indicating the top. (Note: Prepare the label before affixing it to the figure.) Authors should submit 1 original of each figure and 4 copies for review.
27. Authors must request color reproduction in a cover letter with the submitted manuscript. Authors will be notified of the additional cost of color reproduction and must confirm acceptance of the charges in writing.
28. Legends to figures are numbered with arabic numerals in order of appearance in the text. Legends should be printed on separate pages at the end of the manuscript.
29. The *Journal of Athletic Training* follows the redundant publication guidelines of the Council of Science Editors, Inc (*CBE Views.* 1996; 19:76–77; also available on the *JAT* web site at http://www.journalofathletictraining.org). Authors found in violation of redundant publication will have sanctions invoked by the Journal Committee of the National Athletic Trainers' Association, Inc.

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30. Original Research manuscripts will be categorized under the following table of contents subheadings: clinical studies, basic science, educational studies, epidemiologic studies, and observational/informational studies.
31. Only Case Reports and Clinical Techniques that define and establish the optimal standard of care or the practice of athletic training will be considered for publication in *JAT*. All other Case Reports and Clinical Techniques will be considered for publication in the *NATA News*.
32. Media Reviews will appear in the *NATA News*.

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