

JOURNAL OF ATHLETIC TRAINING

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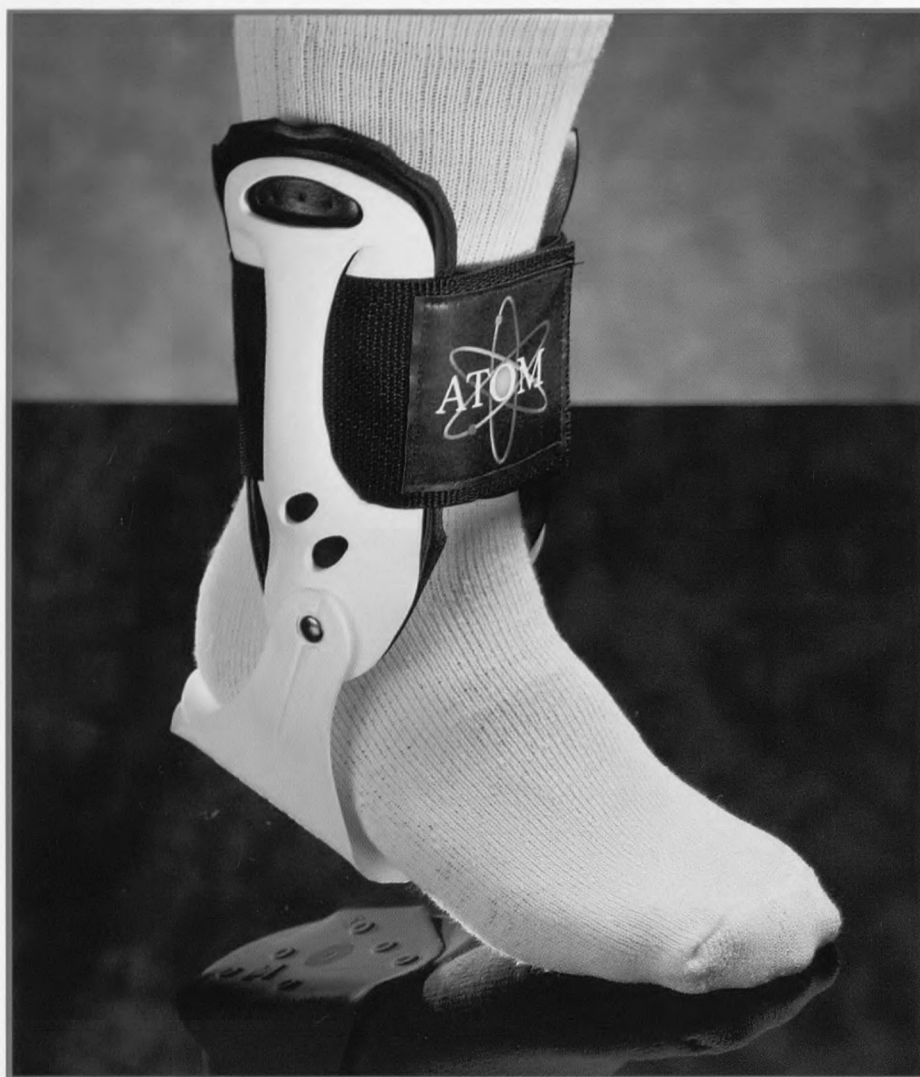
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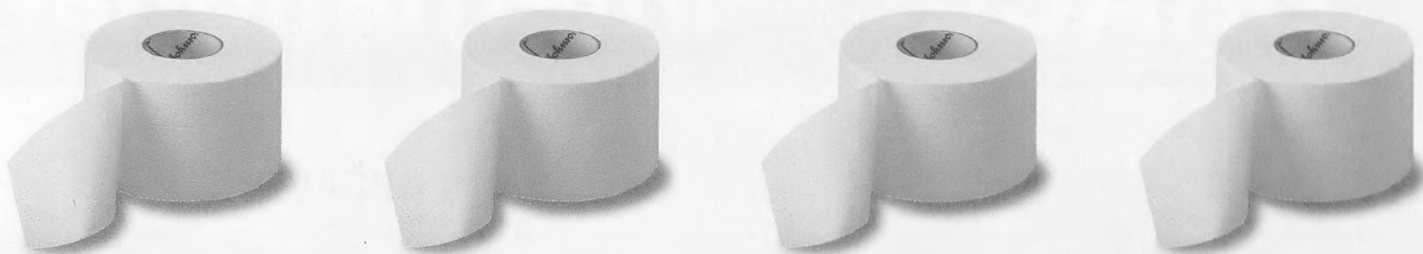
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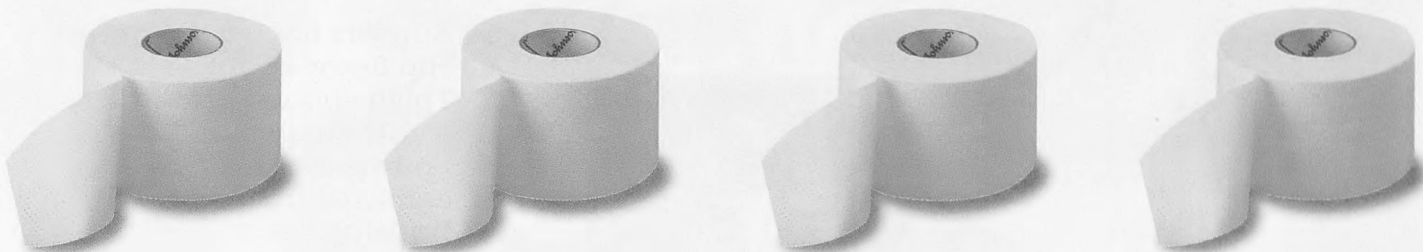
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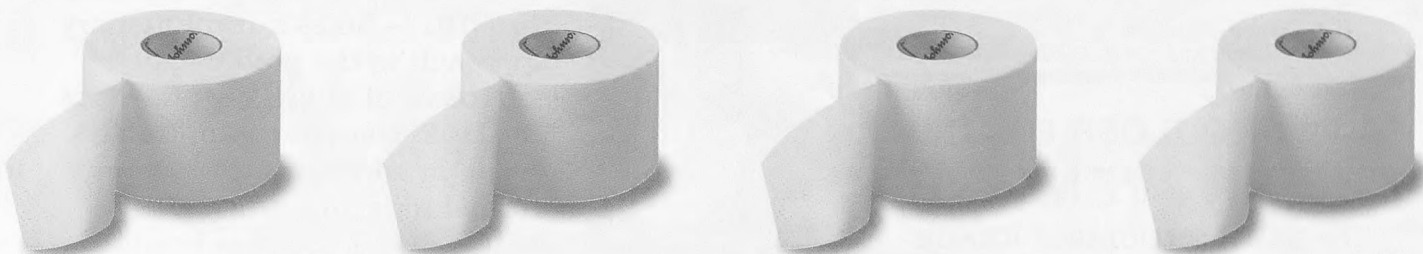
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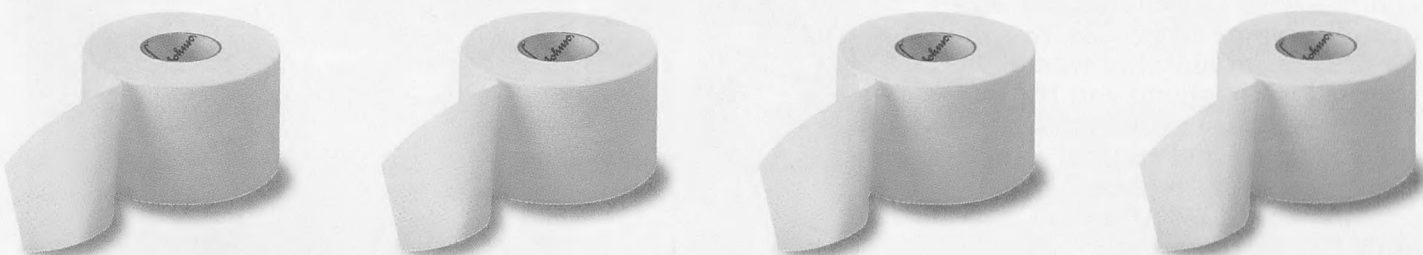
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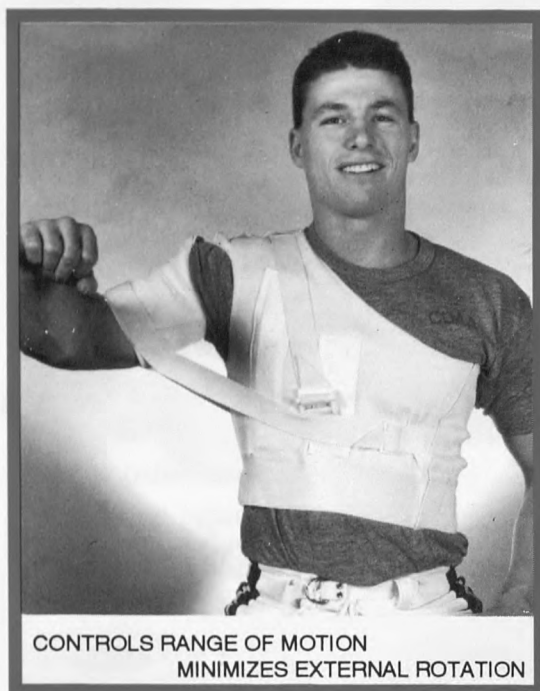


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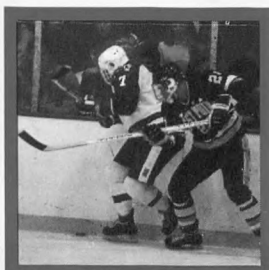
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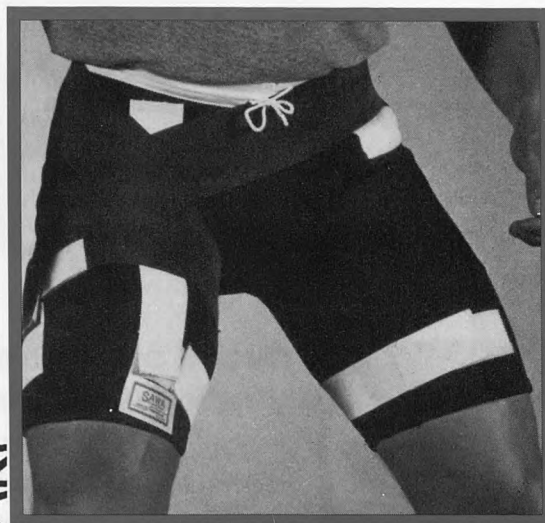
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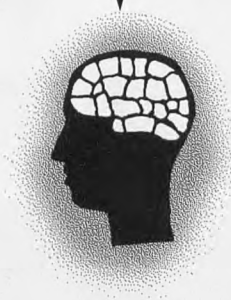
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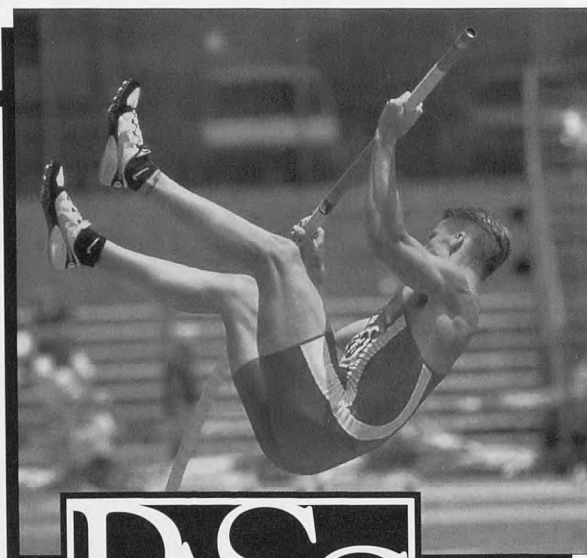
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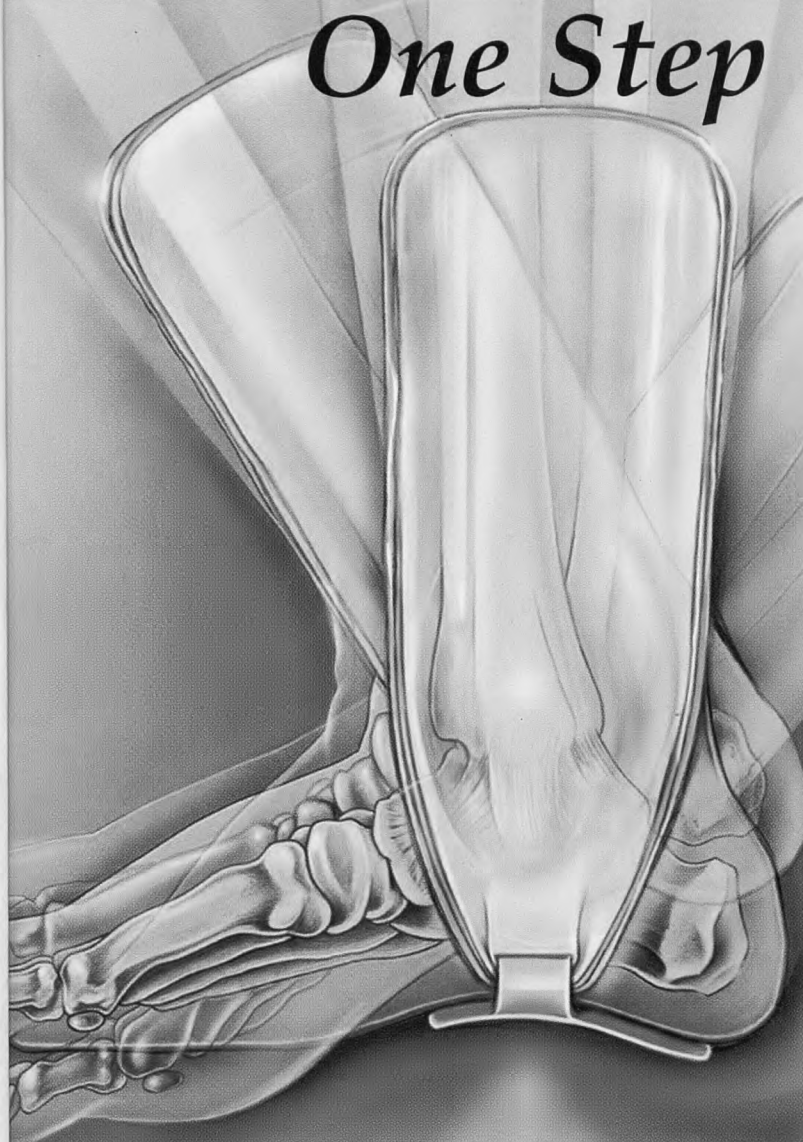
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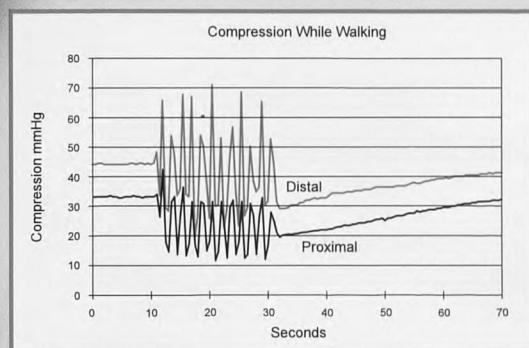
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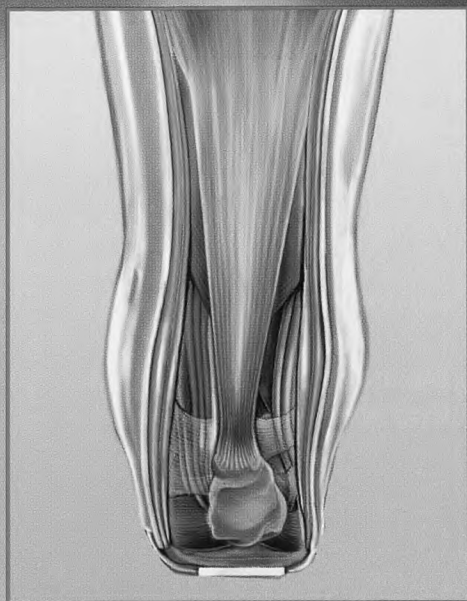
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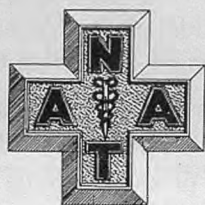
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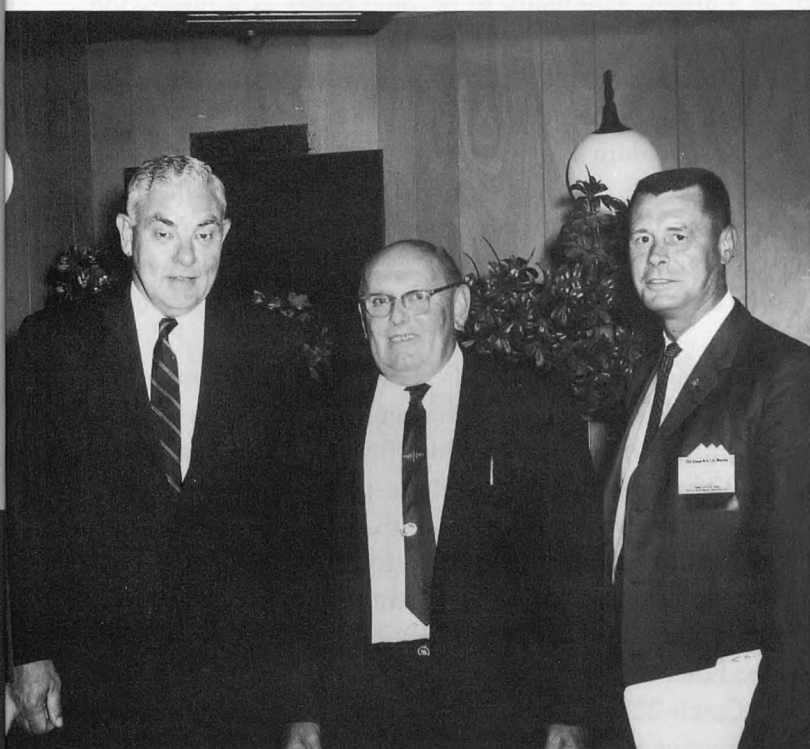
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The Evolving Roles of Athletic Training Educators and Clinicians

Brent Mangus, EdD, ATC
Associate Editor

The National Athletic Trainers' Association is quite young in comparison with many other professional health care organizations. Our struggle for a professional identity goes back more than 10 years. The size of the NATA provides a critical mass for acceptance as a profession by many but, at the same time, makes it difficult to produce change in such a large group with a variety of professional directions.

Now we venture into educational reform as a means to meet the rising standards of all allied health care professions. Many of us are aware of the upcoming changes in the educational practices for professional certification, and we need to prepare and be ready for these changes. In this educational transformation during the next 6 years, such changes in our educational programs will bring our professional preparation in line with other health care educational practices and standards. Although it has taken almost 50 years to get to this point, we must now make sweeping changes in our educational processes in less than 6 years. As with any change, we must be able to understand how and why this change will be better for us as a group. In this editorial, I hope to provide some rationale and reasoning for what I envision as a major portion of the forthcoming change. Individually, we must be willing to accept change, as hard as it may be, and begin to flourish as a group, eventually to become better as a profession.

Possibly one of the most significant changes we must all deal with is the concept of full-time teaching faculty being assigned to the didactic aspect of the entry-level educational program. This change will, in turn, affect the job descriptions and responsibilities of all those involved in the educational process. Clinical staff will, in most instances, now have minor involvement in the classroom education of the curriculum students. Program directors and full-time faculty educators who are not involved in the daily operation of the athletic training room will miss the daily interaction with students, as well as the hands-on portion of the profession. In order for the profession of athletic training to progress, we must adopt the educational model implemented by many of the other allied health professions. To this end, we must expect a further division in the clinical and classroom athletic trainer "role and responsibility" debate before we find resolution.

Some athletic training professionals will make a larger contribution and be more dedicated to the classroom portion of the educational process, and less of their time will be committed to the actual practice and competition aspects of the athletic teams. It is important to understand that, for most professionals in the field, often the faculty's absence from the clinical site is not a decision made by the individual. The assignment of faculty responsibilities is typically a university mandate. The university, college, or athletic department employing these people controls the professional activities of the employees and must view their daily activities as a valuable contribution to the departmental goals and objectives. Alternatively, the clinical staff has the primary responsibility for taking care of athletes and secondarily for educating student athletic trainers. This, then, is where we find the incompatible roles of professionals in our field. There are many reasons why this situation occurs; however, why it occurs at each university or college is not as important as how we as a profession deal with a "Catch-22" situation in which both education and the application of learned skills are critical elements. The most effective way to deal with this conflict of professional duties is to convince the university or college to allow the faculty member to use an athletic training room experience clinical component as the service element in the "teaching, scholarship, service" triad for tenure and promotion. Many university and college administrators do not see this type of service as a valuable contribution to the mission or goals of the university. Rather, they require a higher profile or professional society-type service to meet this requirement for tenure. Coincidentally, athletic departments are not typically charged with the educational progress of entry-level athletic training students but with fielding a successful athletics team.

If this is the case with the educational institution or athletics department, we need to make direct contact and appeal for change at the administrative level. We need a better understanding by our administrators of the current status of athletic training education and the development of our professional education reforms. In the interim, clinical and didactic faculty must work together and find a way to share the educational training of the entry-level student. It is quite difficult for the faculty member to be a part-time member of the clinical athletic training staff, because consistency is necessary when working with athletes and coaches. The clinical faculty must understand that including faculty members in the clinical program is going to be difficult at best. The teaching faculty must be patient as they promote the educational requirements of the students over the needs of the athletic department to field a successful sports team. The athletic training staff and faculty members at each institution must come together and become quite creative in finding ways to meet the needs of the students, staff, faculty, educational program, and university or college.

There are established programs at universities and colleges that meet the needs of all individuals involved in this dilemma and foster excellent working relationships among all parties. A single idea or method of resolving our problems is not going to work at every institution; however, your idea may work at another university. A workable solution for a problem at a smaller college may also be very effective at a larger university. We need to share our ideas on how these types of educational changes can occur in open forums such as the *Journal of Athletic Training*, national and district meetings, educators' workshops, and other forums. Some existing programs lack the necessary cooperation and consideration for a symbiotic relationship. Everyone in the profession needs to be more educated about, and more understanding of, both the process and the desired result as we seek professional change and eventually full recognition by all allied health professions, insurance providers, public and private schools, and many other groups.

For success to be achieved, every professional in our association should be aware of the pending educational changes and their ramifications. We cannot achieve this awareness overnight but, rather, will find ourselves pursuing steady gains over the coming years.

Effects of Strength Training on Strength Development and Joint Position Sense in Functionally Unstable Ankles

Carrie L. Docherty, MEd, ATC*; Josef H. Moore, PhD, PT†; Brent L. Arnold, PhD, ATC‡

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Objective: To examine the effects of ankle-strengthening exercises on joint position sense and strength development in subjects with functionally unstable ankles.

Design and Setting: Subjects were randomly assigned to a training or control group. The training group participated in a 6-week strength-training protocol using rubber tubing 3 times a week throughout the training period. The control group did not participate in the strength-training protocol.

Subjects: Twenty healthy college students (10 females, 10 males, age = 20.6 ± 2.23 years; ht = 176.40 ± 7.14 cm; wt = 74.18 ± 10.17 kg) with a history of functional ankle instability volunteered to participate in this study.

Measurements: We pretested and posttested dorsiflexor and evor isometric strength with a handheld dynamometer and collected joint position sense (JPS) data at 20° for

inversion and plantar flexion and at 10° for eversion and dorsiflexion.

Results: Statistical tests for strength and JPS revealed significant group-by-time interactions for dorsiflexion strength, eversion strength, inversion JPS, and plantar flexion JPS. Simple main-effects testing revealed improvements in training group strength and JPS at posttesting. There were no significant effects for eversion JPS, but the group main effect for dorsiflexion JPS was significant, with the experimental group having better scores than the control group.

Conclusions: Ankle-strengthening exercises improved strength, inversion JPS, dorsiflexion JPS, and plantar flexion JPS in subjects with functionally unstable ankles.

Key Words: proprioception, ankle sprains, rehabilitation

Inversion ankle sprains are the most common ankle injury, with more than 85% of all ankle sprains occurring to the lateral ligaments.¹ These injuries vary in their degree of severity and have been reported to produce a high incidence of chronic ankle instability that can affect both length of rehabilitation and level of participation in sport-related activities.^{2,3} Ankle instability has been attributed most frequently to joint laxity, muscle weakness, and proprioception deficits.⁴

It has been suggested that ankle sprains produce trauma not only to joint ligaments and supporting musculature, but also to sensory nerve fibers within the joint capsule.⁵ These nerve fibers provide feedback from the joint mechanoreceptors to assist in stabilization of the ankle during locomotion. Individuals with ankle sprains that result in ligamentous laxity may compensate by relying on muscle spindle, cutaneous, vestibular, or visual cues. One possible mechanism of compensation is provided by the muscle mechanoreceptors. It has been shown that muscle and tendon vibrations produce a sensation of joint movement.⁶ Specifically, movement is sensed in the direction that a vibrating

muscle would have been stretched. This indicates that muscle mechanoreceptors may aid in controlling joint motion and suggests that ankle rehabilitation might alter the sensitivity of these receptors.

One mechanism of acutely altering muscle mechanoreceptor sensitivity is via muscular contraction. Previous research has shown increased Group Ia sensory activity following muscle contraction.⁷ Similarly, it is believed that strength gains during the first 3 to 5 weeks of strength training are primarily due to neural factors.⁸ For example, strength training has been reported to influence motor unit recruitment, selective activation of agonist muscles and their motor units, and antagonist coactivation.⁹ However, it is unclear whether these longer-term neurologic effects extend to muscle proprioceptors. At least 2 studies^{10,11} have suggested a link between strength and proprioception, while others have not.^{4,12} Thus, the purpose of our study was to determine whether an ankle-rehabilitation protocol consisting of strengthening exercises had an effect on joint position sense (JPS) and strength development in subjects with functionally unstable ankles.

METHODS

Subjects

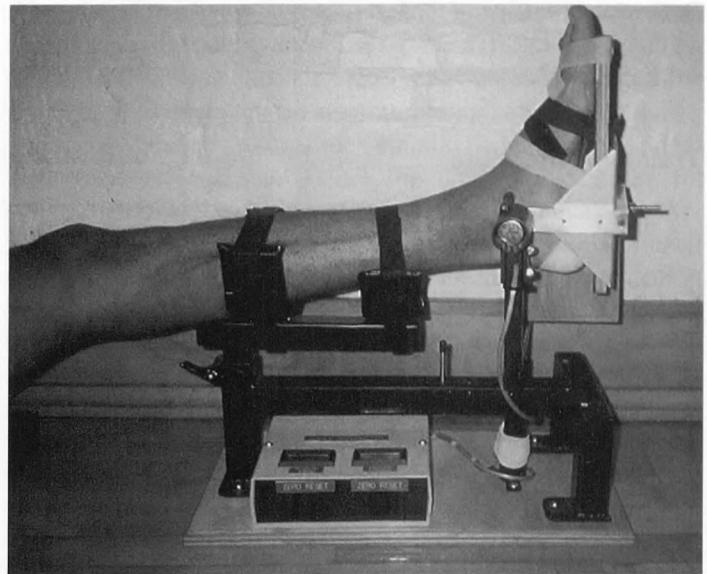
Twenty healthy college students (10 females, 10 males: age = 20.6 ± 2.23 years; ht = 176.40 ± 7.14 cm; wt = 74.18 ± 10.17 kg) volunteered to participate in this study. All subjects had a history of functional instability⁵ of the ankle and no history of other lower extremity injuries or other neuromuscular deficits. Functional instability was defined as a history of 3 or more ankle sprains in the last 5 years. Specific minimum inclusion criteria included a previous diagnosis of a moderate inversion ankle sprain and 1 episode of the ankle "giving way" during the last 12 months. All subjects were asymptomatic and physically active at the time of the study. The subjects were randomly assigned to either the training or control group, with an even number of males and females in each group. The study was approved by the University of Virginia's Human Investigation Committee, and all subjects read and signed a written consent form approved by the university before beginning the study.

Test Procedures

Only the functionally unstable ankle was used in these testing procedures. All subjects were pretested for dorsiflexor and evertor muscle isometric strength, as well as for JPS for the inversion-eversion and plantar flexion-dorsiflexion motions. All subjects performed strength testing before the JPS test. Additionally, each subject warmed up on a stationary bicycle at a comfortable level for 5 minutes before testing. All positioning and testing was performed by the same researcher.

Joint Reposition Sense Testing

Joint reposition sense measurements were taken with a custom-designed electronic goniometer (Figure). The device was rebuilt according to the specifications of Myburgh et al,¹³ with modifications to eliminate excessive movement during testing. First, a small, removable piece of wood was clamped to the transverse axis of rotation to eliminate sagittal plane movement during inversion-eversion testing. The piece of wood was then moved and clamped to the longitudinal axis to eliminate frontal plane movements during plantar flexion-dorsiflexion testing. Then, 2 pieces of hook-and-loop fastener fabric were attached to the footplate to assist in stabilization during the testing. Finally, a removable heel cup was fixed to the footplate to assist in accurate foot placement. Motion was detected by potentiometers placed on each axis of the goniometer. The potentiometers produced an analog signal that was digitally converted and numerically displayed on a liquid crystal display. All subjects were barefoot during testing to avoid positioning errors due to shoes. The subject's functionally unstable leg was supported in the leg rest in full extension, and the foot was placed against the footplate. The footplate was



Electronic goniometer.

positioned to place the ankle in subtalar joint neutral (STJN), and the goniometer was set to zero. Both the leg and the foot were fastened with hook-and-loop fastener fabric strips. The subject was blindfolded throughout the testing to eliminate any visual cues.

Once positioned, subjects were free to go through a full range of motion to familiarize themselves with the device. All subjects were tested at 20 degrees from STJN for inversion and plantar flexion and at 10 degrees from STJN for eversion and dorsiflexion. For each test position, we placed a block at that specific point in the range of motion, and each subject actively moved the foot until the footplate hit the block. Once in each test position, subjects were instructed to concentrate on the position for 15 seconds. The block was then removed, and subjects were instructed to move the foot to the opposite extreme of motion. We then instructed the subjects to move the foot back to the test position. This was repeated for 3 trials, and the difference between the subject's reposition angle and the test angle was recorded as the JPS error. The mean of the 3 trials was used for analysis. Measurements were taken from the electronic readout to the nearest degree.

Strength Testing

A handheld dynamometer (MicroFET2, MicroFET, Draper, UT) was used for the isometric strength testing. All subjects were barefoot during the testing procedures, and peak force was measured by the dynamometer to the nearest 0.1 N. The functionally unstable ankle was tested for both dorsiflexor and evertor strength. To test strength, subjects were positioned with the foot off the end of the table in the supine or side-lying position for dorsiflexion or eversion, respectively. All testing was done consistent with the procedures outlined by Daniels and Worthingham.¹⁴ All contractions were sustained for 3 seconds while the examiner applied an unmoving resistance.

Both muscle-testing procedures were repeated for 3 trials, with a 10-second rest between trials. The highest of the 3 isometric values was recorded as the subject's peak force.¹⁵

Training Procedure

Subjects in the experimental group trained with the unstable ankle 3 times a week for 10 minutes each day. The training protocol was based on clinical experience and was designed to provide progressive resistive exercise and a sufficient training overload. The progressive training protocol (Table 1) consisted of 6 weeks of strength training using elastic tubing (Thera-Band Tubing Resistive Exerciser, The Hygenic Corporation, Akron, OH). For training, each subject sat on the floor with one end of the elastic band attached to a table and the other end attached to the leg. For all exercises, subjects remained on the floor in the seated or semireclined position, with the knee fully extended. Subjects were instructed to use only the ankle joint and not to allow leg movement during the exercises. Once seated, subjects stretched the elastic band to a designated mark on the floor, which was calculated to be 70% of the band's maximal stretch. During each exercise session, subjects performed inversion, eversion, plantar flexion, and dorsiflexion.

Control subjects were asked to refrain from strength training or applying other treatments to their ankles during the study period. However, they were permitted to continue normal daily activities and to maintain current physical activity levels.

Statistical Analysis

A repeated-measures multivariate analysis of variance (MANOVA), with pretest to posttest measures as a within-subjects factor and group membership and gender as between-subjects factors, was performed on the 6 dependent measures. Significant multivariate tests were followed by univariate analyses of variance. Significant univariate F tests were tested post hoc to locate specific group differences. The α level for all statistical tests was .05.

RESULTS

The MANOVA produced a significant Wilks λ ($\lambda = 0.13$, $P < .0005$) for the group-by-time interaction when all the dependent variables were considered simultaneously. Based on this result, gender was eliminated as a factor in subsequent ANOVAs. The mean values for strength and JPS are presented

in Tables 2 and 3, respectively. Univariate tests for strength and JPS revealed significant group-by-time interactions for dorsiflexion strength ($F_{1,18} = 66.07$, $P < .0005$), eversion strength ($F_{1,18} = 9.99$, $P = .005$), inversion JPS ($F_{1,18} = 8.52$, $P = .009$), and plantar flexion JPS ($F_{1,18} = 5.79$, $P = .027$). Simple main-effects testing revealed improvements in training group strength (Table 2) and JPS (Table 3) at posttesting. Additionally, JPS univariate tests revealed no significant effects for eversion JPS, but a significant group main effect for dorsiflexion JPS ($F_{1,18} = 4.55$, $P = .047$), with the experimental group having better scores than the control.

DISCUSSION

Proprioception is the general term attached to the use of proprioceptor inputs to control human movement and posture. If these inputs are perceived by the individual, the more specific term "kinesthesia" is used.¹⁶ The relationship between ankle joint function and proprioception has been previously established.^{4,10,12,17} However, the relationship between joint strength and proprioception is not as clear. For example, a significant relationship between lower extremity muscle strength and postural sway has been demonstrated in the elderly,¹¹ and increases in postural sway and ankle weakness have also been reported in soccer athletes.¹⁰ In contrast, others^{4,12} have not found simultaneous decreases in strength and proprioceptive measures. One reason for this may be the different methods used to assess proprioception. For example, those studies demonstrating proprioceptive deficits^{10,11} used protocols employing active muscle contractions, whereas Lentell et al^{4,12} used either a passive protocol or a rather crude measure of proprioception.

Our results indicate that ankle-strengthening exercises improve inversion JPS and plantar flexion JPS in subjects with functionally unstable ankles. Theoretically, there are two possible sensory mechanisms that may have produced the change. It is possible that joint mechanoreceptors were stimulated by the motion of the exercise, resulting in an increased sensitivity. However, we feel this is not likely. Joint mechanoreceptors respond specifically to extremes in the range of motion and local compression.¹⁸ While our training protocol was performed throughout the entire range of motion, the JPS testing was done only in the midrange of the total range of motion. Thus, we feel that the joint mechanoreceptors were not

Table 1. Resistive Tubing Training Protocol

Week	Tubing	Sets \times Repetitions
1	blue—extra heavy	3 \times 10
2	blue—extra heavy	4 \times 10
3	black—special heavy	3 \times 10
4	black—special heavy	4 \times 10
5	silver—super heavy	3 \times 10
6	silver—super heavy	4 \times 10

Table 2. Control and Experimental Group Mean Strength (N) Scores and Standard Deviations

Movement	Pretest	Posttest
Dorsiflexion		
Control	33.8 \pm 7.2	33.9 \pm 5.0
Experimental	33.3 \pm 4.8	50.6 \pm 6.3*
Eversion		
Control	30.8 \pm 6.0	27.7 \pm 11.6
Experimental	30.9 \pm 6.5	45.0 \pm 4.9*

* Significantly different from control.

Table 3. Control and Experimental Group Mean Joint Position Sense Scores (Degrees of Error) and Standard Deviations

Movement	Pretest	Posttest
Inversion		
Control	6.3 ± 3.17	6.4 ± 2.63
Experimental	6.8 ± 5.0	2.8 ± 2.8*
Eversion		
Control	4.1 ± 2.9	3.8 ± 3.1
Experimental	4.6 ± 4.3	2.1 ± 1.5
Dorsiflexion		
Control	4.6 ± 1.8	4.78 ± 2.1
Experimental	4.2 ± 3.6	1.9 ± 1.2
Plantar flexion		
Control	6.5 ± 4.7	5.5 ± 3.6
Experimental	7.9 ± 6.0	1.4 ± 0.9*

* Significantly different from control.

stimulated due to the lack of extreme range of motion or compression in the testing procedures. However, even if our protocol did stimulate the mechanoreceptors, it has been demonstrated that anesthetizing the joint ligaments and capsule does not affect postural sway or JPS measures.¹⁹ These findings add further support to our belief that the joint mechanoreceptor mechanism is not responsible for the changes we noted.

We believe the more likely mechanism for our results was the muscle spindle. The muscle spindle has two basic physiologic responses. The static response signals sustained spindle length (ie, sustained muscle stretch) and instantaneous spindle length,²⁰⁻²² while the dynamic response signals the rate of length changes.²² In addition to the sensory endings, the spindles also receive connections from static and dynamic gamma-efferent nerves, which enhance the afferent responses.^{23,24} We believe it is possible that the strength training may have increased gamma-efferent activity. Specifically, the spindle may have been more sensitive to instantaneous stretch, resulting in greater acuity in sensing joint position. For example, the training of the evertors and dorsiflexors may have increased the amount of static gamma-efferent activity to the spindles of these muscles. Thus, at posttraining, the evertor and dorsiflexor spindles may have been more sensitive to stretches resulting from inversion and plantar flexion, respectively. It is also possible that dynamic gamma efference increased the sensitivity to the rate of length changes. However, because we used a relatively slow, active motion to assess JPS, it is unlikely that the dynamic spindle receptors were stimulated by our testing protocol. It is important to note that there were no statistically significant improvements for eversion JPS. The reason for this is unclear. Unfortunately, strength data for the invertors were not collected. Thus, it is not possible to establish a relationship between strength and JPS for this muscle group.

Another possible effect of strength training on JPS may have been an improvement in the alpha-gamma coactivation. During volitional concentric contraction, simultaneous activity in the alpha and gamma motor neurons has been reported.^{25,26} Additionally, spindle firing in the contracting muscle has been

observed.²⁷ Since muscle shortening is known to decrease primary-ending firing frequency (even during static and dynamic gamma stimulation),²⁸ the likely function of this coactivation is to maintain an appropriate spindle length during contraction, thereby maintaining spindle firing during shortening. However, our data do not support this mechanism for improving JPS. Specifically, there was an increase in evertor strength without a corresponding increase in eversion JPS. If this mechanism had been responsible for improving JPS, eversion JPS should have improved with strength.

It is also possible that practice of these joint motions without any resistance may have improved JPS. However, this does not seem likely due to the lack of JPS improvement for eversion. Had practice alone been a sufficient stimulus for improvement, improvements in all directions would have been expected.

Other studies using normal²⁹ or functionally unstable ankles^{30,31} have also demonstrated positive balance effects with training protocols involving joint motion. Combined strength and balance training has been shown to improve balance-board performance.³¹ Unfortunately, because the training included both balance and strength components, it was not possible to determine the individual effects of either component. Similarly, ankle-disk training with functionally unstable ankles has been shown to decrease postural sway in both stable and unstable ankles.³⁰ These researchers argued that the bilateral effects of unilateral training suggest a central mechanism of balance improvement rather than the peripheral mechanisms (ie, spindle receptors) we propose. In contrast, Cox et al³² demonstrated no difference in postural sway after balance training without joint motion. Thus, it appears that strength training, proprioceptive training, and combinations of both improve proprioception, balance, or both, provided the training involves joint motion. Questions remain as to what combination of these treatments is optimal and what mechanisms are involved.

Finally, our results revealed a significant main effect in dorsiflexor JPS scores between the control group and training group, which were not different initially. The training group improved sufficiently after training to produce the significant main effect, but not sufficiently to produce a significant interaction.

CONCLUSIONS

We found that our training protocol increased strength, inversion JPS, dorsiflexion JPS, and plantar flexion JPS in subjects with functionally unstable ankles. These findings suggest that strength training can play the dual role of increasing both strength and joint position sense. Our results are most likely due to changes in muscle spindle sensitivity or in central mechanisms related to the spindles, rather than joint mechanoreceptor sensitivity. We believe the training protocol may have increased the gamma motor activity,^{23,24} improved central mechanisms of motor control,³⁰ or produced a combination of central or spindle mechanisms. Future research should

be designed to more specifically detect differences due to gamma activity, alpha-gamma coactivation, or central mechanisms.

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Open and Closed Kinetic Chain Exercises Improve Shoulder Joint Reposition Sense Equally in Healthy Subjects

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Objective: To compare the effects of open and closed kinetic chain exercise on shoulder joint reposition sense.

Design and Setting: Subjects with no previous upper extremity injury participated in a 6-week exercise program consisting of 3 sessions per week.

Subjects: Thirty-nine healthy male military cadets: 13 each in the open, closed, and control groups.

Measurements: Each subject was pretested and posttested for both active and passive joint reposition sense at 30° external rotation, 30° internal rotation, and 10° from full external rotation.

Results: The open and closed kinetic chain groups decreased in reposition sense error scores in comparison with the control group, but no difference was found between the 2 training groups.

Conclusion: Our findings suggest that shoulder joint reposition sense can be enhanced with training in healthy subjects. Also, open and closed kinetic chain exercises appear to be equally effective in improving shoulder joint reposition sense.

Key Words: proprioception, glenohumeral, strength

Proprioception, the combined functions of joint position sense and kinesthesia, has been identified as an important aspect of athletic injury rehabilitation.¹⁻⁶ Joint injury can affect proprioception, disrupting the normal neuromuscular reflexes that serve to protect the joint. Much of the early proprioceptive research focused on ankle and knee instability and produced recommendations on how to treat these proprioceptive deficits.^{3,4,7-11} As such, proprioceptive exercises are commonly prescribed for rehabilitation from lower extremity injury.

More recently, shoulder proprioception has gained attention, especially in instability of the shoulder. Smith and Brunolli¹² demonstrated that subjects with anterior shoulder instability performed more poorly on joint reposition sense testing with the involved shoulder than the uninvolved shoulder. Lephart et al⁵ also found proprioceptive deficits in unstable shoulders. After surgical reconstruction, shoulder proprioception returned to the same level as that of the uninvolved side.⁵

Proprioceptive exercises have been recommended to improve neuromuscular control in individuals with shoulder instability.^{5,13-15} Proprioceptive training may improve the musculoskeletal system's ability to give appropriate feedback to the central nervous system, optimizing joint stability and function. Proprioceptive rehabilitation also enhances cognitive awareness relative to position, motion, and muscular stabilization in the absence of structural restraints. Additional research is needed to determine what types of exercise are optimal for enhancement of shoulder joint proprioception.

Shoulder rehabilitation exercises have been classified as open or closed kinetic chain. In open kinetic chain (OKC) exercise, the terminal segment of the extremity moves freely without any external resistance.¹⁶ The sequential activation of muscles in OKC exercise from proximal to distal allows rapid acceleration and speed of the distal segment.^{13,16,17} Because the upper extremity often functions in an OKC position, this type of exercise is frequently used in rehabilitation settings. In closed kinetic chain (CKC) exercise, the distal segment of the extremity is fixed, and proximal motion takes place in multiple planes.^{13,16} Closed kinetic chain exercise is thought to establish early proximal stability of the joint, providing a stable base for the upper extremity to function.¹³ Furthermore, CKC exercise may train the shoulder girdle musculature to appreciate its own static and dynamic functions.¹³ A shortfall of CKC exercise is that minimal acceleration of the distal extremity is allowed, and this is a key component of upper extremity athletic performance.

Recent reports in the literature have recommended various exercise programs to enhance proprioceptive reposition sense.^{13,18-20} The purpose of our study was to compare the effects of OKC versus CKC exercises on joint reposition sense of the shoulder in adolescent athletes.

METHODS

Subjects

The dominant, injury-free shoulder of 39 volunteer male cadets (age = 16.31 ± 1.54 years; ht = 177.47 ± 4.2 cm; and

wt = 78.70 ± 17.42 kg) was studied. The subjects participated in multiple sports at a military academy but engaged in no active weight training during the study. There was no change in routine activities, including military duties, except for the exercise protocol. We randomly assigned the subjects in equal numbers to 3 groups ($n = 13$). Subjects in group 1 performed an OKC exercise, while subjects in group 2 participated in a CKC exercise. Subjects in group 3, the control group, did no upper extremity exercise for the duration of the study. None of the subjects were familiar with the testing protocol or the testing device. The University of Virginia Committee for the Protection of Human Subjects approved the study, and each subject and his parent or guardian signed a statement of informed consent before participation.

Instrumentation

We used a Cybex II isokinetic dynamometer (Lumex, Ronkonkoma, NY) to assess passive and active shoulder joint reposition sense at 30° of internal rotation, 30° of external rotation, and 10° from full external rotation (active range of motion). Subjects were positioned supine on the Upper Body Exercise Table (Lumex, Ronkonkoma, NY) during testing. Two bathroom scales (model 1706, Healthometer, Saint Louis Park, MN) were used to determine the criterion weight for the OKC exercise group. A flexometer (model 67010, Leighton, Spokane, WA) was attached to the arm of the Cybex to determine the angle of shoulder rotation (Figure 1).

Assessment of Joint Proprioception

Before the training program began, we pretested all subjects for active and passive joint reposition sense. We positioned the subjects supine on the Upper Body Exercise Table with the shoulder joint axis aligned with the axis of rotation of the Cybex. Each subject's upper extremity was placed in 90° of elbow flexion, 90° of shoulder abduction, and neutral rotation. We applied an elastic wrap to each subject's hand to minimize tactile sensation from the lever arm of the Cybex. The orders of the active and passive testing and the angles of reproduction were counterbalanced. For the passive joint reposition test, we instructed subjects to relax while the shoulder was moved by the experimenter to one of the 3 predetermined angles and held for a total of 10 seconds. Once the shoulder was returned to the neutral position, the subject's shoulder was passively repositioned to the test position. We instructed the subjects to say "stop" when they sensed the test position was replicated. The angle at which this occurred was recorded and subtracted from the initial, predetermined angle. This difference was termed the "error." The examiner performed all passive movements at the speed of $6^\circ \cdot \text{sec}^{-1}$, as measured by the Cybex II dynamometer. The procedure was repeated twice at the same angle, and an average of the absolute value of the 3 errors was used for statistical analysis. The remaining 2 angles were tested in the same manner. Active testing was performed using the same



Figure 1. A flexometer was attached to the arm of the Cybex to determine the angle of shoulder rotation.

methods, except each subject actively moved the shoulder to the predetermined test angle with our guidance, then returned to the neutral position before attempting to actively replicate the angle. After 6 weeks of training, subjects were posttested in an identical manner.

Exercise Protocol

Subjects participated in the training program for 6 weeks. The subjects assigned to the CKC training group performed 3 sets of 15 repetitions of standard push-ups 3 days per week. The subjects in the OKC group performed 3 sets of 15 repetitions of the supine dumbbell press 3 days per week. To determine the criterion weight, we asked each subject to assume the up and down push-up position with each hand on identical bathroom scales. The average weight of the up and down push-up position was defined as the criterion or training weight (mean = 26.6 ± 6.55 kg). While the 2 exercises (dumbbell press and push-up) are somewhat different, we attempted to equate them by a criterion weight. The amount of weight lifted for the OKC group was 75% of the criterion weight for the first 2 weeks (mean = 20.6 ± 5.03 kg), 85% of the criterion for weeks 2 through 4 (mean = 23.3 ± 5.66 kg), and 95% the final 2 weeks (mean = 25.9 ± 5.98 kg). The control group performed no upper extremity exercises.

Mean Absolute Error Scores (degrees) \pm Standard Deviations for Pretest and Posttest Joint Position Sense

	30° IR*		30° ER†		10° from Full ER	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
OKC‡	5.41 \pm 1.43	2.12 \pm .88	5.66 \pm 2.18	1.88 \pm .82	6.63 \pm 2.19	2.04 \pm .87
CKC§	5.27 \pm 1.86	2.18 \pm 1.36	5.90 \pm 2.83	2.83 \pm 2.83	6.71 \pm 3.09	2.60 \pm 1.80
Control	4.69 \pm 1.55	5.11 \pm 1.75	6.38 \pm 4.57	5.57 \pm 2.54	6.04 \pm 2.97	6.59 \pm 3.67

* IR, internal rotation.

† ER, external rotation.

‡ OKC, open kinetic chain.

§ CKC, closed kinetic chain.

Data Analysis

The average error scores were analyzed with a mixed-model analysis of variance (ANOVA) with type of training (OKC, CKC, control) as the between-subjects variable and test (pretest versus posttest), angle (30° internal rotation, 30° external rotation, or 10° from full external rotation), and motion (active versus passive) as the within-subjects variables. Tukey post hoc analyses were performed for significant effects. An α level of $P < .05$ was used for all statistical analyses.

RESULTS

The mean error scores obtained for each angle tested are listed in the Table. The ANOVA revealed a significant group-by-test interaction ($F_{2,36} = 29.29$, $P < .001$) (Figure 2). A Tukey post hoc analysis revealed that both the CKC and OKC groups showed significant decreases in mean error score from pretest to posttest in comparison with the control group, which did not show pretest to posttest changes. There was no significant difference between the 2 exercise groups.

A main effect for joint angle was also found ($F_{2,72} = 8.21$, $P < .001$). Ten degrees from full external rotation and 30° internal rotation had significantly less mean error than 30° external rotation. There was no difference between 10° from full external rotation and 30° internal rotation. No main effect

($F_{1,36} = 0.34$, $P = .56$) was found for active versus passive range of motion.

DISCUSSION

The primary finding of our study was that the OKC and CKC exercise groups had significantly improved joint reposition sense from pretests to posttests when compared with the control group. The exercise groups were better able to reproduce angles and had a better awareness of the location of their upper extremity in space in comparison with the control group. This finding is for our subjects who participated in multiple sports at a military institute and cannot necessarily be generalized to all 16-year-old males.

Previous investigators have explored the adaptive effect of upper extremity and lower extremity activity on proprioception.^{1,8} Allegrucci et al¹ found that athletes who participated in unilateral upper extremity sports had greater difficulty detecting motion in the dominant shoulder when compared with the nondominant shoulder. Barrack et al⁸ found that members of a professional ballet company scored more poorly than controls in joint reposition testing of the knee. These authors theorized that decreased proprioceptive sense was due to joint hypermobility in the 2 subject populations. The effect of a specific training regime designed to correct these proprioceptive deficits was not assessed.

In contrast to Allegrucci et al¹ and Barrack et al,⁸ another study found that trained athletes may have heightened proprioceptive awareness.²¹ Lephart et al²¹ demonstrated that gymnasts had a better threshold to detection of knee motion than nonathletic controls.²¹ These investigators also reported that training may refine proprioceptive awareness in athletes with ligament injury and diminished proprioception.²¹ However, further research is needed in this area.

It is not surprising that highly trained athletes (without joint hypermobility) have better joint reposition sense than nonathletes. We were impressed that performing only 1 resistance exercise 3 days a week for 6 weeks made a difference in joint reposition sense in uninjured individuals. Moreover, the exercises used in our study were not specifically designed to train the proprioceptive system, as opposed to the exercises used in other studies.^{2,18}

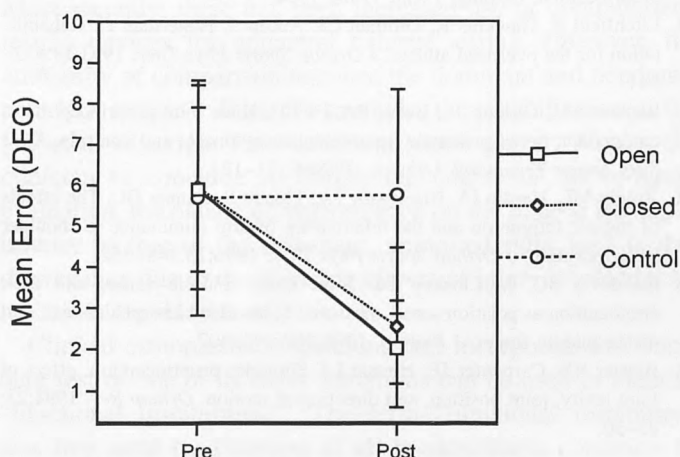


Figure 2. Both the open and closed kinetic chain groups showed significant decreases in mean error score from pretest to posttest.

The mechanism for the improvement of shoulder joint reposition sense in our study is most likely related to the additional stimulation of the joint and muscle receptors brought about by the resistance exercise. How these receptors and the corresponding afferent-efferent loops adapt to bring about these improvements in proprioception is not entirely clear. Receptors responsible for detecting joint position include the Pacinian corpuscles and Ruffini end-organs found in the joint capsule and the Golgi tendon organs and muscle spindles found in the muscle. All these receptors are sensitive to changes in tension within the muscle (Golgi tendon organs and spindles) or noncontractile tissues (Pacinian corpuscles and Ruffini end-organs).

Voight et al²² assessed joint reposition sense in uninjured subjects before and after a shoulder-fatigue protocol. They found significantly greater error in both active and passive reposition testing immediately after strenuous exercise to fatigue when compared with the pretest. These authors emphasized the importance of the muscle receptors in the detection of joint position sense.

Gandevia and McCloskey²³ attempted to isolate the contributions of the joint and muscle receptors to position sense. With the distal interphalangeal joint anesthetized, the ability to detect motion, although altered, was still intact.²³ Thus, it is likely that a combination of both joint and muscle receptors is responsible for joint proprioception.

The relative importance of each type of receptor may be related to the particular position in which the joint is placed.⁹ In the midrange of joint motion, movement results in significant length changes in the muscle, but the tension in the joint capsule increases relatively little.⁹ However, in the endrange of motion, small changes in joint motion are accompanied by large increases in capsule tension that are easily detected by the joint receptors.⁹ In these endranges of motion, there may be only a small amount of change in muscle length, resulting in relatively little stimulation of the muscle mechanoreceptors. In our study, the 30° internal rotation position had a significantly smaller error with reposition testing, along with 10° from full external rotation. These findings are supported by Blasier et al,²⁴ who found the least error in the externally rotated position and theorized that it was due to the increased tautness of the joint capsule. The joint capsule is also taut when moving into internal rotation. It may be that the muscle receptors are just as important as the capsule receptors in controlling joint reposition sense; however, one cannot credit the training sessions, since the difference between the joint angles was a main effect and thus included scores from pretests and posttests.

The clinical implications of our findings are that both OKC and CKC resistance exercise improved joint reposition sense in healthy subjects. A strengthening program designed to improve neuromuscular control may also be of benefit to individuals with shoulder proprioceptive deficits. Further study using subjects with unstable shoulders is needed to confirm our clinical impressions.

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Unilateral Postural Control of the Functionally Dominant and Nondominant Extremities of Healthy Subjects

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Objective: To determine whether a difference in unilateral postural stability exists between the functionally dominant and nondominant legs of a healthy population.

Design and Setting: The unilateral postural control of both legs of healthy subjects was tested using a force platform. Before the postural control examination, each subject performed a series of functional tests to determine functional leg dominance.

Subjects: Ten healthy young adults with a mean age of 19.2 ± 3.2 years volunteered for this study.

Measurements: Functional leg dominance was determined through the use of a battery of tests that included 3 separate evaluations of lower extremity dominance for functional activity. Two measures of postural control, sway area (SA) and sway path length (SPL), were collected for both the dominant and nondominant legs of all subjects. An analysis of variance (ANOVA) was used to determine whether a difference in postural control between the 2 legs was present.

Results: A subject \times leg repeated-measures ANOVA was conducted on both dependent variables, SA and SPL. The SA ANOVA value was not significant. The mean value for the dominant-leg SA measurement was $9737.43 \pm 303.36 \text{ mm}^2$, whereas the mean SA for the nondominant leg was $9431.74 \pm 349.97 \text{ mm}^2$. The SPL ANOVA also showed no significant difference in the bilateral comparison. The mean SPL for the dominant leg was $4321.57 \pm 630.0 \text{ mm}$, and the mean SPL for the nondominant leg was $4341.88 \pm 1,013.31 \text{ mm}$.

Conclusions: We found no difference in unilateral postural stability between the functionally dominant and nondominant lower limbs in a healthy population of young adults. This is of particular interest to the clinician who commonly uses single-leg postural control evaluations in the assessment of an athlete's level of progress in the rehabilitation setting.

Key Words: rehabilitation, functional return

Routine progress evaluations performed on athletes with injuries to the lower extremity commonly incorporate single-leg balance testing, where the performance on the uninjured leg is used as a reference for comparison. Typically, these evaluations are subjective and sometimes ambiguous because of undetermined effects of leg dominance. More recently, there has been increased use of computerized testing devices for unilateral balance testing. However, the ambiguity of comparison between the dominant and nondominant legs remains. Take, for example, the rehabilitation of the left ankle of a right-foot-dominant soccer player. What is the clinician to conclude if, during the course of the progress evaluation, the balancing performance on the injured left leg is inferior to that of the dominant, uninjured right leg? Is this discrepancy due to the lingering effects of injury or could it be related to leg dominance?

Clinical orthopaedic evaluations that incorporate the Romberg test or one of its many variations can be used to identify "functional instabilities."¹ The term "functional instability" was first used by Freeman et al¹ to describe a condition in which subjects complained of their ankle "giving way." In addition to identifying single-leg balance testing as a reliable

indicator of functional instabilities, Freeman and colleagues provided sound support for the use of single-leg proprioceptive training to decrease the effects of functional instabilities. Since that time, clinicians have continued to use single-leg stance manipulations for both the evaluation and rehabilitation of proprioceptive deficits related to orthopaedic injury. However, there has been little investigation into the variability between an individual's healthy legs due to lower limb dominance. The failure to consider the existence of interleg differences related to leg dominance may be problematic in testing situations where one leg serves as a control for the other leg.

An existing problem with the study of dominance is the lack of consensus in the definition and the determinants of limb dominance. In theory, limb dominance can be established on the basis of strength, functional use, and personal preference, as well as other parameters. The literature is equivocal as to which parameters indicate dominance and how dominance can be determined. Such methods as a simple ball kick,²⁻⁴ a step test,⁵ a single-leg hop-for-distance test,⁶ and self-reporting by the subject⁷ appear in the literature. Leg dominance as a factor in strength, function, and personal preference requires consideration. For example, the question remains: Do certain athletes

display different leg dominances for activities such as single-leg jumping (strength) and soccer-goal shooting (function)?

The results of simple postural control evaluations, such as the Romberg test, assist clinicians in many ways. Specifically, they are used in the evaluation of the effects of injury, the development of rehabilitation protocols, and the determination of return-to-participation status. Proprioceptive deficits associated with functional instability have been seen after joint injury.¹ Furthermore, single-leg proprioceptive balance training of injured subjects,^{1,8-10} as well as healthy subjects,¹¹ has been shown to be effective in the rehabilitation of orthopaedic lower extremity injuries.¹² Therefore, it is helpful for the athletic trainer and physical therapist to understand postural control measurement techniques. Furthermore, an understanding of postural control measurements and leg dominance will improve the clinician's ability to evaluate lower limb injuries and their progression.

In order to assess leg dominance effects on postural control, leg dominance must first be defined and the method used to determine the dominant leg must be established. For postural control, leg dominance should be determined in a way that challenges the subject to rely on a single limb for a variety of functional activities. Numerous studies have looked at leg dominance,²⁻⁶ but to date there have been no reports of a standardized battery of tests for determining leg dominance. The primary role of a rehabilitation program is functional return to activity. Therefore, the tests used to determine leg dominance should be related to function.

The purpose of our study was to determine whether a difference exists in the ability to control single-leg stance between the functionally dominant and nondominant legs of a healthy population based on a battery of functional dominance tests.

METHODS

Ten healthy subjects (5 female, 5 male, mean age = 19.2 ± 3.2 years) were tested on a single day. The total testing time per subject was less than 1 hour. The study was approved by the Indiana University Committee for the Protection of Human Subjects. Each subject first performed a block of 6 force-platform trials on the dominant leg and then changed to the nondominant leg. The method of leg-dominance determination is detailed in the following section. A force-platform trial consisted of 15 seconds of single-leg quiet standing on a Kistler Force Platform (Kistler Instrument Company, Amherst, NY) during which center-of-pressure changes were recorded at a frequency of 50 Hz. The force-platform trials were separated by 30 seconds of rest, and the blocks were separated by 5 minutes of rest.

Functional Dominance Determination

Functional leg dominance was determined with 3 functional tests: ball kick, step-up, and balance recovery. Three trials of

each test were conducted. The leg that was used for most trials was identified as the dominant limb for that specific test. The leg used as the dominant leg in most individual tests was categorized as the functionally dominant leg.

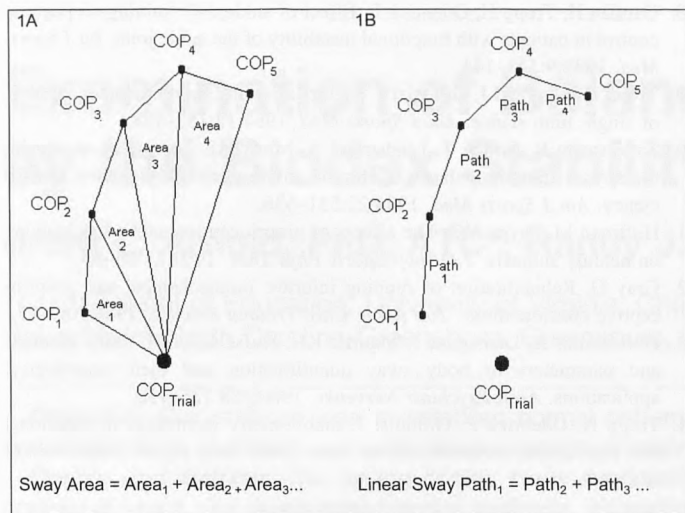
In the ball-kick test, the subject was asked to kick a soccer ball with moderate intensity and maximal accuracy through a set of cones placed 1 m apart and 10 m from the subject. The leg used to kick the ball was identified as the dominant leg. Successfully kicking the ball through the cones was not a criterion for this test. The step-up test required the subject to step onto a 20-cm high step. The leg used to perform the step-up was deemed dominant for each of the trials. In the final test, balance recovery, the subject was nudged off balance from behind by the tester. The perturbation was a nudge applied to the midpoint between the scapulae from directly behind the subject and sufficient to require the subject to respond by taking a step. The leg that the subject used to recover balance was considered the dominant leg for each of the 3 trials. This sequence of the 3 tests was the same for all subjects.

Postural Control Measurement

During each of the balance trials (6 per leg), the subject was asked to assume a comfortable, single-leg stance on the force platform. Before each trial, the subject was instructed to place hands on hips and focus on a visual target aligned at eye level and located 2 m in front of the platform. After a verbal signal from the subject indicating he or she was in a comfortable single-leg stance on the leg being tested, with self-selected hip and knee angles of the nonstance leg, the trial was initiated. In each case, the right leg was tested first. The dependent variables were total sway area (SA) and sway path length (SPL). For this study, the force platform was configured to collect medial-lateral and anterior-posterior data. From bidirectional data, the center of pressure (COP) was calculated for each of the sampling periods. SA was calculated by summing the areas of sway triangles within the sway envelope. A new SA triangle was constructed each time the system collected a sample (50 Hz). The points of the SA triangles were defined by the following COP locations: the current COP, the previous sample COP, and the mean trial COP (Figure). SPL was determined by summing the actual distance between each 2 consecutive COP locations (Figure). A comprehensive explanation of the calculation of these variables has been detailed by Hufschmidt et al.¹³

Statistical Analysis

To evaluate differences between the dominant and nondominant legs of subjects during the single-leg balance task, a subject \times leg repeated-measures analysis of variance (ANOVA) was conducted for both dependent variables, SA and SPL. Additionally, a Pearson product-moment correlation was calculated to determine the relationship between the dependent measures of SA and SPL.



Measurement of sway variables. A, The SA is calculated by summing the areas of each triangle defined by 2 COP locations and the average COP of the trial. B, The SPL mean is the sum of distances between consecutive COP locations.

RESULTS

The individual subject data for both SA and SPL are presented in the Table. The SA ANOVA showed no significant differences between the dominant and nondominant legs ($F_{1,9} = 0.48$, $P = .505$). The mean SA value for the dominant leg was $9737.43 \pm 303.36 \text{ mm}^2$, whereas the mean SA for the nondominant leg was $9431.74 \pm 349.97 \text{ mm}^2$. The SPL ANOVA also showed no significant difference ($F_{1,9} = 0.02$, $P = .896$). The mean SPL for the dominant leg was $4321.57 \pm 630.0 \text{ mm}$, and the mean SPL for the nondominant leg was $4341.88 \pm 1013.31 \text{ mm}$. The correlation between the 2 dependent measures of SA and SPL resulted in a high correlation of $r = 0.90$.

DISCUSSION

The purpose of our study was to determine whether the functionally dominant and nondominant legs of healthy indi-

viduals differ in the ability to control posture in a single-leg stance. This issue is important, because clinicians commonly use single-leg balance evaluations as a measure of rehabilitation progress. To date, we are unaware of any systematic examination of the effects of functional leg dominance on unilateral postural stability. Our results show no difference between the functionally dominant and nondominant legs as they were determined in this study.

These findings are particularly helpful to the clinician who uses single-leg balance testing in the evaluation and rehabilitation of lower limb injuries. When asymmetry is present in single-leg balance testing, it is a function of an acute or chronic injury and not due to functional leg dominance. In addition, our results, combined with the findings of Freeman et al,¹ suggest that patients with unilateral balance deficits likely have some level of functional instability. It is important to note that functional instability, as measured by recurrent ankle sprains, repeated episodes of "giving way," and mechanical instability as measured by joint laxity are not synonymous.¹⁴ We also subscribe to the philosophy that the relationship between functional and mechanical instabilities remains ambiguous.¹⁴

Among specialists in the area of postural control, there is a long-standing debate as to the correct technique for determining leg dominance through the use of the ball-kick test. Some specialists feel that the stance leg should be classified as dominant, while others feel strongly that the kicking leg should be deemed dominant. Based on our findings, there is little reason to pursue the debate, because our findings suggest no difference between the right and left legs of healthy subjects independent of the method of dominance determination. For the researcher, these findings are helpful in the development of methodologies for future studies. We feel that little rationale exists for the incorporation of leg dominance testing and determination.

The analysis of data indicates the possibility of a type II statistical error; that is, the possibility exists that in reality there is a difference between the dominant and nondominant legs of healthy individuals. However, we feel this is highly unlikely, since the differences between the actual mean values for SA and SPL are 3.2% and 0.5%, respectively.

In the future, the relationship between what we have identified as functional dominance and subjective leg preference needs to be investigated. It may well be that there is no difference between the leg the subject reports as preferred for activity and the leg determined as functionally dominant based on the tests used in this study. However, after injury, the subject may have a change in the preferred leg with or without an associated change in the functionally dominant leg. This is yet another relationship where information concerning physiologic adaptations of the body associated with injury may be beneficial to the clinician.

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Mean Sway Data for Sway Area and Sway Path Length

Subject	Sway Area (mm^2)		Sway Path Length (mm)	
	Dominant	Nondominant	Dominant	Nondominant
1	6060.07	5085.00	3558.57	3422.76
2	7755.03	8208.15	3672.45	3743.77
3	7755.48	6772.45	3519.54	2984.36
4	16 167.43	15 639.66	5200.96	6197.81
5	8650.02	5965.75	4085.40	3406.25
6	12 810.42	13 106.65	5103.46	5301.86
7	9178.56	10 047.41	4138.04	4213.52
8	10 055.92	12 491.66	4804.78	5272.40
9	11 597.68	10 360.12	4797.13	4601.70
10	7342.70	6640.55	4335.34	4274.34
Mean	9737.43	9431.74	4321.57	4341.88
SD	303.36	349.97	630.00	1013.31

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Examination of Balance Measures Produced by the Biodex Stability System

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Objective: Our purpose was to establish normal patterns and relationships of stability using the Biodex Stability System.

Design and Setting: The design of this study used both nonexperimental and quasi-experimental methods. All testing was performed in a university sports medicine laboratory.

Subjects: Nineteen healthy subjects (8 males, 11 females, age = 24.4 ± 4.2 years; wt = 70.5 ± 20 kg; ht = 171.2 ± 11.7 cm) with no history of lower extremity injury participated in this study.

Measurements: For data analysis, the medial/lateral stability index (MLSI), anterior/posterior stability index (APSI), overall stability index (OSI), and time-in-balance scores were recorded.

Results: Multiple regression revealed that APSI and MLSI significantly contributed to the OSI, with the APSI accounting for 95% of the OSI variance. Additionally, the percentage of

time spent between 0° and 5° from level was significantly greater than the time spent between 6° and 10° , 11° and 15° , and 16° and 20° . Furthermore, the percentage of time spent between 6° and 10° was significantly greater than the time spent between 16° and 20° .

Conclusions: These data suggest that uninjured individuals spent the majority of the time balanced within 0° to 5° from level and progressively less time at greater angles. Additionally, the data suggest that the OSI is very closely related to the APSI and receives a relatively small contribution from the MLSI. Because of this small contribution, if the clinician is interested in both anterior-posterior and medial-lateral motions, it may be best to use the MLSI and APSI separately rather than the OSI.

Key Words: postural control, proprioception, regression analysis

In the past, several systems¹⁻⁶ have been used to assess balance and postural control. These devices have typically used force plates combined with computer software to determine the movement of the center of pressure (COP). Center of pressure is the central point of pressure that is applied to the foot during contact with the ground or the point of application of the ground reaction force on the foot.⁷ During stance, the COP can be used to measure the movement of the individual's center of gravity over the foot. Thus, the COP can be used to index the amount of movement or sway of the center of gravity during stance. Using this method, Tropp et al^{6,8} have examined single-leg stance stability patterns in individuals with functionally unstable ankles.

In contrast to force plate systems, the Biodex Stability System (BSS) (Biodex, Inc, Shirley, NY) uses a circular platform that is free to move about the anterior-posterior (AP) and medial-lateral (ML) axes simultaneously. In addition to moving about these axes, it is possible to vary the stability of the platform by varying the resistance force applied to the platform. Springs apply this force to the underside of the platform and can be adjusted to preset resistances established by the manufacturer. Rather than measuring the deviation of the COP during static conditions, this device measures the degree of tilt about each axis during dynamic conditions. Thus, the BSS appears to provide more specific information on ankle joint movements. However, it is unclear how knee and hip

motions affect BSS measures or how these measures relate to COP fluctuations.

From the degrees of tilt about the AP and ML axes, the BSS calculates the medial-lateral stability index (MLSI), the anterior-posterior stability index (APSI), and the overall stability index (OSI) (Figure 1). These indexes are standard deviations assessing fluctuations around the zero point (ie, horizontal) rather than around the group mean. The MLSI and the APSI assess the fluctuations from horizontal along the AP and ML axes of the BSS, respectively. In contrast, the OSI is a composite of the MLSI and APSI and, thus, is sensitive to changes in both directions.

In addition to these measures, the system calculates percentage of time in balance for 5° concentric rings (zones) as well

$$APSI = \sqrt{\frac{\sum (0 - Y)^2}{\# \text{ samples}}}$$

$$MLSI = \sqrt{\frac{\sum (0 - X)^2}{\# \text{ samples}}}$$

$$OSI = \sqrt{\frac{\sum (0 - Y)^2 + \sum (0 - X)^2}{\# \text{ samples}}}$$

Figure 1. Formulas for calculating the anterior-posterior stability index (APSI), medial-lateral stability index (MLSI), and overall stability index (OSI).

as for the quadrants around the foot tested (Figure 2). For example, if a 30-second test is performed on the BSS and the individual tested remains balanced in the smallest ring (0° to 5°) for 15 seconds, the system reports a score of 50% for the first ring. If 10 seconds are spent in the second ring (6° to 10°), a score of 33% is reported for the second ring, etc. The BSS also applies this procedure to the 4 quadrants. Thus, the system allows the clinician to establish patterns of time spent away from horizontal as well as standard deviations away from horizontal.

While there has been some research evaluating the reliability of the BSS,⁹ we were unable to find any studies examining stability patterns within the zones or quadrants. However, Tropp et al^{4,6,8} demonstrated that individuals with functionally unstable ankles have a greater dispersion in their COP during single-leg stance. Thus, it seems reasonable to speculate that the amount of time spent in these zones or quadrants may reveal proprioceptive disabilities associated with ankle or lower extremity pathology. Furthermore, there appear to be no existing data examining the relationship between the OSI and the MLSI and APSI. Thus, the goal of our study was to determine normal stability patterns using the BSS and to assess the relationship of MLSI and APSI to OSI.

METHODS

Subjects

Nineteen healthy subjects (8 males, 11 females, age = 24.4 ± 4.2 years; wt = 70.5 ± 20 kg; ht = 171.2 ± 11.7 cm) with no prior lower extremity injury volunteered and gave informed consent to participate in the study. All procedures were approved by the University of Virginia's institutional review board.

Testing Procedures

Subject preparation. Our study design was a pre-experimental 1-time observation with no treatments. All sub-

jects reported to the laboratory on 2 days separated by 24 hours. The first day was a familiarization session, which consisted of 5 practice sessions using the testing protocol. Subjects stood on the BSS with the leg they would use to kick a ball. They were allowed to flex the support knee to no more than 10° but were required to maintain an upright posture with the supporting leg. Additionally, subjects were instructed to keep their hands at their sides and to maintain a comfortable knee angle with the unsupported leg during testing. Once in this position, the stability platform was unlocked to allow motion. The subjects were then instructed to adjust the supporting foot's position until they found a position at which they could maintain platform stability. This was done to establish the subjects' ideal foot positioning for testing. The platform was then locked, and subjects were told to maintain the foot position. This position was used for testing.

Testing protocol. The testing protocol consisted of a single^{10,11} 30-second¹¹ test using all 8 resistances provided by the BSS. We used a single test to reduce the potential effects of learning and fatigue. The intratester reliability of this procedure has been previously reported as 0.43 for MLSI, 0.80 for APSI, and 0.82 for OSI.¹² The force of each resistance level was predetermined by the manufacturer's design, using 8 springs located at the perimeter of the balance platform. Each spring was manufactured from music wire. The springs had an uncompressed length of 13.97 cm, an outside diameter of 3.11 cm, a wire diameter of 0.24 cm, and a spring rate of 13.81 N/cm. When compressed to 7.52 cm, the spring produced 88.9 N of force. The resistance order declined from the most resistant to the least resistant, with each resistance lasting 3.75 seconds. BSS software sampled the degree of tilt from level in the medial-lateral (X) and anterior-posterior (Y) directions at a rate of 20 Hz. These signals were then converted to MLSI, APSI, and OSI values (Figure 1). Additionally, the BSS software used the X and Y signals to calculate the percentage of time in quadrants and zones (Figure 2). If trial subjects lost their balance during the testing, they were permitted to briefly toe touch with the opposite foot or grasp the handrails temporarily to re-establish balance. If subjects were unable to quickly regain their balance, the trial was deleted. Otherwise data collection continued during balance correction.

Statistical Analysis

With the data from the test trial, we performed a stepwise multiple regression using the MLSI and APSI to predict the OSI. The purpose of this analysis was to decompose the OSI into its 2 component parts to determine whether the OSI was biased toward one of its components. Additionally, a 1-way repeated-measures analysis of variance (ANOVA) was performed to test differences in percentage of time in each quadrant (4 levels), and a second 1-way repeated-measures ANOVA was performed to test differences in percentage of

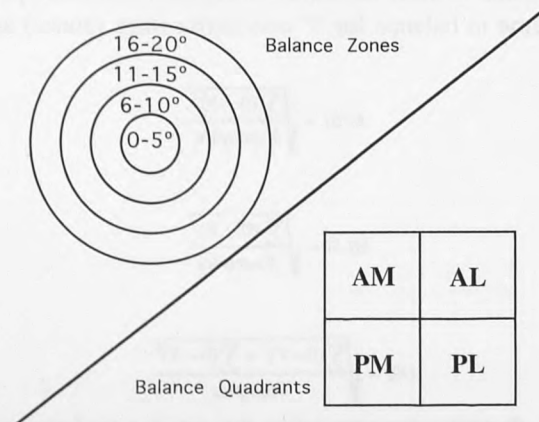


Figure 2. Zones and quadrants used to calculate percentage of time.

time in each zone (4 levels). ANOVA post hoc testing was performed using the Tukey honest significant difference test. The significance level of all statistical tests was set at $\alpha < .05$.

RESULTS

The means and standard deviations for OSI, MLSI, and APSI were $4.07^\circ \pm 1.63^\circ$, $1.77^\circ \pm 0.91^\circ$, and $3.71^\circ \pm 1.58^\circ$, respectively. In the first step of the regression analysis, the APSI entered the regression equation with $R = 0.972$ and $R^2 = 0.944$ ($P < .00005$). On the second step of the regression analysis, the MLSI entered the regression equation, producing $R = 0.998$, $R^2 = 0.996$, and R^2 change = 0.053 ($P < .00005$). The results of the first ANOVA revealed no significant differences ($F_{3,18} = 0.8$, $P = .497$) in the time spent in the 4 quadrants (Figure 3). In contrast, the second ANOVA revealed significant differences ($F_{3,18} = 323.32$, $P < .0005$) in the time spent in the 4 concentric zones. Post hoc testing revealed that the percentage of time spent between 0° and 5° was significantly greater than that of the other 3 zones and that the time spent between 6° and 10° was greater than the time spent between 16° and 20° (Figure 4). Finally, the ANOVA for the stability indexes produced a significant difference among the indexes ($F_{2,18} = 42.64$, $P < .0005$), with post hoc testing revealing that MLSI was smaller than either APSI or OSI (Figure 5).

DISCUSSION

The multiple regression indicates that 95% of the variance in the OSI can be accounted for by the APSI, suggesting that OSI and APSI are nearly identical. This is clearly indicated by our plot (Figure 6) of individual subject scores for OSI, APSI, and MLSI. A departure between OSI and APSI began with subject 11. We believe this is due to the relatively low APSI. Based on the OSI formula, MLSI and APSI have equal weights. Thus, as APSI declines, MLSI has more effect on OSI. Conversely, when subjects have a relatively large APSI, ie, approximately -1 standard deviation or greater (subjects 13–19), the MLSI must approach 1 standard deviation above its mean before it is

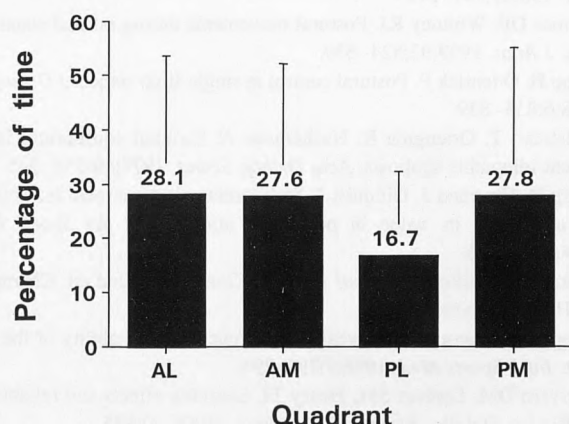


Figure 3. Means and standard deviations for percentage of time in anterolateral (AL), anteromedial (AM), posterolateral (PL), and posteromedial (PM) quadrants.

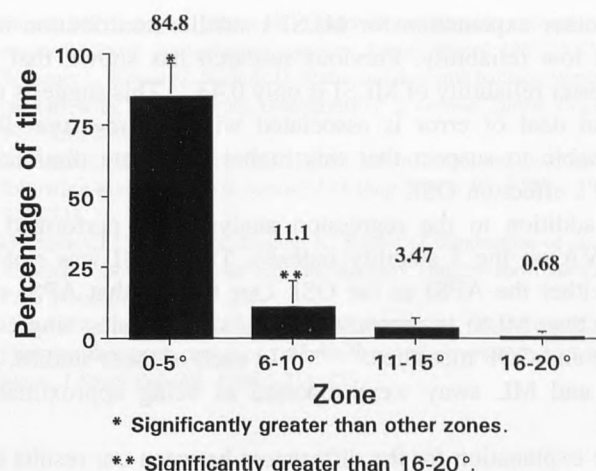


Figure 4. Means and standard deviations for percentage of time in zones.

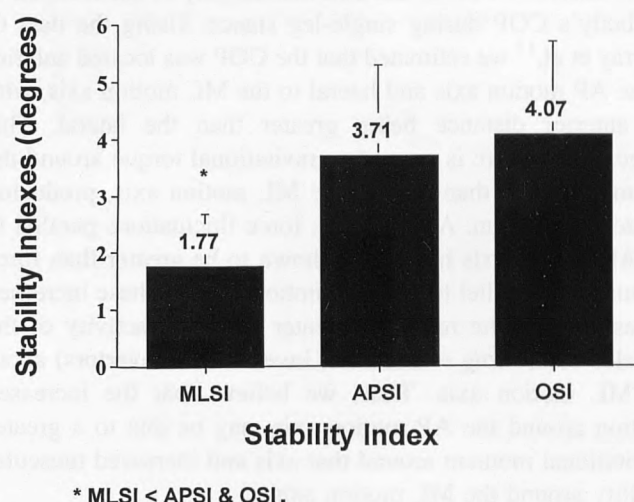


Figure 5. Means and standard deviations for medial-lateral (MLSI), anterior-posterior (APSI), and overall stability (OSI) indexes.

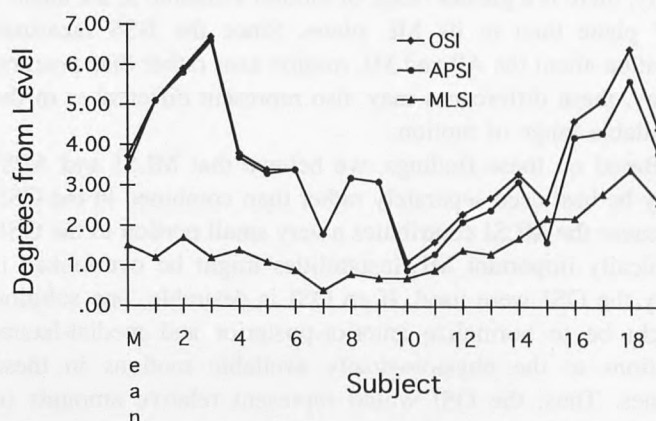


Figure 6. Individual subject scores for anterior-posterior stability index (APSI), medial-lateral stability index (MLSI), and overall stability index (OSI).

large enough to have much of an effect on OSI. It is worth noting that the largest departure of APSI and OSI occurred with subject 13, who displayed a high MLSI combined with a relatively low APSI.

Another explanation for MLSI's smaller contribution may be its low reliability. Previous research has shown that the intratester reliability of MLSI is only 0.43.¹² This suggests that a great deal of error is associated with this measure. It is reasonable to suspect that this higher error rate diminished MLSI's effect on OSI.

In addition to the regression analysis, we performed an ANOVA on the 3 stability indexes. The MLSI was smaller than either the APSI or the OSI. Our finding that APSI was larger than MLSI is contrary to other studies using single-leg stance and COP measures.^{10,13-16} In each of these studies, AP sway and ML sway were reported as being approximately equal.

The explanation for the differences between our results and others appears to be related biomechanical factors, BSS design, and, possibly, anatomical factors. A biomechanical explanation of the differences in AP and ML motion may be the location of the body's COP during single-leg stance. Using the data of Murray et al,¹⁷ we estimated that the COP was located anterior to the AP motion axis and lateral to the ML motion axis, with the anterior distance being greater than the lateral. This suggests that there is a greater gravitational torque around the AP motion axis than around the ML motion axis, producing greater AP motion. Additionally, force fluctuations parallel to the AP motion axis have been shown to be greater than force fluctuations parallel to the ML motion axis.¹³ These increased forces may be the result of greater muscular activity of the muscles controlling rotation (ie, invertors and evertors) about the ML motion axis. Thus, we believe that the increased rotation around the AP motion axis may be due to a greater gravitational moment around that axis and increased muscular stability around the ML motion axis.

The reason for greater single-leg stance AP motion than ML motion may also be related to anatomical factors. Anatomically, there is a greater range of motion available in the ankle's AP plane than in its ML plane. Since the BSS measures rotation about the AP and ML motion axes rather than postural sway, these differences may also represent differences in the available range of motion.

Based on these findings, we believe that MLSI and APSI may be best used separately rather than combined in the OSI. Because the MLSI contributes a very small portion to the OSI, clinically important ML instabilities might be overlooked if only the OSI were used. If an OSI is desirable, one solution might be to normalize anterior-posterior and medial-lateral motions to the physiologically available motions in these planes. Thus, the OSI would represent relative amounts of motion within the available physiologic ranges.

With regard to the time spent in quadrants and zones, our findings were not surprising. We had expected that uninjured individuals would stay near the level platform position. This is consistent with previous force plate studies^{4,6} that measured the COP's area of dispersion. These studies found that individuals with functional ankle instabilities had greater areas of dispersion than did uninjured individuals. It should be empha-

sized that the measurement techniques of these previous studies and ours are very different, which makes direct comparison difficult. Thus, we suggest that future BSS research use injured populations and examine the relationship of BSS measures to other measures such as COP.

In addition to the above studies using single-leg stance,^{4,6,8,13,14} several others¹⁸⁻²¹ have used the Chattecx Balance System (Chattanooga Group Inc, Chattanooga, TN) to study single-leg stance. Unfortunately, these studies used the Chattecx system's postural sway index. Similar to the BSS OSI, the postural sway index is a composite of ML and AP sway, and, thus, cannot be compared with ML and AP sway measures.

Finally, the intent of our study was to establish normal patterns of balance on the BSS. However, our measures did not account for brief losses of balance. For example, in our study, subjects were allowed to briefly toe touch to regain their balance. Thus, it is possible that 2 individuals could have had the same BSS scores despite one subject's having toe touched while the other did not. Clearly, these individuals would not have the same balance ability. We believe future researchers should establish the relationship between BSS scores and toe touches.

In conclusion, we found that MLSI accounted for a very small portion of the OSI variance. Thus, clinicians may find it more useful to use APSI and MLSI separately to assess balance. Furthermore, we found that uninjured individuals had a tendency to spend most of the balance time within 0° to 5° from horizontal, with no differences in time spent within the 4 quadrants.

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An Electromyographic Investigation of 4 Elastic-Tubing Closed Kinetic Chain Exercises After Anterior Cruciate Ligament Reconstruction

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Objective: To determine the electromyographic (EMG) activity of the vastus medialis oblique (VMO), vastus lateralis (VL), semitendinosus and semimembranosus (ST), and biceps femoris (BF) muscles during 4 elastic-tubing closed kinetic chain exercises in postoperative patients with anterior cruciate ligament (ACL)-reconstructed knees.

Design and Setting: A 4×4 repeated-measures analysis of variance design guided this study. Independent variables were type of exercise and muscle; the dependent variable was EMG activity.

Subjects: Fifteen patients, 5 to 24 weeks after ACL reconstruction.

Measurements: Subjects performed 4 exercises (front pull, back pull, crossover, reverse crossover) with elastic tubing

attached to the foot of the uninjured leg. Time- and amplitude-normalized EMG activity was recorded from the VMO, VL, ST, and BF muscles of the injured leg. The hamstrings:quadriceps ratio was calculated.

Results: The normalized VMO, VL, and BF EMG activity ranged from 25% to 50% of maximum voluntary isometric contraction for the 4 exercises. The ST ranged from 12% on the back pull to 58% on the front pull. The hamstrings:quadriceps ratios were 137% (front pull), 115% (crossover), 70% (back pull), and 60% (reverse crossover).

Conclusions: We suggest that clinicians use these exercises during early ACL rehabilitation since they incorporate early weightbearing with hamstring and quadriceps coactivation.

Key Words: EMG, ACL rehabilitation, knee rehabilitation

A major objective for patients in rehabilitation after anterior cruciate ligament (ACL) reconstruction is to strengthen the quadriceps without excessively stressing the ACL graft. Isolated knee-extension exercises performed during the last 60° produce significant strain on the ACL graft.¹ Hamstrings contractions pull the tibia posteriorly, reducing the magnitude of the anterior shear force produced by the quadriceps.²⁻⁴ Exercises involving a cocontraction of the hamstrings have been suggested to strengthen the quadriceps in the last 60° of knee extension without stressing the ACL graft.⁵⁻⁹

During closed kinetic chain exercises, the distal segment of a joint meets with a force that restrains or prohibits its free motion.¹⁰ These exercises increase joint compression, which enhances joint stability and protects the graft.^{3,5,8,9,11} Several authors have also suggested that closed kinetic chain exercises produce a cocontraction of the hamstring muscles, which reduces the anterior shear force at the tibiofemoral joint when compared with open chain knee extension exercises.^{3,5,8,9} However, the muscle activity of specific closed kinetic chain exercises has not been thoroughly researched.

The hamstrings appear to be minimally active, ranging from 1% to 10% maximum voluntary isometric contraction (MVIC) during stair stepping^{2,12,13} and quarter squats.^{3,14} Hamstrings:quadriceps electromyographic (EMG) ratios have been computed for other commonly prescribed closed kinetic chain exercises and range from 61% to 74%.³ These findings have led researchers to question the effectiveness of closed chain exercises in controlling anterior shear forces at the knee.^{2,3,14}

Elastic tubing has been suggested as an effective tool for performing closed kinetic chain exercises.¹ Gray¹⁵ advocated attaching the elastic tubing to the uninjured leg, thus causing resistance through the pelvis to the injured leg. We feel this technique provides resistance to the closed chain leg and can be used to emphasize different muscles, depending on the direction of pull of the elastic tubing in relation to the patient's body.¹⁶ Hamstrings:quadriceps ratios up to 156% have been recorded using this technique, suggesting a strong cocontraction of the hamstrings.¹⁶

All the studies cited used healthy individuals as research subjects. Therefore, the purpose of our study was to describe and compare the EMG activity of the vastus medialis oblique (VMO), vastus lateralis (VL), semitendinosus and semimembranosus (ST), and biceps femoris (BF) muscles during 4

*Dr. Schulthies has a financial interest in Functional PT Products.

elastic-tubing closed kinetic chain exercises in patients 5 to 24 weeks after ACL reconstruction.

METHODS

A 4×4 factorial repeated-measures design guided this study. Normalized EMG activity was the dependent variable. The 2 independent variables were muscle group (VMO, VL, ST, and BF) and exercise (front pull, back pull, crossover, and reverse crossover). Subjects performed all exercises in a single session, with the order of the exercises counterbalanced.

Subjects

Eight males and 7 females (age = 27.4 ± 9.1 years, wt = 71.2 ± 14.2 kg) who were 12.5 ± 5.7 weeks postoperative ACL reconstruction surgery (9 with patellar tendon autografts and 6 with semitendinosus autografts) volunteered for this study. All subjects signed a university-approved informed consent form. The study was approved by the Committee on Human Research at Brigham Young University.

Instrumentation

The start and end of each closed kinetic chain exercise movement was identified using an Advanced Mechanical Technology Incorporated force plate (Newton, MA). Tension in the elastic tubing was recorded using an Omega Engineering

LCK-250 force transducer (Stamford, CT). Positions of the support knee and hip were monitored using Penny & Giles goniometers (Santa Monica, CA). EMG signals were collected with Motion Control preamplifier surface electrodes (Salt Lake City, UT), containing 3 silver-silver chloride discs 12 mm in diameter and a 3-mm interelectrode space. These electrodes have a preamplified gain of 375 at 300 Hz, a bandwidth of 8 to 26 KHz, a common mode rejection ratio of 100 dB at 60 Hz, and input impedance of 100,000 megaohms. Vertical force, EMG, goniometer, and force transducer data were recorded using an AST 486 computer interfaced to the respective amplifiers by an Ariel 16-channel, 12-bit analog to digital converter (La Jolla, CA). Resistance during the MVIC was provided using a Cybex Fitness System leg extension machine (Ronkonkoma, NY), with the resistance arm locked at 50° knee flexion and the resistance level superior to the malleoli. Resistance during the closed kinetic chain exercises was provided using elastic tubing with an internal diameter of 4.8 mm, an outside diameter of 11.1 mm, and a length of 1.83 m; a padded foot strap served to attach the elastic cord to the leg (Functional PT Products, Heber City, UT).

Description of the Exercises

The following procedure was used in each of the 4 exercises. One end of the elastic tubing was attached to the uninjured leg at the level of the malleoli; the other end was attached to the fixed force transducer. The patient stepped away from the

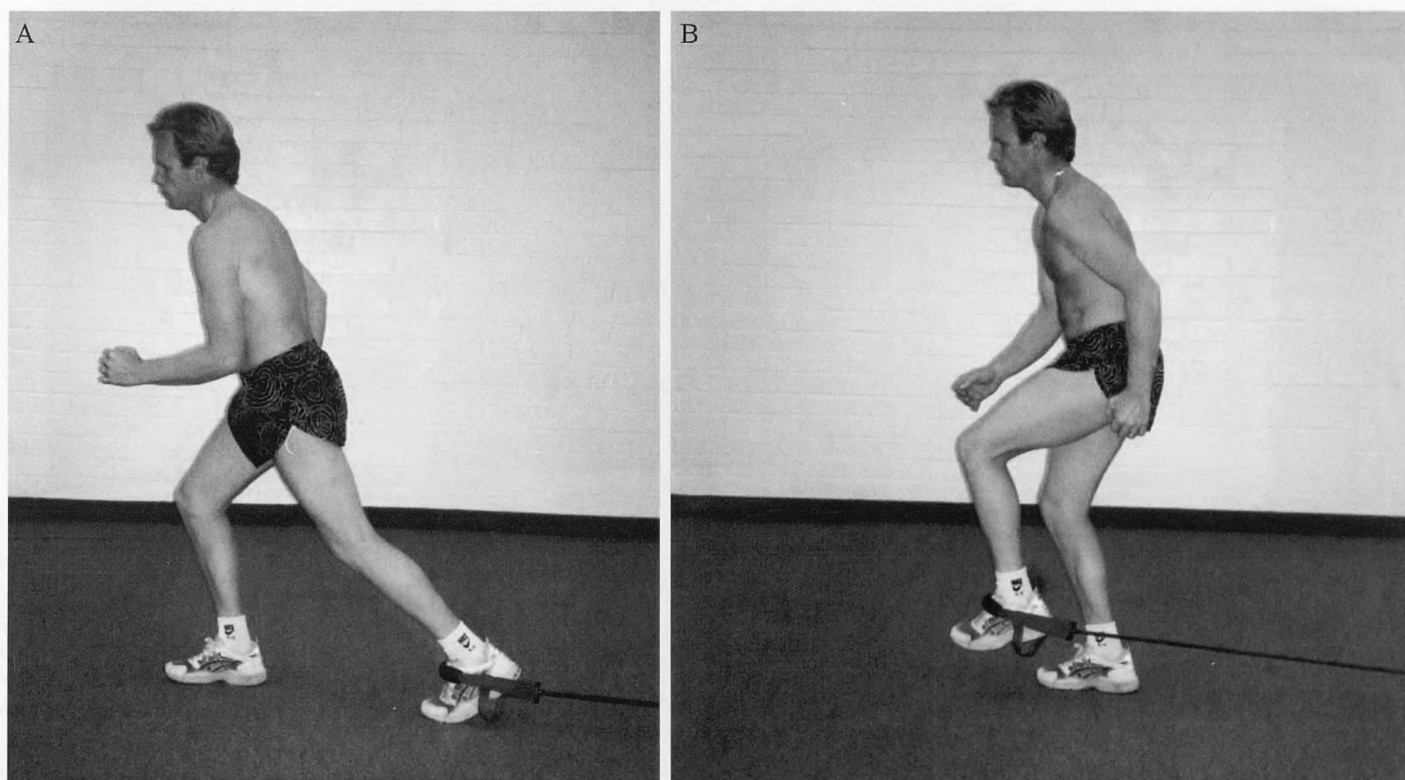


Figure 1. The front-pull exercise at starting and ending positions (A) and at midmovement (B). The subject stands on the injured leg, with the uninjured leg positioned behind the injured leg. While balancing on the injured leg, the subject flexes the uninjured leg at the hip and knee, pulling the tubing forward (B). The subject then slowly returns to the ending position (A).

tubing attachment site, stretching the tubing to obtain a resistance to 20% of body weight. The subject crouched so that the hips and knees were flexed to approximately 50°, with most of the body weight on the injured leg (Figures 1–4).

Front pulls. Subjects faced away from the fixed attachment of the elastic tubing so that the tubing pulled them backward. The subject stood on the injured leg, with the uninjured leg positioned behind the injured leg, and the hip and knee extended (Figure 1A). While balancing on the injured leg, the subject flexed the uninjured leg at the hip and knee, pulling the tubing forward (Figure 1B). The subject then slowly returned to the starting position (Figure 1A).

Back pulls. Subjects faced the fixed attachment of the elastic tubing so that the tubing pulled them forward. The subject stood on the injured leg, with the uninjured leg flexed at the hip and knee (Figure 2A). While balancing on the injured leg, the subject extended the uninjured leg at the hip and knee, pulling the tubing backward (Figure 2B). The subject then slowly returned to the starting position (Figure 2A).

Crossovers. Subjects stood at a 90° angle to the fixed end of the tubing so that the uninjured extremity was closest to the tubing attachment, with the feet slightly wider apart than shoulder width (Figure 3A). Subjects adducted the hips, crossing the uninjured leg in front of the injured leg (Figure 3B), and returned slowly to the starting position (Figure 3A).

Reverse crossovers. Subjects stood at a 90° angle to the fixed end of the tubing so that the injured extremity was closest to the tubing attachment, with the hips adducted and the legs crossed so that the foot of the uninjured leg was in front of the

foot of the injured leg (Figure 4A). Subjects abducted the hips until the feet were slightly wider apart than shoulder width (Figure 4B) and returned slowly to the starting position (Figure 4A).

Procedures

An orientation session preceded the testing session by 2 days. During orientation, subjects practiced the exercises until they could maintain balance on the affected extremity and execute each exercise through the required range of motion (between 35° and 60° of flexion for both the hip and knee) in a smooth fashion, as subjectively determined by the investigator. During the testing session, surface electrodes were placed overlying the VMO, VL, ST, and BF muscles of the injured leg, with the electrodes aligned parallel to the muscle fibers. We attached the VMO electrode superomedial to the patella over the most prominent portion of the contracted muscle.¹² The VL electrode placement was at one half the distance between the superior pole of the patella and the anterior superior iliac spine on the lateral aspect of the thigh. We positioned the biceps femoris electrode at a superolateral point one third of the distance between the ischial tuberosity and the lateral joint line. The ST electrode was positioned at a superomedial point one third of the distance between the ischial tuberosity and the medial joint line. Each subject completed 3 1-second MVICs of the quadriceps and hamstrings. The contraction with the largest average amplitude was used to normalize the EMG signals collected during the exercise. The maximum contrac-

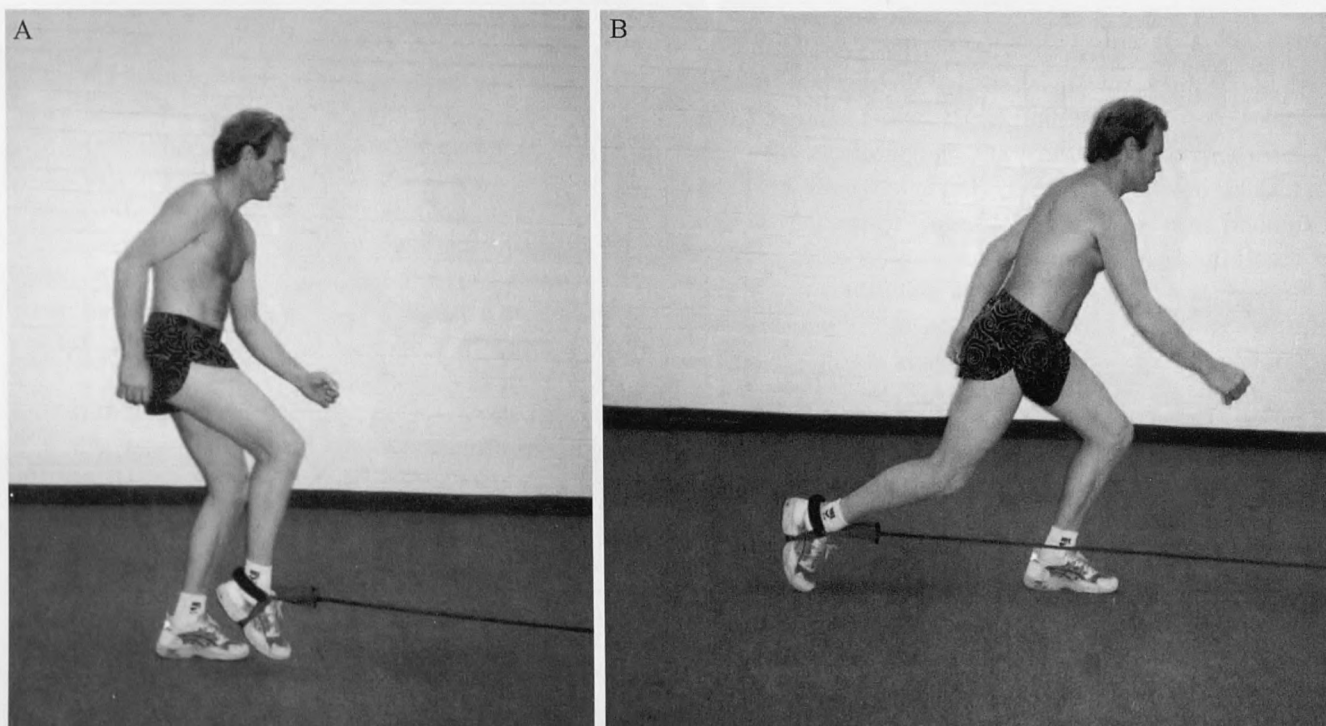


Figure 2. The back-pull exercise at starting and ending positions (A) and at midmovement (B). The subject stands on the injured leg, with the uninjured leg flexed at the hip and knee (A). While balancing on the injured leg, the subject extends the uninjured leg at the hip and knee, pulling the tubing backward (B). The subject then slowly returns to the ending position (A).

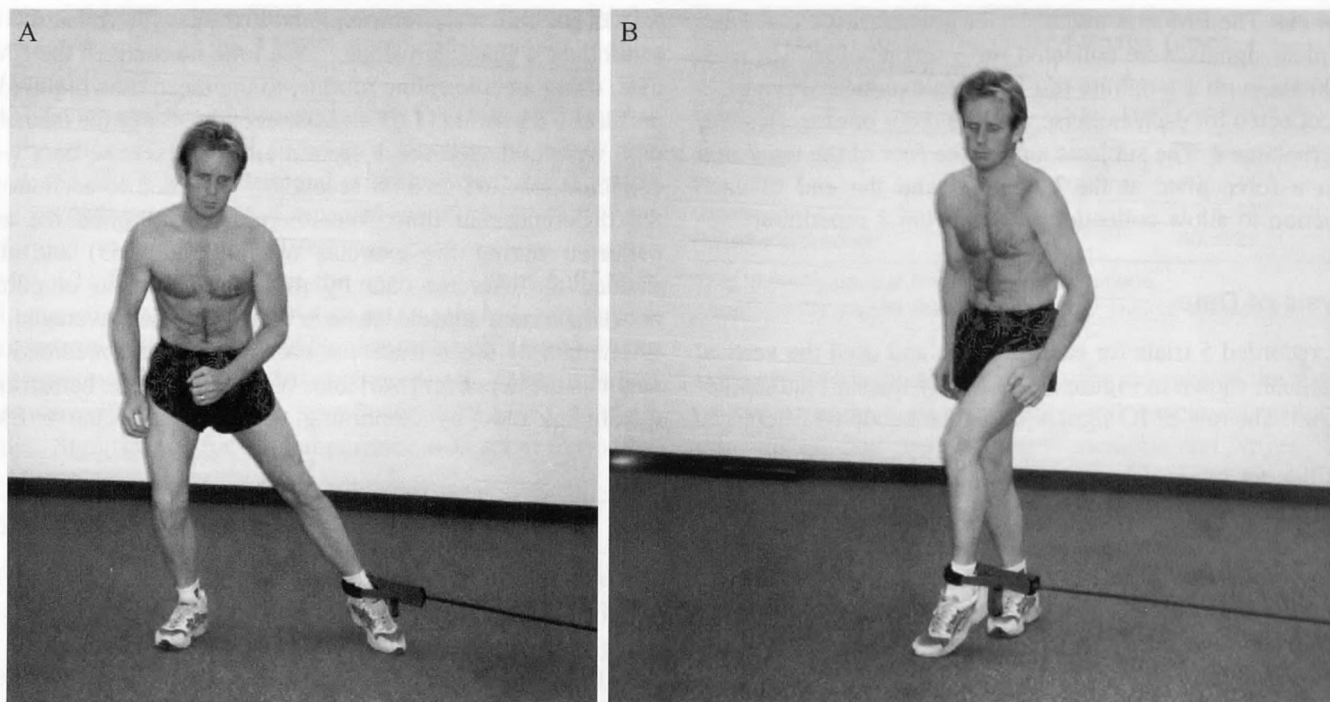


Figure 3. The crossover exercise at starting and ending positions (A) and at midmovement (B). The subject stands at a 90° angle to the fixed end of the tubing so that the uninjured extremity is closest to the tubing attachment, with the feet slightly wider apart than shoulder width (A). The subject adducts the hips, crossing the uninjured leg in front of the injured leg (B), and slowly returns to the ending position (A).

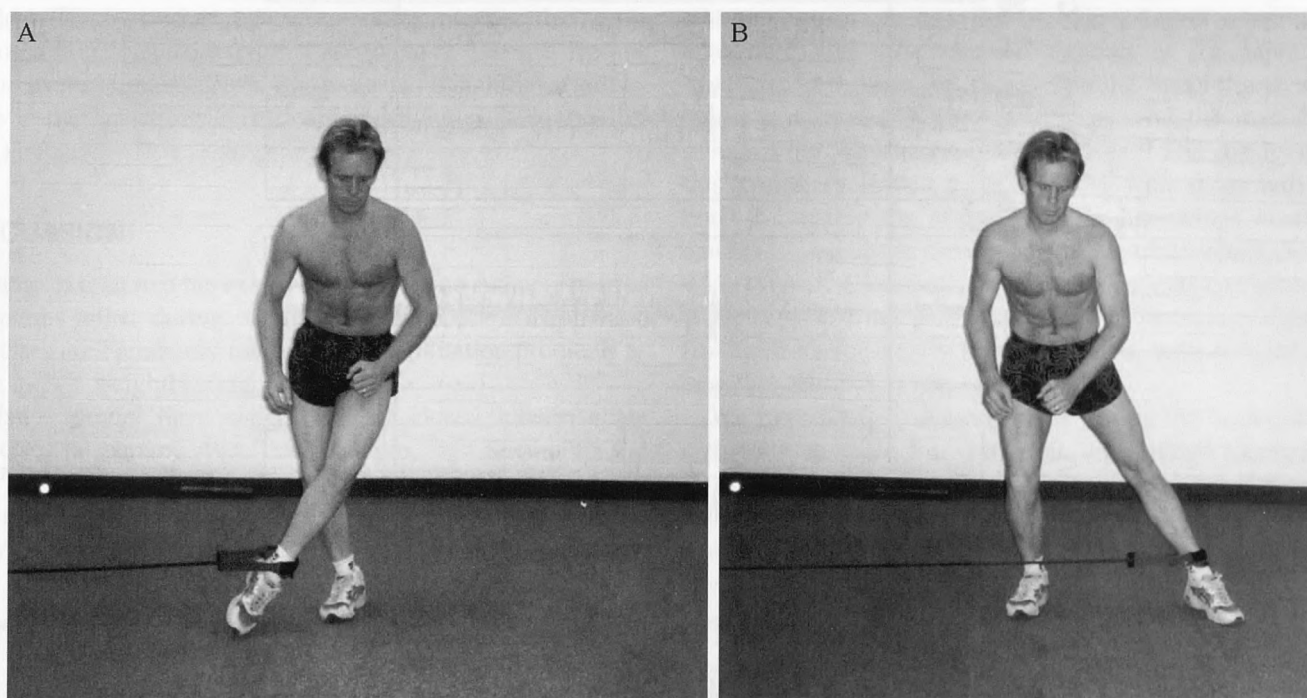


Figure 4. The reverse-crossover exercise at starting and ending positions (A) and at midmovement (B). The subject stands at a 90° angle to the fixed end of the tubing, so that the injured extremity is closest to the tubing attachment, with the hips adducted and the legs crossed so that the foot of the uninjured leg is in front of the foot of the injured leg (A). The subject abducts the hips until the feet are slightly wider apart than shoulder width (B) and slowly returns to the ending position (A).

tions were performed with the subjects in a sitting position, with the hip at 90° and the knee at 50° of flexion, as measured with a goniometer. A 3-minute rest period was given between the MVICs and the experimental trials to prevent fatigue.

The elastic tubing resistance level was recorded throughout the movement. Since elastic tubing resistance is variable, the exercises were set up so that a resistance of 20% of the subject's body weight was achieved midway through the

movement. The EMG, goniometer, tension in elastic cord, and force plate signals were collected for 3 seconds for each trial, at 1000 Hz, with a 1-minute rest between exercises. Five trials were collected for each exercise, and the order of exercises was counterbalanced. The subjects tapped the foot of the uninjured leg on a force plate at the beginning and the end of each contraction to allow collection of data from 1 repetition.

Analysis of Data

We recorded 5 trials for each exercise and used the vertical force signal, shown in Figure 5, to identify the start and end of each trial. The raw EMG signals were then bandpass filtered 20

to 500 Hz, full-wave rectified, and low-pass filtered at 6.0 Hz to produce a linear envelope.¹⁷ We time normalized the EMG data, using a cubic spline routine, to the mean time required to perform 1 repetition (1.65 ± 3.08 seconds). Since the isometric data were collected for 1 second and the exercise data were collected for 1.65 ± 3.08 seconds, we needed to account for the differences in time. We, therefore, multiplied the area collected during the exercise by 0.606 ($1/1.65$) and then divided the exercise data by the MVIC data to amplitude normalize each muscle at each trial. We then averaged the EMG data of the 5 trials for each muscle and recorded the result as the dependent variable. We calculated the hamstrings: quadriceps ratio by combining the average of the 5 EMG

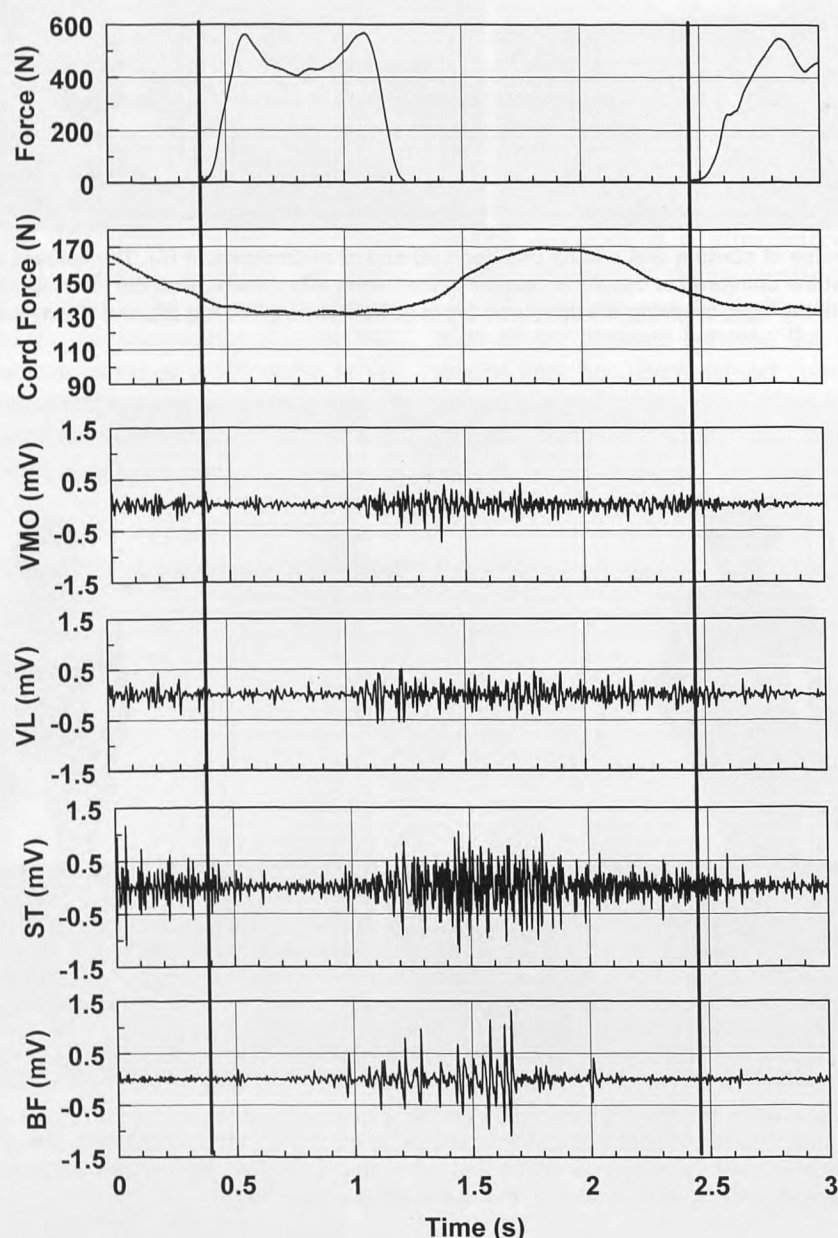


Figure 5. Typical trial for a front-pull exercise showing ground reaction force, elastic tubing force, and raw EMG for VMO, VL, ST, and BF muscles. The subject taps the foot of the uninjured leg on the force plate at the start and end of each trial. The solid vertical lines indicate the start and end of each trial, which are identified from the force plate data. Only the data between the solid vertical lines were retained for analysis in our study.

signals of the BF and the ST (hamstrings), then dividing by the combined average of the 5 EMG signals of the VMO and the VL (quadriceps).

A 1-factor analysis of variance (ANOVA) was performed to test the effect of surgical technique. Because no effect was found, the data were pooled, and statistics were performed on these pooled data. A 4×4 repeated-measures ANOVA was performed to determine differences between the muscles (VMO, VL, ST, and BF) and the exercises (front pull, back pull, crossover, and reverse crossover). A single-factor repeated-measures ANOVA was used to determine differences in the hamstrings:quadriceps ratio between exercises. Tukey post hoc tests were used to test for significant differences between groups. Significance for all comparisons was set at $P = .05$.

RESULTS

The EMG values for each muscle recorded during the 4 closed kinetic chain exercises are found in Table 1. Results of the main-effects test on muscle showed no difference between muscles ($F_{3,42} = 0.45$, $P = .72$). Results of the main-effects test on exercise indicated significant differences between exercises ($F_{3,42} = 34.69$, $P = .001$). The results indicated a muscle-by-exercise interaction ($F_{9,126} = 19.28$, $P = .001$). We were primarily interested in the muscle differences, so only muscle-within-exercise post hoc comparisons are listed in Table 1. The hamstrings:quadriceps ratios recorded during the 4 closed kinetic chain exercises are found in Table 2. Results of the exercise main-effects test indicated a significant difference in the hamstrings:quadriceps ratio ($F_{3,42} = 28.16$, $P = .001$).

DISCUSSION

Subjects tolerated the exercises well, and no subject reported symptoms either during or after the exercises. In fact, these exercises are commonly used in our rehabilitation protocols as soon as full weightbearing is achieved.

Many authors have suggested that closed kinetic chain exercises be part of ACL rehabilitation.¹⁸⁻²⁰ Shelborne and Nitz²⁰ recommended closed kinetic chain exercises as soon as unassisted weightbearing of the involved extremity is possible. They emphasized the need for immediate weightbearing before

Table 2. Normalized Mean EMG Values of the Hamstrings:Quadriceps Ratios for 4 Elastic-Tubing Closed Kinetic Chain Exercises

Exercises	Hamstrings:Quadriceps Ratios (%)
Front pull	137 \pm 62 ^a
Back pull	70 \pm 44
Crossover	115 \pm 44 ^b
Reverse crossover	60 \pm 21

^a Significantly greater than all other conditions.

^b Significantly greater than back pull and reverse crossover.

exposure to dangerous joint loads for the sake of the patient's tolerance, normal proprioceptive and functional patterns in musculature, and coordination.²⁰ Mangine and Noyes¹⁹ suggested that early weightbearing is important in rehabilitation after ACL reconstruction. They recommended that balance, hamstring strength training, and control of joint forces during weightbearing be emphasized.¹⁹ Malone and Garrett¹⁸ suggested that middle range-of-motion weightbearing activities are better tolerated and are safer than their open chain counterparts. We feel that these 4 elastic-tubing exercises accomplish these goals of early weightbearing using middle range of motion, controlling the joint forces by activating the hamstrings, and stressing balance, coordination, and proprioception.

We hypothesized that resistance during the front-pull exercise tends to cause hip flexion, hip external rotation, knee extension, and knee external rotation of the injured leg. Muscular resistance to these motions should activate the hamstrings more than the quadriceps, and the medial hamstrings more than the lateral hamstrings.¹⁶ Our results support this hypothesis in that the ST and BF were more active than both the quadriceps (Table 1). This hamstrings contraction generates a posterior shear force on the tibia, which decreases ACL stress.¹³ Our results suggest that patients can activate the quadriceps with a cocontraction of the hamstrings during the front-pull exercise early in rehabilitation, with reduced risk of stressing the ACL graft.

We hypothesized that resistance during the back-pull exercise tends to cause hip extension, hip internal rotation, knee flexion, and internal rotation of the injured leg. This should activate the quadriceps more than the hamstrings and the lateral hamstrings more than the medial hamstrings.¹⁶ Our results

Table 1. Normalized Mean EMG Values for the 4 Muscles During 4 Elastic-Tubing Closed Kinetic Chain Exercises

Exercise	Muscle Component (% MVIC) of			
	VMO	VL	ST	BF
Front pull	42.33 \pm 17.4	35.70 \pm 10.3	57.63 \pm 25.3 ^a	49.38 \pm 20.2 ^b
Back pull	37.10 \pm 14.5 ^c	38.21 \pm 10.8 ^c	12.82 \pm 5.4	39.99 \pm 14.2 ^c
Crossover	31.43 \pm 11.2	27.18 \pm 8.3	39.96 \pm 21.4 ^d	27.34 \pm 12.2
Reverse crossover	32.56 \pm 12.37 ^c	35.38 \pm 12.5 ^c	15.89 \pm 9.8	25.11 \pm 10.6 ^c

^a Significantly greater than VMO and VL.

^b Significantly greater than VL.

^c Significantly greater than ST.

^d Significantly greater than VL and BF.

support this hypothesis, showing the VMO, VL, and BF muscles to be more active than the ST (Table 1). While hamstrings activity and the hamstrings:quadriceps ratio were less than for the front pull, hamstrings activity is comparable with that previously recorded during the quarter-squat exercise.³

We hypothesized that resistance during the crossover exercise tends to cause hip abduction, hip external rotation, knee flexion, and external rotation of the injured leg. This should activate the hamstrings more than the quadriceps and the medial hamstrings more than the lateral hamstrings. Our results support this hypothesis, showing that the ST was significantly more active than the VL or the BF (Table 1). The hamstrings:quadriceps ratio was significantly higher in the crossover exercise than in the back-pull and reverse-crossover exercises, second only to the front-pull exercise.

We hypothesized that resistance during reverse-crossover exercise tends to cause hip adduction, hip internal rotation, knee flexion, and internal rotation of the injured leg. This should activate the quadriceps more than the hamstrings, and the lateral hamstrings more than the medial hamstrings. Our results support this hypothesis, showing that the VMO, VL, and BF muscles were all more active than the ST, and the VL was more active than the BF (Table 1).

Closed kinetic chain exercises have been prescribed during rehabilitation because of the cocontraction of the hamstrings;²¹ however, many closed kinetic chain exercises produce a relatively low hamstrings:quadriceps ratio.^{2,4,7,8} Studies conducted on stair-stepping activities have resulted in hamstrings activity ranging from 4% to 15% of maximum contraction and hamstrings:quadriceps ratios from 10% to 30%.^{2,12,13} Brask et al² suggested that the contraction of the hamstrings muscles may be insufficient to control anterior shear forces. Quarter squats have resulted in hamstring activity from 3% to 4%, with hamstrings:quadriceps ratios of approximately 4%.¹⁴ Graham et al³ studied 5 closed kinetic chain exercises, including unilateral one-quarter squats, leg extensions, lateral step-ups, and movements on the Fitter (Fitter International, Inc, Calgary, AB, Canada), Stair Master 4000 (Stair Master Sports/Medical Products, Inc, Kirkland, WA), and slide board.³ Mean hamstrings:quadriceps ratios ranged from 21.5% for the leg extension to 73.9% for the slide board. Graham et al³ suggested that the higher ratios will better reduce the anterior shear forces. The front-pull and crossover exercises have the greatest hamstrings:quadriceps ratios reported by any closed kinetic chain exercises in the current literature. Our study is the first to report the ratios using patients with ACL-reconstructed knees as subjects. The hamstrings:quadriceps ratios were 137% (front pull), 115% (crossover), 70% (back pull), and 60% (reverse crossover). Bachler et al¹⁶ reported ratios of 156% for the front pull and 83% for the crossover. While all 4 exercises produced hamstrings:quadriceps cocontraction, the front-pull and crossover exercises produced significantly higher hamstrings:quadriceps ratios. Theoretically, this may reduce the anterior

shear force. We believe these exercises can be safely performed early in ACL rehabilitation.

Most of our exercises produced myoelectric activity in excess of 30% of MVIC, higher than that produced by squats, stair stepping, or step-ups (3.5% to 25%).^{2,3,12,14,16} While muscle length changes, contraction velocities, contraction type, and other factors have hindered a description of the precise EMG-tension relationship,²¹ exercises that produce high EMG activity should result in greater strength gains than exercises that produce low EMG activity.^{17,22} Therefore, performing our exercises may result in greater strength gains, especially in the hamstrings, than previously described closed kinetic chain exercises. However, due to differences in subjects, methods, instrumentation, contraction velocities, and range of motion, comparisons of myoelectric activity between studies is difficult. In order to test this hypothesis, patients should exercise using different closed kinetic chain exercises and be tested for differences in strength gains.

Patellofemoral pain has been reported as a common side effect after ACL reconstruction.²⁰ Patellofemoral pain is also believed to be caused by increased VL activity when compared with VMO activity.²⁴ The activity of the VMO when compared with the VL may, therefore, be of clinical interest. Bachler et al¹⁶ showed a significant difference between the activity of the VMO when compared with the VL for the front-pull and the crossover exercises.¹ Our VMO-VL difference showed a trend similar to the results of Bachler et al,¹⁶ yet it was not significant at the $P \leq .05$ level. Since the number of patients with patellofemoral pain in our study was not recorded, direct conclusions about the treatment of patellofemoral pain with these exercises are not possible. We suggest that the activity of the VMO and VL during these exercises be recorded on patients with patellofemoral pain.

CONCLUSIONS

Based on our results, we recommend all 4 closed kinetic chain elastic-tubing exercises for ACL rehabilitation. The front-pull and crossover exercises have high hamstrings:quadriceps ratios that may reduce the anterior shear forces and are therefore indicated in early ACL rehabilitation.

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Contrast Therapy Does Not Cause Fluctuations in Human Gastrocnemius Intramuscular Temperature

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Objective: Contrast therapy has a long history of use in sports medicine. Edema and ecchymosis reduction, vasodilation and vasoconstriction of blood vessels, blood flow changes, and influences on the inflammatory response are physiologic effects attributed to the ability of this modality to evoke tissue temperature fluctuations. Our purpose was to measure the change in human gastrocnemius intramuscular tissue temperature during a typical contrast therapy treatment.

Design and Setting: A randomized-group design was used to examine differences between 2 groups of subjects following a 31-minute warm whirlpool (control) and a 31-minute contrast therapy (experimental) treatment. A hydrotherapy room in a small-college sports medicine facility served as the test environment.

Subjects: Twenty (7 females and 13 males) healthy college students (age = 20.9 ± 1.2 years; ht = 178.5 ± 11.1 cm; wt = 79.2 ± 21.7 kg) volunteered to participate in this study. Subjects were randomly assigned to either a control or a treatment group.

Measurements: Intramuscular tissue temperatures in the gastrocnemius were recorded every 30 seconds.

Results: There was a significant difference in mean overall temperature change between the experimental group ($0.85^{\circ}\text{C} \pm 0.60^{\circ}\text{C}$) and the control group ($2.10^{\circ}\text{C} \pm 1.50^{\circ}\text{C}$). In addition, there were significant differences between the 2 groups at 10, 15, 16, 20, 21, 25, 26, 30, and 31 minutes. At each recording point, the control group temperature change was significantly higher than that of the experimental group. There was no difference in absolute temperatures at the 11-minute recording point between the groups.

Conclusions: Contrast therapy did not lead to significant fluctuations in muscle tissue temperature at 4 cm below the skin's surface. Therefore, it seems unlikely that the physiologic effects attributed to these fluctuations occur. A 1-minute exposure to a cold whirlpool during a typical contrast treatment does not appear to be long enough to significantly decrease tissue temperature after exposure to the warm hydrotherapy environment.

Key Words: contrast bath, temperature probe, cryotherapy

Contrast therapy has a long history as a modality used by the sports medicine community. Contrast therapy combines heat (thermotherapy) and cold (cryotherapy) modalities, usually alternating between immersion in warm and cold water. Traditionally, contrast therapy has been thought to reduce edema through a "pumping action," alternating between vasoconstriction and vasodilation.^{1,2} Contrast therapy has been indicated in subacute and chronic conditions and is believed to produce a number of physiologic effects, including increased tissue temperature, changes in blood flow in both the ipsilateral and contralateral extremities, increased blood flow, hyperemia of the superficial blood vessels, reduced muscle spasm, reduced inflammation, and improved range of motion.³ In our own clinical practice, we use contrast therapy as a transition between early cryotherapy and subsequent thermotherapy treatments.

The most effective time ratio between hot and cold treatments has not been determined. The most commonly used ratios have been 4:1 (warm:cold), with warm baths ranging in temperature from 37°C to 43°C alternating with cold baths ranging in temperature from 12°C to 15°C .⁴ Contrast treat-

ments are typically 20 to 30 minutes in length and are often repeated 2 or 3 times daily. Range-of-motion exercises can be performed during the heat phase to promote movement and improve flexibility and during the cold phase when pain and swelling are minimized.

Depending on the stage of the injury, the desired effect of the treatment, and the ability of the patient to participate, the contrast treatment may terminate after either warm or cold application.⁵ In the subacute stage, the treatment typically concludes with cold application, whereas treatment of a more chronic condition may conclude with heat application. Furthermore, if vasoconstriction is desired, treatments typically finish with cold; if vasodilation is desired, treatments end with heat. There is no evidence to suggest that ending with either heat or cold is more effective.

Despite the popularity of contrast therapy as a treatment modality, little research has been performed to examine its purported physiologic effects. A recent study by Myrer et al³ examined the effects of contrast therapy on intramuscular tissue temperature in the calf. They suggested that contrast therapy did not produce any significant physiologic effects in

the muscular tissue 1 cm below the subcutaneous tissue. They theorized that, in order for the purported physiologic effects of contrast therapy to occur, substantial fluctuations in tissue temperature must be produced by the alternating heat and cold applications.

Several studies have addressed the independent physiologic effects of heat and cold.⁵⁻¹⁰ It is generally accepted that cold application reduces the signs and symptoms associated with the inflammatory process. Cold retards swelling and soft tissue bleeding through vasoconstriction of the blood vessels and decreases in cellular metabolism, thus impairing the inflammatory response.^{3,4} Heat increases collagen extensibility and blood flow, acts as an analgesic agent, and can lessen muscular spasm and joint stiffness.^{5,7,11} In addition, heat facilitates soft tissue repair through accelerated cellular metabolism and decreases swelling by improving vascular and lymphatic flow.^{4,11} Lehmann et al¹² suggested that target tissue temperature must reach at least 40°C for the physiologic effects of heat therapy to be produced.

Using methodology similar to an earlier study by Myrer and colleagues,³ we were interested in examining the effect on tissue temperature in the leg of a longer exposure to both the warm and cold environments. Our purpose was to determine whether differences in gastrocnemius intramuscular tissue temperature existed between subjects receiving a conventional warm whirlpool treatment and subjects receiving a contrast therapy treatment.

METHODS

Subjects

Twenty (7 female and 13 male) college students (age = 20.9 ± 1.2 years; ht = 178.5 ± 11.1 cm; wt = 79.2 ± 21.7 kg) volunteered to be subjects in this study. All subjects were asked to fill out a health questionnaire and read and sign a consent form approved by a college institutional review board. Subjects were free of any leg pathologies and general circulatory problems. All health questionnaires were read by, and approval to participate was granted by, a licensed physician.

Test Procedures

We measured right calf girth (in mm) at the largest circumference while each subject lay prone on a plinth. Average girth measurements were 36.8 ± 5.1 cm in the control group and 37.5 ± 4.5 cm in the contrast group. A spot along the circumference measurement was marked using a sterile marking pen. Using a Lafayette skinfold caliper (Lafayette Instrument Co, Lafayette, IN), we performed a total of 3 skinfold measurements at the spot marked on the posterior calf. The average of these 3 skinfold measurements was used to determine the depth of subcutaneous fat between the skin and gastrocnemius muscle. Average skinfold measurements were 7.1 ± 3.5 mm in the control group and 7.2 ± 2.9 mm in the

contrast group. By dividing the average of the 3 skinfold measurements in half, the appropriate depth was then determined.¹³ An L-ruler was placed over the mark on the posterior calf to measure a depth of 2.5 cm (Figure 1). Using a sterile marker, a second mark was made. The L-ruler was designed and used to insure that the temperature microprobe was inserted at the same site in the gastrocnemius muscle of each subject.¹⁴ We cleansed the area around the second mark with an iodine solution and prepared it for insertion of the microprobe.

We used a YSI Tele-Thermometer (Yellow Springs Instruments, Inc, Yellow Springs, OH), along with a reusable YSI Series 500 hypodermic temperature probe, to measure and display intramuscular temperature of the gastrocnemius muscle. After each use, the hypodermic temperature probe was gas sterilized at a local hospital. We used a conversion chart to convert the displayed temperatures into degrees Celsius. Using sterile technique, we inserted the microprobe into the right calf region at the spot that was prepared and cleaned. The temperature probe's sensor tip was inserted to a depth of 4 cm below the skin's surface (Figure 2). The hypodermic temperature probe was then connected to the digital temperature display monitor. We recorded a baseline intramuscular temperature after 2 minutes.

Each subject sat in a whirlpool chair located directly in front of 2 whirlpools (Ferno Corporation, Wilmington, OH) placed side by side. This whirlpool arrangement allowed the subjects in the contrast group to move quickly and efficiently between heat and cold exposures. Between treatments, we disinfected both whirlpools according to the manufacturer's recommendations, using tap water and an iodine-based whirlpool cleaner. Each subject immersed the right leg into the whirlpool to the base of the patella. The leg remained at a distance of 20 cm from the agitation device. The agitation flow and level remained constant throughout all treatments.



Figure 1. Use of an L-ruler to measure a depth of 2.5 cm on the posterior calf for placement of the hypodermic temperature probe.

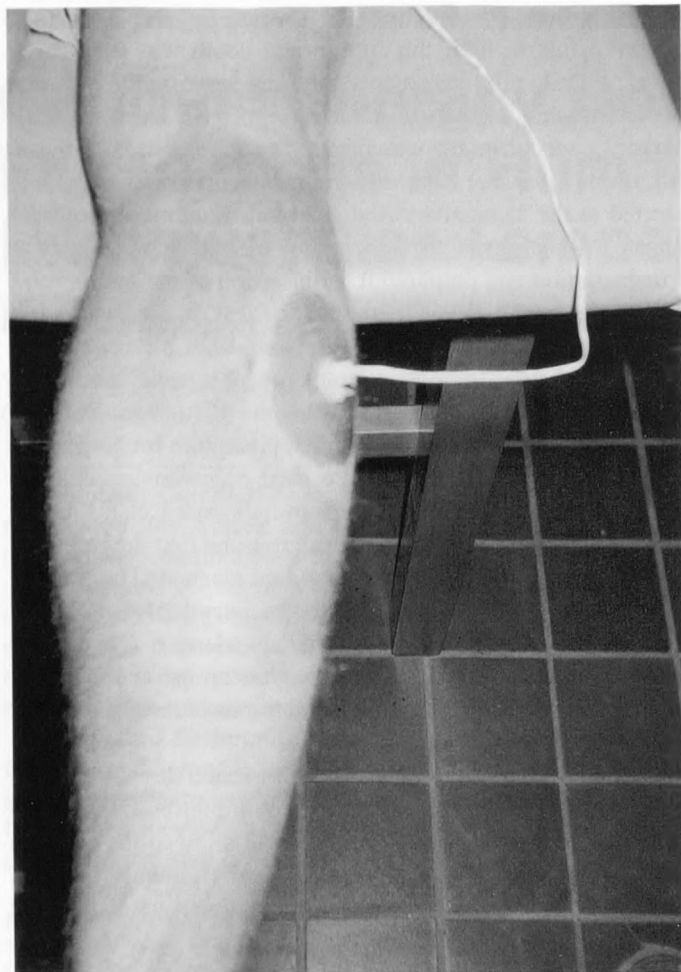


Figure 2. Hypodermic temperature probe inserted into the posterior calf at a depth of 4 cm.

Subjects assigned to the control group immersed the treatment leg into a warm whirlpool (40°C) for 31 minutes. Subjects assigned to the experimental group underwent a contrast therapy treatment for 31 minutes. Each experimental group subject spent the first 10 minutes with the treatment leg immersed in a warm whirlpool (40°C). Then the treatment leg was immersed in a cold whirlpool (15°C) for 1 minute, after which the subject began to cycle the treatment leg through a series of warm (4 minutes) and cold (1 minute) whirlpool sequences to maintain a warm-to-cold time ratio of 4:1. Four cycles were completed. We recorded intramuscular tissue temperature in both groups every 30 seconds during the 31-minute treatment.

At the end of each treatment, we removed the hypodermic microprobe and cleansed the insertion site. We then applied an antibiotic ointment and covered the site with an adhesive bandage strip. None of the subjects developed signs of infection.

Data Analysis

We used a 2-tailed *t* test for independent samples to determine whether differences existed between the 2 groups in relation to overall temperature change after the 31-minute

treatment. We analyzed the effect of contrast therapy on intramuscular tissue temperature by calculating the temperature change (either positive or negative) from baseline to the end of each warm and cold immersion. Ten points in time (10, 11, 15, 16, 20, 21, 25, 26, 30, and 31 minutes) were analyzed across both groups. We used a mixed-model analysis of variance (ANOVA) with 1 between-subject factor (group) and 1 within-subject factor (time point), to determine whether differences existed between the 2 groups with respect to temperature change from baseline over the 10 points in time. A Tukey post hoc analysis was used to closely examine any significant differences. An a priori α level of 0.05 was used for all statistical tests.

RESULTS

Overall Temperature Change

The mean baseline temperature in the control (warm whirlpool) group was $34.95^{\circ}\text{C} \pm 1.56^{\circ}\text{C}$, while the mean baseline temperature in the experimental (contrast therapy) group was $35.87^{\circ}\text{C} \pm 0.68^{\circ}\text{C}$. The overall temperature change in the control (warm whirlpool) group ranged from 0.83°C to 5.88°C , while changes in the experimental group ranged from 0.01°C to 1.91°C . A significant difference in overall temperature change between the 2 groups ($t_{18} = -2.48$, $P = .02$) was derived from the *t* test for independent samples. The overall temperature change in the control (warm whirlpool) group was significantly higher ($2.1^{\circ}\text{C} \pm 1.5^{\circ}\text{C}$) than that of the experimental (contrast) group ($0.85^{\circ}\text{C} \pm 0.60^{\circ}\text{C}$).

Time Point Temperature Changes

The ANOVA resulted in a significant group-by-temperature change (control versus experimental) from baseline interaction ($F_{9,62} = 22.01$, $P < .001$) (Figure 3). Tukey post hoc analysis determined that differences of $\geq 0.28^{\circ}\text{C}$ were considered significant. There were significant differences in temperature change between the 2 groups at all points in time (10, 15, 16, 20, 21, 25, 26, 30, and 31 minutes), except from baseline to 11 minutes. In each time period, the temperature change was greater in the control group (warm whirlpool) when compared with the experimental group (contrast).

DISCUSSION

Contrast therapy is commonly used in the treatment of athletic injuries. There is, however, limited evidence in the literature to support the purported physiologic effects of this treatment modality. The primary purpose of our study was to examine the ability of contrast therapy to produce temperature changes that lead to the physiologic responses previously reported. We found the mean overall temperature change in the control (warm whirlpool) group to be significantly greater than that of the experimental (contrast therapy) group. Both groups

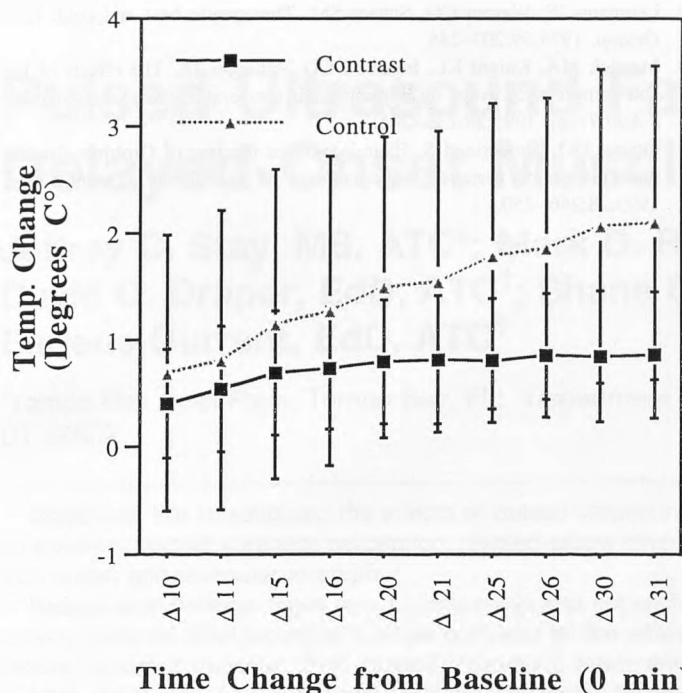


Figure 3. Significant interaction between group (control versus experimental) and temperature change from baseline.

showed slight increases in tissue temperature and support the earlier findings of Myrer et al.³ However, the tissue temperature in the Myrer et al study³ was measured at a depth of 1 cm, and the total treatment time was only 20 minutes. The difference in tissue temperatures between the 2 groups supports the concept that the longer a heating modality is applied, the greater the heat exchange between the modality and the targeted tissue. We can assume that the control (warm whirlpool) group experienced a larger temperature increase because they were exposed to the warm water environment for the entire 31 minutes of treatment. The experimental (contrast therapy) group was exposed to a warm water environment for only 26 of the 31 total treatment minutes. Despite the statistical significance of the temperature changes in our study, careful consideration must be given to the clinical significance. Lehmann et al¹² reported that tissue temperatures must reach at least 40°C in order to produce a significant physiologic response to heat. Temperatures below this threshold produce only placebo effects. Interestingly, in our study no subjects in either the control or experimental group experienced tissue temperatures at or above 40°C. Clinicians should carefully assess the ability of both warm whirlpool and contrast therapy treatments to elicit any significant physiologic benefits associated with deep heat modalities.

The temperature change from baseline data enabled us to examine whether or not fluctuations in temperature occurred in the subjects involved in the contrast therapy treatments, as has been previously suggested. A significant group-by-temperature change from baseline interaction occurred (Figure 3). It appears that, from the 11-minute mark to the end of the 31 minutes of treatment, the contrast therapy group had very little

change in tissue temperature. Conversely, the warm whirlpool group experienced a gradual increase in tissue temperature as exposure time increased, thereby leading to the significant differences between tissue temperatures at those time points beyond 11 minutes. These differences can be explained by the duration of heat exposure of the control group subjects. It has been thought that contrast therapy significantly decreases tissue temperature during exposure to the cold whirlpool environment and evokes a vasoconstriction response.^{1,2} Our results are in conflict with this premise because there was no fluctuation in tissue temperature; in fact, the temperatures increased.

We conclude that contrast therapy does lead to changes in intramuscular tissue temperature at a depth of 4 cm below the skin's surface. However, this change consists of an overall gradual increase in tissue temperature and not the rise and fall in temperature brought about by alternating between hot and cold environments. Furthermore, it seems unlikely that the physiologic effects attributed to this alternation would occur. Exposure to the cold whirlpool environment for only 1 minute, as was used in our study, does not appear to be long enough to significantly decrease the tissue temperature in the calf immediately following exposure to the warm whirlpool. However, exposure to the cold whirlpool, at the intervals used in our study, does appear to decrease the rate at which the overall tissue temperature increases. Further study is needed to examine the effects of using different hot-to-cold time ratios during a contrast therapy treatment. We would advise clinicians to carefully assess their treatment objectives when using contrast therapy as part of their rehabilitation program.

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Pulsed Ultrasound Fails To Diminish Delayed-Onset Muscle Soreness Symptoms

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Objective: We investigated the effects of pulsed ultrasound on swelling, muscle soreness perception, relaxed-elbow extension angle, and muscular strength.

Design and Setting: Eight sets of concentric and eccentric actions induced delayed-onset muscle soreness of the elbow flexors. Group 1 received 20% pulsed ultrasound treatments (1-MHz, 7 minutes, 1.5 W/cm² temporal peak intensity) twice a day immediately after postexercise assessments and at 3, 24, 27, 48, 51, 72, and 75 hours postexercise. Group 2 received sham treatments immediately after postexercise assessments and at 3, 27, 51, and 75 hours postexercise and true treatments of pulsed ultrasound at 24, 48, and 72 hours postexercise. Group 3 received sham treatments of no ultrasonic output immediately after postexercise assessments and at 3, 24, 27, 48, 51, 72, and 75 hours postexercise.

Subjects: Thirty-six college-age females.

Measurements: We recorded upper-arm circumference, perceived soreness, relaxed-elbow extension angle, and elbow-flexion strength before (pretest), immediately postexercise, and at 24, 48, 72, and 96 hours postexercise.

Results: We noted differences over time but no treatment effect between groups or interactions between time and group for upper-arm circumference, perceived soreness, relaxed-elbow extension angle, or elbow-flexion strength.

Conclusions: Pulsed ultrasound as used in this study did not significantly diminish the effects of delayed-onset muscle soreness on soreness perception, swelling, relaxed-elbow extension angle, and strength.

Key Words: swelling, pain, modalities

Exercise-induced muscle soreness is a common occurrence in athletics. Athletes starting a new season, a new training program, or a weightlifting program involving unaccustomed concentric and eccentric work will likely experience delayed-onset muscle soreness (DOMS). DOMS is easily induced by relatively intense, slow, eccentric muscle actions.^{1,2} These eccentric actions produce microinjury to the active muscle fibers,³⁻⁶ exhibiting muscular soreness, loss of joint range of motion, swelling, and decreased force production.^{4,7-12} Clinical signs of DOMS include increases in plasma enzymes,^{8,10,12} muscular fiber degeneration,¹³ and the protein degradation¹⁴ that accompanies the degeneration.

Previous researchers^{3,4,15-17} have explained possible etiologies and mechanisms for DOMS. Relatively few studies have examined the effect of therapeutic modalities in reducing the detrimental effects of DOMS. Previous researchers¹⁸⁻²³ focused on reducing the symptoms associated with DOMS. To prevent or significantly diminish the symptoms of DOMS, a few researchers²⁰⁻²³ applied various modalities and treatments immediately after high-intensity exercise. These studies achieved little success in preventing DOMS. It has been suggested in previous research,¹⁹ articles,^{24,25} and textbooks^{26,27} that, in order to achieve maximal benefit, ultrasound

treatments should begin soon after injury and acute conditions should be treated once or twice daily.

The purpose of our study was to investigate the effects of pulsed ultrasound on the following symptoms associated with DOMS: upper-arm swelling, muscle soreness perception, decreased range of motion, and decreased muscle strength.

METHODS

We investigated the effects of pulsed ultrasound on upper-arm swelling, muscle soreness perception, relaxed-elbow extension angle, and muscle strength loss associated with DOMS. The design of this study consisted of pretest assessments, exercise protocol, postexercise measures, and treatment protocol.

Participants

Thirty-six college-age females (age = 21.5 ± 2.0 years; ht = 164.5 ± 6.2 cm; wt = 57.5 ± 6.5 kg) volunteered for participation in this study, which was approved by the Committee on Human Research at Brigham Young University. Participants read and signed an institutionally approved consent form, which outlined the procedures of the study. All

participants reported pain-free range of motion about their elbow joints and no arm pain for at least 3 months before the study. Participants were allowed to perform their normal activities of daily living during the testing period but were asked not to stretch, take pain medication, or receive any other therapy.

Instrumentation

The Omnisound 3000 (Accelerated Care Plus-LLC, Topeka, KS) ultrasound unit was used for the treatments. The 5-cm² transducer contained a crystal made of lead zirconate titanate. The effective radiating area of the crystal registered 3.7 cm², and the beam nonuniformity ratio was listed at 2.8:1.0. The Omnisound 3000 ultrasound unit was calibrated before the study. UltraPhonic ultrasound gel (Pharmaceutical Innovations, Inc, Newark, NJ) served as the conducting medium.

We measured upper-arm circumference using a retractable, flexible steel tape measure (J.A. Preston Corp, New York, NY). One end of this tape measure had a tension gauge with a preset mark to register consistent tension on the tape. Relaxed-elbow extension angle was measured using a 50-cm-long, full-circle plastic goniometer. Elbow-flexion strength was assessed using free-weight dumbbells in increments of 0.45 kg and a preacher curl bench.

Pretest Assessments

We assessed circumference, perceived soreness of the elbow flexors, relaxed-elbow extension angle, and elbow-flexion strength of the subject's nondominant arm before the exercise bout. To maintain uniformity in measurements and protocol, one investigator took the daily measurements throughout the study.

Upper-arm circumference measurements were taken at 4 sites²⁸ (4 cm, 6 cm, 8 cm, and 10 cm above the elbow joint) to evaluate swelling of the elbow flexors. The investigator placed the tape measure around the upper arm so that he consistently pulled the tension gauge to the left and obtained measurements while the relaxed arm was hanging at the subject's side. The investigator used a black permanent ink pen to mark measurement sites on the arm and to darken the sites each day. We recorded circumference to the nearest 0.1 cm.²⁹ The accuracy of this technique has been previously established to be within 2 mm.³⁰

Participants subjectively reported perceived soreness in their elbow flexors using the following soreness rating scale: 0 (none), 1 (very slight), 2 (mild), 3 (moderate), 4 (severe), and 5 (extreme). Subjective soreness rating scales similar to this have been used by others.^{7-10,12,14,15} The investigator applied light palpation to the elbow flexors while the participant rated her soreness according to the scale. Participants could not see any previously reported scores.

Next, we assessed relaxed-elbow extension angle, which was defined as the angle between the humerus and ulna when

the subject was standing with the arm hanging by her side in a semipronated position. The investigator used a permanent marker to label anatomical reference points on the arm at the lateral edge of the acromion at the shoulder, the lateral epicondyle of the elbow, and the ulnar styloid process of the wrist. The investigator placed the goniometer over the lateral epicondyle of the humerus with the measurement arms of the goniometer aligned along the lateral markers on the shoulder and wrist. The reliability ($r = 0.9$)^{31,32} of this measurement procedure using a standard goniometer has been previously established.

Participants performed a 1-repetition maximum (1RM) biceps curl using free-weight dumbbells and a preacher curl bench to assess elbow-flexion strength. The bench stabilized the upper arm at a 45° angle of shoulder flexion. The 1RM was established when the participant could perform a biceps curl from full elbow flexion to approximately 10° elbow flexion with a dumbbell weight, yet could not perform the curl with a 0.45-kg heavier weight.

Exercise Protocol

To exercise and induce DOMS, participants performed concentric and eccentric dumbbell curls. The elbow flexors were isolated by stabilizing the arm on a preacher curl bench. First, each participant performed 4 sets of concentric and eccentric actions consisting of 10 repetitions or muscular failure at 80% of her 1RM. Next, participants completed 4 sets of eccentric actions consisting of 10 repetitions or muscular failure at 100% of 1RM. The participants slowly (over 5 seconds) lowered the dumbbell from a fully flexed to a fully extended position. The researcher returned the weight to the starting position of full elbow flexion after each eccentric repetition to emphasize the eccentric action of the elbow flexors. The participant rested 1 minute between sets.

Postexercise Assessments

Postexercise measurements were taken to assess upper-arm swelling, perceived soreness in the elbow flexors, relaxed-elbow extension angle, and elbow-flexion strength immediately postexercise and 24, 48, 72, and 96 hours postexercise. We followed the same procedures for measurement as for pre-exercise assessments. To measure the effects of the previous day's treatments, we recorded assessments before ultrasound treatment.

Treatment

After the postexercise assessments, participants received either 20% pulsed ultrasound treatment (1 MHz, 7 minutes, 1.5 W/cm²) or a sham treatment to an area 10 cm × 5 cm on the anterior surface of the upper arm and elbow joint. A precut template, secured to the arm, ensured that treatment size was consistent. Participants were positioned supine on a treatment

table during each treatment, and the ultrasound machine was placed out of sight. The examiner maintained slow, constant motion of the ultrasound head within the template. While giving placebo treatments, the examiner manipulated the timer to signal the end of each treatment.

Participants were randomly assigned to 1 of 3 treatment groups (12 subjects per group). Group 1 received pulsed ultrasound treatments twice a day immediately after postexercise assessments and at 3, 24, 27, 48, 51, 72, and 75 hours postexercise. Group 2 received sham treatments immediately after postexercise assessments and at 3, 27, 51, and 75 hours postexercise and true treatments of pulsed ultrasound at 24, 48, and 72 hours postexercise. Group 3 received sham treatments of no ultrasonic output immediately after postexercise assessments and at 3, 24, 27, 48, 51, 72, and 75 hours postexercise.

Statistical Analysis

A 3×6 factorial repeated-measures analysis of variance was used to test for significant differences ($P < .05$) in upper-arm circumference, perceived soreness, relaxed-elbow extension angle, and 1RM elbow-flexion strength. The between-subjects factor (group) had 3 levels (twice-daily applications; once-daily application of pulsed ultrasound, followed by once-daily sham application of pulsed ultrasound; and twice-daily sham applications of pulsed ultrasound). The within-subjects factor (time) had 6 levels (pretest, immediately postexercise, 24, 48, 72, and 96 hours). Tukey tests were used for all post hoc comparisons.

RESULTS

The exercise protocol produced significant differences over time for swelling, soreness, relaxed-elbow extension angle, and strength. We did not find significant interactions between time and group, nor were there significant differences among groups for the symptoms of DOMS. Post hoc analysis of power indicated that statistical power ranged from 0.25 to 0.72.

Circumference

The responses over time were similar at all 4 circumference sites; as a result, we reported only the 4-cm measures (Table 1). The time effect was significant at 4 cm above the elbow joint ($F_{5,29} = 32.71$, $P < .001$). The 4-cm circumference measures

immediately postexercise and at 24, 48, 72, and 96 hours were all significantly different from pretest measures (Table 1). There were no significant interactions between time and group ($F_{10,165} = 0.49$, $P = .90$). Neither were there significant differences in swelling at 4 cm among groups ($F_{2,33} = 1.38$, $P = .27$).

Perceived Soreness

There was a significant time effect for perceived soreness ($F_{5,29} = 102.13$, $P < .001$). Perceived soreness measures immediately postexercise and at 24, 48, and 72 hours were all significantly different from pretest measures. The 96-hour measures were not significantly different from the pretest measures (Table 2). There were no significant interactions between time and group ($F_{10,58} = 0.67$, $P = .75$). Neither were there significant differences in soreness among groups ($F_{2,33} = 0.49$, $P = .62$).

Relaxed-Elbow Extension Angle

There was a significant time effect for relaxed-elbow extension angle ($F_{5,29} = 13.59$, $P < .001$). Relaxed-elbow extension angles immediately postexercise and at 24, 48, 72, and 96 hours were all significantly different from pretest measures (Table 3). There were no significant interactions between time and group ($F_{10,58} = 0.79$, $P = .63$). Neither were there significant differences in relaxed-elbow extension angle among groups ($F_{2,33} = 0.83$, $P = .45$).

Strength

There was a significant time effect for strength decreases ($F_{5,165} = 56.13$, $P < .001$). Strength decreases immediately postexercise and at 24, 48, 72, and 96 hours were all significantly different from pretest measures (Table 4). There were no significant interactions between time and groups ($F_{10,165} = 0.62$, $P < .79$). Neither were there significant differences in strength decreases among groups ($F_{2,33} = 0.14$, $P < .87$).

DISCUSSION

DOMS usually has a gradual onset within 24 hours postexercise, peaks in intensity at 24 to 72 hours, and then declines. Symptoms gradually subside within 10 days postexercise.^{1,2}

Table 1. Mean Circumference (cm) 4 cm Above the Elbow Joint by Treatment Group and Time

Group	Pretest	Time Postexercise				
		Immediately	24 h	48 h	72 h	96 h
Twice daily	23.3 \pm 2.0	24.0 \pm 2.0	23.6 \pm 2.0	23.6 \pm 2.0	23.6 \pm 2.2	23.6 \pm 2.1
Once daily	22.5 \pm 1.9	23.0 \pm 1.8	22.7 \pm 1.8	22.8 \pm 1.9	22.8 \pm 1.9	22.8 \pm 1.9
Placebo	22.2 \pm 1.3	22.8 \pm 1.3	22.5 \pm 1.2	22.5 \pm 1.2	22.4 \pm 1.2	22.4 \pm 1.2
Time mean	22.7 \pm 1.8	23.3 \pm 1.7*	22.9 \pm 1.8*	23.0 \pm 1.7*	22.9 \pm 1.8*	22.9 \pm 1.8*

* Immediately, 24, 48, 72, and 96 hours postexercise means were all significantly different from pretest mean.

Table 2. Mean Perceived Soreness Level of Elbow Flexors by Treatment Group and Time

Group	Pretest	Time Postexercise				
		Immediately	24 h	48 h	72 h	96 h
Twice daily	0.0 ± 0.0	0.9 ± 0.8	2.7 ± 0.5	2.7 ± 0.9	1.4 ± 0.9	0.5 ± 0.5
Once daily	0.0 ± 0.0	1.2 ± 0.9	2.5 ± 0.8	2.6 ± 0.8	1.2 ± 0.8	0.2 ± 0.5
Placebo	0.0 ± 0.0	1.5 ± 1.1	3.0 ± 1.0	2.5 ± 0.9	1.5 ± 0.9	0.2 ± 0.5
Time Mean	0.0 ± 0.0	1.2 ± 1.0*	2.7 ± 0.8*	2.6 ± 0.8*	1.4 ± 0.9*	0.3 ± 0.5

* Immediately, 24, 48, and 72 hours postexercise means were significantly different from pretest mean.

Table 3. Mean Relaxed-Elbow Extension Range of Motion (degrees) by Treatment Group and Time

Group	Pretest	Time Postexercise				
		Immediately	24 h	48 h	72 h	96 h
Twice daily	164.3 ± 3.5	159.2 ± 3.8	160.0 ± 4.1	158.2 ± 2.7	160.2 ± 3.9	161.0 ± 3.6
Once daily	162.7 ± 3.5	160.7 ± 4.7	160.2 ± 4.4	159.8 ± 4.4	160.7 ± 4.8	161.4 ± 4.2
Placebo	162.2 ± 4.0	158.5 ± 5.7	158.6 ± 5.2	156.2 ± 5.9	158.6 ± 5.2	159.5 ± 5.0
Time mean	163.1 ± 3.7	159.5 ± 4.7*	159.6 ± 4.5*	158.1 ± 4.6*	159.8 ± 4.6*	160.6 ± 4.3*

* Immediately, 24, 48, 72, and 96 hours postexercise means were all significantly different from pretest mean.

Table 4. Mean 1RM (kg) for Elbow Flexion by Treatment Group and Time

Group	Pretest	Time Postexercise				
		Immediately	24 h	48 h	72 h	96 h
Twice daily	5.8 ± 1.0	3.9 ± 1.2	4.2 ± 0.6	4.4 ± 0.9	4.7 ± 0.7	4.9 ± 0.9
Once daily	5.4 ± 1.2	3.8 ± 1.4	4.1 ± 1.4	4.3 ± 1.4	4.7 ± 1.3	4.9 ± 1.3
Placebo	5.5 ± 0.9	4.2 ± 0.8	4.2 ± 0.7	4.5 ± 0.9	4.9 ± 0.9	5.1 ± 0.7
Time mean	5.6 ± 1.1	3.9 ± 1.1*	4.2 ± 0.9*	4.4 ± 1.0*	4.8 ± 1.0*	4.9 ± 1.0*

* Immediately, 24, 48, 72, and 96 hours postexercise means were all significantly different from pretest mean.

DOMS allowed us to assess the effectiveness of pulsed ultrasound treatment on swelling, perceived soreness, loss of relaxed-elbow extension, and loss of strength over 96 hours. We also examined the effects of an immediate application of pulsed ultrasound on preventing or significantly decreasing the symptoms of DOMS.

Prevention

With the immediate postexercise application of pulsed ultrasound to the elbow flexors, we hoped to prevent or significantly decrease the symptoms of DOMS. Even with the immediate treatment, the symptoms associated with DOMS were equally prevalent in all groups at 24 hours postexercise. We, like previous investigators^{20,21} using modalities to prevent symptoms of DOMS, did not find any significant prevention of or decrease in symptoms of DOMS with a treatment given immediately postexercise. Ice massage, ice massage with exercise, and exercise alone have not significantly prevented or reduced soreness, strength, or range-of-motion losses associated with DOMS.²⁰ In another study,²¹ when massage, microcurrent electrical stimulation, upper body ergometry, and a postexercise resting control group were compared, treatments applied immediately and 24 hours postexercise did not prevent soreness or strength loss. Conversely, Mickey et al²³ suggested that a 20-minute ice pack application followed by pulsed ultrasound (7 minutes at 20% duty cycle, 1

MHz, 1.0 W/cm²) applied immediately postexercise and once daily for 3 days may be more effective than ice alone for the prevention and treatment of DOMS.

Treatment

DOMS is temporary, repairable damage to muscle.^{1,11,33} We used pulsed ultrasound in this study because the mechanical effects, stable cavitation, and microstreaming are believed to aid tissue regeneration and healing.³⁴⁻³⁶ Acoustic microstreaming and cavitation increase the diffusion of ions and metabolites across cell membranes and enhance the reparative process.³⁷ Changes in calcium permeability are associated with enhanced tissue healing.³⁷ Increased sodium permeability may reduce pain and spasm by altering neural activity.³⁷ Any significant evidence of circumference, perceived soreness, relaxed-elbow extension angle, or strength measures returning to pretest measures at a faster rate would have indicated healing and a treatment effect. We did not find any evidence of a treatment effect.

Circumference

Previous investigators^{4,16,19} have claimed the degree of soreness DOMS produces is influenced by increased muscle pressure causing swelling within the exercised muscular area.

Other researchers^{22,38,39} have shown that DOMS is not caused by increased muscle pressure and swelling. Swelling has been observed as a similar response in DOMS and acute inflammation, yet DOMS has been shown to be different from an acute inflammatory response.^{28,33} When pulsed ultrasound has been endorsed^{24,37,40} as successful in treating swelling, it was being used to treat an acute inflammatory response. We found that the treatments did not reduce swelling in DOMS.

Soreness

Our exercise protocol induced soreness in the elbow flexors in all the participants of our study. The time course of DOMS was consistent with other studies¹⁸⁻²² using modalities on DOMS. Previous researchers¹⁹ observed that pulsed ultrasound alleviated muscle soreness perception of DOMS at 48 hours. In our study, as in previous studies,^{21,22} the mean values for perceived soreness at 24 hours and 48 hours were statistically the same for all treatment groups.

There were many differences between our study and the former study¹⁹ that might have influenced soreness perception. Groups in our study had (a) multiple treatments (from 0 to 7 applications) at multiple times; (b) continual movement of the ultrasound transducer (1 MHz, 1.5 W/cm² temporal peak intensity, 7 minutes, 20% duty cycle); (c) a 5 × 10-cm treatment site on the upper extremity; and (d) strength measures based on a small muscle group (elbow flexors). Conversely, groups in the previous study¹⁹ had (a) 1 treatment at 24 hours postexercise; (b) stationary positioning of the ultrasound transducer (1 MHz, 0.8 W/cm², 20 minutes, 20% duty cycle); (c) 2 36-cm treatment sites on the lower extremity; and (d) strength measures based on a large muscle group (quadriceps).

Relaxed-Elbow Extension Angle

Little research has been performed on range of motion and pulsed ultrasound. Continuous ultrasound, with its thermal effects, is normally used when an increase in range of motion is desired.⁴¹ In our study, all groups significantly changed in relaxed-elbow extension angle immediately postexercise, and this change remained significant through the final assessment. The greatest mean loss (5°) in relaxed-elbow extension from pre-exercise measures was at the 48-hour postexercise assessment. We did not find pulsed ultrasound to significantly restore relaxed-elbow extension angle.

Strength

Pulsed ultrasound has been used in the past for stable cavitation and microstreaming to heal injured muscle. Loss of strength is a sign of injured muscle.^{2-4,7,19} Hasson et al¹⁹ observed that the percentage deviations from baseline for isometric contraction, maximum-extension torque, and knee-extension work were significantly less at 48 hours for subjects

who received pulsed ultrasound compared with placebo treatment and control subjects. The authors concluded that pulsed ultrasound accelerates restoration of normal muscle performance and, thus, was effective in decreasing DOMS. Our results differed: for all groups, the 1RM strength values decreased equally and then slowly increased over the 5-day assessments, yet no group was able to achieve its original 1RM mean.

CONCLUSIONS

Pulsed ultrasound as used in our study did not significantly diminish the effects of DOMS on soreness perception, swelling, relaxed-elbow extension angle, or strength. Other protocols using ultrasound may be effective in reducing symptoms of DOMS. Further studies are needed, however, to establish this effectiveness.

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Perceptions of Athletic Training Services by Collegiate Student-Athletes: A Measurement of Athlete Satisfaction

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Objective: I evaluated the perceptions student-athletes had of their athletic trainers and of the medical coverage provided them by the athletic departments at their institutions. My intent was to assess differences between male and female athletes, between athletes of high-profile and low-profile sports, and between athletes who competed at the NCAA Division I and Division II levels. The research design was also directed at identifying any subgroup of student-athletes who demonstrated a significantly different perception toward their athletic trainer(s).

Design and Setting: Questionnaires were sent to 32 athletic training programs at 28 NCAA Division I and II institutions. Eighteen of the 32 programs participated, yielding a 56% response.

Subjects: A total of 343 student-athletes from 18 selected athletic programs at both the NCAA Division I and II levels participated. One questionnaire contained response errors and was not included in the analysis.

Measurements: A questionnaire was developed and pilot tested at 3 collegiate settings apart from those participating in

the study. Validity and reliability analyses were conducted and confirmed by additional professionals in the field of athletic training. Cumulative mean perception scores between groups were measured using independent *t* tests. Differences in scores between subgroups were measured using a 1-way analysis of variance.

Results: I observed significant differences in mean cumulative perception scores between sex and sport-profile groups. Male athletes and athletes in high-profile sports demonstrated a higher mean perception score than did females and athletes in low-profile sports. There was no difference in scores when compared across athletic divisions. Subgroups of all the athletes participating were identified. Several subgroups demonstrated significant differences in mean cumulative perception scores.

Conclusions: Males and females in low-profile sports at Division II schools and females in high-profile sports at Division II schools had significantly lower mean perception scores than did other subgroups of athletes.

Key Words: relationship, attitude, responsibility, quality

Professionals in the field of athletic training uniformly agree that they are valuable members of the sports medicine team. The prevention of injuries and illness related to athletic participation has traditionally been the responsibility of the athletic trainer. Athletic trainers are also the primary link between the athlete and the medical community.^{1,2} Results from the Role Delineation Study³ conducted by the National Athletic Trainers' Association identified injury prevention, evaluation, the rehabilitative process, administrative duties, and professional development as fundamental responsibilities of the athletic trainer. While conducting activities associated with injury assessment and rehabilitation, the athletic trainer must maintain a quality relationship with the athlete in order to facilitate the process. In fact, the importance of the relationship between the athletic trainer and the athlete has been identified as being of fundamental importance in providing medical services to athletes.⁴ Most athletic trainers would agree that it is important to develop a strong rapport with their athletes. There are, however, questions about how the athlete perceives the athletic trainer and views the medical services he or she provides. Do athletic trainers assume they are respected by their athletes while providing them with a

variety of health care services? Do athletes accept the professional nature of an athletic trainer's service? Do athletes respect the athletic trainer's knowledge and the way in which the delivery of health care service is provided? Do athletic trainers take it for granted that an athlete is expected to respond favorably and without question to their presumed expertise? Do athletes favorably perceive their athletic trainer as having the skills necessary to provide them with a quality health management system? Answers to questions such as these are pertinent when addressing how student-athletes view the medical services provided them by the athletic program at their institution.

It has been suggested that collegiate athletes enjoy access to a medical delivery system far surpassing that at many other competitive levels.⁴ Directing the sport health care system at the college level is the athletic trainer. How the collegiate student-athlete perceives the delivery of medical services can assist the athletic trainer in providing quality medical care. The perception athletes have of the injury evaluation process has been demonstrated in the literature.⁵ How an athlete's perception of treatment influences rehabilitation adherence has also been documented.⁵⁻⁸ The athlete's perception of the medical

delivery system has been shown to significantly affect the relationship between the athlete and the athletic trainer.⁵⁻⁸ I felt that further examination of the perceptions athletes have of their athletic trainers was indicated and that the athletic training environment at the collegiate level offered the best model for this study.

A thorough investigation of the athlete's view of the medical delivery system provided by athletic trainers has not been conducted. My purpose was to investigate whether athletes of different subgroups demonstrated differences in perceptions of their athletic trainers' medical delivery service by measuring differences in cumulative perception scores by sex, sport profile, and level of competition (NCAA Division I versus Division II). These results may offer the professional athletic trainer an understanding of the athlete's perception of how the athletic trainer does his or her job. Knowledge of the level of an athlete's satisfaction and whether or not the athlete has a positive perception of the athletic trainer's service could assist athletic trainers in providing an environment that will enhance health care delivery to all their athletes.

METHODS

Subjects

Fourteen athletic training programs from 12 institutions that were members of the Southeastern Conference, an NCAA Division I athletic conference, were selected to participate. Seventeen athletic training programs at institutions that were members of the Gulf South Conference, a conference at the NCAA Division II level, were identified and used as a comparative group. Two athletes from each male and female sport at the institutions identified for participation were systematically selected as subjects from the alphabetic rosters for each team. The specific chronologic number for each athlete on every roster was identified for selection. I acquired approval by the University of Arkansas Institutional Review Board for Protection of Human Subjects before requesting subject participation. Eighteen of the 31 programs invited to participate responded, yielding a 58% response rate. One hundred sixty-five male athletes and 178 female athletes ($n = 343$) participated in the study. One questionnaire contained response errors and was not included in the analysis.

Instrumentation

I developed a questionnaire for the data collection process in this study. A description of the questionnaire and directions for administration were also developed. The questionnaire, consisting of 2 sections, was consistent with the method of summated ratings for Likert scale questionnaires.⁹⁻¹¹ The questionnaire comprised 36 questions designed to collect responses along a Likert-type scale and 14 questions designed to obtain "yes" or "no" responses. Questions were developed from subject matter contained in each section of the Role

Delineation Study conducted by the National Athletic Trainers' Association.³ The role delineation outline provided a description of the duties an athletic trainer is required to perform. Each question was constructed to elicit responses reflective of how the student-athletes perceived their athletic trainers' performance of the duties identified in the Role Delineation Study.³ Also included were questions designed to elicit responses representative of the athletes' perceptions of the general medical coverage provided by the athletic trainers at their institutions.

I conducted a pilot study of 3 athletic programs at institutions not involved with the actual study to validate the questionnaire. The pilot test sites were representative of the sample identified for participation in the study. By initiating a pilot test of the research instrument, I was able to acquire face validity from professionals in the field of athletic training. Content validity was established by constructing questions that addressed issues related to each domain of the athletic trainer's professional responsibility as established by the NATA Role Delineation Study.³

I conducted reliability testing by using 2 forms of reliability analysis. A split-half test for internal consistency was conducted for the initial evaluation of measuring test reliability. The split-half test yielded a 0.8211 correlation coefficient for measuring the relationship between equally divided portions of the test. A Cronbach coefficient α test was conducted in order to establish further internal stability from a variety of internal comparisons of the instrument. A 0.9017 coefficient was produced by the test, demonstrating a strong measure of internal consistency for the questionnaire.

Data Collection

I developed a scoring procedure for the purpose of measuring and tabulating the responses each student-athlete provided for every statement in the questionnaire. Measuring positive statements along a scale originally developed by Likert has been demonstrated in the literature.^{9,10} In order to quantify student-athlete response, a point value was assigned to each response. "Strongly agree" was given a point value of 4, "moderately agree" a point value of 3, "neutral" a point value of 2, "moderately disagree" a point value of 1, and "strongly disagree" a point value of 0. A response written in by the subject as "not applicable" or that was not answered was weighted the same as if a "neutral" response had been chosen, equaling a score of 2 for that particular question. The section of the student-athlete response form that required a "yes" or "no" response was also scored. A "yes" response was weighted with a score of 1, and a "no" response elicited a score of 0. Questions that initiated a "yes" or "no" response directly addressed specific points related to the research intent. Cumulative scores elicited by completion of the questionnaire were used for analysis between groups and for determination of differences between subgroups. Analysis of responses to the

"yes" or "no" questions was conducted in order to identify differences in responses by subgroup.

Data Analysis

Male athletes who competed in football, basketball, or baseball and female athletes who played basketball were classified as participating in high-profile sports. All other athletes were grouped in the low-profile category. I was able to classify sports into high and low profile by conducting a survey of sports information directors before the data collection process. Participating sports information directors were asked to list the sports for which they received the most requests for information from either media representatives or the fan base. Football, men's and women's basketball, and baseball were clearly identified as sports that all the directors reported as receiving the largest number of requests for information. From the substantial difference in demand or requests for information about these sports, I identified them as high profile.

To examine differences among sex, sport profile, and athletic division, I used a *t* test for independent measures to compare the cumulative mean scores for each group. Subgroups of athletes were created by combining sex, sport profile, and athletic division (Table). To determine whether any subgroup of athletes was identifiable as having a significant difference in cumulative mean scores, a 1-way analysis of variance (ANOVA) was performed. A post hoc test for least significant difference was used to identify the significance by subgroup for the results obtained by the 1-way ANOVA.

RESULTS

I calculated cumulative mean scores for each subject. Each score represented a general rating for student-athletes' perceptions of their athletic trainers and the services they provided at their institutions. The mean scores for male and female athletes were tabulated and compared by conducting a *t* test for independent samples. The mean cumulative response score for male athletes was 137.1394, compared with the mean score of 130.6685 for female athletes. One hundred and sixty-five males and 178 females participated in the study; therefore, an unequal *t* test for equality of means was used to determine a level of significance. The results revealed a significant difference in cumulative mean scores between male and female

athletes ($t_{324.27} = 3.91, P < .001$). The mean score for males was higher than that of females, from which I inferred that male athletes viewed their athletic trainers more favorably than did female athletes.

I also compared the mean cumulative scores for athletes who competed in high-profile sports and athletes who competed in low-profile sports. The cumulative mean score for the 120 athletes of high-profile sports was 138.1833, and the mean score for the 222 athletes of low-profile sports was 131.3288. The *t* test for equality of means revealed a significant difference in cumulative mean perception scores when compared by sport profile ($t_{307.01} = 4.26, P < .001$). Results showed that athletes who participated in high-profile sports possessed a more favorable perception of their athletic trainers and the medical services provided than did the athletes who participated in low-profile sports.

Of the student-athletes participating in the study, 224 were at NCAA Division I programs. The remaining 118 student-athletes were from programs at the Division II level. The mean score for subjects in Division I programs was 134.8, compared with the mean score of 131.8 for athletes in Division II programs. An unequal *t* test for equality of means demonstrated no significant difference in perceptions held by athletes in Division I athletic programs and athletes in Division II athletic programs ($t_{206.87} = 1.60, P > .05$).

I determined differences between cumulative mean scores of subgroups by conducting a 1-way ANOVA. Significant difference between subgroups was indicated by delineation of subjects in data uncovered by earlier comparisons of mean scores among sex, sport profile, and athletic division. A 1-way ANOVA revealed a significant difference in cumulative mean scores of the 8 subgroups of athletes participating in the study ($F_{7,334} = 3.92, P < .0004$).

There was a significant separation in mean scores for subgroups 4, 7, and 8 versus the remainder of the subgroups within the sample (post hoc for least significant difference, $P > .05$). Females in low-profile sports at both the Division I and Division II level (subgroups 7 and 8) demonstrated a considerably lower cumulative mean score in their perception of athletic trainers and medical services provided at their institutions. Males in low-profile sports at Division II institutions (subgroup 4) also demonstrated a significant difference in mean scores when compared with other subgroups. The only subgroup of athletes who competed in low-profile sports and had a mean score that was in the top half of the rankings was males who compete at the Division I level (subgroup 3).

Subgroups Identified by Sex, Sport Profile, and Athletic Division

Subgroup	Delineation
1	Male, high profile, Division I
2	Male, high profile, Division II
3	Male, low profile, Division I
4	Male, low profile, Division II
5	Female, high profile, Division I
6	Female, high profile, Division II
7	Female, low profile, Division I
8	Female, low profile, Division II

DISCUSSION

Results of the comparison between sex and sport profile identified females and athletes in low-profile sports as demonstrating a lower cumulative mean perception score. The lower cumulative perception score indicated that females and most athletes in low-profile sports perceived their athletic trainers less favorably than did most male athletes and athletes in

high-profile sports. Additionally, females in low-profile sports at Division II schools (subgroup 8) were identified as having the lowest mean cumulative perception score. Females in low-profile sports at Division I (subgroup 7) institutions and men in low-profile sports at Division II institutions were also identified as having significantly lower cumulative mean scores when compared with other subgroups (Table).

Generally, the results of this study suggest that there were student-athletes at the collegiate level who did not view their athletic trainers as positively as did others. Athletes in low-profile sports accounted for the 3 lowest perception scores when compared with other subgroups of athletes. Two of the subgroups in the lowest percentile were female athletes, both at Division I and Division II schools. The only subgroup of low-profile sport athletes that did not differ significantly from others and whose mean score did not reflect a lower perception rating was male athletes in low-profile sports at Division I institutions. A collective analysis can be made that females in low-profile sports at both Division I and Division II schools, as well as men in low-profile sports at Division II schools, demonstrated that they had a significantly less favorable perception of their athletic trainers than did the rest of the sample. Also, females and athletes (both male and female) in low-profile sports collectively demonstrated a lower perception rating than did male and female athletes in high-profile sports.

The results of this study suggest that female athletes and most athletes in low-profile sports did not perceive their athletic trainers as positively as did other athletes. The perception rating acquired from these subjects may be an indicator of athletes' satisfaction with the medical services provided by the athletic departments for which they compete. Results from studies of patient satisfaction with health care delivery within the medical community support the theory that the higher the level of satisfaction with health care, the better the perception the patient had of the health care provider, thus enhancing the treatment or consultation experience.¹¹ Other findings of consumer (patient) satisfaction suggest that understanding the perception of the patient (in this case, the athlete) of the medical delivery personnel can assist in improving the quality of health care delivery.^{6,7,12} Further understanding of the athlete's perception of and satisfaction with athletic training services might enhance the communication between the athletic trainer and the athlete. Results of this study suggest that athletic trainers may not have demonstrated to all student-athletes from all sports at all levels the same emphasis in providing their medical services. At the very least, the results suggest that not all student-athletes hold the same perception of the medical delivery provided for them by their athletic trainers. The perception athletes have of their athletic trainer provides an initial evaluation of their level of satisfaction with

their health care delivery. It can be suggested that the more satisfied the athlete is with his or her health care, the more trust the athlete will place in the athletic trainer. Most athletic trainers would agree that maintaining a good level of trust between the athlete and the athletic trainer is important in providing consistent management of the health care system within the athletic arena. Further, the *NATA Code of Ethics*² and the *NCAA Sports Medicine Handbook*¹³ offer statements that support equal quality of health care across the athletic population without regard to sex, sport profile, or level of competition. The results of this study suggest that there are student-athletes who perceive some of their athletic trainers as having not demonstrated an equal level of treatment toward all their student-athletes. In addition, by addressing the perceptions athletes have of their services, athletic trainers can both maintain and strive to improve the already high level of quality medical services without regard to sex, sport, or level of competition.

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The Pars Interarticularis Stress Reaction, Spondylolysis, and Spondylolisthesis Progression

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Objective: To review the classification, etiology, clinical and radiologic evaluation, and management of the pars interarticularis stress reaction, spondylolysis, and spondylolisthesis progression.

Data Sources: Grateful Med was searched from 1980 to 1998 using the terms "spondylolysis," "spondylolisthesis," "female athlete," "spondylogenic," and "pars interarticularis."

Data Synthesis: The progression from pars interarticularis stress reaction through spondylolysis to spondylolisthesis is common in adolescent athletes, and, because of hormonal influences and cheerleading and gymnastic maneuvers, females are particularly at risk. Proper diagnosis and manage-

ment include a thorough evaluation, radiographs (possibly with technetium bone scan or single-photon emission computed tomography), activity modification, dietary counseling, a therapeutic exercise program focusing on proper trunk and hip muscle strength and extensibility balances, and education regarding proper back postures, positioning, lifting mechanics, and jump landings.

Conclusions/Recommendations: The athletic trainer plays an integral part in managing this injury progression, particularly with identifying at-risk individuals and intervening appropriately.

Key Words: low back pain, female athlete, lumbar vertebra

Back pain is one of mankind's greatest afflictions.¹ Financial compensation for low back pain in the adult work force has stimulated great interest in its treatment.² Surprisingly, as many as 36% of school-age children also report low back pain, and 7% seek medical attention.³ Increased exposure time and sports participation have been correlated with a rise in reported low back pain of various diagnoses among adolescent athletes,⁴ now accounting for approximately 5% to 8% of total athletic injuries.⁵ More young people and more females are participating in highly competitive athletic programs.⁶ Over the 6-year period from 1971 to 1976, female participation in competitive sports increased 94%.⁷

Strenuous training can lead not only to assorted soft tissue injuries but also to symptomatic bony defects in the posterior elements of the lumbar spine, elements otherwise referred to as the pars interarticularis (pars).⁸ Factors that commonly predispose young athletes to low back pain include a sudden growth spurt, abrupt increases in training intensity or frequency, improper technique, unsuitable sports equipment or playing surfaces, leg length inequality, poor trunk muscle strength, and poor extensibility of the hamstring and hip flexor muscles.⁵ Any changes in the length-tension relationships of any lower extremity muscle with pelvic attachments can have tremendous effects on lumbosacral alignment. These changes often result in accumulated microtrauma at the pars.

The lumbar spine proper consists of 5 pairs of diarthrodial facet joints, each containing a superior and an inferior facet and a capsule (Figure 1). When the junctions between the 12th thoracic and 1st lumbar vertebrae (T12-L1) and between the 5th lumbar and 1st sacral vertebrae (L5-S1) are included, 6 facet joint pairs are located in this region. These facet pairs are located on the vertebral arches.¹ The pars refers to the area of the vertebral arch between the superior and inferior facets.¹ Although injuries to this spinal region are usually the result of repetitive hyperextension and hyperlordosis, a genetically predisposed weak point in the pars has been suggested as the cause of spondylolysis. This predisposition can lead to stress fracture, even from the impact forces of normal upright gait.⁹ Although the exact etiology is controversial, repetitive microtrauma to this posterior vertebral sector often expresses itself as a "pars interarticularis stress reaction." When this reaction is not managed correctly, it may progress to spondylolysis and potentially to spondylolisthesis.

Spondylolysis (Figure 2) is most common at the lumbar region, being found in about 5% of Caucasian North American adults and more frequently in certain races, suggesting a possible congenital etiology.⁸ The term "lysis" is Greek for "loosening, coming apart, or dissolving."⁸ In spondylolysis, the pars loses its bony integrity and dissolves. A bilateral pars defect results in the lumbar vertebra being divided into 2 sections. If these sections separate, the condition is called spondylolisthesis (Figure 3).¹

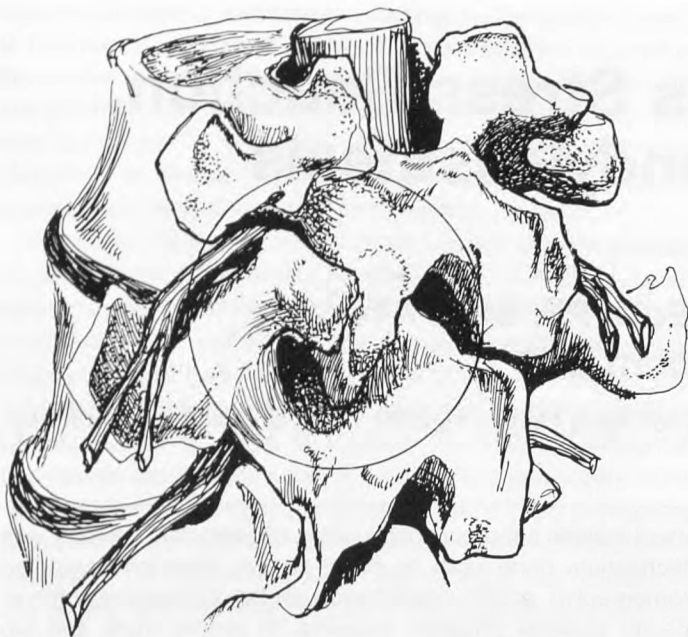


Figure 1. Typical lumbar facet joint with capsule removed.

The sequence from the pars interarticularis stress reaction through spondylolysis to spondylolisthesis represents one of the most common bony injury progressions of the athletic spine, with spondylolysis being the primary diagnosis of 47% of adolescent athletes who experience low back pain.¹⁰ A high incidence of lumbar spondylolysis has been reported in football players;¹¹ however, gymnastics places unparalleled demands on the low back.¹² Reports show that female gymnasts exhibit an incidence of pars defects that is 4 times greater than in a general population of females of comparable age.¹¹ Jackson et al¹² studied 100 female gymnasts and found that 11% displayed pars defects on lumbosacral radiographs. Females usually have a lower center of gravity than males because of their generally wider pelvis and shorter extremities. While this may be advantageous in sports requiring balance, such as gymnastics and cheerleading, these factors also contribute to injury susceptibility by increasing the likelihood of poor lower extremity alignment, poor lifting and jump-landing mechanics, and potentially greater dependence on the noncontractile components of postural stability.¹³ Back injuries in gymnasts can be the result of single or repeated episodes of hyperextension or hyperlordotic positioning and flexion or twisting (Figure 4), which create progressively increased pain with daily activities.^{14,15} Common repetitive mechanisms that have been related to lumbar stress fractures are hyperextension, flexion overload,⁴ forced rotation,¹⁴ unbalanced shear forces, or these in combination.^{8,14} The demands placed on the back from both the dramatic range of motion and the high levels of muscular power required for gymnastics are believed to exceed those of other sports,¹⁵ and more spine injuries occur from gymnastics than from football.¹⁶ Also, the pattern of lumbar vertebral motion that occurs during repetitive jump landings can further exacerbate low back pain, even more so when poor techniques are used.^{17,18}

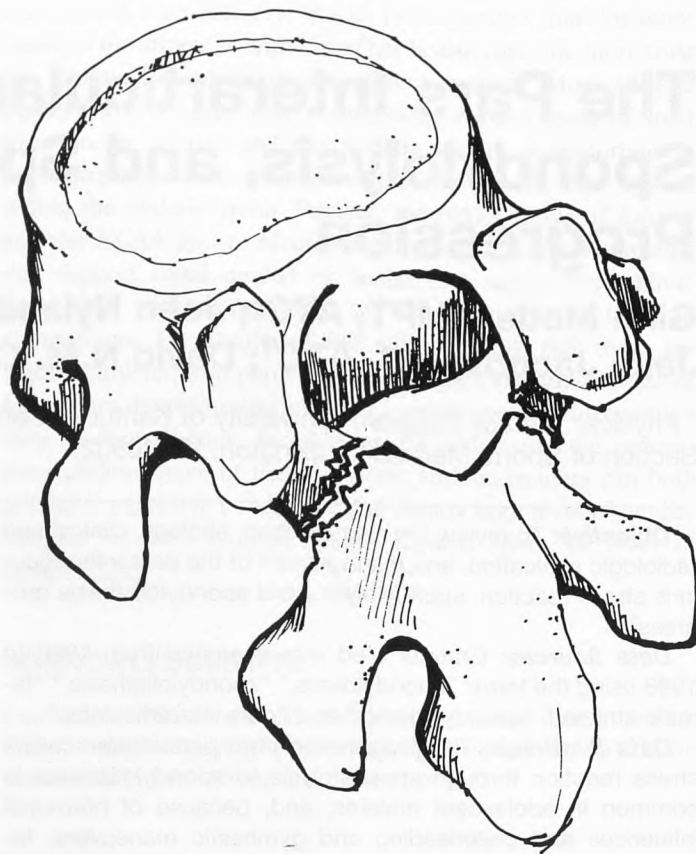


Figure 2. Spondylolysis of a lumbar vertebra.

Adolescent females who overtrain to the point of menstrual dysfunction may be risking permanent bone damage. Since girls often begin cheerleading and gymnastic competition before menarche, the harmful effects of hormonal dysfunction may begin without observable risk factors such as menstrual irregularities, altered diet, or low body weight. In a study of female collegiate gymnasts, over 60% met the diagnostic criteria for disordered eating, leading to the conclusion by the author that "disordered eating may be the normative behavior in this population."¹⁹ The hormone imbalances that cause spondylolytic conditions are dependent on the severity, intensity, duration, and interrelationship of risk factors such as family history, menstrual irregularities, excessive exercise, decreased bone mass, poor nutrition/disordered eating patterns, rate of weight loss, and psychological stresses.²⁰ Certainly, any combination of these factors in conjunction with the performance demands of gymnastics and cheerleading may have considerable effect on the lumbar spine. Preadolescent and adolescent female athletes with menstrual irregularities may suffer irreversible bone mineral density losses if estrogen is not available in sufficient quantities to promote bone growth during this important time in their lives.²¹

CLASSIFICATIONS AND DEFINITIONS

The term "spondylogenic" refers to low back pain during activity in the absence of all objective signs or other patholo-



Figure 3. Spondylolisthesis of L5 on S1.

gies. In these patients, both bone scans and radiographs are negative, yet low back pain persists.⁸ A pars interarticularis stress reaction refers to a pars stress lesion characterized by negative (normal) radiographs but a positive bone scan. The isthmic classification of pars stress fractures occurs most frequently among adolescent athletes and has been attributed to repeated hyperextension causing shear at the posterior vertebral elements. The fifth lumbar vertebra is affected most often, followed by L4 and then L3. This incidence is increased among participants in sports associated with repetitive flexion-extension activities, such as gymnastics.^{14,15}

Wiltse et al^{22,23} developed a working classification of spondylolisthesis lesions based on both causal mechanisms and anatomical factors (Table 1). The lesion classification of most concern to the clinician who works with athletes is the isthmic or spondylolytic type of spondylolisthesis. Meyerding²⁴ developed a grading system for spondylolisthetic lesions based on the magnitude of the "slippage" in relationship to the anteroposterior diameter of the superior aspect of the subjacent vertebra (divided into 4 equal quadrants) (Table 2; Figure 5).

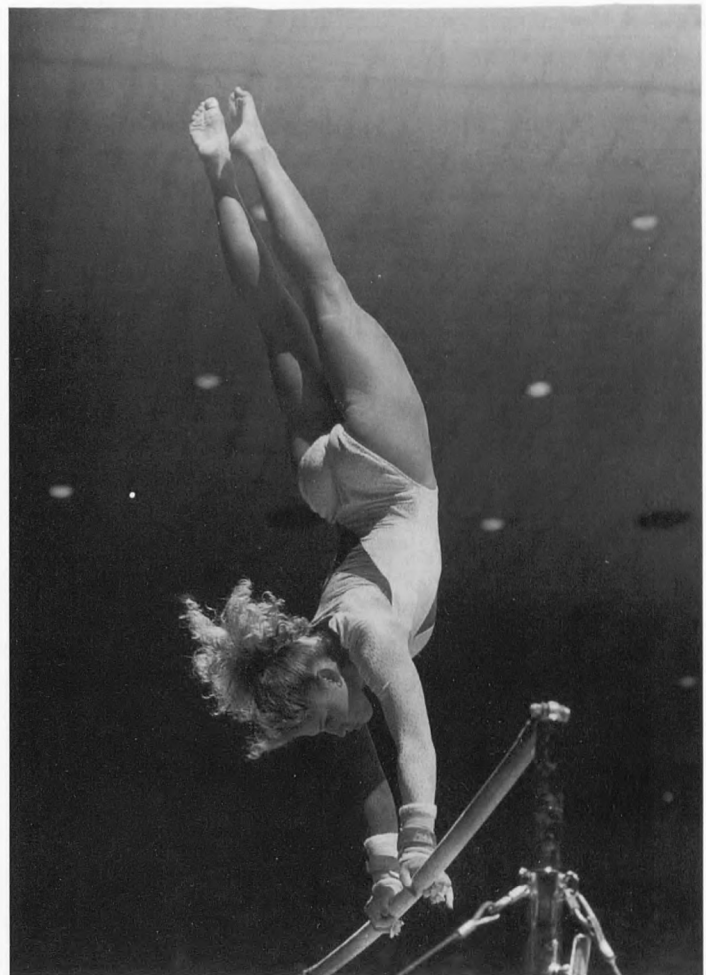


Figure 4. Combined hyperlordosis and twisting in a gymnast.

Table 1. Spondylolisthesis Classifications of Wiltse et al²²

- A. Dysplastic: congenital abnormalities of the upper sacrum or the arch of the fifth lumbar vertebra allow spondylolisthesis to occur
- B. Isthmic or spondylolytic: a pars interarticularis lesion, which can be a lytic-fatigue fracture of the pars, an elongated but intact pars, or an acute fracture (most common type among adolescent athletes)
- C. Degenerative: result of a longstanding pars intersegmental instability
- D. Traumatic: occurs after fractures in other areas of the bony hook (not the pars)
- E. Pathologic: involves generalized or localized bone disease

ETIOLOGY

Aside from their duties of supporting the body's weight and any additional external loads, the intervertebral joints at any instant are subjected to a complex interplay of muscle forces and ligament tension.^{25,26} Although the exact mechanism is still unknown, pars injuries are believed to most commonly be the result of repetitive microtrauma.²³ In a balanced upright stance, the spinal column, along with its ligaments and musculature, including the iliopsoas, abdominals, erector spinae, and quadratus lumborum, supports the weight of the upper trunk.²⁶ Imbalances in trunk musculature strength, endurance,

Table 2. Meyerding's Spondylolisthesis Grading System²⁴

Grade	Displacement
I	≤25%*
II	26% to 50%
III	51% to 75%
IV	>75%

* Displacement remains within the first quadrant.

and extensibility affect jump-landing-force attenuation capacity, promote lumbosacral malalignment, and increase the load on the bony aspects of the spine. In flexion, gravity provides a forward turning moment on the upper body, which is immediately counteracted by trunk extensor muscle activation that either controls the amount of further forward flexion (eccentric activation) or returns the body to its upright position (concentric activation). In the later stages of flexion, the spinal ligaments become solely responsible for support of the forward moment, while the upper body's weight creates a compressive force at all lumbar spine joints and an anterior shear force at L5-S1. Most muscles that act directly upon the lumbar spine are located at an angle to the intervertebral joints. This positioning produces compressive and shear forces, as well as a turning moment on the intervertebral joints. The L5-S1 joint is equipped with antitorsional characteristics (enlarged transverse processes), so most of the damaging stresses of flexion overload, unbalanced shear forces, and forced rotation occur at the level above it (L4-L5).²⁶ However, spondylolisthesis is most common at L5-S1 as the pars of L5 fractures or dissolves.²⁰

Researchers question whether repetitive microtrauma or improper biomechanics are mainly responsible for the onset of spondylolysis or spondylolisthesis. Many believe that other pathologic or congenital factors predispose the skeletal tissue to injury. Pars lysis is often accompanied by disc degeneration and a shortened spinal posterior ligamentous system.²⁶ Most experts agree that spondylolisthesis and spondylolysis are more commonly the result of repetitive microtrauma and should not be termed acute fractures, although a single episode of forced hyperextension can sometimes result in an acute fracture of the posterior elements of the lumbar spine.²³

Many athletes train excessively, train in a neuromuscularly fatigued state, regularly attempt skills that are beyond their physical capabilities, and develop training-induced muscle strength and extensibility imbalances. Either individually or in combination, these factors further reduce the athlete's ability to attenuate the kinetic energy of jump landings, twisting movements, and lifting, promoting greater dependence on noncontractile structures for postural maintenance. This leaves a greater amount of energy, or stress, to be dealt with by noncontractile tissues, such as bone, and adjacent capsuloligamentous structures. When these factors are present during a "growth spurt," the likelihood of sustaining an overuse injury increases. If such activities are practiced repeatedly, these noncontractile tissues can gradually fail, and stress fractures can occur.²⁷

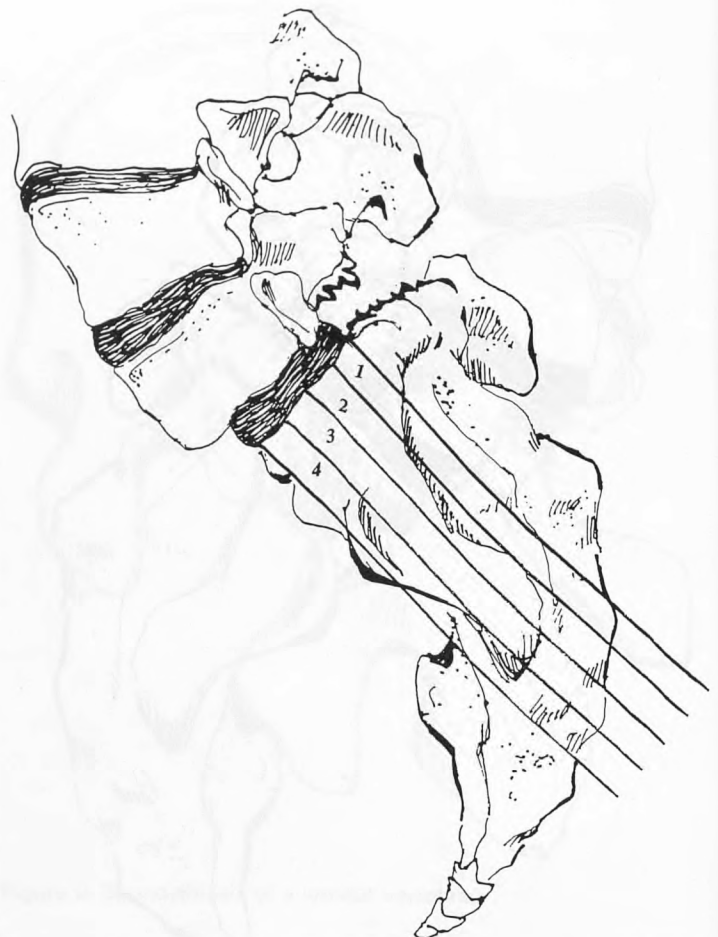


Figure 5. Meyerding's classification system for spondylolisthesis.²⁴

Reports indicate that athletes who train at a high intensity, with few or no rest intervals, and in excess of 24 hours/week over a period of years increase their risk of developing a pars defect.²⁷ Such training programs should be modified to include periods of active rest with training-variable manipulations to allow sufficient time for structural adaptations to occur. This is particularly true for the preadolescent and adolescent athlete; however, how much training constitutes too much training remains a matter of debate and warrants further investigation. Conditioning and skill levels can be maintained while allowing active rest of the pars through various low-impact activities, such as aquatic exercises, or through the use of impact-absorbent surfaces to diminish the stresses commonly associated with pars defects. Instruction in proper jump-landing methods may also be useful.^{18,28,29}

Pars defects can develop early in life and may have a strong hereditary basis.²⁷ Although infant cadaver dissections have failed to reveal defects²⁶ and no clinical evidence of defects in children under 5 years of age has been reported,⁸ Wiltse et al²² have reported an incidence of 40% among children over 10 years of age among members of a 36-family study.²² The most common age of manifestation on radiograph was between 5 and 7 years, with the period of most rapid vertebral slippage between 9 and 15 years.²² This information may provide a foundation for modifying the frequency of participation in

high-risk sports for this age group, particularly if there is a positive family history.

CLINICAL EVALUATION

Diagnosis of the cause of low back pain can be difficult, since symptoms usually cannot be related to a single traumatic event and initial radiographs are often normal. Correct diagnosis is imperative, however, since misdiagnosis can lead to permanent disability.¹² Regardless of the magnitude of pars involvement (stress reaction, spondylolysis, mild spondylolisthesis), the following is a representation of possible symptoms and findings in a theoretical athlete's initial evaluation.^{8,27}

Subjectively, the athlete complains of mild to moderate low back pain that began as a dull ache but has gradually increased in intensity. He or she may report pain along the posterior belt line, with occasional radiation along the posterolateral thighs and buttocks; however, no specific traumatic history is noted. Observation may reveal a hyperlordotic posture. Athletes with a body build in which the torso appears short, the rib cage appears low and the iliac crests high, the buttocks are flat or heart-shaped (from a relatively vertical sacral position in relationship to the lower lumbar spine and increased bi-iliac diameter), the abdomen protrudes, or there are transverse abdominal creases are more likely to have, or to develop, spondylolisthesis.²⁵ The classic gait pattern in this condition is stiff legged, with a short stride length due to tight hamstrings, often referred to as the "pelvic waddle."^{8,25,27}

Active trunk rotation and twisting, lateral flexion, and repetitive flexion and extension elicit pain; however, this pain is relieved by rest. On examination, trunk flexion is generally pain free, but returning to an upright extended position causes pain. Evaluation of function fails to reveal lower extremity muscle weakness. Poor abdominal muscle strength is noted, however, and this finding correlates highly with the progression of pars conditions.¹⁵ Active hamstring extensibility is usually decreased when the athlete attempts to actively extend the knee from a supine starting position of 90° hip flexion and 90° knee flexion.¹ Iliopsoas extensibility is decreased during the Thomas test.¹ Rectus femoris extensibility is decreased during the modified Thomas test.¹ Neurologic assessment fails to reveal nerve root signs, and all deep tendon reflexes are normal and bilaterally equal. Palpation reveals a possible L5 spinous process step sign (dependent on the degree of spondylolisthesis) and may detect protective lumbosacral paravertebral muscle spasms.

RADIOGRAPHIC EVIDENCE

Radiographic studies supply the best diagnostic information, with 2 oblique views being necessary to adequately observe a unilateral pars defect. The presence and extent of spondylolisthesis can also be shown with this technique. Oblique films of the lumbosacral spine will usually demonstrate a pars abnormality, depicted as the collar of the "Scotty dog" sign in

isthmus defects. Flexion and extension views and cineradiography⁹ may be beneficial in determining instability. If standard radiographs are nondiagnostic (failing to show evidence of a fracture line or bone defect) and significant pain or disability, or both, are present, a technetium bone scan can delineate an acute lesion within 5 to 7 days after the onset of symptoms.^{8,30} The bone scan is used to separate acute from chronic injuries, with the belief that acute injuries have the capacity to heal. The bone scan can also be used to assess the healing activity of established lesions. A pars defect that appears on initial radiographs requires close observation for evidence of the bony rounding and reabsorption that are indicative of a chronic condition.^{8,31} When the athlete can return to activity and at what intensity level are largely dependent upon whether the radiographic evidence is suggestive of an acute or chronic defect. Recurrence of a pars defect has not been reported after the fracture has completely healed and when the bone scan is negative.⁶ Single-photon emission computed tomography has recently been found to be useful in identifying pars defects in athletes who are symptomatic but who appear normal during radiographic or scintigraphic examination.^{25,32,33} Single-photon emission computed tomography has been shown to be the most sensitive method of diagnosing a pars interarticularis stress reaction or spondylolysis, making possible early intervention to prevent injury progression.

TREATMENT

Accurate diagnosis when evaluating the acute or chronic nature of a pars lesion must be emphasized, since this will have profound significance for both prognosis and treatment. The treatment approach for spondylolysis or spondylolisthesis depends upon the athlete's age and symptoms and the magnitude of the deformity. In each instance, both conservative treatment modalities for pain and inflammation control and restoration of normal, pain-free function are initiated and progressed as tolerated, with avoidance of postures that replicate the injury mechanism or impact forces.

Pars interarticularis stress reactions that present with a positive bone scan but no radiographic evidence of a fracture line are best treated by restricting activities to pain-free limits and by antilordotic bracing (at least 8 to 12 weeks) to allow the stress reaction to effectively remodel without developing a weak point in the pars.³⁴ After bracing, another 4 to 6 weeks of conditioning may be required to return an athlete to competition. Patients with this diagnosis are treated conservatively with emphasis on pure healing, while patients with chronic cases of spondylolysis or spondylolisthesis are treated more for symptom reduction, since the likelihood of complete healing is very remote once a true bony defect has occurred.

Adolescents with acute spondylolysis usually respond well to conservative treatment, including a shorter period of antilordotic bracing (4 to 8 weeks) and cessation of activities requiring hyperextension or impact loading of the spine. If diagnosed and treated appropriately, this fracture will not

progress to spondylolisthesis. Unilateral spondylolysis is a rare disorder, usually representing an acute spondylolysis that has healed on one side only and producing pain and a positive bone scan only on the unhealed side. When this diagnosis is made, further time and treatment should be considered to achieve bilateral bony healing.

Adolescents with chronic or long-standing spondylolysis who present with recurring back pain are usually immobilized for a shorter period of time (2 to 4 weeks, since complete bony healing is very unlikely), only to relieve the acute pain and spasm. As the pain subsides, the other conservative treatment components are progressed as tolerated. In general, this is also the progression for patients with grade I or II spondylolisthesis.

Conservative methods of treating the pars interarticularis stress reaction, spondylolysis, and spondylolisthesis progression may include custom-fitted thoracolumbosacral orthoses or casts fitted from the chest to the knees to prevent excessive lumbar lordosis.²⁷ Even in the absence of bony healing, 88% of persons with a pars defect using a thoracolumbosacral orthosis eventually return to sports activities symptom free;²⁷ however, an additional 3 months of brace use during sports may be needed. Recently, a new surgical method of direct spondylolysis repair has been reported as another viable treatment option that may promote bony healing and earlier return to competition.³⁵

Conservative treatment measures are recommended for athletes with low-magnitude lumbar spondylolisthesis without radicular symptoms. Bell et al³⁴ reported that all of 28 patients with grade I or II spondylolisthesis were pain free and free of radiographic evidence of increased slippage or sacral inclination after, on average, 25 months of antilordotic bracing. Pizzutillo and Hummer³⁶ concurred that approximately two thirds of adolescents with grade I or II spondylolisthesis improve when treated conservatively. The skeletally immature athlete with spondylolisthesis should be reassessed frequently with plain radiographs to determine if there has been progression of the lesion.

Progression is rare in the skeletally mature athlete, but failure to improve with treatment or frequent symptom exacerbations warrants repeat radiographs to make sure that further slippage has not occurred. Grade I and II slips are usually considered mild in the skeletally mature patient, while grade III and IV slips are more severe, more often cause symptoms, and more often require surgery. Only when conservative treatment measures have been exhausted or when slippage progression is relatively rapid and intractable radicular pain associated with nerve root entrapment is evident are surgical methods such as lumbar fusion recommended.⁴ Return to contact sports after lumbar fusion is unlikely because of the limitations placed on the athlete by spinal surgery. If the surgical option is chosen, most orthopaedic surgeons prefer a posterior approach to spinal fusion for the skeletally immature patient with a documented spondylolisthesis progression.

In general, continued spondylolisthesis progression in a skeletally mature athlete denotes segmental instability and

probably requires surgery, while progression associated with pain in an immature athlete requires modification of activities or repetitive postures that may promote further slippage, regular radiographic assessment of the lesion status, and symptomatic treatment. In the adolescent athlete, anterior vertebral slippage of less than one third of the vertebral-body width can usually be treated with activity restriction, use of a molded lumbosacral orthosis to promote neutral lumbar alignment, and serial radiographs to monitor for further slippage over a 3- to 6-month time frame. Anterior vertebral slippage of more than one third of the vertebral-body width in an adolescent athlete may warrant surgical intervention, even if the athlete is asymptomatic; however, establishing a definite relationship between pain and segmental instability is recommended before surgery, such as bony fusion or another method of pars stabilization, is performed.⁸ Severe cases of spondylolisthesis may also require paravertebral nerve blocks to relieve radicular symptoms from nerve root irritation.³⁷

Females and athletes with repeated episodes of spondylogenic low back pain are at greater risk for spondylolisthesis progression, particularly if they present with (1) anterior slippage of greater than 50% of vertebral-body width, (2) a domed or rounded first sacral vertebra, and (3) evidence of an increasing angle between the adjoining surfaces of the involved vertebral pair. As with other conditions, conservative measures including activity restrictions should be exhausted before surgical management is selected.

Most symptomatic athletes can be treated conservatively through proper lumbosacral posture and positioning training, as well as activity modifications.³⁷ Faulty body mechanics or postures that promote excess lumbar lordosis need to be discouraged.⁴ Use of a lumbosacral corset with or without a moldable insert (form fitted in neutral lumbar alignment) may be useful during activities to decrease pain and help teach proper low-back posture and positioning.

Back school programs are a treatment approach that arose out of the belief that low-back injury prevention would be more cost effective than treatment. Back school programs focus on ergonomic adjustments in the work place, proper body mechanics and posture instructions, and strengthening or extensibility exercises for existing imbalances. Effective programs usually comprise all of these components. Although they are generally more effective when implemented for injury prevention, these programs are usually initiated after acute back injury, with the primary goal of facilitating pain-free functional movements and improved kinesthetic awareness of body positions and postures.² While a recent study has reported back schools to be limited in their prevention of work-associated low-back injuries, multiple variables (including, but not limited to motivation, perceived secondary gain, compliance, and the establishment of bona fide modifications in "low-back use" behavior) contribute to their effectiveness.³⁸ Daltroy et al³⁸ demonstrated that subject knowledge of safe "low-back use" behavior was increased by back school training. By introducing back school concepts to younger individuals in physical

education classes and athletics, perhaps behavioral changes can help to prevent the development of pars defects. Teaching proper lifting and jump-landing mechanics and other "back-saving" measures, such as muscle strength and extensibility imbalance correction, may be more effective if they occur concurrently with the development of other motor skills. Presentations in educational settings would also enable more frequent instruction and reinforcement of proper "low-back use" behaviors. These types of interventions could progress from instruction in proper static postures through more dynamic movements, always relating the importance of a healthy lumbar spine to activities of daily living, as well as sports performance. This type of "athletic back school" format may more effectively stimulate the interest of the athlete, and the techniques may become assimilated more effectively than programs that fail to include improved performance connotations.

Athletes who experience mild to moderate low back pain benefit greatly from relaxation techniques, including ice or moist heat, nonsteroidal anti-inflammatory medications or muscle relaxants, and brief bed rest to alleviate initial acute pain, inflammation, and anxiety.^{4,37} As soon as possible, these measures should be implemented in conjunction with progressive active low-back mobility challenges, preferably within the context of the athlete's sport and position or event. Exercises (as the ultimate treatment modality) should be initiated with the focus on dynamic spinal stabilization, where the patient learns to maintain a neutral lumbar alignment during various movement challenges and perturbations.² Abdominal and low-back musculature strengthening⁴ and hip-muscle extensibility (with special emphasis on the iliopsoas muscles and hamstrings) should also be considered.⁸ Trunk-flexion exercises have been found to be more effective than trunk-extension exercises for pain relief among athletes with spondylogenic disorders. Caution should be used with lumbar intervertebral joint mobilizations to avoid creating pain that radiates to the lower extremities (indicative of possible lumbar disc and spinal nerve involvement).

SUMMARY

Since athletes will continue to train through lumbar spine pain in an effort to achieve or maintain competitive status in their specific sport, they must be closely and constantly scrutinized for pars defects. Early detection of the defect is essential to a complete and expedited recovery. Ignoring the signs and symptoms of a pars defect is a tremendous mistake. Consider pain a warning sign for potential lumbar vertebra damage that could lead to permanent disability.¹ The pars interarticularis stress reaction, spondylolysis, and spondylolisthesis progression can often be prevented or at least managed effectively if clinicians acknowledge its multifactorial basis. Optimal management should include screening for high-risk individuals based on family history or somatotype, education in "back-saving" measures, nutritional counseling, avoidance

of overtraining, and establishing a normal interplay of trunk and lower extremity muscle strength, endurance, and extensibility. Postural training encouraging proper lumbosacral alignment and avoiding excessive posterior vertebral loading during static postures and positions is important, as is increased use of the lower extremity musculature during jump landings and overhead lifting.

Competitive female athletes, particularly gymnasts and cheerleaders, may be particularly at risk for developing spondylolisthesis due to both the movement and training demands of their sport and the interactive effects of the hormonal changes associated with menarche. Future research needs to focus on female athletes' fracture risk related to menstrual irregularities. Careful consideration should be given not only to promoting exercise as beneficial but also to identifying the female athletes who are at risk for decreased bone mineral density. Once these athletes have been identified, therapeutic measures should be instituted to improve nutrition, modify activities, and implement a corrective exercise regimen.

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Fibromyalgia and Chronic Fatigue Syndrome: An Update for Athletic Trainers

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Objective: Primary fibromyalgia syndrome (PFS) and chronic fatigue syndrome (CFS) are clinical conditions characterized by a variety of symptoms, including prominent fatigue, myalgia, and sleep disturbances. Although the incidence of these syndromes is infrequent, when manifested, they can completely disrupt the life and career of those affected. When they are manifested within the physically active population, they can jeopardize the futures of the most promising athletes.

Data Sources: Public documents available from the U.S. Department of Health and Human Services, Public Health Services, and the National Institutes of Health were researched. MEDLINE and CINAHL were researched back to 1988 with the following key words: chronic fatigue syndrome, primary fibromyalgia syndrome, sports participant, physically active, mononucleosis, myalgia, rehabilitation, reconditioning, athlete, and sports medicine.

Data Synthesis: The definition of CFS in 1988 included disabling fatigue of unknown cause of at least 6 months' duration. Primary fibromyalgia syndrome was once considered a subsyndrome of CFS. PFS is diagnostically characterized as a nonarticular rheumatism. The "yuppie flu" was a catch phrase

of the 1980s for CFS, which was then named chronic Epstein-Barr virus syndrome. Initially the condition was thought of as simple infectious mononucleosis, but we now have a medically defined set of symptoms to describe what are called CFS and PFS. Training interruptions, feelings of loss of control, and concerns over possible psychologic or psychiatric referral can occur. Relaxation therapy, exercise, image therapy, serotonin supplementation, and antiviral therapy are in clinical trials now as the best options for management of CFS and PFS.

Conclusions/Recommendations: Current statistics on those affected by CFS and PFS in the general population are less than 2% for CFS and 2% for PFS. Comprehensive documentation of signs, symptoms, and complaints, along with judicious physician follow-up, are important during the course of treatment leading up to and following a diagnosis of CFS or PFS. Professional evaluation of the affected player's neuropsychological status is important and necessary as a care plan is developed.

Key Words: primary fibromyalgia syndrome, sports participant, physically active, mononucleosis, myalgia, rehabilitation, reconditioning, athlete, sports medicine

Primary fibromyalgia syndrome (PFS) and chronic fatigue syndrome (CFS) are clinical conditions characterized by a variety of symptoms, including prominent fatigue, myalgia, and sleep disturbances.¹ Although the incidence of these syndromes is infrequent, when manifested, they can completely disrupt the life and career of those affected. When they are manifested within the physically active population, they can jeopardize the future status of the most promising athletes.²⁻⁴ My purpose in this review is to assist athletic trainers by explaining current methodology in the clinical identification of PFS and CFS in order to correct the misinformation that so often surrounds these conditions. This knowledge is important to protect the physically active population from the common types of misinformation that so often occur with PFS and CFS.¹

BACKGROUND

Chronic Fatigue Syndrome

Chronic fatigue syndrome is defined by the Centers for Disease Control and Prevention (CDC) as a combination of the

following patient complaints and diagnostic results.^{1,5} The definition of CFS in 1988 included disabling fatigue of unknown cause of at least 6 months' duration.¹ Reports of this disease phenomenon came from around the world.⁵ People affected are mostly between 20 and 50 years of age.^{1,5} Symptoms reportedly start after a flu-like illness,^{1,5} although no specific triggering disease has yet been identified. About half the population identified with and treated for CFS must also be treated for clinical depression.¹ In half of those cases, the depression was present before the diagnosis of CFS. Clinical depression was found in 22% of control populations over the course of a lifetime versus 73% for CFS patients.^{1,5} Whether depression is causal for or a component of CFS is determined by the attending physician.^{1,5}

Primary Fibromyalgia Syndrome

Primary fibromyalgia syndrome was once considered a subsyndrome of CFS.^{6,7} PFS is diagnostically characterized as a nonarticular rheumatism.⁸ There are widespread musculoskeletal aches with stiffness and 18 characteristic locations of potential tenderness on palpation. Chronic fatigue, systemic complaints, and sleep disturbances are also common with

PFS.⁸ PFS should not be confused with myofascial pain syndrome (MPS), which also includes local muscle complaints (trigger points) but lacks the systemic malaise associated with PFS.⁹ There is more muscle belly pain with MPS, whereas PFS tenderness is seen near the musculotendinous junctions.¹⁰ In addition to the history of widespread pain, the 18 sites for bilateral palpation are part of the specific diagnostic criteria for PFS (Table).¹⁰ For a positive evaluation, 11 of 18 sites should be "painfully" tender with the application of a 4-kg palpation force.¹¹ The average age of patients treated for PFS is 49 years.¹¹ It should be noted that the clinical similarities in people who meet current classification criteria for PFS and CFS are impressive.^{6,7,12-16}

A Path of Discovery

In the 1980s, "yuppie flu" was a catch phrase for CFS, which was then known as chronic Epstein-Barr virus syndrome. This syndrome defined an illness that consisted of prolonged bouts of extreme fatigue, painful body aches, inability to perform minor physical tasks, and sleep disturbances. Initially the condition was thought of as simple infectious mononucleosis, but now we have advanced to a new and more comprehensive medically defined set of symptoms to describe what are called CFS and PFS.^{1,17,18} Although most research activity on CFS and PFS has occurred in the last decade, documentation in the medical literature dates back more than 120 years.¹⁷ The terms used to describe CFS at that time were myalgic encephalomyelitis or neurasthenia. Yet other reports included names like Iceland Disease or Royal Free Disease.^{17,18}

The CDC produced pamphlet information on CFS for the public and physicians in 1990.¹ While the CDC focused on the definitions of CFS and PFS from 1985 to 1990, its attention has now turned to the identification of causal factors and treatments. Most research has suggested that CFS is caused by interactions between 2 primary components. The first component is an episode of acute infection usually involving the Epstein-Barr virus seen in infectious mononucleosis. The second component is the individual's neuropsychological profile suggesting a finding of clinical depression.^{1,17,18}

The development of treatment strategies changed from the analysis of individual case reports to clinical trials in 1989. Pharmacologic agents selected were based upon a hypothesized cause of CFS. The antiviral medicine acyclovir was not

helpful in treating the conditions.¹⁷ Tricyclic antidepressants were more promising after 3 to 4 weeks of clinical trials, as were other antidepressants. When nonsteroidal anti-inflammatory agents were included with tricyclic antidepressants, higher levels of effectiveness were reached after 12 weeks,¹⁷ and these were more prevalent with PFS patients.¹⁴ No pharmacologic course has proved curative at this point. Case-by-case lifestyle changes were proposed for patients who did not respond favorably to drugs. Diet, rest, light exercise, stress reduction, and new personal goals have been proposed as nonpharmacologic alternative treatments for CFS and PFS.^{17,19}

Recent advances have offered some breakthroughs regarding CFS and PFS. The pain associated with CFS and PFS, which was thought to be muscular in etiology, has been shown to possibly be a central nervous system phenomenon.²⁰ Studies of magnetic resonance images showed no pathology present in the areas of PFS patients' muscle pain.^{14,20} A conflicting study recently demonstrated proof via electron microscopy that histologic changes are seen in muscles of PFS patients. A possible neuroregulatory defect contributing to a cause of CFS or PFS, or both, is now under study.¹⁵ Other areas of research include the role of stress as a cause of CFS, genetic predisposition for those whose DNA may be more susceptible to viral precursors and environmental toxins such as pesticides, and unsanitary conditions.^{15,21}

Effects on the Physically Active

The effects on all patients, including the physically active, can prove devastating. Training interruptions may occur frequently when energy levels (either perceived or physiologic, or both) do not keep pace with the need or desire to participate. With continued bouts of weakness and fatigue, feelings of loss of control may fill the mind of the athlete. Concerns over possible psychologic or psychiatric referral can, and in many cases do, occur.¹⁸ Inability to compete at prior performance levels increases as the feelings of weakness and fatigue grow.²² Self-esteem can plummet as the participant's identity as a physically active person is adversely affected. Depression and panic disorder are documented possibilities for sports participants with CFS and PFS.^{2-4,17} Studies do not separate the incidence of CFS and PFS between sedentary and active populations. Specific studies do give some hope for physically active people, demonstrating that PFS does not significantly affect $\text{VO}_{2\text{max}}$.²³ This finding may hold some hope for those persons involved in cardiovascular endurance activities. However, people participating in activities requiring more powerful short-term muscular activity may be more negatively affected, since maximal voluntary isometric contraction forces do decrease in subjects with PFS.^{23,24}

Current Treatment Options and Research

Relaxation therapy,¹⁹ exercise,²⁵ image therapy,²⁶ serotonin supplementation,²¹ and antiviral therapy¹³ are in clinical trials

Determining Fibromyalgia*: Palpation Sites†

- Occipital protuberances
- Low cervical spine (anterior to transverse spaces C5-7)
- Upper trapezius muscles
- Medial origins of the supraspinatus muscles
- Second costochondral junctions
- Lateral humeral epicondyles (2 cm distal)
- Gluteals (outer quadrant, anterior fold)
- Greater trochanters (posterior to prominence)
- Knees (medial fat pad proximal to joint line)

* Adapted with permission from the *Journal of Musculoskeletal Pain*.¹⁰

† Sites are palpated bilaterally.

now as the best options for management of CFS and PFS. Relaxation therapy is used for the control of stress. Exercise is useful in counteracting the effects of PFS.²⁵ Image therapy is selected for maintaining a competitive mindset.²⁶ Serotonin is prescribed for a possible neurologic etiology of PFS.²¹ Antiviral therapy is prescribed for immune system manifestations.¹³ Antidepressants are used for depressive symptoms. Current studies are focusing on an immunologic etiology,²⁷ although there are many factors that continue to be considered.^{6,7,13-16,27} The recommendations for competitive athletes include continued physical training for sport as fatigue and recovery allow, psychologic or psychiatric consultation to maintain the "edge," and keeping possible neurologic, viral, and depressive effects at a minimum.

DISCUSSION

Current statistics on those affected by CFS and PFS in the general population are less than 2% for CFS and 2% for PFS.¹³ The possibility exists that up to 2 per 100 sports participants may eventually be diagnosed with CFS or PFS. It is very unlikely, though not impossible, that a player may be classified with CFS or PFS before college participation. Early recognition by the athletic trainer is difficult, since the syndrome must be present for at least 6 months to be considered chronic.

Comprehensive documentation of signs and symptoms, along with judicious physician follow-up, is important during the course of treatment leading up to and following a diagnosis of CFS or PFS. Professional evaluation of the affected player's neuropsychologic status is important and necessary as a care plan is developed.

When considering continued participation or return to participation, sports with midrange requirements for both $\text{VO}_{2\text{max}}$ and maximal muscular contraction should demonstrate less negative impact from the effects of CFS or PFS. When an athlete with a possible case of CFS or PFS presents in our athletic training practice, we must, with our physicians, still ask the questions presented by Komaroff and Goldenberg²⁷ in 1989: Was there a flu-like illness when symptoms began? Are there fevers, night sweats, or swollen tonsils? Are there abnormal findings on laboratory tests? Are there any neurologic aberrations on examination? Is the student-patient-athlete clinically depressed? Is it viral, causing a defect in immunologic containment? Was it brought on by stress? Is there genetic predisposition? Could environmental toxins play a role?

An eventual cure depends on medical research in these areas. Until that time, careful monitoring of and support for our players who must deal with CFS or PFS may be the strongest tools of the attending athletic trainers and physicians. A comprehensive team approach will be required to provide the best available care to an athlete. The team should include a physician, psychologist, and athletic trainer. The team can be formed once the physician makes the diagnosis of CFS or PFS, or both.^{6,7,14-16,27}

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Pneumomediastinum in a High School Football Player: A Case Report

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Objective: To provide athletic trainers with information about the mechanism, evaluation, and treatment of pneumomediastinum.

Background: This is a case study of a high school football player who suffered pneumomediastinum as a result of a flat-handed thump to his sternal area during a blocking drill. Pneumomediastinum is a relatively rare occurrence in sports. Common mechanisms include direct blunt trauma, vomiting, sneezing, Valsalva maneuver, and forceful coughing. Typical signs and symptoms include chest pain, dyspnea, tenderness, crepitus in the neck that can be aggravated with swallowing, and a positive Hamman's sign with auscultations.

Differential Diagnosis: Pneumothorax, pneumopericardium, sternal contusion, rib fracture, upper respiratory infection, and myocardial infarction.

Treatment: Conservative management includes restriction from athletic activities, prophylactic antibiotics, and sleeping in

a semireclined position. Surgical repair of the defect may be indicated if repeat radiographs fail to show improvement after 1 week.

Uniqueness: It is rare that a relatively light blow through shoulder pads would result in a pneumomediastinum. Review of the literature does not include this athlete's symptoms of congestion, nasal voice, or sore throat as typical signs of pneumomediastinum.

Conclusions: The literature indicates that an uncomplicated pneumomediastinum will typically resolve in 2 weeks' time. In this case, symptomatic evaluation warranted only 1 week of rest before the athlete was allowed to return to full activity.

Key Words: mediastinal emphysema, football injuries, retro-sternal chest pain

Pneumomediastinum is a rare occurrence in sports, but, like other chest wall injuries, it can result in potentially life-threatening consequences. Pneumomediastinum is the presence of air or gas in the mediastinum, which may interfere with respiration and circulation and can lead to pneumopericardium, pneumothorax, and pneumoperitoneum.¹ The athletic population most affected is healthy, young males, as in the present case. There are several causes of pneumomediastinum, including direct blunt trauma, vomiting, Valsalva maneuver, sneezing, and forceful coughing.² It may also be associated with marijuana smoking, bronchial asthma, anorexia nervosa, childbirth, and pulmonary function testing.² In the event of a respiratory obstruction, a spontaneous pneumomediastinum may occur.³ For the athletic population, blunt trauma and Valsalva maneuver are the most frequent causes.³

ANATOMY

A brief review of the related anatomy includes the alveoli of the respiratory system and the mediastinum. The alveoli are the terminal ends of the bronchi and the area of gas exchange for the system. The alveoli are surrounded by the extensive bronchovascular system. The mediastinum is the mass of tissue and organs separating the 2 lungs, between the sternum anteriorly and vertebral column posteriorly, and between the thoracic inlet superiorly and the diaphragm inferiorly. The 4

regions of the mediastinum contain the heart and its major vessels, trachea, esophagus, thymus, lymph nodes, and other structures.¹

In the case of pneumomediastinum, change in pressure as a result of some mechanism causes an alveolar rupture that allows free air to travel along the bronchovascular system to the mediastinal area. When this free air builds up in the mediastinum, the air can escape into the subcutaneous tissue (subcutaneous emphysema).³ This air in the subcutaneous tissues can be painful and the air bubbles can be palpable. The resulting variety of signs and symptoms are relatively benign, but can lead to more serious conditions if not recognized and monitored.

HISTORY

A 17-year-old male varsity high school football player reported to the training room 1.5 hours after the morning practice during "daily doubles." The athlete weighed 54.43 kg (120 lb) and was 167.64 cm (5 ft 6 in) tall. He typically played wide receiver and defensive cornerback. He complained of a sore throat and slight difficulty in swallowing. Further questioning ruled out other viral symptoms and revealed a mild incident that had occurred 3 hours earlier during football practice in a "bump-and-run" defensive drill. The object of the drill is to start low in the stance, then drive off the line with

outstretched arms to deliver a blow to the sternal and chest area with the purpose of pushing the opposing receiver off balance. The athlete was selected for the predrill demonstration. He received the midsternal blow from a 79.38-kg (175-lb) coach and indicated it was hard enough to cause him to step backward 1 or 2 steps, but did not knock him down. At the time the blow was delivered, he did not note any symptoms and continued with the remaining 1.5 hours of practice. Toward the end of practice, during wind sprints, he felt slight shortness of breath and tightness in his chest. He was able to complete the conditioning and did not report anything unusual to his coaches or athletic trainers. He went to lunch approximately 2 hours after the contact occurred, at which time he first noted difficulty in swallowing and thought his voice sounded "nasal." This voice change was not immediately audible to other people. After lunch he reported to the athletic training room and was evaluated by the certified athletic trainer.

PHYSICAL EXAMINATION

The athlete denied any previous history of injury to his upper thorax and was a nonsmoker. He reported environmental allergies, for which he was treated with Claritin (Schering Corporation, Kenilworth, NJ), and denied a history of asthma. The athlete was wearing a properly fitted helmet and shoulder pads at the time of the injury. Chief complaints included difficulty in swallowing, a sore throat, slight tightness in the chest, congestion, and feeling that his voice was sounding "nasal." Observational findings were unremarkable, and there was no visible redness or swelling of the throat. There was no palpable tenderness in the face, neck, chest, or shoulder. Neck and shoulder range of motion and manual resistive muscle testing were within normal limits. The athlete was not distressed, and there were no unusual chest sounds, wheezing, or shortness of breath. Clinical impressions after the preliminary evaluation included possible pneumothorax versus a viral condition, allergy or asthma, or sternal, esophageal, or rib contusion.

TREATMENT AND CLINICAL COURSE

Following the initial evaluation, the athlete was restricted from participation in afternoon practice and given an ice bag for his sternum. At this time, his mother was notified of the injury, and he was referred for medical follow-up with his family physician. The complaint of the nasal voice was more audible to others, but there was no other change in symptoms.

His family physician found that his lungs were clear and noted a Hamman's sign (audible crepitance over the precordium with heart tones.) There was also palpable crepitance (air bubbles) along the anterior neck muscles bilaterally. Radiographs confirmed pneumomediastinum and ruled out pneumothorax. The athlete was immediately transferred to the emergency room for further evaluation and treatment.

At the emergency room, the attending physician concurred with the diagnosis, and the athlete's condition was noted to be

stable. The patient was treated empirically with antibiotics for prevention of infection and Tylenol (McNeil Consumer Products Company, Fort Washington, PA) for chest and throat discomfort. He was discharged with instructions to sleep in a semireclined position to reduce and prevent the aggravation of symptoms. Changing positions from lying to standing resulted in an increase in pain due to the movement and change of air pressure. The athlete and his mother were warned of symptoms, such as fever, chills, acute shortness of breath, or cyanosis, that would indicate associated complications. He was also restricted from all physical activities pending a follow-up with his family physician the next day. Repeat radiographs were performed the next day to check healing and air resorption. With all symptoms remaining stable, the athlete then made an appointment to be seen in 1 week by a general surgeon to determine return-to-activity status.

At 1 week postinjury, all signs and symptoms had resolved, and the follow-up chest radiographs showed complete resolution of the pneumomediastinum. The surgeon indicated that the uncomplicated resolution suggested that the air leak was transient and had subsequently healed. The athlete was given permission to return to unrestricted football practice. He participated in the remainder of the football season without incident or recurrence.

DISCUSSION

Common signs and symptoms of pneumomediastinum include acute chest pain (80% to 90% of cases); dyspnea (50% of cases); pain, tenderness, and crepitus in the neck; and a positive Hamman's sign with auscultation.^{4,5} Hamman's sign is a crunching sound that is heard in time with the cardiac cycle.⁴

The signs and symptoms may be aggravated by coughing, deep inspiration, swallowing, or lying down.³ The development of a congested, nasal voice in this patient was a clinical finding related to the pneumomediastinum that was not mentioned in other published case studies.

The diagnosis of pneumomediastinum is primarily based on radiographic analysis (Figures 1 and 2). Anterior-posterior and lateral radiographs are necessary for showing gas bubbles that appear as thin lines outlining the various mediastinal structures.^{3,6} Computed tomography scans may be ordered to supplement the radiographic findings or to determine whether permanent damage has occurred.

Treatment includes restriction from athletic and strenuous activity, medication including antibiotics and analgesics, and rest in comfortable positions (usually sitting or semireclined).³ In some cases, surgery is indicated for repair and decompression, but most incidents are self-limiting and resolve within 2 weeks without complications.⁵ Full return to activity is usually allowed when symptoms decrease and radiographic studies reveal a resolution of the pneumomediastinum. In the present case, the athlete was released from the physician's care and returned to unrestricted football in 1 week.

Although pneumomediastinum is not, in isolation, a medical emergency, rapid assessment and diagnosis are necessary

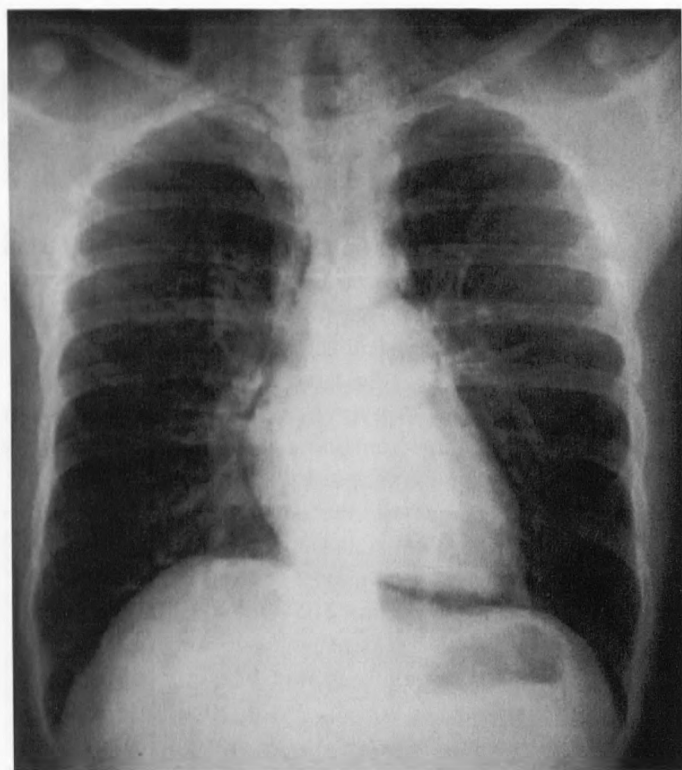


Figure 1. Anterior-posterior view of a pneumomediastinum. Note the lucent lines of free air surrounding the mediastinum. "Figures 1 and 2 published with kind permission from Thieme. To appear in Broderick L, Knisely B, Kuhlman J. *Chest Imaging: A Case Approach*. New York, NY: Thieme; 2000."

because of possible complications. Differential diagnosis is necessary for the various causes of retrosternal chest pain. Other common injuries resulting in retrosternal chest pain include pneumothorax and pneumopericardium. The development of pneumothorax (accumulation of air in the pleural space) is the most common complication associated with pneumomediastinum. A patient with pneumothorax may have a collapsed lung and may present with incomplete breaths, unilateral chest pain, increased respiratory rate, tachycardia, hypotension, and sometimes tracheal deviation.^{3,4} Radiographic findings show free air lining the mediastinal structures, as in pneumomediastinum, and decreased lung size.⁶

In pneumopericardium, the free air surrounds the heart rather than the mediastinum.⁶ Another helpful finding for differential diagnosis is that the placement of the free air will change with positional changes in pneumothorax and pneumopericardium, but not in pneumomediastinum.⁶ Sternal and rib contusions, rib fractures, and myocardial infarction should also be ruled out when assessing retrosternal chest pain.

CONCLUSIONS

Based on our experience with this case, pneumomediastinum is possible in the athletic population and should be considered when assessing a patient with retrosternal chest pain. Furthermore, this case has established that it is possible to



Figure 2. Lateral view of a pneumomediastinum. Note the lucent lines of free air surrounding the mediastinum.

sustain such an injury from a relatively slight amount of force. The complications that can be associated with pneumomediastinum make it necessary to obtain a timely, accurate assessment and begin proper treatment quickly.

Although this patient did not experience complications, it is important to employ conservative injury management when presented with unusual or indistinct symptoms. When we do so, the athlete will have the best opportunity to receive the highest standard of care.

ACKNOWLEDGMENTS

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Osteochondritis Dissecans of the Talar Dome in a Collegiate Swimmer: A Case Report

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Objective: To present the case of an intercollegiate swimmer with a stage IV lateral talar dome injury and associated bony fragments.

Background: Lack of distinct diagnostic symptoms, low index of clinical suspicion, and the difficulty of visualizing the early stages of this injury on standard x-rays cause frequent misdiagnosis of talar dome lesions.

Differential Diagnosis: Ganglion cyst, with inflammatory synovitis secondary to rupture of cyst; loose bodies from previous occult fracture; osteochondral fracture.

Treatment: Initial treatment with nonsteroidal anti-inflammatory drugs and a posterior splint for comfort, followed by arthroscopic excision of loose bodies with abrasion and drilling arthroplasty.

Uniqueness: Patient presented to the team physician for care of acute left medial ankle pain after the athletic trainer had attempted to rupture a ganglion cyst on the anterolateral aspect of the patient's ankle.

Conclusions: Increased clinical suspicion is necessary to correctly diagnose osteochondral lesions, particularly in the early stages. Aggressive treatment of talar dome lesions has a good success rate and may be an attractive option for competitive athletes.

Key Words: ganglion cyst, inflammatory synovitis, osteochondral fracture

Disagreement on the etiology of talar dome lesions has given rise to a number of terms to describe a similar injury. Osteochondritis dissecans was the first term used to describe this injury because it was believed to result from disrupted blood flow to the talar dome from mild, recurrent injury or hereditary factors. The health of the bone would degenerate from lack of blood supply, and a lesion would develop. Osteochondral fracture, transchondral fracture, and flake fracture are all terms that imply that talar dome lesions have a traumatic etiology. In 1959, Berndt and Harty¹ proved that in vitro trauma could cause medial and lateral talar dome lesions resembling those found clinically. They experimentally generated posteromedial lesions in cadaver specimens by strong inversion and plantar flexion, while anterolateral lesions were created by inversion and dorsiflexion. Currently, although vascular and hereditary factors are considered important etiologies for medial lesions, lateral lesions are thought to be almost exclusively traumatic in origin.²⁻⁴

The differences between lateral and medial lesions extend beyond the injury mechanism. As demonstrated by the Berndt and Harty¹ experiment, medial and lateral lesions form on different aspects of the dome's surface. Lateral lesions are typically located on the anterior portion of the talar dome, while medial lesions tend to be located posteriorly. The shapes of the lesions are also dissimilar. Lateral lesions are shallow and wafer shaped, as opposed to the deeper, cup-shaped medial lesions. The morbidity of talar dome lesions is affected by this

difference in shape. Because of the shallow shape of lateral lesions, they are more often displaced into the joint and are unlikely to heal spontaneously.²

In order to describe the progression of talar dome lesions from mild to severe, Berndt and Harty¹ classified them into 4 stages (Figure 1, A-D): stage I, a small area of compressed subchondral bone; stage II, a partially detached osteochondral fragment; stage III, a completely detached osteochondral fragment remaining in the talar crater; stage IV, a displaced or rotated osteochondral fragment. Berndt and Harty's 4-tier progression is the most widely used scale in talar dome lesion research and literature, but other slightly modified scales are sometimes used.

CASE REPORT

A 20-year-old, male intercollegiate swimmer presented to the athletic trainer with a complaint of lateral left ankle pain. He indicated that he had sprained his ankle several days earlier, while dry-land training, and was now experiencing pain when pushing off the wall during his turns. The athlete admitted a history of a "weak ankle" and recurrent mild left ankle sprains while running and walking. The athlete had not sought care before this episode. His ankle was treated with contrast baths, electrical stimulation, and strengthening exercises. Over the next 2 weeks, his symptoms improved. The athlete did not complain of any remaining symptoms other than some soreness when swimming.

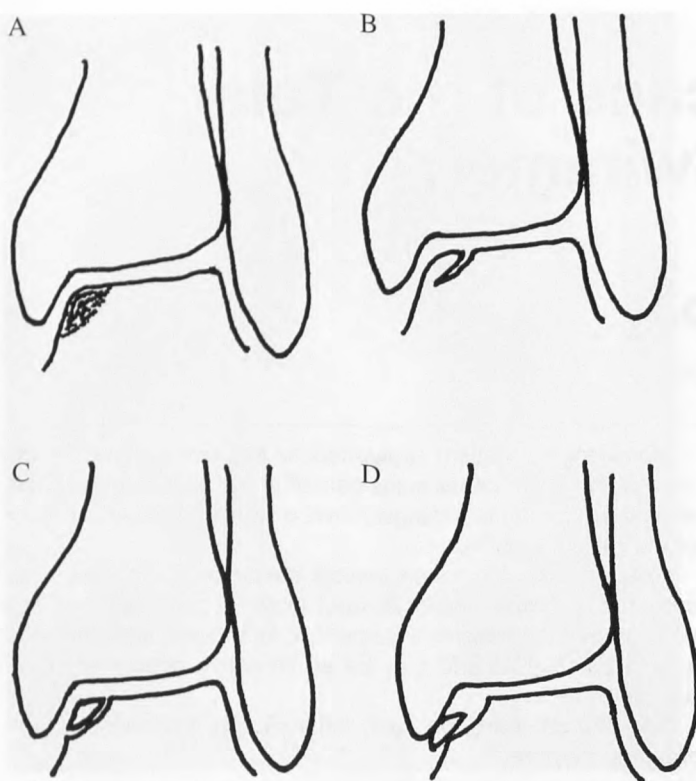


Figure 1. Berndt and Harty's¹ classification of talar dome lesions. A, Stage I; B, Stage II; C, Stage III; D, Stage IV.

The athlete presented to the team physician 2 weeks after the ankle sprain with acute anteromedial left ankle pain. The athlete had sought assistance from the athletic trainer the day before when he noticed a cyst on his ankle. The athletic trainer had ruptured a ganglion cyst on the anterolateral aspect of the athlete's ankle by applying pressure to the cyst. While this had resolved the mass on the lateral aspect of his ankle, he began experiencing acute pain, and a new mass appeared on the anteromedial side. Pain, especially with plantar flexion, prohibited him from sleeping at night and kicking while swimming.

Physical examination revealed mild swelling over the anterior and anterolateral aspects of the ankle joint. Range of motion was decreased 10° for both dorsiflexion and plantar flexion. The athlete experienced no pain with dorsiflexion, but both active and passive plantar flexion elicited pain across the top of the ankle joint. On stability testing, the anterior drawer sign was negative and equal to the uninjured ankle, but a slight increase in talar tilt was noted. Strength testing revealed normal strength except for 4+/5 resistance to eversion. Resistance to both eversion and inversion was painful.

Palpation revealed some localized tenderness over the anterior talofibular ligament and 2 firm masses. The first mass was located at the anterolateral aspect of the joint and was estimated to be approximately 3 mm in diameter. The second and more tender mass was located at the anteromedial aspect and was approximately 5 mm in diameter on palpation. These

masses did not appear to be associated with the tibialis anterior or extensor tendons. The athlete was treated with a nonsteroidal anti-inflammatory drug and a posterior splint for sleeping, and x-rays were ordered. (The athlete was examined in the training room. X-rays were obtained at the health center 2 days later.)

X-rays confirmed 2 large, well-corticated bony fragments in the left ankle (Figure 2, A-C). Fragment A projected anterior to the joint space of the talus, and fragment B was positioned superolateral to the superior surface of the talus. Follow-up computed tomography (CT) images showed a superolateral defect in the talar dome and added further information as to the size and location of the bony fragments (Figure 3, A-C). Fragment A was 20 mm by 14 mm, and fragment B measured 4.5 mm by 11 mm. Inspection of the fragments showed that the edges were rounded, and fragment B contained 2 horizontal cracks.

Approximately 2 weeks after presentation to the team physician, the athlete underwent left ankle arthroscopy with removal of fragments A and B. The superolateral portion of the talar dome was treated with abrasion and drilling arthroplasty to encourage growth of new fibrocartilage. Postoperatively, a compressive dressing was applied over the wound. The athlete was restricted to nonweightbearing activities for 6 weeks and no running or cutting for a total of 12 weeks. He was treated with a rehabilitation therapy program of ice, active range of motion, and progressive strengthening exercises.

Eight days after the operation, the sutures were removed. The athlete returned to swimming 2 weeks after surgery, wearing an ankle brace for support in the pool. Three weeks postoperatively, the athlete had no pain or swelling in his ankle. X-rays taken 5 months postoperatively indicated a flattening of the talar dome with some bony sclerosis. Other regions of the ankle joint were unremarkable (Figure 4, A-C). The physical examination at that time showed that the affected ankle was stable to stress testing, and range of motion was limited 5° in dorsiflexion. The patient stated that he had experienced no more pain in his left ankle.

DIAGNOSIS

Talar dome lesions are traditionally difficult to diagnose because they are not associated with distinct symptoms or clear indications in the patient's medical history. Patients most often report symptoms that are consistent with a sprain and usually have some history of ankle trauma. The symptoms found in patients with acute talar dome lesions can include swelling, ecchymosis, and limitation of active and passive range of motion.³ Patients with chronic lesions may have a deep aching sensation or intermittent swelling that improves with rest. However, chronic lesions can also be asymptomatic.⁵

In a study of 22 patients with osteochondral lesions, 11 were initially misdiagnosed as having a sprained ankle.³ In retrospect, the lesion could be seen on 9 of the initial x-rays.

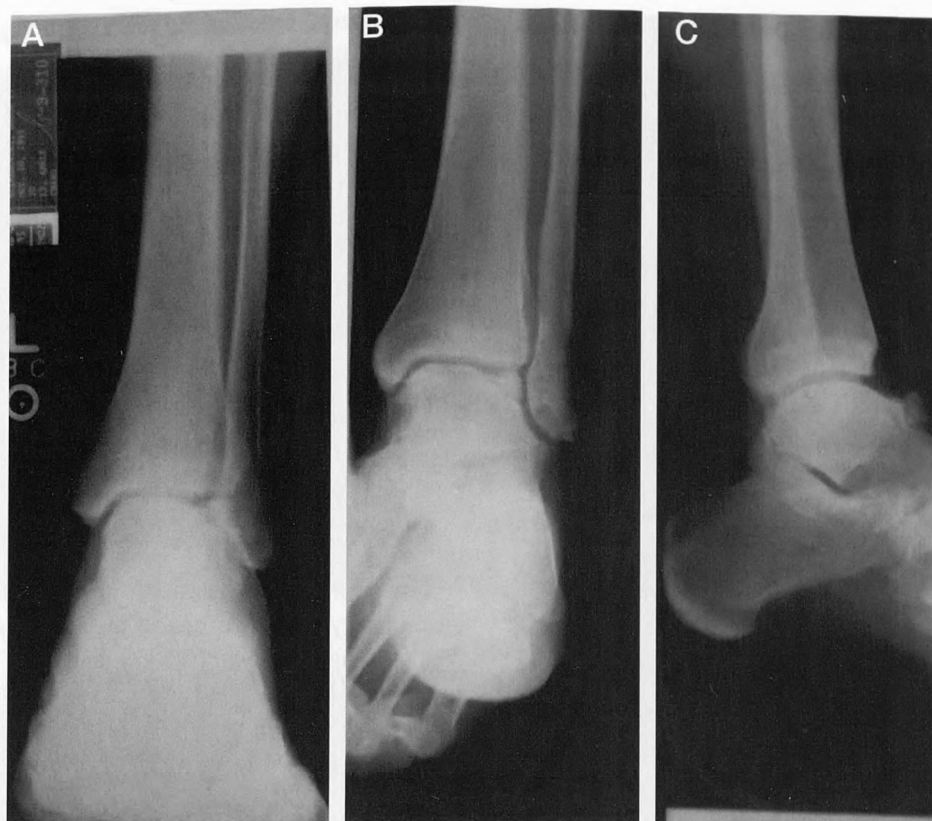


Figure 2. Initial left ankle x-ray series. A, Anterior-posterior view showing fragments A and B. B, Mortise view with better visualization of fragment B. C, Lateral view showing position of fragment A.

Because of the difficulty in diagnosing talar dome injuries using symptoms or patient medical history, radiographic images become the primary diagnostic tool. The main keys to identifying talar dome lesions are awareness that the pathology can exist and the ability to recognize talar lesions on radiographic images.

Part of the uniqueness of this case report arises from the events leading to the final diagnosis. The athlete presented with acute medial ankle pain after his athletic trainer attempted to rupture a ganglion cyst. Inflammatory synovitis secondary to rupture of a cyst may have precipitated the diagnosis of the osteochondral lesion, and there is at least 1 example in the literature of an osteochondral lesion that presented as a ganglion cyst.⁶ A more likely hypothesis suggests that pressure placed on fragment A in an attempt to rupture the "cyst" could have caused the fragment to move from an anterolateral to an anteromedial position in the ankle. This theory would explain why the athlete felt that the mass on the anterolateral aspect of his ankle was resolved, but began experiencing acute anteromedial pain and the appearance of a new mass immediately after the "rupture."

Although most lateral talar dome lesions are considered traumatic in origin, the athlete's history of mild, recurrent ankle sprains indicates a case of osteochondritis dissecans. The athlete's final diagnosis was a remote lateral osteochondritis dissecans that had progressed to stage IV. The CT scan demonstrated that Fragment B was clearly a portion of the lateral talar dome. The rounded edges of the bony fragments

indicated the chronicity of the talar dome injury. Horizontal cracks in fragment B also indicated that fragment B may have been the donor site of fragment A. The cause of the initial acute medial ankle pain cannot be determined with any certainty.

TREATMENT

Conservative treatment of early-stage talar dome lesions consists of immobilizing the ankle in a short-leg, nonweight-bearing cast for at least 6 weeks. By 6 weeks, x-rays or CT images may be used to determine whether the lesion has united with the talar dome or is healing (stage I or II lesion). If complete healing has not occurred, immobilization may be continued for as long as 18 weeks.

Surgical treatment most often includes arthroscopic excision of osteochondral fragments with drilling and curettage of the fragment bed. Less often, surgical treatment consists of internal fixation of osteochondral fragments with screws or Kirschner wires. Internal fixation is more common with an acute lesion that occupies 30% or more of the talar articular surface; however, there is no universal protocol for the application of conservative versus surgical therapies.

Most authors agree that stage I and stage II lesions should be treated conservatively. When conservative therapy is used, subjective and objective data demonstrate 75% good results for stage I lesions and 25% good results for stage II/III lesions.⁴ For stage III lesions, the site of the fragment becomes an

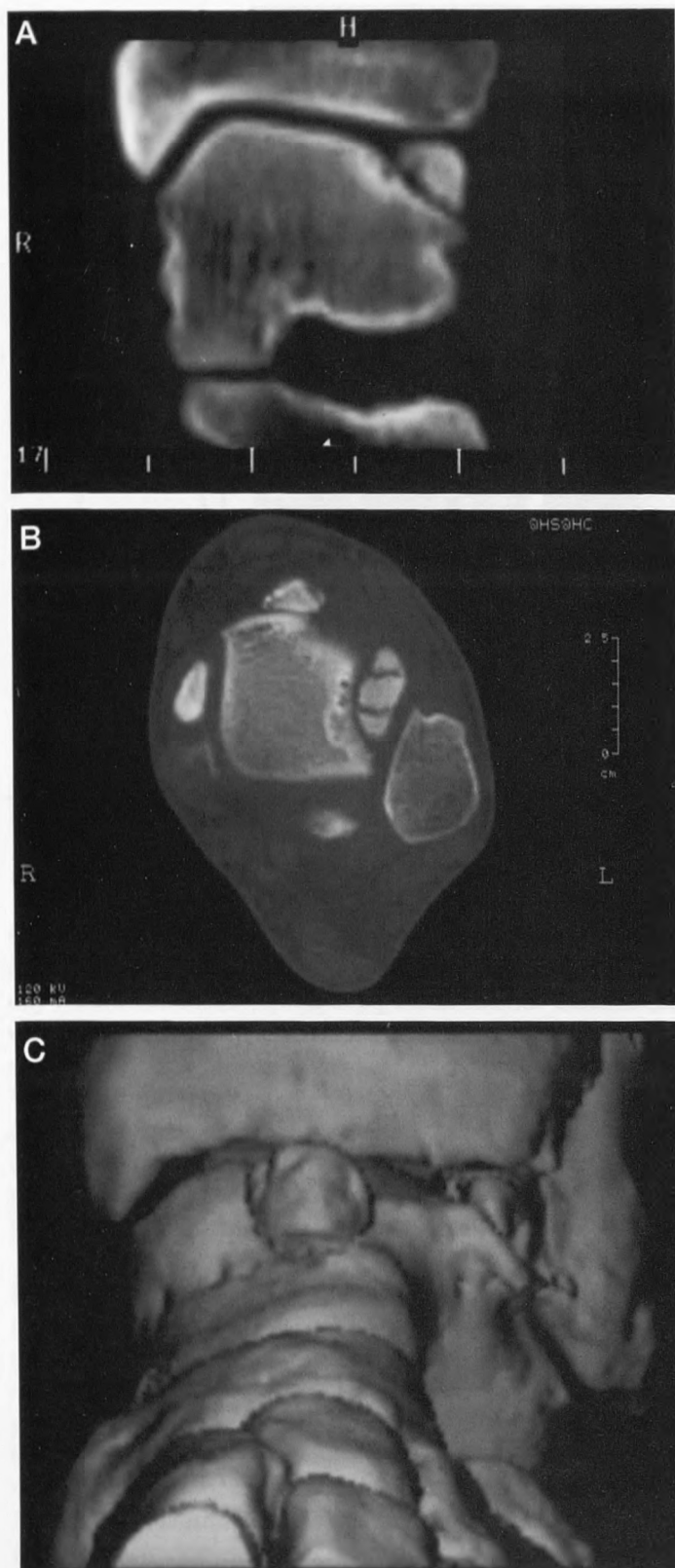


Figure 3. CT scan of left ankle. A, Fragment B on coronal image; note the sclerotic edges. B, Fragments A and B on axial image; note the fragmentation of B. C, Reconstructed 3-D image.

important deciding factor in treatment. Medial stage III lesions are more likely than lateral stage III lesions to demonstrate a good outcome with conservative therapy.^{2,7} For this reason,

some experts recommend conservative therapy for medial stage III lesions and surgical treatment for lateral stage III lesions. Consensus suggests that all stage IV lesions and lesions that fail to improve with conservative therapy should be treated surgically.

A more aggressive approach to treatment suggests that all symptomatic stage II, III, and IV lesions should be treated surgically. Conservative treatment can require up to 18 weeks of immobilization, and, on average, 75% of stage II or III lesions had fair or poor results with conservative treatment.⁴ Surgical treatment of talar dome lesions is more successful, with the literature reporting 71% to 88% good or excellent results overall and one authority citing good or excellent results with 82% of stage I/II lesions.⁴ The potential for the lesions to develop subchondral cysts can be considered an additional motivation for operative treatment at stage II.^{3,8,9}

The appropriate treatment of the athlete presented in this case history was clear due to the late stage of the talar injury. The treating physician (C.J.C.) discussed with the surgeon and the athlete the possibility of removing only fragment A at the time and postponing the removal of fragment B until after swimming season. This would have allowed for a faster return to weightbearing activity, but the delay in removing fragment B could have negatively affected the final result.⁷ Both fragments were removed, and aggressive postoperative management was employed.

Authorities suggest that postoperative nonweightbearing activity continue for 6 to 12 weeks, depending on the severity of the injury. Despite the severity of this injury and the size of the fragments, the athlete was kept nonweightbearing for only the minimum 6-week period. The ankle is typically immobilized for 3 to 5 days, after which time passive and then active range-of-motion exercises are begun. The athlete in this study was treated with active range-of-motion exercises immediately after immobilization. Some experts⁸ advocate this type of early, active range of motion to help "mold" the new fibrocartilage.

CONCLUSIONS

Osteochondral fractures of the talar dome are thought to occur in approximately 6.5% of all ankle sprains.¹⁰ Because of the frequency of this injury and the lack of distinct symptoms, the possibility of a talar dome lesion should be considered in every ankle sprain, especially those with an inversion component.¹¹ Radiographic examination is necessary for the diagnosis of talar lesions and thus may be indicated for patients with more serious sprains and for those who continue to complain of persistent pain for several weeks after a mild injury. If no lesion appears on plain radiographs, and, despite rehabilitation, the ankle does not appear to be healing, a CT scan, magnetic resonance imaging, or bone scan may be clinically appropriate. These imaging techniques are more sensitive to early-stage lesions and may locate a previously undetected injury (Figure



Figure 4. Postoperative left ankle series at 5 months (A-C), with comparison views of uninjured right ankle (D-F). A and D, Anterior-posterior view. B and E, Mortise view. C and F, Lateral view.

5, A and B). The use of CT images is also helpful for defining the size, location, and stage of talar dome lesions.

In the case of this athlete, operative intervention was necessary to remove the loose bony fragments around the ankle joint. Patients can consider a more conservative approach with earlier-stage lesions. However, athletes may consider a surgical

approach more attractive because of the higher rate of failure and the potentially lengthy immobilization period required for conservative therapy. Surgical therapy offers a better chance of good or excellent results with stage II/III lesions and requires a 6- to 12-week immobilization period versus the 6 to 18 weeks suggested for conservative therapy. Aggressive postoperative



Figure 5. Presentation of early osteochondritis dissecans with a negative x-ray in a 19-year-old female tennis player. A and B, Positive bone scan. C, Lesion seen on MRI.

management can also be successful in effectively and rapidly healing the ankle. The athlete in this case was able to return quickly to competitive swimming and had no further problems at follow-up examinations.

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Incorporating Stress Management into Athletic Injury Rehabilitation

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Objective: Our objective is to provide a paradigm that can assist certified athletic trainers in selecting and implementing techniques to help athletes cope with the stress associated with injury.

Background: The psychological impact of injury and the stress associated with rehabilitation are well known in the athletic training room. Specific stress management techniques should be determined by the personality of the athlete, the specific stressors associated with the injury and rehabilitation process, and the education and expertise of the certified athletic trainer. Therefore, it is important that certified athletic trainers be proficient in stress theory regarding the psychological aspects of injury, as well as the techniques to address them.

Description: We provide a framework that applies transactional theory to athletic injury and suggests that an athlete's belief about injury plays a central role in the stress reaction. It describes the role of the certified athletic trainer in addressing the 4 components of transactional theory: 1) increased awareness, 2) information processing and appraisal, 3) modified behavior, and 4) peaceful resolution with injured athletes.

Clinical Advantages: The application of this conceptual framework allows certified athletic trainers to differentiate stress management techniques based on the individual athlete's reaction rather than apply a generic approach.

Key Words: coping, sports medicine, athletic trainers

While there exists a considerable body of literature regarding the psychology of injury and the stress reaction involved in athletic injury,¹⁻⁶ the literature regarding direct application of stress management techniques by the athletic trainer in the rehabilitation process is limited.⁷⁻¹⁰ In this article, we will discuss the role of the certified athletic trainer in reducing the impact of the stress reaction on injured athletes.

Throughout this article the word "stress" is used to denote the "nonspecific response of the body to any demand made upon it,"¹¹ and the term "stressor" is used to denote the situation or demand that produces stress. "Rehabilitation" refers to retraining and reconditioning the musculoskeletal system to regain the level of physical fitness present before the injury.

The model by Andersen and Williams¹² of stress and athletic injury describes the stress response as a precursor to injury. Once an athlete is injured, however, the injury itself is associated with the stress response in a reciprocal manner. The level of stress experienced may continue to be a function of the athlete's personality, history of stressors, coping resources, and stress management interventions, as suggested by Grove and Gordon,¹³ who extended the Andersen and Williams¹² model. Too much or too little stress may hinder the ability of the athlete to effectively perform rehabilitation.

Stress and coping are ways the body reacts and adapts to stressors to return to a state of equilibrium after a traumatic event (ie, injury). The development of individualized stress management techniques is therefore necessary to help athletes

effectively cope and adjust to injury, as well as to the rehabilitation process.

Lazarus¹ conceptualized stress and coping as a unique interaction between the individual and the environment and later developed a transactional (bidirectional, dynamic, mutually reciprocal) model.¹⁴ This model incorporated an individual's cognitive appraisal of stressors into the stress response. This model suggests that a person's belief, as well as his or her appraisal of the event, plays a central role in how the person reacts to that event. The 4 components of the transactional theory are 1) increased awareness, 2) information processing and appraisal, 3) modified behavior, and 4) peaceful resolution. These components may provide a paradigm for athletic trainers to incorporate stress management into the rehabilitation process.

APPLICATION PROCESS

Increased Awareness

Increased awareness involves a series of interactions in which both the athletic trainer and the injured athlete develop a clear understanding of the stress associated with the injury. This awareness includes discussing and viewing the injury in a narrow perspective (the rehabilitation process) as well as a broad perspective (the ripple effect of the injury in the athlete's life). The establishment of open and trusting relationships between athletic trainers and athletes allows athletic trainers

opportunities to assess athletes' perceptions of their stressors and to affect athletes' abilities to cope.

To use this information effectively and efficiently, athletic trainers may also benefit from courses, seminars, workshops, or lectures related to personality and personality assessments associated with stress and coping. For example, having a ballpark idea about Type A and Type B personalities¹⁵ may help the athletic trainer anticipate some aspects of an athlete's reaction to the stress of injury and rehabilitation.

For instance, Megan is a 21-year-old long distance runner at a Division I school, and she has a stress fracture. She reacts to her injury with behaviors that are common to Type B personalities in stressful situations (ie, withdrawal, avoidance, and absence of time urgency¹⁴). Increased awareness of this personality trait allows the athletic trainer to discuss with Megan the interaction of personality traits with the rehabilitation process. The suggestion of techniques and strategies (relaxation, cognitive restructuring, visualization) may help Megan to actively engage in the rehabilitation process. Being actively engaged in the rehabilitation process will reflect her commitment and counteract the athletic trainer's perception that she is unmotivated and noncompliant.

Information Processing and Appraisal

Awareness of athletes' personalities leads athletic trainers toward an understanding of how personality interacts with injured athletes' appraisals of the information related to injury and rehabilitation. According to Lazarus,¹ information processing is divided into primary and secondary appraisal.

Primary appraisal assesses the existing harm or loss that the stressor elicits. In the example of Megan, the primary appraisal is that the injury has taken away her ability to run and compete in a sport she loves. It has removed her from teammates and social support. The athletic trainer can assume a social support role by listening to Megan.

The secondary appraisal process determines existing coping strategies that can reduce the stress reaction resulting from the primary appraisal of harm or loss and then reviews steps toward modifying behaviors associated with the stress response. At this point in the example, rather than assuming that Megan is not coping, the athletic trainer discusses with Megan how she sees herself adjusting and explores with her ways to employ coping strategies.

Modified Behavior

The psychological impact associated with injury has been shown to affect motivation,¹⁶ positive self-talk,¹⁷ concentration,¹⁸ and feelings of control¹⁹ during rehabilitation sessions. Coping strategies addressing these issues can be psychological (eg, cognitive restructuring) or physical (eg, behavioral modification). The athletic trainer engages in an interactive process with the athlete that matches stress symptoms to specific coping strategies. For example, a psychological symptom such

as worry can be linked to the psychological technique of self-talk, and physical symptoms of exhaustion can be linked to the physical technique of relaxation.

The application of stress management techniques must be tailored to fit each athlete's personality and environment and assumes that the athlete is able to employ the technique. Before implementation, the athletic trainer needs to ask the athlete to explain the stress management technique back to the athletic trainer. In the case of Megan, she agrees with the athletic trainer that daily goal setting would help her gain time to accomplish what she wants and that she should interact with her teammates. However, when the athletic trainer asks Megan how she plans to set her goals, she responds by saying, "I don't know." At this point in the process of modifying Megan's behavior, the athletic trainer needs to teach a technique for goal setting or refer to an appropriate resource so Megan can learn the coping strategy chosen.

Some athletes cope very well with injury and rehabilitation and may not need or want additional intervention. These athletes may already effectively employ psychological or physical stress management techniques and may have developed the buffers necessary to deal with the stress associated with injury. The difference between buffers and stress management techniques is that stress management techniques deal directly with the stressor the athlete is experiencing (eg, worry), whereas buffers are strategies or healthy lifestyle behaviors (eg, good nutrition) that absorb the initial impact of the injury.²⁰ The link between the rehabilitation process and a healthy lifestyle may be one that the athletic trainer wants to reinforce with these athletes.

Through implementing stress management techniques or reinforcing lifestyle buffers, the athlete learns to share control of the rehabilitation process with the athletic trainer. Teaching the athlete to assume some control and responsibility for the rehabilitation process helps to increase compliance and avoid feelings of helplessness.

Peaceful Resolution

The final component of Lazarus's¹⁴ model is for the injured athletes to arrive at a peaceful resolution. This is not to say the perfect solution must be achieved, but it must be one that produces peace of mind. To achieve a peaceful resolution, the athletic trainer reviews the rehabilitation process with the injured athlete and helps the athlete evaluate the psychological and physical accomplishments associated with the rehabilitation process. This process also incorporates a discussion of decisions related to the athlete's continued involvement in sport.

Regardless of the decision, emotional support for the athlete is not terminated. It is important to note that the athletic trainer can provide emotional support and be on the athlete's side without having to be in total agreement with the decision the athlete has made. For example, supporting Megan, who wants to continue competing, is not the same as agreeing that it is the

best thing for Megan. However, acknowledgment that the athlete has the right to make decisions about his or her life is important. If a peaceful resolution is not reached and the stressor is still present, performance in rehabilitation or sport may continue to be adversely affected.

CONCLUSIONS

The paradigm described in this manuscript serves as a guide for athletic trainers to incorporate stress management into the rehabilitation process. Specific techniques for employment in the rehabilitation process should be determined by the personality of the athlete and the specific stressors associated with the injury and rehabilitation process, as well as the education and expertise of the athletic trainer. Therefore, it is important that athletic trainers be knowledgeable in the psychological aspects of injury, as well as in the psychological and physical techniques necessary to address them.

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Bandy WD, Irion JM, Briggler M. The effect of static stretch and dynamic range of motion training on the flexibility of the hamstring muscles. *J Orthop Sports Phys Ther.* 1998;27:295-300.

To date, limited information exists describing a relatively new stretching technique, dynamic range of motion (DROM). The purpose of this study was to compare the effects of DROM with static stretch on hamstring flexibility. Fifty-eight subjects, ranging in age from 21 to 41 years and with limited hamstring flexibility (defined as 30° loss of knee extension measured with the femur held at 90° of hip flexion), were randomly assigned to one of 3 groups. One group performed DROM 5 days a week by lying supine with the hip held in 90° of flexion. The subject then actively moved the leg into knee extension (5 seconds), held the leg in end-range knee extension for 5 seconds, and then slowly lowered the leg to the initial position (5 seconds). These movements were performed 6 times per session (30 seconds of total actual stretching time). The second group performed 1 30-second static stretch, 5 days per week. The third group served as a control group and did not stretch. Before and after 6 weeks of training, flexibility of the hamstring muscles was determined in all 3 groups by measuring knee extension range of motion (ROM) with the femur maintained in 90° of hip flexion. Data were analyzed with a 2 × 3 (test × group) 2-way analysis of variance (ANOVA) with repeated measures on 1 variable (test) and appropriate post hoc analyses. The results of the 2-way ANOVA revealed a significant interaction. Further statistical post hoc analysis of data to interpret the interaction revealed significant differences between the control group (gain = 0.70°) and both stretching groups, as well as a significant difference between the static stretch group (gain = 11.42°) and the DROM group (gain = 4.26°). The results of this study suggest that, although both static stretch and DROM will increase hamstring flexibil-

ity, a 30-second static stretch was more effective than the newer technique, DROM, for enhancing flexibility. Given the fact that a 30-second static stretch increased ROM more than 2 times that of DROM, the use of DROM to increase flexibility of muscle must be questioned.

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Journal of Orthopaedic and Sports Physical Therapy.

Gross MT, Burns CB, Chapman SW, Hudson CJ, Curtis HS, Lehmann JR, Renner JB. Reliability and validity of rigid lift and pelvic leveling device method in assessing functional leg length inequality. *J Orthop Sports Phys Ther.* 1998;27:285-294.

Clinicians commonly include an assessment of leg length inequality (LLI) as a component of a musculoskeletal examination. Little research is available, however, documenting reliability and validity of clinical methods for assessing LLI. The purpose of this study was to determine the reliability and validity of assessing functional LLI using a pelvic leveling device. Subjects were 19 women and 13 men between the ages of 18 and 55 who reported having a diagnosed or suspected LLI. Clinical determination of LLI was made by placing rigid lifts under the suspected shorter lower extremity until the leveling device indicated that the iliac crests were level. This measurement was made twice by one investigator and once by a second investigator. Standing radiographic measurements of LLI using rigid lifts were used to establish validity of the clinical method. Intraclass correlation coefficients [ICC(2,1)] and absolute difference values were computed to assess reliability and validity. The mean absolute difference between the 2 clinical measurements of LLI by the same investigator was 0.29 cm (± 0.52), with an ICC equal to 0.84. The mean absolute difference between clinical measurements of LLI by the 2 investigators was 0.49 cm (\pm

0.46), with an ICC equal to 0.77. The ICC and mean absolute difference reflecting agreement between radiographic measurements and clinical measurements of LLI was 0.64 and 0.58 cm (± 0.58), respectively, for one investigator and 0.76 and 0.55 cm (± 0.37), respectively, for the second investigator. The intratester reliability, intertester reliability, and validity assessments included instances in which paired observations disagreed regarding which lower extremity was the shorter lower extremity. Factors that may be associated with the unacceptable reliability and validity of the clinical assessment method include asymmetric positioning of the ilia, body composition of the patient, and design of the clinical instrument. The authors discuss clinical implications related to assessment of LLI.

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Journal of Orthopaedic and Sports Physical Therapy.

Kyrolainen H, Takala TE, Komi PV. Muscle damage induced by stretch-shortening cycle exercise. *Med Sci Sports Exerc.* 1998;30:415-420.

PURPOSE: Strenuous stretch-shortening cycle exercise was used as a model to study the leakage of proteins from skeletal muscle. **METHODS:** The analysis included serum levels of creatine kinase (S-CK), myoglobin (S-Mb), and carbonic anhydrase (S-CA III). Blood samples from power-trained ($n = 11$) and endurance-trained ($n = 10$) athletes were collected before, at 0 hours after, and at 2 hours after the exercise, which consisted of a total of 400 jumps. **RESULTS:** The levels of all determined myocellular proteins increased immediately after the exercise ($P < .05-.001$) among both subject groups. In the endurance group, the protein levels increased ($P < .05-.001$) further during the following 2 hours after the exercise, and the ratio of S-CA III and S-Mb decreased ($P < .05$) in a before-after comparison.

This was not the case among the power group, despite their greater mechanical work ($P < .001$) and higher ratio of eccentric and concentric EMG activity of the leg-extensor muscles ($P < .05$). CONCLUSIONS: The differences of the determined protein levels between the subject groups might be due to obvious differences in the muscle fiber distribution, differences in recruitment order of motor units, and/or differences in training background.

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*Medicine and Science in
Sports and Exercise.*

Wilson LQ, Weltman JY, Martin DE, Weltman A. Effects of a functional knee brace for ACL insufficiency during treadmill running. *Med Sci Sports Exerc.* 1998;30:655-664.

PURPOSE: To assess the effects of a functional knee brace (FKB) for anterior cruciate ligament insufficiency (ACLI) on physiologic and perceptual parameters during treadmill running. **METHODS:** Thirteen ACLI subjects (time since injury, 5.8 ± 5.3 years) performed an incremental test to exhaustion and 2 constant-load 20-minute tests, one at an intensity below lactate threshold (bLT) and the other at an intensity above LT (aLT), each with and without the FKB. **RESULTS:** Bracing had no effect on peak variables except for higher ratings of perceived exertion at the legs (RPE-L) at the velocities associated with a blood lactate concentration [HLA] of 4.0 mM and at peak. Bracing had no effect when exercising at bLT but did significantly alter the metabolic profile developed during the performance of the aLT tests ($83\% \pm 0.03\% \text{VO}_{2\text{peak}}$). In particular, FKB resulted in elevated blood [HLA] (23%), VO_2 (4%), VE (12%), VCO_2 (7%), and VE/VO_2 (7%). HR and slow-component VO_2 did not differ between the brace and no brace aLT tests. RPE-L and RPE-knee were significantly elevated during aLT when the brace was worn. Suspected mechanisms include alterations in muscle recruitment patterns and/or occlusion. **CONCLUSIONS:** When ACLI individuals wear a FKB

during high intensity straight-ahead running exercise of long duration, physiologic parameters are affected.

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*Medicine and Science in
Sports and Exercise.*

Escamilla RF, Fleisig GS, Zheng N, Barrentine SW, Wilk KE, Andrews JR. Biomechanics of the knee during closed kinetic chain and open kinetic chain exercises. *Med Sci Sports Exerc.* 1998;30:556-569.

PURPOSE: Although closed (CKCE) and open (OKCE) kinetic chain exercises are used in athletic training and clinical environments, few studies have compared knee joint biomechanics while these exercises are performed dynamically. The purpose of this study was to quantify knee forces and muscle activity in CKCE (squat and leg press) and OKCE (knee extension). **METHODS:** Ten male subjects performed 3 repetitions of each exercise at their 12-repetition maximum. Kinematic, kinetic, and electromyographic data were calculated using video cameras (60 Hz), force transducers (960 Hz), and EMG (960 Hz). Mathematical muscle modeling and optimization techniques were employed to estimate internal muscle forces. **RESULTS:** Overall, the squat generated approximately twice as much hamstring activity as the leg press and knee extensions. Quadriceps muscle activity was greatest in CKCE when the knee was near full flexion and in OKCE when the knee was near full extension. OKCE produced more rectus femoris activity, while CKCE produced more vasti muscle activity. Tibiofemoral compressive force was greatest in CKCE near full flexion and in OKCE near full extension. Peak tension in the posterior cruciate ligament was approximately twice as great in CKCE and increased with knee flexion. Tension in the anterior cruciate ligament was present only in OKCE and occurred near full extension. Patellofemoral compressive force was greatest in CKCE near full flexion and in the

mid range of the knee-extending phase in OKCE. **CONCLUSION:** An understanding of these results can help in choosing appropriate exercises for rehabilitation and training.

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*Medicine and Science in
Sports and Exercise.*

Jarrett, GJ, Orwin, JF, Dick RW. Injuries in collegiate wrestling. *Am J Sports Med.* 1998;26:674-680.

We evaluated the data of the National Collegiate Athletic Association Injury Surveillance System on collegiate wrestling with a focus on musculoskeletal injuries. Over 800,000 athlete-exposures during an 11-year period compose these data. Findings particular to wrestling and a comparison with other collegiate sports are included. Collegiate wrestling had a relatively high rate of injury at 9.6 injuries per 1000 athlete-exposures. It was second to spring football in total injury rate. Most injuries in this study were not serious, with 6.3% resulting in surgery and 37.6% resulting in a week or more off from wrestling. There was only one catastrophic, nonfatal injury. The knee, shoulder, and ankle were the most commonly injured regions, and injuries to them were often more serious. Sprains, strains, and contusions were the most common injury types. Takedowns and sparring were the most common activities at the time of injury. Mechanism of injury was evaluated; rotation about a planted foot and contact with environmental objects were identified as areas needing further attention. Illegal action accounted for only 4.6% of injuries in competition. Competition had a significantly higher injury rate than practice, but the injury profiles of these two areas showed both to be equally important. The preseason and regular season had higher injury rates than the postseason, but, again, the injury profiles of these periods were similar. Injury percentages were similar among the 10 weight classes.

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American Journal of Sports Medicine.

Wojtys EM, Huston LJ, Lindenfeld TN, Hewett TE, Greenfield ML. Association between the menstrual cycle and anterior cruciate ligament injuries in female athletes. *Am J Sports Med.* 1998;26:614-619.

Anterior cruciate ligament injury rates are four to eight times higher in women than in men. Because of estrogen's direct effect on collagen metabolism and behavior and because neuromuscular performance varies during the menstrual cycle, it is logical to question the menstrual cycle's effect on knee injury rates. Of 40 consecutive female athletes with acute anterior cruciate ligament injuries (less than 3 months), 28 (average age, 23 ± 11 years) met the study criteria of regular menstrual periods and noncontact injury. Details concerning mechanism of injury, menstrual cycle, contraceptive use, and previous injury history were collected. A chi-square test was used to compute observed and expected frequencies of anterior cruciate ligament injury based on three different phases of the menstrual cycle: follicular (days 1 to 9), ovulatory (days 10 to 14), and luteal (day 15 to end of cycle). A significant statistical association was found between the stage of the menstrual cycle and the likelihood for an anterior cruciate ligament injury ($P = 0.03$). In particular, there were more injuries than expected in the ovulatory phase of the cycle. In contrast, significantly fewer injuries occurred in the follicular phase. These hormones may be a factor in the knee ligament injury dilemma in women.

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Fees M, Decker T, Snyder-Mackler L, Axe MJ. Upper extremity weight-training modifications for the injured athlete: a clinical perspective. *Am J Sports med.* 1998;26:732-742.

The ability of the health care professional to make correct decisions about the progression of weight-training is critical to the rehabilitation process. The purpose of this article is to describe our approach to modification of weight-lifting techniques using the injured shoulder as a model. Additionally, the impact of various upper extremity weight-training techniques on healthy athletes is discussed. The effects of grip, hand spacing, bar trajectory, and start and finishing positions on microtraumatic injury and return to weight-training activities after injury are considered. Several weight-training functional progressions for common multijoint exercises (such as bench press, shoulder press, power clean) are presented. Adaptations for periodization are also presented for implementation in the rehabilitation sequence. The weight-training modifications described in this paper will assist the health professional to safely return athletes to the weight room after shoulder injury.

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Vaes PH, Duquet W, Casteleyn PP, Handelberg F, Opdecam P. Static and dynamic roentgenographic analysis of ankle stability in braced and nonbraced stable and functionally unstable ankles. *Am J Sports Med.* 1998;26:692-702.

Patients suffering from functional ankle instability were selected based on a structured interview. Talar tilt was measured using supine ankle stress roentgenographs, and standing talar tilt was measured using erect ankle stress roentgenographs. A digital roentgenocinematographic analysis of a 50-degree ankle sprain simulation was performed to measure dynamic talar tilt and inversion distance between two video images (inversion speed). A significant decrease in pathologic supine talar in unstable ankles was found in the braced compared with the nonbraced situation (talar tilt = 13.1 degrees versus 4.8 degrees with brace). The talar tilt with the brace after activity was still significantly lower than the initial value without the brace. The standing talar tilt of unstable ankles was shown to be significantly lower with the orthosis than without (standing talar tilt = 16.6 degrees versus 12.0 degrees with brace). Roentgenocinematographic evaluation of ankle sprain simulation showed that the mean dynamic talar tilt during simulated sprain decreased significantly in the braced ankles compared with the nonbraced ankles (dynamic talar tilt = 9.8 degrees versus 6.4 degrees braced). A significant decrease in the digital measurement of inversion distance (from 110.6 pixels to 92.4 pixels) was observed in the total sample of 39 ankles during the initial high-speed phase of the simulated sprain. The brace significantly slows down the inversion speed.

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Book Reviews

The Clinical Orthopaedic Assessment Guide

Janice Loudon, Stephania Bell, and Jane Johnston

Human Kinetics, Champaign, IL

1998

248 pages

ISBN: 0-88011-507-6

Price: \$29.00

The Clinical Orthopaedic Assessment Guide is a concise source of information for clinicians who perform manual therapy techniques. The authors are experienced in orthopaedic manual physical therapy. The *Guide* is divided into 5 sections: 1) "Introduction to Biomechanical Principles," 2) "Head and Spine," 3) "Upper Extremity," 4) "Lower Extremity," and 5) "Posture and Gait."

This publication is truly a "guide," with the text presented in an outline format. This streamlined layout provides rapid access to information, so the reader need not wade through volumes of extraneous material. Diagrams, charts, and tables supplement the text without being redundant. Highlight boxes effectively emphasize specific topics. Although the boxes are useful for providing quick and easy reference, the information provided therein is occasionally too brief. An example of this is the highlight box featuring the Craig test for femoral anteversion. The box describes how to do the examination and arrive at a certain number, but it does not explain the significance of a number that is too high or too low.

Although one of the authors is a member of the National Athletic Trainers' Association, athletic trainers will find that the text is directed primarily at orthopaedic physical therapists. Even so, the text is not limited to practitioners of sports medicine. From an athletic trainer's viewpoint, differences in terminology are noted, such as the use of "end-feel" rather than "end-point" or "sweater-finger sign" instead of "rugger-jersey injury."

The Clinical Orthopaedic Assessment Guide appears in a softbound edition and is moderately priced. This book is appro-

priate as a reference for an established and busy clinician. It would also be useful when studying for board examinations in either sports medicine or physical therapy. I would not recommend it as a primary text for a beginning student in manual therapy techniques.

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Biomechanics of Musculoskeletal Injury

William C. Whiting and Ronald F. Zernicke

Human Kinetics, Champaign, IL

1998

273 pages

ISBN: 0-87322-779-4

Price: \$49.00

Biomechanics of Musculoskeletal Injury is a comprehensive text on the anatomy, kinesiology, and mechanics of musculoskeletal injury. This is a unique and worthwhile text that contributes significantly to the disciplines of exercise science, kinesiology, athletic training, physical therapy, and other allied health programs. This volume would be ideal as the primary text for a course on the biomechanics of injury or as a secondary reference for a clinically oriented course in mechanical kinesiology or basic biomechanics.

The material is divided into 8 chapters, which are systematically and logically presented. The chapters flow very nicely and are quite readable, enhancing the reader's comprehension of the material.

Appropriately, the text begins with a chapter entitled "Introduction to Injury." The authors define injury and present numerous perspectives, providing the reader with a sound understanding of the dynamics of musculoskeletal injury. Of particular interest is the section on historical perspective that reviews injury origin and treatment in a chronologic order. Chapter 2 provides the basis for understanding musculoskeletal injury by

covering the development, structure, and function of biologic tissues (bone, tendon, ligament, muscle) and classifying joint structure and function. The illustrations in this chapter are excellent; the figures are large and easy to understand. Clinical applications bridge the gap between theory and practice. In the following chapter, explanations of basic biomechanical principles, material mechanics, and computer modeling and simulation provide the reader with a good foundation for understanding specific mechanisms of injury.

Chapter 4 quite adequately relates biomechanical, biochemical, and molecular principles to biologic tissue injury. Also, this chapter describes many factors that can affect growth, maturation, and development of normal tissue and predispose it to injury. Chapter 5 discusses the mechanisms and classification of injuries occurring to biologic tissues and presents many factors that contribute to injury. Furthermore, this chapter explains a variety of injuries that can occur to various tissues.

In each of the last 3 chapters, injuries to specific regions of the body are presented, along with the biomechanical origins of these injuries. A complete etiology of the specific injuries is introduced and supported with current relevant references.

At \$49.00, this text is moderately priced considering the amount of information contained. This volume represents a wonderful compilation of biomechanical principles and theory, supported by clinical applications. Since very few texts of this type are currently available, this book is a must for the individual who desires a better understanding of the biomechanics of injury. Although primarily written for the undergraduate student, this book would also be useful as a secondary source for the practicing clinician in various allied health and medical professions.

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Medical Problems in Athletes

Editors: Karl B. Fields and Peter A. Fricker

Blackwell Science, Malden, MA

1997

412 pages

ISBN: 0-86542-480-2

Price: \$79.95

Medical Problems in Athletes is a text that provides a review of various medical conditions and how each affects athletes. According to the editors, this book is intended as a guide for sports physicians to help athletes enhance performance and maximize safe participation in activity. It is also an appropriate text for any professional working with a physically active population.

The book is divided into 3 parts, with each part made up of several chapters. Each chapter is authored or coauthored by experts in that particular field. The text opens with a short introduction, "Medical Assessment Prior to Sports." This section provides a brief discussion of preparticipation screening, as well as areas of potential concern before an athlete begins athletic participation. Part I is titled "Infectious Problems in Athletes." Chapter topics in this section range from a general overview of the effects of infectious diseases on athletic performance to infectious issues associated with regional and international travel. A chapter that may be of particular interest to athletic trainers covers bloodborne pathogens and sports. Other chapters of note cover upper respiratory infections, mononucleosis, and bronchitis and pneumonia.

Part II, "Cardiologic and Other Regional Medical Conditions and Chronic Illness," contains 22 chapters covering various medical conditions. The first several chapters of this section focus on cardiac issues, including a chapter on sudden cardiac death. The second part of part II includes chapter topics that deal with systemic concerns such as ear, nose, and throat problems, gastroenterologic and neurologic problems, and issues in nephrology, dermatology, and hematology.

Part III, "Special Medical Problems in the Athlete," covers a wide variety of topics, from hyperthermia and heat-related illness to blood doping and drugs.

In this section, 2 chapters stand out: chapter 45, "Nutritional Strategies for Athletic Performance," and chapter 47, "Physical Activity and Mental Health: Anxiety, Depression and Burnout in Athletes." The former chapter is practical and offers suggestions for fat loss and lean mass gain strategies, including dietary recommendations for the athlete. The latter chapter discusses mental health issues commonly seen in athletes, including signs and symptoms and treatment options.

Medical Problems in Athletes has several strengths. The medical conditions and topics covered are wide ranging. The book is well organized, with similar chapters grouped together within the 3 major sections. While the chapters are written in different styles, each is reader friendly, providing pertinent information in a clear and concise manner. Although the chapters are not comprehensive, the information they provide is useful and what one would expect in a text covering such a variety of topics. Each chapter has a reference list (several are quite extensive) for those in need of more detailed information. The text has several color photographs, which, although small, are useful in illustrating several dermatologic conditions.

As stated in the introduction and on the back cover of this text, this book is designed to be a guide for primary care physicians and sports physicians. It can also serve a similar role for other professionals working with athletes. Some of the topics covered in this text can be found in greater detail in most comprehensive athletic training books. However, there are several chapters on topics useful and informative to athletic trainers and not commonly covered in depth in a typical athletic training text ("Sinusitis, Otitis Media, Otitis Externa, and Conjunctivitis," "Arrhythmias," "Eating Disorders," and "Implementation of a Drug Testing Program"). This text would serve an athletic trainer best as a supplement, a guide to refer to for information on both common and unique medical issues. The one significant drawback of this text is its price. For \$79.95, it is a somewhat costly, yet useful, supplement

to the resource library of a professional working with the physically active.

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The Elbow in Sport: Injury, Treatment, and Rehabilitation

Todd S. Ellenbecker and Angelo J. Mattalino

Human Kinetics, Champaign, IL

1996

202 pages

ISBN: 0-87322-897-9

Price: \$32.00

The effective management of elbow pathologies in the active population is predicated on the understanding of several critical elements: anatomy, pathokinetics, assessment methodology, and rehabilitation protocols. In a concise presentation, the authors of *The Elbow in Sport* have provided clinicians and educators an opportunity to learn (or relearn) not only these elements but also some of the scientific bases for the management techniques in current practice.

Clinical practice and application are underlying themes throughout the book, with frequent references to pathokinematics directly associated with specific sports. Tennis, golf, and baseball receive appropriate coverage, with emphasis on overuse injuries and their management.

While the sections on anatomy and diagnostic testing offer only cursory summaries for the general population, the authors' frequent citations of clinical scientific papers direct the reader to abundant sources of additional information on these topics.

The clear strengths are found in the sections covering the etiology of overuse injuries, clinical evaluation (physical assessment), and rehabilitation techniques for overuse injuries. Numerous photographs and diagrams provide visual support for the well-written text. The authors make frequent reference to specific clinical presentations that will be familiar to anyone dealing with upper extremity sports. In the clinical evaluation section, appropriate attention is paid to the integration of the fundamentals of anatomy and biomechanics that clearly

present the rationale for evaluation techniques.

Overuse injuries are the central focus of this book. The reader should not anticipate any significant information on traumatic injury associated with acute trauma, such as fracture or acute musculotendinous disruption. While there is passing reference to proprioceptive rehabilitation patterns, the literature on proprioceptive assessment is not covered.

Chapter 7, "Case Presentations," as well as the appendixes on rehabilitation protocols that follow, is an effective resource for the athletic trainer or physical therapist, providing ideal reference materials for the training room.

The Elbow in Sport is written for a broad audience. It will serve as a valuable reference for use in training rooms and clinics. Authors Ellenbecker and Mattalino integrate their ample clinical experience into a presentation that will broaden the clinician's understanding of overuse injuries to the elbow.

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Running Past 50

Richard Benyo
Human Kinetics, Champaign, IL
1998
242 pages
ISBN: 0-88011-705-2
Price: \$16.95

Richard Benyo presents a comprehensive look at running, with specific emphasis on issues relevant to those aged 50 and older. He speaks from experience as an accomplished long-distance runner, author, and race director, and he includes information derived from the habits of other similarly qualified runners. Interesting biographic inserts of skilled athletes over the age of 50 years serve to illustrate salient points. This book is directed at motivating the senior athlete.

The text is separated into several sections that cover preparticipation evaluation, training aspects, fluids and nutrition, injuries, and psychological aspects such as motivation and burnout. These topics are presented in an easily readable format that avoids technical drudgery. The advice is sound, conservative, and relatively thorough from a sports medi-

cine standpoint. A significant portion of the book is dedicated to techniques to keep runners "running through" injury, motivational problems, and aging. These topics are mainly designed for established long-distance runners; however, this knowledge is also useful for the novice.

Running Past 50 is an informative and inspiring text for runners in this age group. It is reasonably priced, quite readable, and written with the authority of experience.

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Imaging in Musculoskeletal and Sports Medicine

Brian Halpern, Stanley A. Herring,
David Altchek, and Richard Herzog
Blackwell Science, Malden, MA
1997
275 pages
ISBN: 0-86542-418-7
Price: \$125.00

Imaging in Musculoskeletal and Sports Medicine provides an in-depth look at various imaging modalities and their applications in the diagnosis of injuries resulting from athletic competition and training. Since it is well known that imaging is very important in the accurate diagnosis of these injuries, the aim of this book is to provide the reader with a better understanding of imaging modalities and the role that injury assessment plays in imaging selection. This book also explains injury pathology and its relationship to the signs and symptoms noted during injury assessment.

The authors have incorporated into their text the comments of more than 30 experts, thereby providing a wealth of information in each chapter. The book begins with a chapter on the epidemiology of sports injuries, with an overview of common athletic injuries that are detailed in the subsequent chapters.

Chapter 2 explains the various imaging modalities, which include plain films, fluoroscopy, computed tomography, radiotracer imaging, sonography, and magnetic resonance imaging. The authors explain the principles behind these techniques and the processes by which the images are produced. The

positive and negative points concerning the use of each modality are discussed, and the reader is offered valuable insight into the advantages of selecting one imaging modality over another for the diagnosis of a specific injury.

The remainder of the book explains the use of these imaging techniques to diagnose injuries to the head, face, and cervical soft tissue; cervical, thoracic, and lumbar spine; chest; shoulder; elbow; hand and wrist; abdomen; pelvis; knee; lower leg; and ankle and foot. Each chapter begins with a review of anatomy and explains the imaging modalities and techniques recommended for each specific body segment. The authors stress that proper imaging selection plays a very important role in making an accurate diagnosis, and they explain how other components of the assessment process determine the selection of an imaging method.

Each chapter thoroughly covers specific common injuries by explaining the mechanism and anatomy of each injury and the way imaging is used to make a diagnosis. Each chapter is very inclusive, with some less common injuries also discussed. For example, the chapter on the elbow covers radial head and neck fractures, olecranon fractures, dislocations, collateral ligament injuries and instability, tendon ruptures, osteochondritis dissecans, epicondylitis, and nerve injuries.

Although the book is moderately expensive at \$125.00, it contains over 250 tables and figures, making it well worth the cost. These figures enable the reader to visualize many types of injuries and provide an excellent review of anatomy. This book would make an excellent supplement to any course on the pathology and assessment of injury; however, a background in anatomy would be necessary to fully comprehend all the information provided in this text. Any health care professional involved in the assessment of athletic injuries should find this book extremely helpful as both an educational tool and a general source of information.

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Serious Strength Training

Tudor O. Bompá and Lorenzo J. Cornacchia
Human Kinetics, Champaign, IL
1998
301 pages
ISBN: 0-88011-834-2
Price: \$19.95

Serious Strength Training is a how-to guide for designing and implementing a comprehensive strength training or bodybuilding program for novices through experienced weight lifters. The primary focus of this text is to introduce the concept of periodization of training as a way to achieve optimal gains in strength and body sculpting.

The text is organized into 3 major sections. Part I provides general background information for effective program planning. Chapter 1 introduces basic muscle physiology and describes what happens to muscle during strength training, while chapters 2 and 3 discuss the basics of weight-training program design to maximize muscular gain and training goals. Bompá's presentation of periodization in part II and the associated training phases in chapters 4-10 are, to my mind, the strength of this text. While his focus is primarily on bodybuilding, the principles and examples of periodization of workouts are research based and would be beneficial to all interested in proper weight-training design. Variations in design are also presented to adjust for an athlete's level of ability and training experience. Part III provides supplementary information on nutrition and health. Chapter 11 describes basic lifts for each muscle group, including demonstration photographs and a description of the proper technique for each lift. Chapters 12-14 address basic nutrition concepts, muscle recovery and injury issues, and an in-depth discussion of the various performance-enhancing drugs used by bodybuilders.

Because this text is geared primarily to the bodybuilder and is not a general instructional text on weight training, it is not well suited for use in most educational courses. At best, it may be useful as a supplementary source for a weight-training activity class. The material covered on muscle physiology, nutrition concepts, and muscle injury and recovery is too basic to provide adequate

instruction in these areas and serves only as supplementary material for the principles on program design. With the exception of chapter 11, the numerous photographs of fitness models and professional bodybuilders throughout the text contribute little to the overall content and are more distracting than helpful. However, for those interested in this topic, the text is well written and clearly organized. The material presented appears to be scientifically based, and there is a clear emphasis on appropriate and safe training based on level of ability. The cost, at \$19.95, is very reasonable.

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Essentials of Musculoskeletal Care

Editor: Robert K. Snider
The American Academy of Orthopaedic Surgeons, Rosemont, IL
1997
686 pages
ISBN: 0-89203-162-X
Price: \$85.00

The American Academy of Orthopaedic Surgeons and The American Academy of Pediatrics have combined their resources to create a reference text for musculoskeletal care. The text is divided into 2 sections: general orthopaedics and pediatric orthopaedics. These sections are subdivided into 7 anatomic sections: hand and wrist, elbow and forearm, shoulder, spine, hip and thigh, knee and lower leg, and foot and ankle.

The anatomic sections include the most common musculoskeletal problems. Each condition is outlined with the definition, the appropriate physical examination, clinical symptoms, differential diagnosis, conservative management, adverse outcomes, and "red flags" (ie, diagnoses that will require a referral). The reader who is familiar with musculoskeletal care will find the text easy to understand.

Each section provides the pertinent facts of a specific diagnosis, without expanding on natural history, pathophysiology, or surgical indications. The excellent differential diagnosis section offers the reader other common conditions to consider in the diagnostic process. The "red flag" portion is effective in helping

the clinician recognize problems that need emergent care or an additional evaluation.

This book contains excellent illustrations of techniques used for physical examinations and injections. The extremity section adequately assists in the diagnosis of most injuries that an athletic trainer would encounter. We feel, however, that an expansion of the hand and wrist topics would be beneficial to the athletic trainer, specifically in reference to flexor and extensor tendon injuries. The text does not provide guidelines for on-the-field evaluation, treatment, and transfer of patients with spine and head injuries. Also, relevant topics such as hydration and drugs in sports are not included.

In summary, the text is an excellent reference for the most common acute and chronic musculoskeletal problems. Orthopaedic surgeons, athletic trainers, physical therapists, and primary care physicians can use this text to assist in making a diagnosis, researching other possible conditions, and following general treatment guidelines. This book would be a valuable resource to any health care provider who deals with chronic and acute musculoskeletal problems.

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Fit to Pitch

Tom House
Human Kinetics, Champaign, IL
1996
204 pages
ISBN: 0-87322-882-0
Price: \$17.95

The objective of *Fit to Pitch* is to physically prepare the overhead thrower to pitch effectively and correctly, while minimizing the potential for injury. The book is written for use by the player, coach, and parent; however, the text is also extremely useful for the athletic trainer and physical therapist. The book explains and illustrates preventive conditioning exercise drills and specific programs to maximize pitching performance and minimize the risk of injury. The

author also provides useful information regarding rehabilitation programs and exercises aimed at enabling pitchers to successfully return to competition after an injury.

Each chapter is well written and easy to read. Most exercises are illustrated, making each drill easier to comprehend. Chapter titles include "Principles of Conditioning," "Flexibility Training," "Aerobic and Anaerobic Conditioning," "Muscular Strength and Endurance Conditioning," and "Specific Training Programs," and topics such as integrated flexibility, dynamic balance, and aerobic running programs are discussed. Thoroughly discussed practical throwing programs include short toss, long toss, "towel-throwing drill," uphill throwing, and off-the-mound programs, just to mention a few.

The author discusses a typical in-season training program for use between pitching days, which is beneficial for both the starter and the relief pitcher. Dr. House also addresses the importance of proper nutrition and makes specific suggestions regarding meals, snacks, and pregame nutrition.

This book is written by an individual who is well respected in the area of baseball. Dr. House (his PhD is in psychology) was a major league pitcher for 13 years and has been a pitching coach for the last 18 years. He is also a student of the biomechanics of pitching. In this

text, the author provides practical and useful information for conditioning and rehabilitating the overhead pitcher. The only negative aspect of the textbook is the lack of references.

I highly recommend this book to athletic trainers involved in the physical conditioning and rehabilitation of the throwing athlete. This book provides vital background information but also can be used as a reference text later.

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Stronger Abs and Back

Dean Brittenham and Greg Brittenham
Human Kinetics, Champaign, IL
1997

ISBN: 0-88-11-558-0

Price: \$16.95

This father-and-son tandem have written a book based on sound scientific principles concerning the strengthening and conditioning of our abdominal and back musculature. The text is not one designed for use in an athletic training curriculum but is a good supplement or reference text for the clinical sports health care professional.

Stronger Abs and Back is written in a manner that flows well and is easily read. The text is not advanced material, and certified athletic trainers should be familiar with the described principles

and concepts. The first few chapters deal with the importance of the trunk musculature and basic conditioning principles. Chapter 5 details a variety of trunk-stabilization exercises and techniques that may be helpful to the clinician. Abdominal musculature is emphasized in chapters 6-8, which identify distinct fitness, strength, and power exercises. The final chapter is used to help the reader formalize a quality trunk-conditioning program.

The many and varied exercises detailed by the authors provide the sports health care professional with a quick reference for numerous potential exercises for injury prevention or rehabilitation. In addition to good descriptions, the photographs aid the reader's understanding. The authors do not try to cover too much material, and they suggest related reading in other areas, such as nutrition.

Although the current text is well written, adding references to quality research may improve the introductory chapters. Overall, *Stronger Abs and Back* provides examples of many quality exercises for the conditioning of a critical region for athletes. At \$16.95, the text would be a good library addition for anyone involved in exercise prescription.

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V

ideo Reviews

Massage for Sports Health Care: For Enhanced Athletic Performance and Recovery

Benny Vaughn

Human Kinetics, Champaign, IL

1998

45 minutes

ISBN: 0-88011-919-5

Price: \$29.95

This video is an excellent supplement for any athletic health care professional. It could easily be incorporated into an advanced undergraduate athletic therapy modalities course, but it may be even more valuable for individuals who wish to improve their sport massage techniques. Certainly, it requires the basic knowledge of both massage therapy and the mechanisms and treatment of athletic injuries. Contraindications to massage therapy and the preparation of both the therapist (eg, fingernail length, oil application, use of pads, sensitivity to muscle tension) and the athlete (eg, relaxed position, pain and discomfort sensations) are not as fully presented as they would be in a certification course for massage therapists. Similarly, the basis for the selection of a particular technique will not be fully appreciated unless the viewer already understands the physiologic, biomechanic, and psychological factors involved in athletic performance and injury.

Particularly noteworthy is the presentation of this material in the university setting and the use of real student athletic trainers and athletes. With this technique, Mr. Vaughn seems to capture the

full scope of the unique challenges associated with using massage therapy in training room and on-the-field settings versus clinic or private settings. For example, he discusses the portability and affordability of massage tables and field chairs that can accommodate the height and weight of the largest athletes. The emphasis on not improvising with gels and lotions, a common practice in many training rooms, is well appreciated. The video explains the purpose of each technique and the time required to perform it. Partitioning athletic performance into phases (pre-event, recovery, and common chronic injury) and matching each with a specific, well-explained massage technique should provide a useful framework for both the instruction and application of massage therapy. Additionally, suggestions for improved techniques are provided while the basic massage strokes are attempted by the students. The video presents case demonstrations of massage therapies for some of the injuries seen most commonly in the training room.

The video is exceptionally well organized and easy to follow. The first section includes an explanation and demonstration of 6 basic massage strokes (compressive effleurage, compressive petrissage, compression broadening, deep transverse friction, active assisted massage/static compression, and lengthening and broadening). The remainder of the tape demonstrates how these strokes are combined for a particular purpose, a particular performance phase, or both, as mentioned above. No more than 3 mas-

sage strokes are combined in any demonstration, which simplifies the application of massage in the athletic setting. Each demonstration is sprinkled with useful comments about such factors as hand position, stance, pace, purpose, and benefit. Although the comments may make replaying the tape necessary, they remain remarkably valuable. Additionally, Mr. Vaughn's CCT (condition, characteristic, and technique) model approach to athletic massage therapy provides a needed organizational tool for the instruction in injury mechanisms, prevention, and treatment, as well as for the administration of massage therapy in conjunction with other modalities.

The variety of common musculoskeletal complaints and injuries covered in this video range from ankle to neck, but, interestingly, coverage does not extend to the lower back. Also, there is no mention of special situations (eg, degree of edema) or special populations (eg, those with neurologic or circulatory impairments). I believe it would be helpful, in future editions, to include comments about back pressure on a stroke (which should be light) and how most strokes incorporate pressure toward the heart.

The obvious audience for this video is the athletic trainer and the healthy competitive athlete. The cost is very reasonable, either for an individual or an institution, and the return is high.

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1999 REQUEST FOR PROPOSALS

The NATA Research & Education Foundation is pleased to announce that \$120,000 is available in 1999 for Research and Education Grants. Priority consideration will be given to proposals which include a certified athletic trainer as an integral member of the research or project team.

Research Grants

No. of Awards:	Multiple awards are available
Available:	\$105,000 total, no minimum or maximum dollar amounts for individual grants
Deadlines:	March 1 and September 1
Notification:	July and February

I. General Grants

The Foundation will fund a number of studies which address important issues in four categories: basic science, clinical studies, sports injury epidemiology and observational studies.

II. Pediatric Sports Health Care

The Foundation encourages research studies that will have clinical relevance to the development of the pediatric athlete, and the prevention, treatment and rehabilitation of injuries sustained by the physically active pediatric participant. A great need exists for epidemiologic studies to determine pediatric injury patterns and specific populations at risk.

Background

Very little experimental evidence concerns the impact of physical activity upon the general development of the child. The recent, tremendous growth of children's participation in organized sport has outpaced efforts to clearly understand the consequences of intense physical activity on the developing young adult. The incidence of organized sports participation by preadolescents and adolescents has increased dramatically in the past two decades. Children represent the largest group of individuals engaging in organized sport in this country. However, little is known about the incidence and severity of injuries associated with child or adolescent participation in these activities.

Furthermore, the number of children and adolescents participating in sport increases regularly from year to year. Despite this increase, the President's Council on Physical Fitness has determined that the fitness levels of young adults in this country are on the decline and urges regular participation in sport and exercise by a much higher percentage of the childhood population.

It is assumed that exercise and sports participation have positive effects on children, and there is increasing evidence that regular exercise is important to their physical and psychological well-being. The United States Department of Health and Human Services in its compendium on National Health Promotion and Disease Prevention Objectives recommends significant increases in daily physical activity for children to combat problematic sedentary lifestyles and obesity among young adults. Many experts believe that lifestyles leading to adult heart disease often begin in childhood and that habitual physical activity during development may play an important role in slowing the progression of cardiovascular disease, particularly in high-risk children. Moreover, the increasing awareness and interest in exercise as a treatment medium by the medical community has undoubtedly influenced parents' perceptions of the importance of regular physical activity in the lives of their children.

Yet, participation in sport does pose risks. Exercise is a human stressor which results in bodily adaptations that can have beneficial or adverse effects on health. Childhood and adolescence as developmental periods, introduce variables that are not found in the adult athlete. Asynchronous rates of development among similarly-aged children present difficult challenges to those who teach and supervise the physical activity of young athletes. Attempts to develop training programs for the young athlete pose a dilemma that the exercise

science and medical professions have yet to resolve satisfactorily. A developing child differs significantly in anatomical and physiological parameters from the mature adult. These differences must be taken into account when prescribing exercise programs for young athletes. Children in the 8-15 year age group are in a complicated and critical growing period. Muscular development also varies considerably and the actual strength of muscle relates to the stresses that can be placed on the skeletal framework without injury. If children and adolescents are involved in organized sports, it is obvious that a considerable amount of skeletal growth is occurring simultaneously with periods of intense physical activity.

The repetitive microtrauma and overuse syndromes associated with sports, and their development in children's growth plates have been widely debated. Traumatic sports injuries to the growth plate do occur and the potential for a growth disturbance is always a concern of parents and physicians. While the growth plate seems relatively immune to damage from overuse, it remains to be seen if this sensitive area of children's anatomy remains protected from the increasingly rigorous training to which young athletes are subjected.

Objectives

The Research and Education Foundation, therefore, encourages high quality research proposals that will help establish a firm scientific foundation for basic and applied programs in pediatric sports health care. Areas of interest may include but are not limited to: epidemiology of athletic injuries in children and adolescents; the role of pre-participation physical examination in the identification of injury risk factors among children and adolescents; the efficacy of specific safety equipment in preventing or reducing the incidence and severity of injury; injury mechanisms and exercise pathophysiology in children; prevention, treatment and rehabilitation of pediatric athletic injuries; conditioning of the child athlete; and musculoskeletal healing processes in children. Given the present funding available, it is expected that grant proposals emphasizing local and regional epidemiological approaches will initially be submitted with the intent to develop data bases and model approaches to injury surveillance which can lead to future large scale epidemiologic or intervention studies on a national level.

III. Doctoral Research Grants

No. of Awards:	Two
Available:	\$2,500 for each grant
Application Deadline:	March 1
Notification:	April 15
Sponsor:	Active Ankle Systems

Applicants must be current certified member of the NATA. You must be a doctoral student at the institution where the research is to be performed and have doctoral student status during the term of the grant to be considered for funding.

Education Research and Program Grants

No. of Awards:	Multiple awards are available
Available:	\$10,000 total, no minimum or maximum dollar amounts for individual grants
Deadlines:	March 1 and September 1
Notification:	July and February

I. Clinical Instruction and Learning Styles

Research indicates that knowledge of student learning styles directly impacts the quality of clinical instruction in other allied health professions. However, no studies have been undertaken to determine the relevance of student learning styles in athletic training clinical education. The Foundation will fund proposals addressing this area including (a) what factors affect learning styles in the clinical setting, (b) assessment of learning styles for student athletic trainers and clinical instructors, (c) incorporation of learning styles in traditional versus non-traditional clinical settings, and (d) the effectiveness of matching the learning styles of student athletic trainers and clinical instructors. The goal of this research is to better meet the needs of students by enhancing the quality of clinical instruction in athletic training.

II. Education Research Grants

Include studies investigating teaching methods and evaluation and learning tools used in the area of athletic training education. Areas of particular interest to the Foundation are computer and competency-based learning and methods used to evaluate clinical learning skills.

III. Education Projects / Program Grants

Include seed money for seminars, lectures, or any other education program focusing on the health care of the physically active or athletic training education. Project and program grants may include, but are not limited to:

- educational conferences/workshops and other programs
- technology-based projects
- development of clinical assessment tools

Larger-Scale Projects

Those seeking funding for projects which exceed the dollar figures indicated in the RFP, may do so by submitting a letter of inquiry – no longer than 3 pages – outlining a statement of the problem, a description of methods, expected outcomes and estimated budget. If interested, the Foundation will request a full application. There are no deadlines for letters of inquiry.

Application Procedure

To receive a copy of the Grant Application or the Doctoral Research Grant Application, please write to NATA Research & Education Foundation, 2952 Stemmons, Dallas, TX 75247, e-mail the request to BarbaraN@nata.org or call 800-TRY-NATA ext. 121. ■

(Revised January 1998)

The mission of the *Journal of Athletic Training* is to enhance communication among professionals interested in the quality of health care for the physically active through education and research in prevention, evaluation, management, and rehabilitation of injuries.

SUBMISSION POLICIES

1. Submit one original and five copies of the entire manuscript (including tables and figures) to: *Journal of Athletic Training* Submissions, Hughston Sports Medicine Foundation, Inc, 6262 Veterans Parkway, PO Box 9517, Columbus, GA 31908. The term *figure* refers to items that are not editable, either halftones (photographs) or line art (charts, graphs, tracings, schematic drawings), or combinations of the two. A *table* is an editable item that needs to be typeset.
2. All manuscripts must be accompanied by a letter signed by each author and must contain the following statements: "This manuscript 1) contains original unpublished material that has been submitted solely to the *Journal of Athletic Training*, 2) is not under simultaneous review by any other publication, and 3) will not be submitted elsewhere until a decision has been made concerning its suitability for publication by the *Journal of Athletic Training*. In consideration of the NATA's taking action in reviewing and editing my submission, I the undersigned author hereby transfer, assign, or otherwise convey all copyright ownership to the NATA, in the event that such work is published by the NATA. Further, I verify that I have contributed substantially to this manuscript as outlined in item #3 of the current Authors' Guide." By signing the letter, the authors agree to comply with all statements. Manuscripts that are not accompanied by such a letter will not be reviewed. Accepted manuscripts become the property of the NATA. Authors agree to accept any minor corrections of the manuscript made by the editors.
3. Each author must have contributed to the article. This means that all coauthors should have made some useful contribution to the study, should have had a hand in writing and revising it, and should be expected to be able to defend the study publicly against criticism.
4. Financial support or provision of supplies used in the study must be acknowledged. Grant or contract numbers should be included whenever possible. The complete name of the funding institution or agency should be given, along with the city and state in which it is located. If individual authors were the recipients of funds, their names should be listed parenthetically.
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10. Published manuscripts and accompanying work cannot be returned. Unused manuscripts will be returned if submitted with a stamped, self-addressed envelope.

STYLE POLICIES

11. Each page must be printed on one side of 8½ by 11-inch plain paper, double spaced, with one-inch margins. Do not right justify pages.
12. Manuscripts should contain the following, organized in the order listed below, with each section beginning on a separate page:
 - a. Title page
 - b. Acknowledgments
 - 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 ($\text{m}\cdot\text{sec}^{-1}$ or m/sec), angular velocity in degrees per second ($^{\circ}\cdot\text{sec}^{-1}$), 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.

17. A structured abstract of 75 to 200 words must accompany all manuscripts. Type the complete title (but not the authors' names) at the top, skip two lines, and begin the abstract. Items that are needed differ by type of article. **Literature Review:** 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 three to five 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 one- to two-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. The active voice is preferred. For examples, consult the *AMA Manual of Style*.
19. The body or main part of the manuscript varies 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. 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—but 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, exam, etc), diagnosis, treatment and clinical course (rehabilitation until and

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Authors' Guide

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. **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.
21. 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.
22. 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.

23. 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.
24. **Table Style:** 1) Title is bold; body and column headings are roman type; 2) units are set above

Books:

1. van Dyke JR III, Von Trapp JT Jr, Smith BC Sr. Arthroscopic management of post-operative 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.

Presentations:

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

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.

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■ 21st Annual NATA Student Writing Contest ■

In an effort to promote scholarship among young athletic trainers, the National Athletic Trainers' Association, Inc sponsors an annual writing contest.

1. The contest is open to all undergraduate members of the NATA.
2. Papers (eg, original research articles, literature reviews, case reports, clinical techniques articles, or communications articles) must be on topics germane to the profession of athletic training.
3. Entries must neither have been published by, nor be under consideration for publication by, any journal.
4. The winning entrant will receive a cash award and recognition as the winner of the Annual NATA Student Writing Contest. The winning paper will follow the normal process of submission and review for possible publication in the *Journal of Athletic Training*. One or more other entries may be given honorable mention.
5. Entries must conform to the *Journal's* Authors' Guide, which provides the most current information on format and style. For advice about writing, we suggest that authors consult Kenneth L. Knight and Christopher D. Ingersoll's "Structure of a Scholarly Manuscript: 66 Tips for What Goes Where" (*J Athl Train.* 1996;31:201-206) and "Optimizing Scholarly Communications: 30 Tips for Writing Clearly" (*J Athl Train.* 1996;31:209-213).
6. Entries must be received by March 1, 1999. The winner will be announced at the Annual Meeting and Clinical Symposia in June.
7. The Writing Contest Committee reserves the right to make no awards if, in its opinion, none of the entries is of sufficient quality to merit recognition.
8. An original and two copies of each entry must be received at the following address by March 1, 1999:

NATA Student Writing Contest
Deloss Brubaker, EdD, ATC
Life College
1269 Barclay Circle
Marietta, GA 30060

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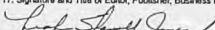
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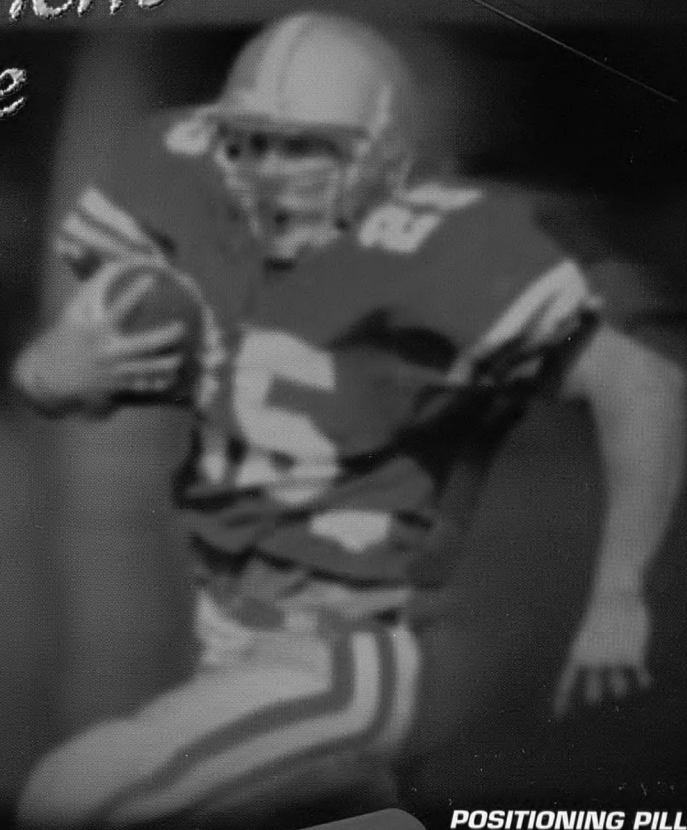


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