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More Professionalism Needed

I would like to applaud Weidner and Vincent for their study, "Evaluation of Professional Preparation in Athletic Training by Employed, Entry-Level Athletic Trainers" (JAT, 1992;27:304). I feel this study presents some good insight into specific areas where Athletic Training must begin to place increased emphasis to ensure continued growth and development of professionalism.

The results of this study revealed that while entry-level trainers felt adequately prepared to provide preventative first aid and emergency care, they felt less prepared to conduct rehabilitation and reconditioning, counseling, guidance, education of athletes, and organization and administration of a training room. I submit that trainers who are not competent in these areas are not complete trainers. Injury prevention and first aid are vital services provided by our profession, but they are only the beginning. Without the ability to rehabilitate, counsel, provide guidance, educate, or administrate, a trainer’s efforts in prevention and first aid often will be for naught.

Many of my own experiences confirm the findings of this study. The organizational and administrative skills initially displayed by many of my student trainers are far from adequate for a professional. This inadequacy of skills covers a continuum ranging from such personal skills as time management, to such organizational skills as developing a procedural manual or administering an insurance claim. All of these skills are vital, especially at a time when a new trainer’s first job might be a solo venture in a high school or other setting. Supervising trainers have a responsibility to encourage students to discover courses which will increase their knowledge of these skills.

Guidance, counseling, and teaching skills also appear to have been put on the back burner in some programs. The lack of emphasis on these skills is mystifying to me. Any trainer with a modicum of experience realizes that an athlete’s ability to perform or rehabilitate is as dependent on his/her mental status as on physical ability. These “people” skills come naturally to only a lucky few. Students must be allowed to develop these abilities through practical experience, role-playing, and observation in classes and training room environments.

Not adequately training a new trainer in the skills of rehabilitation and reconditioning is a gross injustice to a new trainer. All too often, I have witnessed a student trainer who has been given the responsibility of caring for a team, and his/her knowledge of therapy is to apply a modality and send the athletes on their way. A trainer who cannot proficiently rehabilitate or recondition is not a complete trainer.

The student trainer should not deduce from this letter that all these skills should be spoon-fed by their mentors. Athletic Training is a profession which requires self-motivation and initiative. If a person cannot apply these characteristics as a Student Trainer, then he/she should consider another profession.

In closing, I would hope that the points presented by Weidner and Vincent do not go unnoticed. It is important that professionalism continue to develop in the field of Athletic Training. I feel an important step toward ensuring this growth is to adopt the recommendations presented by Weidner and Vincent.

Steve Nellis, MED, ATC
University of San Diego
San Diego, California

"MD, ATC?"

In a recent editorial (JAT, 1992;27:10), Knight outlined policies concerning the use of abbreviations to signify degrees and credentials. The mere existence of this editorial conveys the fact that a large and increasing percentage of certified athletic trainers have demonstrated a desire to promote their professional and educational standing within the allied health professions. Pick up any Journal of Athletic Training and you will see a multitude of combinations of degree or credential abbreviations before and after ATC. One combination that I have not seen much of, however, is MD, ATC.

On June 22, 1990, athletic training was recognized formally as an allied health profession by the American Medical Association, the nation’s largest medical organization. This endorsement laid the foundation for significant enhancement of athletic trainers’ roles in the health field.

Increased numbers of MD, ATCs could solidify existing roles and establish inroads for further allied health positions for ATCs through public relations and membership on the Council of Medical Education. Therefore, it is my intention to encourage more student and professional athletic trainers to consider obtaining MD, ATC credentials, not only for the personal benefit of increased professional opportunities, but also for the benefit of the NATA and athletic trainers for generations to come. I would like to convey how I became an MD, ATC as an example and then list some general recommendations for this pursuit.

The incorporation of athletic training education and practice into medical education and practice was a natural one for me. As I entered West Chester University (WCU) as an athletic training major under the auspices of Phillip Donley, PT, ATC, I already was planning on additional postgraduate training. I considered physical therapy school primarily at the outset, but as my education and training developed, I realized my greatest potential and breadth of practice on sports medicine would come through MD training. I contacted the pre-medical director about halfway through college, found out what additional prerequisites I needed for medical school (only one extra course in my case) and then took the Medical College Admissions Test (MCAT) after graduating from WCU. I
applied to both PT and MD programs in the Philadelphia area and actually started in a Masters of Physical Therapy program before acceptance to Hahnemann University School of Medicine.

Medical applicants typically apply after MCATs in the fall of the year preceding the actual year of matriculation. I spent my one year between college and medical school as a staff trainer, instructor and coach at Ursinus College. I found that my athletic training education and practical experience were a large plus on my applications and interviews. I had clinical experience that most of my competitors for the medical school slots did not have. I also improved my chances for admission by working in medical research at the Alfred I duPont Institute, through volunteer hours at the Chester County Hospital Emergency Room, and Special Olympics and the visually impaired program at West Chester, in addition to my employment at physical therapy centers. It sounds like a lot of extra effort, but it fell into place easily from experience and contacts made through athletic training education and practice. Once in medical school, you can elect courses and research related to sports medicine. Outside work is possible, and I discovered that working in various athletic training positions not only reduced financial burdens, but also allowed practical application and, therefore, better comprehension of related medical course information.

The MD and ATC educations are complimentary. Being an athletic trainer can make you a better medical student because of your musculoskeletal expertise and interpersonal skills regarding health care issues. The general medical education will leave you much more well-rounded as an athletic trainer, seeing the "big picture" in the overall health care issues of handling athletes. It is also relatively easy to keep up with ATC CEU requirements through medical education credits.

Toward the end of medical school, you will choose specialty training. Several specialties offer subspecialization in sports medicine, including orthopedics, physical medicine and rehabilitation (PM&R), and family practice. There are currently several sports medicine fellowships available in these fields. I chose PM&R for the opportunity to manage people with the vast majority of musculoskeletal complaints that do not require operation, plus handle presurgery and postsurgery conditioning and rehabilitation.

Looking back, becoming an MD, ATC was an excellent decision for me. It provided focus and substance to my education and excitement when I ponder my future. Although I am only in residency training, it is easy to see how my MD, ATC credentials enhance my career potential in sports medicine. Whether you are still in college or a seasoned certified athletic trainer, if you desire a broader scope of sports medicine knowledge and practice, consider the following basic guidelines for obtaining a medical education:

1. Contract your local college premedical advisor for information about prerequisite courses for medical school and the adequacy of your academic coursework thus far. Additional insight might be obtained from medical school admissions offices, MDs with whom you work or your personal physician.
2. If your experience has been confined strictly to standard athletic training, consider some brief volunteer work in medical research, Special Olympics or related charity efforts, an emergency room, or at a doctor's office. This will confirm your own interest in general medicine and is important to admissions committees.
3. Once you know you want to pursue medical school, enroll in the required courses that are deficient in your educational record.
4. Obtain MCAT preparation materials and take the test when you are ready.
5. Identify physicians and other allied health professionals you have had good experiences with who can write positive influential letters of recommendation.
6. Apply to as many medical schools as you and your advisor feel is necessary to obtain admission.
7. Let your athletic training education, skills, and desire for greater professional opportunity take you the rest of the way.

Good luck to you and our fine profession.

Harold J. Einsig, MD, ATC
Reading Hospital & Medical Center
Reading, Pennsylvania
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The Role of Limb Torque, Muscle Action and Proprioception During Closed Kinetic Chain Rehabilitation of The Lower Extremity

Edwin E. Bunton, MS, ATC
William A. Pitney, MS, ATC
Alexander W. Kane, ATC
Thomas A. Cappaert, ATC

Abstract: This paper defines the differences between open and closed kinetic chain exercise and explains the role of limb torque, muscle action, and proprioception during rehabilitation of the lower extremity. Closed kinetic chain rehabilitation is shown to decrease shear forces, increase proprioception, and increase muscle group coordination through examples of progressive exercises. The authors conclude that closed kinetic chain rehabilitation is an economical, efficient, and effective means of rehabilitation, with the ultimate goal of enhancing proprioception, thus gaining lower extremity joint stability.

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Alexander W. Kane is a graduate assistant trainer at Eastern Michigan University.
Thomas A. Cappaert is a clinical athletic therapist at American Rehabilitation Network.

Over the past 10 years, isokinetics has become the exercise modality of choice for rehabilitating the lower extremity. However, a review of the literature indicates that closed kinetic chain exercises have advantages over open kinetic chain exercises. Because of the relative position of the body during activity, closed chain exercises allow more functional patterns of movement with regard to athletics, and provide for multiplanar isometric, concentric, and eccentric contractions. Furthermore, a significant feature of closed kinetic chain rehabilitation is the optimal development of proprioceptors. Moreover, because of conversion limb torque at the subtalar joint, closed kinetic chain rehabilitation appears to be clinically safer than open kinetic chain rehabilitation due to reduced shear forces at the knee.

The purpose of this paper is to explain kinematic chains and highlight the role of limb torque, muscle action, and proprioception. As closed kinetic chain rehabilitation grows in popularity, it becomes imperative for clinicians to understand these roles. Although a discussion of these concepts could singularly be papers in and of themselves, our goal is to provide the reader with a broad foundation of closed kinetic chain exercise and bridge the gap between technical and practical aspects. The following discussion of closed kinetic chain exercise will accentuate rehabilitative aspects of the lower extremity, specifically the knee. Additionally, alternative exercise to enhance existing rehabilitation protocols will be discussed.

Kinematic Chains Defined
The term kinematic chain is most familiar in engineering. It refers to a series of links in a mechanical system. Within the context of the human body, however, the kinematic chain refers to a combination of successively linked motor segments. Closed chain movements, whereby the extremity is fixed in a kinematic system, will produce a predictable pattern of motion in other segments of the system. For example, when the subtalar joint is supinated, the tibia will rotate externally. Open kinematic chain systems consist of end segments moving freely in space and not necessarily producing predictable movement from another segment in the system.

Biomechanically, closed chain kinematics is in effect when a person is in a weight-bearing, standing position. Open chain kinematics is in effect when the limb is moving freely as with a swing phase while walking, or knee extension on an isokinetic machine.

Limb Torque
Elements of segmental torque are transmitted through the distal extremity to the subtalar joint. In the closed kinetic chain, an important function of the subtalar joint is to act as a torque converter of the lower leg and attenuate transverse plane rotation.

The articulation of the talus into the ankle mortis causes the lower extremity to internally rotate with subtalar joint pronation and externally rotate with subtalar joint supination. Open chain exercises, such as knee extension and flexion, allow much of the torque generated by the quadriceps to be absorbed by the patellofemoral joint, whereas closed kinetic chain exercises...
Muscle Action during Closed Chain Kinetics

The dynamics of muscle action allow for the complex but unconscious task of accelerating and decelerating the lower extremity during locomotion in three planar environments: sagittal, frontal, and transverse. Factors that influence these tasks include: weight, terrain, joint hypermobilities and hypomobilities, and ground reaction forces. Limb pathologies can greatly affect gait performance. Muscle actions, therefore, can be affected significantly and result in abnormal compensations during closed kinetic chain activity.

Fifteen muscles are involved in closed kinetic chain function of the lower extremity. The principle roles of these muscles are to control multianiplanar acceleration and deceleration of the lower limbs. Although all 15 muscles are crucial in a kinetic system, 6 will be discussed here: the gluteus maximus, hamstring, popliteus, gastrocnemius, posterior tibialis, and quadriceps.

The gluteus maximus cannot be ignored when addressing pathologies of the lower extremity because of its size and influence. Three fourths of the gluteus maximus meshes into the iliobibial (IT) band which inserts into the proximal tibia. The gluteus maximus employs a powerful contraction through the IT band and decelerates internal rotation of the lower leg at midstance and accelerates the lower leg into external rotation at heel strike.

The hamstring muscle is comprised of a medial and lateral aspect. The medial side comprises the semimembranosus and the semitendinosus with insertions to the proximal medial tibia and origination at the ischial tuberosity. The lateral hamstring or biceps femoris inserts at the tip of the fibular condyle and has one head that originates at the ischial tuberosity and another that originates at the lateral femur, specifically the linea aspera. The hamstring is responsible for decelerating hip flexion and accelerating hip extension. The semimembranosus muscle is an active stabilizer of the medial knee and helps to prevent valgus collapse. In addition, the hamstring acts as a load regulator of the knee during extension when the anterior cruciate ligament is overloaded.

The popliteus is highly innervated, with a crucial role in rotary stabilization of the knee. The origin lies just above the lateral knee joint line on the lateral condyle of the femur and inserts into the posterior aspect of the upper medial tibia above the soleal line. Because of its size, the popliteus is sometimes overlooked when assessing knee joint stability. However, its relationship with the lateral meniscus and posterior cruciate ligament is significant because it pulls the lateral meniscus posteriorly away from the rapidly receding lateral femoral condyle.

The gastrocnemius spans the posterior aspect of the femoral condyles, finally inserting into the base of the calcaneus. The gastrocnemius decelerates internal rotation of the femur. Subsequently, tibial rotation is decelerated by the soleus and posterior tibialis muscles, thus decreasing torque at the knee.

The posterior tibialis originates on the lateral portion of the tibia and the proximal two thirds of the medial surface of the fibula, inserting on the navicular tuberosity, three cuneiforms, cuboid, and the base of the second, third, and fourth metatarsals. The responsibility of the posterior tibialis is to decelerate the tibia at midstance, just prior to propulsion, thus causing closed chain leg extension. Additional responsibilities include deceleration of subtalar joint pronation by eccentrically controlling subtalar joint excursion and lower leg internal rotation.

The quadriceps femoris is divided into five parts: rectus femoris, vastus medialis, vastus medialis longus, vastus lateralis, and vastus intermedius. The quadriceps femoris is responsible for controlling deceleration of knee flexion upon heel strike. The quadriceps works in concert with the posterior tibialis to decelerate the knee and subtalar joint pronation, respectively, in the sagittal and frontal planes. Unfortunately, open chain rehabilitation does not duplicate the same pronation forces that occur in closed kinetic chain rehabilitation and results in increased shear forces at the knee. Knee flexion/extension exercises result in a minimal co-contraction across the knee, implicating increased shear forces, lack of hip movement, and isometric stabilizing contraction of the gluteus maximus and tibialis anterior.

The premise of closed chain rehabilitation is to optimize functional capacity. Although quantifiable measures of muscle girth and peak torque in a pathological knee might be clinically important, they do not necessarily relate to functional ability. Therefore, rehabilitation should focus on re-educating proprioceptors in a manner that recreates the functional movements found in athletic performance, in addition to developing muscle girth and strength.

Enhancing Proprioception through Closed Kinetic Chain Activities

When an area is injured and subsequently rested or immobilized, both muscles and proprioceptors "forget" their role in controlling lower extremity acceleration and deceleration, with a resulting lack of function regardless of girth. Developing proprioception and incorporating intricate timing with muscular force are essential for accurately performed functional activities.

A closed kinetic chain progression of slow to quicker movements against resistance theoretically results in central nervous system engram patterning,
“Nice game, son.”

“Thanks, Coach.”

“I thought that knee would keep you out for the season.”

“Really?”

“Yeah, most guys would’ve quit. But you came back and we’ve still got a shot at a bowl game.”

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providing that the emphasis is on precision of movement.31 Furthermore, much of the adaptation that occurs during the training will be specific to the type of training that takes place.

If an open kinetic chain progression is used where the development of muscle strength and girth are paramount and the proprioceptors are neglected, the athlete might complain of the knee or ankle “giving out,” despite noticeable gains in strength and size. Historically, criteria for returning an athlete to activity have been peak torque values and muscle girth. Unfortunately, these criteria do not relate to returning an athlete to previous functional levels.17 Therefore, proprioception is of primary importance during rehabilitation.

Proprioception involves sensory activation of the tendons, ligaments, capsules and muscles.1 The need for advanced and controlled weight-bearing exercises to re-educate the proprioceptive process of the injured sensory endings has been argued.9 Moreover, a lack of position sense is overlooked in many rehabilitation programs and might be most responsible for recurring injuries after the integrity of the muscles and ligaments have been restored.11,16 Supporting the concept, Kesher states that an analysis of complex motor patterns by assessing range of motion, sensory integrity, or the strength in each body part does not assist us in determining how that patient will perform such a multisegmental movement as walking or running.14

Closed kinetic chain rehabilitation exercises address the integration of proprioceptors, specifically Ruffini’s endings, Pacinian corpuscles, Golgi-Mazzoni corpuscles, Golgi-Tendon Organs, Golgi-Ligament endings and muscle spindles. During rehabilitation, these receptors slowly adapt in that they continue to send impulses to the central nervous system as long as the neurological stimulus is present.29 A successful rehabilitation program must include activities that address the role of proprioceptors. The functional use of multiplanar movements used with closed kinetic chain exercises facilitates normal proprioceptive feedback.9

Because closed kinetic chain exercise uses the body’s natural movements and planes, all proprioceptors are stimulated to some capacity. Open kinetic chain exercise operates in one plane per isolated exercise and limits the development of full joint proprioception by not stimulating all of the proprioceptors necessary for functional movement. Singing out proprioceptors is impossible because no one specific proprioceptor is trainable or isolated by a specific exercise. However, what follows is a discussion of the neurological characteristics of each proprioceptor and suggestions for enhancement through closed kinetic chain activities.

Proprioceptors

Ruffini’s endings are joint receptors found within fibrous joint capsules. Ruffini’s endings monitor the rate and direction of the joint position. These receptors respond vigorously with a volley of impulses at the beginning of joint movement and then taper off to a steady state during different angular positions.29 The BAPS (Biomechanical Ankle Platform System) board is an excellent tool for facilitating changes in joint position by allowing multilplanar movements (Fig 1). Furthermore, the BAPS board encourages an athlete to control pronation at the knee and subtalar joint. By virtue of the board’s design, proprioceptive feedback is facilitated further. However, a postinjury athlete might find the BAPS board awkward because the proprioceptors are dysfunctional as a result of trauma. The complex innervation of the joint capsule with its multiple types of mechanoreceptors indicates its importance not only as a stabilizing structure, but also as a source of sensory input.15 An athlete will often “skip” the medial portion of the board even after being instructed to mobilize the board so that all sides touch the floor. Therefore, the athlete continually must be cued of his/her role in controlling limb pronation during this particular closed kinetic chain exercise.

Pacinian corpuscles are the largest, most highly structured end organs in cutaneous and tendinous tissue.29 These corpuscles are found in tendon sheaths and intramuscular connective tissue. They rapidly adapt at the onset of joint movements during sudden changes in stress. They are particularly sensitive to high-velocity changes in limb acceleration and deceleration. Closed chain rehabilitation can provide the combination of rapid joint movements at a variety of velocities and joint stresses, thus proving to be especially suited to enhancing the development of Pacinian corpuscles. For example, clinical plyometrics allow for such change in acceleration and deceleration (Fig 2).
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Recommended consumption: 1 - 3 hours before activity: 12 ounces GatorLode; 8 ounces GatorPro.
Golgi-Mazzoni corpuscles are found in joint capsules and tendon surfaces and respond to perpendicular axial loading, but not to stretching of the capsule. Having the athlete provide a simple ground reaction force, eg, weight bearing, provides a perpendicular axial load. Rehabilitation protocols involving step-systems, stair climbers, Nordic Striders, and slide boards are excellent examples of sport-specific ground reaction forces (Figs 3, 4, and 5).

The golgi tendon organ (GTO) consists of a mass of nerve endings enclosed in connective tissue and embedded in the tendon. The GTO detects muscle tension and responds to the contraction and stretching of a muscle. When the GTO is stretched, it sends signals to the CNS and causes the muscle to relax. The GTO can be stimulated using a combination of stretching and contracting exercises. In a closed chain environment, this can be achieved using such exercises as the hip movements with Thera-band (Fig 4), leg press plyometrics (Fig 2), and squats (Fig 6).

Muscle spindles are located within the mid-substance of the muscle belly and lie between the fibers. When the spindle is stretched, an impulse is sent from the sensory nerve at the center of the spindle to the central nervous system. A reflex loop facilitates motor neurons which cause the muscle to contract.

Techniques that can be used to stimulate the muscle spindle include such activities as standing, stationary cycling (Fig 7), mini-trampoline, medicine ball workouts (Fig 8), walking, running, and incorporation of oscillatory sensations as produced when using the Body Blade (Fig 9).

Golgi ligament endings are the largest receptors found in intrinsic and extrinsic ligaments. They are stimulated by both the rate of joint movement and the force of gravity, and provide the CNS with information of bony segmental positions. Because Golgi ligament endings respond to tension stimuli, there is a need to provide biomechanical and physiological stress to the joint during rehabilitation. Moreover, the neurosensory role might be more important than the structural role.

Specific exercises can be used to facilitate these joint stresses. For example, the BAPS board, once again, is one such exercise that can be used to provide stress in a controlled and progressive manner. The rationale for using the BAPS board is to stimulate proprioceptors traumatized by excessive valgus force, resulting in damage to primary and secondary restraint structures. Because the medial capsule is innervated with stress-responding tension receptors, we must provide an appropriate exercise that progressively recreates an environment to provide feedback, thus improving joint timing during ground reaction forces. We must recreate the mechanism of injury in a progressive and controlled manner, so that the joint can learn to control the particular movement. Controlled pronatory movements that occur when using the BAPS board provide proprioceptive feedback that can reinforce joint integrity when tension receptors found throughout the medial capsules are stressed.

Discussion
The documented research comparing closed and open kinetic chain

Fig 3a-b.—The use of step systems and Nordic Striders are excellent ways of stimulating proprioceptors. Besides the patterns shown above, there are several ways to provide dynamic influences to the lower extremity, including oblique and asymmetrical patterns.

Fig 4a-b.—Slide boards and resistive tubing provide dynamic influences. These exercises should be completed in several planes as shown above.

Fig 5.—Step system exercise should be completed from simple (eg, foot contacting flat on the ground) to complex (eg, heel barely striking the ground).
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Fig 6.—Mini-squats can be performed by using either a pulley system, as shown above, or resistive tubing.

Fig 7.—Standing stationary hiking is a more challenging exercise and allows for integrated group muscle action. Note: for increased difficulty, retro-cycling can be performed as shown on the right.

Rehabilitation is clinically significant. The lower extremity is not just controlled by the quadriceps and hamstring muscles, but by a complex movement system comprised of deceleration, acceleration, pronation, and supination of the aforementioned muscles and joints. Unfortunately, the quadriceps and hamstrings are trained traditionally in a uniplanar motion, for example, training knee flexion and extension on an isokinetic machine. Group muscle action assists in controlling the forces of gravity and decreasing torque about the hip, knee, and ankle, while the subtalar joint acts as the torque converter in a closed chain system.

Conversely, torque is converted at the knee in an open chain system, which would be a consideration when rehabilitating ACL injuries and patellofemoral symptoms.

Closed kinetic chain exercises allow for reactivation of the proprioceptors, whose role is to sense the amount, speed, and timing of joint positioning. In a closed chain environment, proprioceptors respond to such extrinsic factors as change in terrain, footwear, ground reaction forces, speed, and direction of activity. The patient needs to be placed in an environment that is biomechanically and clinically safe to induce proprioceptive enhancement via closed kinetic chain exercises. Furthermore, much of the adaptation that occurs during closed chain rehabilitation will be specific to the activity the athlete will incur during performance. In other words, the body will adapt specifically to the demands placed on it during the rehabilitation process.

Closed kinetic chain exercises function in multiplanar environments, use acceleration and deceleration, and can incorporate countless external stimuli, allowing for a much more sport-specific form of rehabilitation. Unfortunately, isolated exercises still appear to be standard protocol even though there is overwhelming evidence that such isolation of knee movement increases tibial translation, compromises secondary restraint structures, increases shear forces at the knee, and stretches ACL graphs when involved. Implementing closed kinetic chain exercises early in the rehabilitation process has been suggested by Seto et al. Moreover, Shelbourne and Nitz reasoned that the increased weight bearing found with closed chain kinetic exercise provides inherent joint stability, thus allowing for more strenuous pain-free workouts without the increased shear forces at the patellofemoral joint that can accompany open chain exercise.

In conclusion, the ultimate goal of closed kinetic chain exercise is to enhance proprioception, thus gaining lower extremity stability when an unpredictable change in direction or speed occurs. In order for movements to be accomplished accurately, the central nervous system must be held accountable for controlling external forces. Therefore, proprioception plays an integral role in the rehabilitation process.

Performing open chain rehabilitation does not expose the limb to proprioceptive feedback mechanisms. Emphasis should be placed on the stability of functional movement patterns that the patient requires and not on the abstract capabilities of uniplanar systems under artificial testing situations. Although strength deficits need to be addressed, we need to analyze critically the methods being used to justify or quantify an athlete’s ability to return to play. Uniplanar movement, for example, isokinetic testing machines, does not duplicate the true function of the lower extremity and its capabilities in a closed chain system. Closed kinetic chain exercise is an economical, efficient and effective means of rehabilitation that is limited only by the clinician’s imagination. Performing multiplanar closed kinetic chain rehabilitation allows for sport-specific adaptations to occur. We always must seek the most effective means of returning the athlete to participation and never be afraid to use our own creativity in the process!
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Acknowledgements

We would like to acknowledge Pam Sparks for technical assistance in preparing this manuscript. Photographic credit is given to Alex Kane, and pictorial assistance was provided by Deana Blessing and Barb Kane. Bruce Hymanson, president of Bruce Hymanson, Inc, developed the Body Blade and provided exemplary support. We offer special thanks to Gary Gray who has pioneered closed chain kinetics and provided support for this manuscript.

References


Fig 9a-b.—The oscillatory sensations of the Body Blade allow for stimulation of proprioceptors. The Body Blade exercises can be made more complex by combining them with mini-trampoline and slide board exercises.
Proprioceptive ankle disk training is a popular exercise used in the clinic and training room for injury rehabilitation (Fig 1). Many athletic training programs, especially at high schools, are unable to purchase such expensive equipment as the Biomechanical Ankle Platform System, BAPS™ (Camp International). Therefore, many athletic trainers construct their own balance boards. Progression is difficult to achieve on most board designs, unless you have several differently sized balls attached to several different platforms. I have discovered an alternative method of varying the difficulty of the balance board exercises. It involves placing spacers between the ball and the platform (Fig 2). Increasing the height of the board from the ground increases the demands of the exercise and allows for progression of difficulty.

Constructing a Balance Board
The wood shop teacher at my high school constructed my balance board disk system, free of charge. If you purchase the materials, the estimated cost is less than $10. Below is a complete list of materials and a step-by-step procedure for construction and assembly.

Materials
1—18"x18" piece of 1" plywood
1—3"x3" piece of 1/2" plywood
1—3" Croquette ball
1—3/8"x1" nut coupling
4—bolts
1—3/8"x1"
1—3/8"x1 1/2"
1—3/8"x2"
1—3/8"x2 1/2"
1—3/8" washer
epoxy glue

A Progressive Ankle Disk System
Mark Hoffman ATC, EMT

Procedures (Fig 3)
- Cut 18" diameter circle from 1" plywood for balance board
- Cut spacers - one 1/2"x3" and four 1"x3" (from corners of 18" square)
- Drill 1/2" hole through center of 18" circle and all spacers
- Drill 1-1/4" counter sinking hole 3/8" deep in balance board (18" circle)
- Cut Croquette ball in half
- Drill 5/8" hole 1" deep in half ball
- Glue nut coupling in half ball
- Assemble board

Balance Board Exercises
Because balance boards have become common in rehabilitation of ankle and knee conditions, detailed instructions for their use are not presented. However, there are several avoidable errors that athletes commonly make when using ankle disks.

1. Athletes tend to lock the knee in terminal extension during this activity. Locking the knee will decrease the amount of motion at the ankle and knee joints, as well as decrease the amount of muscular activity in the quadriceps and hamstrings. If the balance board is being used in the rehabilitation of a knee condition, for example, patellofemoral maltracking, the quadriceps, and especially the vastus medialis obliquus, must be targeted. To maximize its benefits, the exercise should be conducted with slight flexion (10° to 20°) of the knee. The amount of flexion will vary through the specified range during rotation of the ankle disk.

2. Motion at the hip must be limited to allow for re-education of the knee and ankle joint receptors, which are responsible for proprioceptive feedback. Often, the athlete will rotate the pelvis or hip to aid the motion. During rotation of the system, the pelvis should remain perpendicular to the long axis of the foot.

3. The ankle joint will move through multiple planes while being exercised on the ankle disk system, yet the foot should remain aligned in the sagittal plane. There is a tendency for athletes to internally and externally rotate the hip to aid in board movement. If excessive motion occurs at the pelvis, the ankle will not move through its complete range of motion.

Discussion
Closed kinetic chain rehabilitation activities, for example, ankle disk training, incorporate the application of proprioceptive concepts and functional

Fig 1.—Athlete developing lower extremity proprioception using a wobble board.

Mark Hoffman is a graduate student at San Jose State University and an athletic trainer at Homestead High School in Cooperativo, CA 95014.
activities. Proprioception, an integral part of closed chain activities, simultaneously promotes variations in concentric, eccentric, and isometric muscle contractions during an activity. This muscular coordination allows the body to control joint motion, as well as limit the joint range to normal planes. In theory, proprioceptive exercises enhance the body’s ability to adapt to changing stresses encountered in athletic activities. When used in conjunction with sport-specific functional activities, closed chain activities prepare the athlete for return to sport.

Ankle disk training is a closed kinetic chain activity commonly incorporated in rehabilitation programs of the lower extremity. Because it is a closed chain activity, neuromuscular coordination of all lower extremity muscles is required. Muscles acting on the ankle and knee contract concentrically and eccentrically to initiate and control motion, while the muscles at the hip and trunk isometrically stabilize the body over the foot.

Of all lower extremity injuries, ankle injuries are among the most common, and a significant number (40%) of ankle injuries result in chronic functional instabilities. Functional instabilities are identified by the subjective complaint of the ankle “giving way.” Functional instabilities are believed to be related to three pathologies: 1) anatomical instability, 2) proprioceptive deficits, and 3) muscle weakness. Independent of the underlying etiology, ankle disk training has been used to re-establish proprioception and muscle recruitment in subjects with functional instabilities.

Athletic trainers, especially in high schools, continually explore new avenues to acquire economical rehabilitation equipment. The idea of attaching half of a ball to a circular board to make a balance board is not unique. The major disadvantage of most of these self-constructed systems is that progression of exercise difficulty is often overlooked. Through the use of the plans and suggestions presented above, a balance board with varying levels of difficulty is constructed easily and can be a viable alternative to more expensive, purchased boards.

Acknowledgements
I would like to thank Frank Garcia for the drawings of the Balance Board Disk System and Mary Brkich, MA, ATC, for review of the manuscript.

References
Abstract: The use of closed kinetic chain knee rehabilitation exercises has been advocated in recent years. The primary reason cited for employing closed kinetic chain exercises is that these exercises result in less anteroposterior (A/P) shear force at the knee joint, when compared with traditionally used open kinetic chain exercises. The purpose of this study was to determine the electromyographical (EMG) activity ratio of quadriiceps to hamstrings occurring in the following exercises: unilateral one quarter squats, leg extensions (N-K Table), lateral step-ups, and movements on the Fitter (Fitter International, Inc), Stairmaster 4000 (Randall Sports/Medical Products, Inc), and slideboard. Ten female student-athletes participated in this study. EMG surface electrodes were applied over the rectus femoris and biceps femoris muscles. The subjects completed three maximum isometric contractions for both muscle groups to obtain baseline EMG data. They then performed repetitions of each exercise. These movements were videotaped simultaneously with a stationary shuttered video camera operating at 30 Hz. A computer program was used to analyze the videotaped performances for knee joint range of motion (ROM). Three trials of data were averaged. Baseline EMG activity was used to determine percentage of maximum EMG activity for each exercise. There were significant differences (p<.01) among the exercises for the following dependent variables: ROM, maximum angle, percent of maximum contraction, time of contraction, and total EMG (EMG area under the curve). This study suggests that the five closed kinetic chain exercises studied result in minimal A/P shear forces at the knee joint.

Victoria L. Graham is Head Athletic Trainer in Women's Athletics at Ball State University in Muncie, IN 47306.
Gale M. Gehlsen is a professor and Director of the Biomechanics Laboratory at Ball State University.
Jennifer A. Edwards is an instructor in biomechanics and anatomy in the Department of Physical Education at Ball State University.

Electromyographic Evaluation of Closed and Open Kinetic Chain Knee Rehabilitation Exercises

Victoria L. Graham, MS, ATC
Gale M. Gehlsen, PhD
Jennifer A. Edwards, MA

A major problem for the athletic trainer is selecting the appropriate exercise regimen for the anterior cruciate ligament (ACL) deficient knee. A properly designed exercise program should consider the disruptive potential of anteroposterior shear forces. A/P shear forces result from increased quadriceps femoris muscle tension, which produces a potentially dangerous situation in which too much force can be directed through an injured or reconstructed ACL.

Several authors have found that open kinetic chain exercises have been advocated in recent years. The use of closed kinetic chain knee rehabilitation exercises has been found to be beneficial in ACL rehabilitation programs.

Minimal research is available documenting the amount of muscle activity involved in commonly used closed kinetic chain knee rehabilitation exercises. The purpose of our study was to determine the electromyographical (EMG) activity ratio of quadriiceps to hamstrings occurring in the following exercises: unilateral one quarter squats, leg extensions (N-K table), lateral step-ups, and movements on the Fitter, slideboard, and Stairmaster 4000.

Methods
Ten female student-athletes (age=21.0±1.3 yr; ht=170.9±4.4 cm; wt=68.1±5.2 kg) participated in the study. The subjects were recruited on the basis of availability, lack of pathological knee condition, and ability to perform the exercises without undue stress. All subjects gave informed consent prior to participation. The University Human Subjects Review Committee approved the experimental protocol prior to experimentation.

We used silver chloride surface electrode leads connected to two preamplifiers (P15, Grass Instrument Co) to obtain the EMG signals. The preamplifiers were interfaced to a Macintosh IIci computer. We used the Superscope computer program (GW Instruments, Inc; Somerville, Mass) to filter and rectify raw EMG signals.

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Bandwidth was 7 Hz to 6 kHz. The video recording procedures involved a stationary Panasonic Digital 5000 shuttered video camera recording at 30 Hz. The camera was located 30 ft from and perpendicular to the subject’s sagittal movement plane. A wide-angle lens allowed the entire movement to be viewed. A 386 Zenith computer with a BCE Associated video controller circuit board was interfaced to the video playback system (Sony PVM 1341 video monitor and Panasonic AG-7300 video cassette recorder). We used a computer program designed by Peak Performance Technologies, Inc to encode sequentially every frame of the tape. The time between any two given frames was determined with an accuracy of 1/60th of a second. To facilitate the location of segmental endpoints during the film analysis, we placed contrasting markers on the joint centers of each subject. We placed black and white plastic tape on the following anatomical landmarks: great toes, right lateral and left medial malleoli, right lateral and left medial tibial condyles, and the right greater trochanter. Each subject reported individually to the laboratory for two experimental sessions. The first session involved practice trials of the various exercises; anthropometric measurements were taken at this time as well. The second session involved EMG and video data collection. We applied the EMG electrodes as closely as possible to the motor end plates of biceps femoris and rectus femoris muscles of the subject’s dominant leg, with a 10mm distance between electrode centers. The ground electrode was placed over the fibular head. All hair in the area of electrode placement was removed prior to placement. The subject’s skin was scrubbed with an alcohol-soaked gauze pad and electrodes were attached with double adhesive collars.

Subjects completed three maximum isometric contractions each for the extensor and the flexor muscles of their dominant leg. While seated on an N-K table, the knee was positioned and restrained at 45° from full extension for maximum isometric extension trials and at 90° for maximum isometric flexion trials. These contractions provided information needed for initial adjustments of electrodes and amplifiers and baseline data for further contrasts.

Subjects performed six repetitions of each of the following exercises: unilateral one quarter squats (to approximately a 60° angle formed between the upper and lower leg; no external resistance), leg extensions on an N-K table (lifting 25% of body weight), lateral step-ups (20.3 cm step), and movements on the Fitter (two cords if body weight was <73 kg; three cords if >73 kg), Stairmaster 4000 (manual setting, level 7, steady climb), and slideboard (width was two times lower extremity measurement from ASIS to medial malleolus). A reference marker was provided for the subjects during the squat exercise to ensure proper depth of squats. We controlled the speed of movement for each exercise with a metronome (4 seconds per one complete movement of unilateral quarter squats and leg extensions, and 2 seconds per one complete movement of the lateral step-ups, Fitter, Stairmaster, and slideboard movements). The EMG recorder and video camera began recording after the subject had completed three cycles of the exercise under consideration and continued for three more complete exercise cycles. The order of the exercises was counterbalanced among subjects to prevent a treatment effect.

There was a 10-minute interval between exercises.

We analyzed the EMG data for both concentric and eccentric phases. Three cycles of EMG data for all experimental conditions were averaged. Using baseline EMG activity (initial isometric contraction data), we calculated percent of maximum EMG activity (%MVC) for each exercise. The percent of maximum values then were used to determine the quadriceps to hamstring ratio. We then analyzed the ratio values using an analysis of variance (ANOVA) with repeated measures. Film data were analyzed for knee joint range of motion. A data smoothing computer procedure (Butterworth digital filter) was applied to the displacement data prior to calculating velocity and acceleration. Following additional statistical analyses with ANOVAs, we determined significant differences in percent of maximum EMG, peak angular velocity, and maximum range of motion as dependent variables. Scheffé’s post hoc procedures were applied. A minimum level of significance of p < .01 was chosen.

Results

Mean and standard deviation values for minimum angles achieved and for total range of motion during each exercise are presented in Table 1. ROM was greater during leg extension than during

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<tr>
<td>Leg extension</td>
<td>80.1±9.1d,e</td>
<td>123.4±46.9</td>
<td>9.6±7.1</td>
</tr>
<tr>
<td>Quarter squat</td>
<td>55.9±6.5</td>
<td>91.5±21.7</td>
<td>3.2±4.1</td>
</tr>
<tr>
<td>Slideboard</td>
<td>54.8±10.6</td>
<td>162.3±48.5b,c,f</td>
<td>27.6±10.3b,c,f</td>
</tr>
<tr>
<td>Step-up</td>
<td>68.5±7.6</td>
<td>269.8±41.0b,c,d</td>
<td>5.5±8.1</td>
</tr>
</tbody>
</table>

* significantly different (p < .01) than Fitter
* significantly different (p < .01) than Stairmaster
* significantly different (p < .01) than leg extension
* significantly different (p < .01) than quarter squat
* significantly different (p < .01) than slide board
* significantly different (p < .01) than step-up
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quarter squat, slideboard, and Fitter exercises and less during Fitter than during Stairmaster and lateral step-up exercises \( (F[5,179]=24.13, p<.0001; \text{Scheffé, } p<.01) \). In addition, ROM was greater during the Stairmaster exercise than during the slideboard exercise. Fitter and slideboard exercises had similar minimum angles which were larger than all other selected exercises \( (F[5,179]=99.99; p<.0001) \).

Angular velocity means and standard deviation data are presented in Table 1. The greatest angular velocity values were recorded for lateral step-ups \( (269.8°/s) \) and the smallest values for quarter squats \( (91.5°/s; F[5,179]=91.85; p<.0001) \). The angular velocity of the lateral step-up was greater than all other activities \( (\text{Scheffé, } p<.01) \). Slideboard values were less than the step-ups and greater than all other exercises except Stairmaster \( (\text{Scheffé, } p<.01) \). Quarter squat values were smaller than those of the Stairmaster, lateral step-ups, and slideboard \( (\text{Scheffé, } p<.01) \).

Peak activity of the hamstrings and quadriceps during each activity, expressed as a percentage of each subject’s maximum voluntary contraction \( (%\text{MVC}) \), is presented in Table 2. In addition, the ratio of the activity of the two muscle groups is presented in Table 2 as the hamstring \%MVC divided by the quadriceps \%MVC.

Mean hamstring activity values ranged from 15.9% MVC for quarter squats to 41.3% MVC for the slideboard. The slideboard was greater than all other activities, and the Fitter greater than the squat and leg extension \( (F[5,179]=38.57, p<.0001) \).

Average quadriceps activity ranged from 84.9% MVC for leg extensions to 25.9% MVC for quarter squats. The leg extension \%MVC was greater than that of all other exercises, and the slideboard value was different from the quarter squat and Stairmaster values \( (\text{Scheffé, } p<.01; F[5,179]=42.93; p<.0001) \).

During the leg extension exercise, the hamstrings produced 25.23% as much activity as the quadriceps. In the other five exercises, this percentage was greater than 64%. Hamstring activity as a percentage of quadriceps MVC was less during the leg extension than during the Fitter \( (F[5,59]=7.85, p<.0001) \).
leg extension (F[5,59]=27.532, p<.0001; Scheffe, p<.01).

Mean and standard deviation values for total EMG (area under the curve) derived from EMG data for the hamstrings and quadriceps are presented in Table 4. The leg extension produced the largest hamstrings total EMG (0.052 mV-s), and the Stairmaster produced the smallest hamstrings total EMG (0.02 mV-s). The leg extension value was significantly different than that of all other exercises except the quarter squats (F[5,59]=13.96, p<.0001).

The leg extension produced the greatest quadriceps total EMG (0.116 mV-s), and the Stairmaster again produced the smallest total quadriceps EMG (0.041 mV-s) (F[5,59]=20.82, p<.0001). The leg extension value was significantly different (p<.01) than all other exercises. In addition, Stairmaster was significantly different from squats.

Discussion

The quantification of differences among exercises is dependent upon the speed of movement and the range of movement. Any EMG data difference is dependent upon the nature of the movement. Although the subjects in this study served as their own control, caution is needed when comparing different exercises. During different stages of rehabilitation, speed and degree of movement vary, largely according to the individual’s ability to perform in a particular ROM and according to the individual’s limits of pain. The differences between exercises as presented here only show one limited movement speed and ROM; healthy subjects were used to help eliminate the variables of ROM and pain.

Several authors[11,16,17,21] have reported a relationship between anterior forces and knee angle. Anterior tibial translation applying elongating straining forces across the ACL occurs at knee angles greater than approximately 70° with quadriceps contraction[18]; therefore, to minimize anterior translational forces, rehabilitation activities should consider ROM values. The kinematic results of this study clearly show a difference in ROM among the selected exercises. The lateral step-ups, the slideboard, the Stairmaster, and the leg extension exercises had maximum angular displacement values greater than 70°.

If full ROM is the selection criteria of a rehabilitation exercise, then the lateral step-up, the leg extension, and the Stairmaster exercises should be considered. These particular exercises allow for movement throughout the entire range of motion allowable at the knee joint. ROM is controlled largely by the individual during rehabilitation, particularly in the early stages, when pain and effusion are factors. In this study, ROM of the quarter squat was controlled experimentally, but the limited ROM achieved on the slideboard and Fitter is a valid concern during knee rehabilitation. While we have concerns about the limited ROM on the slideboard and Fitter exercises, it is clear that both are effective means of improving quadriceps and, particularly, hamstring strength. The data suggest that what might be “lost” in terms of working throughout the entire ROM while using these exercises is outweighed by what is gained in proprioception and the recruitment of other muscle groups (ie, adductors, gluteals). If the slideboard or the Fitter exercises are used, it is important to incorporate another exercise into the rehabilitation protocol that does work throughout the ROM.

It is important to increase resistance and ROM as soon as tolerable for each of the closed kinetic chain exercises in order to maximize the strengthening benefits of each. For example, the relatively low quadriceps %MVC for the quarter squat is not particularly surprising, given the limited ROM allowed for this exercise. It does suggest, however, that both ROM and resistance be increased as soon as tolerable, and that the athlete be progressed to the weight room quickly in order to achieve the maximum benefits of the squat exercise.

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Resistance and ROM can be increased on any of the closed kinetic chain exercises, which would result in increased muscular contraction and greater strength gains.

The hamstrings play a significant role in providing knee joint stability and are, therefore, of great importance in ACL rehabilitation. In this study, the highest hamstring %MVC occurred during the sideway exercise. However, magnitude of muscular involvement without consideration of contraction time might lead to a faulty assumption. The total EMG activity values (magnitude X time) might be a more appropriate criterion in rehabilitation technique evaluation. The total EMG difference between exercises was greatest for the leg extension and least for the Stairmaster exercise.

The magnitude of A/P knee shear force is related to quadriceps to hamstring ratios. Quadriceps to hamstrings ratios up to 2.25:1 during isokinetic leg extension exercises (30/s) have been reported. Our EMG-based data at approximately 60/s indicate a 4.65:1 quadriceps to hamstring ratio for an isotonic leg extension exercise. The relatively high involvement of the quadriceps during the leg extension exercise is supportive of the leg extension being an effective method of strengthening the quadriceps; however, because A/P shear forces are increased during leg extensions, it seems prudent to select alternate exercises to strengthen the quadriceps after ACL reconstruction. The quadriceps to hamstrings ratios of the closed kinetic chain exercises we studied ranged from 1.41:1 to 1.64:1 (Table 3); therefore, our data support the view that the closed kinetic chain exercises studied had lower associated A/P shear forces.

Speed of movement did not appear to influence the quadriceps to hamstrings ratio in closed kinetic chain exercises. The maximum knee velocity for the quarter squat exercise was 91.5%/s, and the maximum knee velocity for the lateral step-ups exercises was 269.8%/s. The hamstring/quadriceps percent values were 61.08% and 61.48%, respectively. Proportional increases in action potentials in both muscle groups might not occur with increases in speed.

Our lateral step-up exercise data do not agree with Brask et al, who reported lateral step-up ratios of 2.78:1 to 2.41:1 between the rectus femoris and biceps femoris and 6.77:1 to 10.65:1 between vastus medialis and semimembranosus/semitendinosus. Based on this evidence, Brask et al concluded that contraction of the hamstring muscles appeared to be of insufficient magnitude to neutralize the A/P shear force produced by the quadriceps femoris muscle. The subjects in the Brask et al study were not athletes, were not of the same gender, and ranged in age from 15 to 30 years. The lack of agreement between our study and the Brask et al study might be related to: 1) differences among subjects, 2) subjects’ familiarity with the exercise regimen, 3) subjects’ ability to perform a maximum contraction, 4) different muscle groups studied, and 5) cross talk between electrodes.

When selecting an exercise regimen for an individual with an ACL injury, primary considerations are: 1) safety (primarily minimizing A/P shear forces), and 2) the effectiveness of the exercise in strengthening appropriate muscle groups. The closed kinetic chain exercises studied appear to result in minimal shear forces at the knee joint. These exercises also appear to be an appropriate and effective means of improving both quadriceps and hamstrings strength. It is important to closely monitor the program in order to increase ROM and resistance as tolerable for the individual and to, therefore, achieve optimal results. It is equally important to select an effective combination of exercises. It is up to the individual clinician to determine precisely what benefit he/she hopes to derive from each exercise, and how each exercise fits into the rehabilitation protocol designed for each athlete.

Acknowledgement
This study was supported by a grant from the National Athletic Trainers’ Association Research and Education Foundation.

References
Tip from the Field

There is increasing evidence that closed kinetic chain exercise (for example, squats, lunges, step-ups, and heel raises) is playing a major role in early lower extremity rehabilitation. Closed kinetic chain exercise facilitates a tricotomy of knee-stabilizing muscles (hamstrings, quadriceps, and gastrocnemius), elicits a variety of muscle contractions to occur within one movement (ie, squatting allows isometric, eccentric, and concentric muscle contractions to occur in one exercise), and places less strain on the anterior cruciate ligament (ACL) than does open kinetic chain exercise.3,9

Most closed kinetic chain exercises can be performed with free weights, elastic tubing, and elastic bands, or by using such exercise devices as the leg press and hip sled machine. Although these exercises are beneficial in rehabilitation programs, they are not without risk or drawbacks. These are: 1) awkward positioning of the resistance loads by supporting a barbell on the upper back or by holding dumbbell weights in your hands; 2) the potential for injury when holding dumbbell weights, placing a weighted bar on the upper back, or anchoring rubber tubing with your feet when performing an exercise; and 3) the inability to perform exercises in a functional position without loading the spinal column or shoulder girdle.

The Squat Board was developed to overcome these problems while permitting overloads at the appropriate sites. It combines the simplicity of an exercise platform, the versatility of rubber tubing, and the convenience of a waist belt. Rubber tubing permits a regular progression of overload which can be varied by using shorter or longer lengths. The resistance progression begins by using longer rubber tubing lengths (less resistance) and advances to shorter tubes as the patient becomes accustomed to that resistance. Variations in progression can also be achieved by using rubber tubing of different thicknesses or by adding additional tubes. The waist belt allows the resistance to be placed directly beneath the center of gravity, thus eliminating stress on the upper extremity and torso. This also places the load in its more natural position over the lower extremity. In addition, it is inexpensive, takes up little space and is a practical rehabilitation tool for any athletic training room. We have used it at Princeton University for 2 years without injury or incident.

Constructing a Squat board

The Squat Board is an exercise platform constructed of a 36x46x3/4-inch plywood top over a 2x4-inch baseframe (Fig 1). Six eye bolts (three per side) are fastened to the top surface at 3, 15, and 27 inches from the front edge of the board. Apply a center line with paint strip or plastic tape from the front to the back of the board. The centerline helps the athlete to locate the proper stance and foot position for optimal balance.

Rubber Tubing

The waist belt (Viper®) and rubber tubing are designed specially by Speed City. The waist belt has four D-rings (one per side and two on the rear) to which the rubber tubes are attached. The rubber tubing is specially fabricated with snap bolt fasteners at each end. When in use, these rubber tubes are attached to the eye bolts on the Squat Board and the D-rings of the waist belt. The resistance offered by the rubber tubing is varied by using cords of different lengths. Because the resistance offered by a rubber tube is a function of the stretched length as a percentage of the resting length, the shorter the cord, the greater the resistance through a given range of motion. The Squat Board is not intended to be a tool for finite measures, but a daily training tool with means of regular progression.

Selecting the proper length of rubber tube to use is a matter of trial and error. The beginning lengths are selected according to the athlete’s height and strength. Once you find the appropriate size for the athlete, progressively shorten the length as the rehabilitation progresses. Typically, squats and lunges are performed with 11-, 9-, and 7-inch tubes, while step-ups and heel raises are usually performed against 17-, 15-, and 13-inch tubes.

Squat board Exercises

The exercises our athletes perform on the Squat Board are squats, lunges, step-ups, and heel raises. Good lifting technique is always stressed when performing any resistive exercise, and the athlete should receive instruction prior to performing these exercises.1,2,5,8
Squats
Fasten the rubber tubing from the D-rings on the side of the waist belt to the middle or rear set of eye bolts on the Squat Board (Fig 1). The squats are first performed with a chair behind the athlete, which prevents the athlete from going beyond 90° of knee flexion. After the athlete is accustomed to the desired depth of the squat, the chair can be removed.

Lunges
Fasten the rubber tubing from the D-rings on the side of the waist belt to the middle set of eye bolts on the Squat Board. Situate the athlete with his/her feet parallel to and within an inch of the center line of the Squat Board. The injured leg is flexed approximately 30° and supports most of the body weight. The uninjured leg is back and is used mostly for balance. Perform repetitions by flexing and extending the injured leg between 30° and 90° (Fig 2). Keep the head and back straight or slightly arched.

Step-ups
Three different types of step-ups can be performed on the Squat Board.

Front step-ups: Fasten the rubber tubing from the D-rings on the side of the waist belt to the middle set of eye bolts (Fig 3). Start slowly (15 cycles/min) and increase the cadence as tolerated up to 30 cycles/minute.

Front and over step-ups: Fasten four rubber tubes from the waist belt to the Squat Board for this exercise. The front hook-up connects the D-rings on the side of the waist belt to the front set of eye bolts on the Squat Board. The rear hook-up connects the rubber tubing from the D-rings on the rear of the waist belt to the back set of eye bolts on the Squat Board. Begin by stepping up on the step with the involved leg (Fig 4a), then eccentrically lowering the unin­volved leg forward to the platform (Fig 4b), and then return to the starting position.

Side step-ups: Fasten the rubber tubing from the D-rings on the side of the waist belt to the middle set of eye bolts on the Squat Board. The step is placed parallel to the center line of the Squat Board. Side step-ups are performed with both the involved and unin­volved leg on the step and with an eccentric contraction lowering the unin­volved leg to the platform and returning to the beginning position (Fig 5).

Heel raises: Fasten the rubber tubing from the D-rings on the side of the waist belt to the middle or rear set of eye bolts
Performing heel raises in internal and external tibial rotation, in addition to heel raises in neutral, promotes isolation of the accessory muscles of the lower leg and knee (ie, evertors and invertors of the subtalar joint and the vastus medialis).

The Squat Board eliminates the potential problems of closed kinetic chain exercises using other machines or devices. It is a convenient exercise apparatus that allows a regular overload resistance progression to be applied in a functional position and eliminates the awkward and sometimes unsafe positioning of the resistance.

Acknowledgements
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References

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Closed Kinetic Chain Rehabilitation for the Glenohumeral Joint

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Closed kinetic chain exercises are common in rehabilitation programs for the lower extremity, especially anterior cruciate ligament reconstruction procedures. These exercises permit natural lower extremity function with enhanced joint stability through weight-bearing and muscular co-contractions. Although not reported in the literature, although a cadaver study by Warner et al indicates static glenohumeral stability is enhanced by a joint compressive force.

Most athletes use the upper extremity in an open kinetic chain fashion, eg, throwers or pitchers, volleyball players, basketball players, and ice hockey players. Certain athletes, however, do bear weight on or move their bodies over a stationary upper extremity, causing the upper extremity to function in a closed kinetic chain manner. If rehabilitation programs simulate muscle and joint activity used in sport, then closed kinetic chain exercises should be included in rehabilitation programs for athletes using the upper extremity in that fashion. Artistic gymnasts, male and female, support body weight with the upper extremity while performing on floor, vault, pommel horse, high bar, and even and uneven parallel bars. A swimmer moves the body through the water over a stationary hand. Rowers, canoers, and kayakers, with oars or paddles as extensions of the upper extremity, also move their bodies (in a boat) past a stationary oar or paddle.

Glenohumeral joint rehabilitation addresses range of motion deficits first. Once range of motion approximates normal for the athlete and that required for his/her sport, muscular strength and endurance programs start, first for the rotator cuff and then for the entire upper body. Traditional rotator cuff exercises use dumbbells or sandbag weights in an open kinetic chain fashion and emphasize high repetitions, up to 100, and low weight, starting at 1 pound. Lightweight surgical tubing can be substituted for dumbbells or sandbag weights. As rotator cuff strength increases, free weight or machine weight exercises for the upper body are introduced to develop strength in the entire upper body, especially the prime movers and stabilizers of the upper extremity. We introduce upper body strength training in the weight room when the athlete completes the 50 to 100 repetitions of each rotator cuff exercise with 2 to 3 pounds.

Once he/she performs 50 to 100 repetitions of each rotator cuff exercise with 3 to 4 pounds and does his/her team’s upper body weight room routine for 2 to 3 weeks, we introduce upper extremity closed kinetic chain exercises for athletes who bear weight on the upper extremity or move their body over a stationary hand. The athlete does not perform all exercises every day.

New closed kinetic chain exercises are introduced one at a time, so we can monitor soreness and/or pain. Fitter exercises lead off the program, with Shuttle and step-ups added on subsequent days. Following successful completion of 1 to 2 weeks of these exercises, slide board alternates with Fitter, and circles/figure 8’s/cariocas alternate with step-ups. Alternating similar exercises helps reduce boredom with the program. Stairmaster begins 2 to 3 weeks after initiation of the closed kinetic chain program. If the athlete experiences soreness and/or pain the day of or the day following exercise,
progression is evaluated and possibly slowed down. These exercises are integral parts of rehabilitation programs for closed kinetic chain upper extremity athletes. Our athletes ranged from artistic gymnasts to canoers with glenohumeral pathologies, including dislocations, subluxations, and labral tears. Some athletes received surgical treatment, some nonsurgical. Obviously, these exercises affect the entire upper extremity and might be applicable for other glenohumeral and upper extremity pathologies. To date, we have used them for the above-mentioned glenohumeral pathologies only.

Exercise #1 Fitter®
To begin, the athlete places his/her hands on the Fitter platform (Stack Enterprises - Calgary, Alberta, Canada). Starting with one cord on the Fitter, the athlete is perpendicular to the Fitter and horizontally abducts and adducts the glenohumeral joint, moving the platform in the frontal plane (Fig 1). The athlete moves parallel to the Fitter and, by flexing and extending the glenohumeral joint, moves the platform in the sagittal plane (Fig 2). By orienting the body at 45° to the Fitter, diagonal motions of the upper extremity are possible. Increase the exercise intensity by adding more cords to the Fitter and performing the movements with greater amplitude. Body position progresses from a quadruped position, to a modified push-up position, a full push-up position, and a feet-elevated position over several weeks. The Fitter program starts with one set of 10 to 12 repetitions and increases to three to five sets of 10-12 repetitions with proper form.

Fig 2.—Athlete using Fitter in sagittal plane motion.

Exercise #2 Slide board
After placing socks on the hands, the athlete moves the glenohumeral joint in reciprocal flexion and extension on the slide board, starting with two to three sets of 10 to 15 seconds (Fig 3). When the athlete holds proper form (arms straight, shoulders and back level) for three to five sets of 30 to 60 seconds in the flexion/extension exercise, he/she begins simultaneous horizontal abduction and adduction exercises, again starting at two to three sets of 10 to 15 seconds (Fig 4). When proper form (arms straight, shoulders and back level) is held for three to five sets of 30 to 60 seconds in the horizontal abduction/adduction exercise, the athlete adds circular clockwise and counterclockwise patterns in synchronous and reciprocal motions, working up to three to five sets of 30 to 60 seconds here, also. If form deteriorates, maintain the number of sets, but shorten the exercise time for the day. All motions start small and increase in amplitude as strength and control increase. Body position proceeds as in Exercise #1.

Exercise #3 Shuttle 2000®
The athlete kneels on the Shuttle 2000,(CMC Systems - Bellingham, Wash) facing the foot plate. Using arms together, he/she presses away from the foot plate in a motion similar to a bench press (Fig 5). Initial resistance is one band, increasing one band when the athlete can complete successfully five sets of 25 repetitions at the lower resistance. Once the athlete can perform five sets of 25 repetitions at three cords with both arms, he/she starts a single arm press with one cord. Progression is the same as for the double arm press.

The athlete also can lie supine on the Shuttle 2000 with his/her head toward the foot plate. The athlete puts his/her hands above the head on the foot plate and presses away, doing a handstand push-up (Fig 6). Progression is the
Fig 5.—Athlete using Shuttle 2000 in bench press motion.

same as the kneeling Shuttle 2000 exercise.

Exercise on the Shuttle 2000 also can develop upper body power. Using both kneeling and supine positions and starting with one cord, the athlete performs plyometric bounds with the arms. He/she pushes away from the foot plate, then catches and rebounds as quickly as possibly. Sets are completed as quickly as possible, also. Because these exercises are quite stressful, they begin once the athlete can complete five sets of 25 repetitions of Shuttle 2000 strength exercises with at least five resistance cords.

Exercise #4 Step-ups
This exercise is a single compound arm press, similar to lower extremity step-ups. The athlete, using arms, steps up and down off a stool or box in sideways and forward directions (Fig 7). The athlete begins with two sets of 10 to 12 repetitions, increasing to four to six sets of 20 to 30 repetitions, while maintaining proper form (arms straight, shoulders and back level). Step height increases when the athlete can complete six sets of 20 to 30 repetitions. Body position progresses as in Exercise #1.

Exercise #5 Circles/Figure 8's/Cariocas
The athlete uses his/her arms to take several sequential "steps" sideways, returns to start, then moves in the opposite direction the same number of steps. The exercise is performed in circles, figure 8's, cariocas, or any other pattern. This exercise is timed, starting with 15 seconds and progressing to 2 to 3 minutes, with the athlete maintaining proper form (arms straight, shoulders and back level). During any one session, patterns are performed in both directions for equal amounts of time. The athlete progresses through body positions as Exercise #1.

Exercise #6 StairMaster 4000PT®
In this exercise, a single-arm compound arm press, the athlete rides the StairMaster 4000PT using hands instead of feet (Fig 8). A StairMaster 4000PT rate of 10 to 12 (stepping rate 103 to 121 per minute) with a "body weight" of 5 pounds is a good starting place. Five minutes is the lowest time setting on the StairMaster 4000PT, but, initially, most athletes cannot complete 5 minutes of this exercise. Set the StairMaster 4000PT for 5 minutes, but limit exercise time to 1 minute, gradually increasing the time as the athlete's muscular and cardiovascular condition improves, to a maximum of 10 minutes. With enhanced strength and conditioning, "body weight" is increased. Body position progression is the same as Exercise #1. Manual or random programs have worked best for us, but other Stairmaster preset programs are also beneficial.

Discussion
For rehabilitation exercise specificity, athletes using the upper extremity in a closed kinetic chain fashion must have programs using these types of exercises. Glenohumeral rehabilitation programs begin with open kinetic chain exercises to isolate and strengthen the rotator cuff. Once the rotator cuff musculature has regained strength and the athlete has returned to normal upper body weight training for 1 to 2 weeks, closed kinetic chain exercises are employed to complete the rehabilitation process and return the athlete to his/her previous level of performance.

Acknowledgement
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References


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Subjective Evaluation of Function Following Moderately Accelerated Rehabilitation of Anterior Cruciate Ligament Reconstructed Knees

Vanessa Draper, PhD
Chip Ladd, PT, ATC

Abstract: Rehabilitation protocols following anterior cruciate ligament reconstructions have become increasingly aggressive in the past several years, preparing the patient to return to sport activities within 4 to 6 months. In 1989, we initiated a moderately accelerated protocol and were interested in the long-term effects of early weight bearing, immediate full motion, early incorporation of closed chain activities, and early return to sport. We received responses from 58 of 180 patients surveyed. All had undergone a bone-patellar tendon-bone autograft reconstruction procedure 12 to 21 months prior and had followed the rehabilitation protocol described. Results of the Lysholm Knee Scoring Scale and a questionnaire regarding preinjury and postinjury activity levels, pain and stability ratings, and current activity indicated that the majority of these patients had returned to sport and recreation and were participating at levels of moderate to high intensity with little or no difficulty.

Vanessa Draper, is Research Director at the Knoxville Orthopedic Clinic in Knoxville, TN 38919.

Chip Ladd is Director of Sports Medicine/Physical Therapy at the Orthopedic Rehabilitation Center at the Knoxville Orthopedic Clinic.

A CL tears are one of the more prevalent injuries encountered in the sports medicine clinic. In recent years, surgical reconstruction procedures, and, consequently, rehabilitation protocols have undergone considerable change. A better understanding of graft fixation and revascularization, as well as less invasive, less traumatic surgical techniques, has allowed a more aggressive approach to the recovery of range of motion and quadriceps strength during the very immediate postoperative phases of rehabilitation. Thus, an earlier return to functional activities is possible.

While there is a general trend toward an accelerated rehabilitation process, current protocols vary somewhat concerning the actual time when motion, weight bearing, and functional activities are allowed. There are numerous reports on the objective outcomes of these various rehabilitation protocols. Objective measures usually include range of motion, knee-arthrometer measures of ligament stability, and isokinetic measures of quadriceps and hamstring peak torque and endurance. These measures are intended to lend credence to recovery methods and provide the physician, athletic trainer/therapist, and patient a means of estimating postoperative progress and a basis on which to determine return to functional activity. While we agree that this objective information is extremely important and necessary in tracking a postoperative course, we suggest that other measures such as pain, sensations of mechanical abnormalities (locking, catching, etc) and the patient’s perception of knee stability, although subjective, might contribute as much or more to the patient’s decision to resume his/her preinjury activity level.

Approximately three years ago, we began a more aggressive approach to ACL rehabilitation, ie, immediate full range of motion, immediate partial weight bearing, full weight bearing with crutches at 4 weeks, off crutches by 6 weeks, closed chain activities at 4 weeks, and a return to functional activities and sports by 6 months. (More recently, we have shortened these time frames.) Three years ago, this was considered an aggressive protocol in light of traditional beliefs that a maximal control of external forces was necessary to protect the integrity of the graft. While the objective results during the standard follow-up of these patients (range of motion, isokinetic strength tests, and ligament laxity assessment) suggested that this protocol was not damaging and did facilitate a faster recovery, we were interested in the patients’ assessments of their knee functions, as well as their activity levels 1 to 2 years after the procedure.

Materials and Methods
We surveyed 180 patients who had undergone a bone-patellar tendon-bone autograft reconstruction procedure between January and November 1990. All of these procedures were performed by one of two surgeons in one clinic, and all patients had followed the same rehabilitation protocol (Table 1). Although 74 patients responded, only the 58 who were at least one full year beyond surgery (range of 12 to 21 months, x=16) were included in this study. The group consisted of 34 females and 24 males and ranged in age from 14 to 56 years (x=29). Twenty-two of 58 had undergone meniscal repairs as well.
Rehabilitation Activities

were level 3 or 2 (regular run­

Results

Objective measures of strength and

Discussion

Table 1.—Modified Accelerated Rehabilitation Program

<table>
<thead>
<tr>
<th>Time After Reconstruction</th>
<th>Rehabilitation Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-op (7-10 days)</td>
<td>QF and HS isometrics; SLRs (all planes); HS stretch; ROM (A, AA and PROM); cryotherapy</td>
</tr>
<tr>
<td>2-3 days</td>
<td>Discharge from hospital. Prerequisites: 1) able to do SLR; 2) full extension; 3) 90° flexion desirable; 4) 20- to 30-lb weight-bearing emphasis on heel-toe gait. Continue pre-op activities.</td>
</tr>
<tr>
<td>5-7 days</td>
<td>ROM-full extension; active-assisted flexion; strengthening: E-stim and/or biofeedback-assisted SLRs, partial weight-bearing (heel-toe gait); patellar mobilization; outpatient physical therapy 2/wk to 3/wk</td>
</tr>
<tr>
<td>10-14 days</td>
<td>ROM (0°-90°); bicycle for ROM only; SLRs with weights; Continue pre-op activities</td>
</tr>
<tr>
<td>2-4 weeks</td>
<td>ROM (0°-120°); multi-angle (90°-45°) isometric QF workout on Kin-Com; hydrotherapy (SLRs, ROM, gait training)</td>
</tr>
<tr>
<td>4-6 weeks</td>
<td>ROM (0°-140°); full weight-bearing with crutches as tolerated (wean from crutches when normal gait is possible); closed chain activities: Nordic track, Stairmaster, mini-squats, step-ups; passive mode concentric QF/HS exercise on Kin-COM (90°-45°); Isotonic PREs with light weights (90°-45°); bicycle for conditioning</td>
</tr>
<tr>
<td>6-12 weeks</td>
<td>Increase isotonic PREs (QF and HS curls, leg press, hip, calf raises); eccentric HS on Kin-Com; proprioceptive training</td>
</tr>
<tr>
<td>3-4 months</td>
<td>KT-1000 evaluation; velocity mode on Kin-Com for QF and HS; continued closed chain activity; Proprioceptive training; sport cord running in pool (forward/backward); continue PREs; light running allowed</td>
</tr>
<tr>
<td>4-6 months</td>
<td>Isokinetic evaluation at 60°/s and 180°/s; KT-1000; in a functional brace begin agility workouts and sport-specific activities</td>
</tr>
<tr>
<td>6-8 months</td>
<td>Return to athletics with functional brace</td>
</tr>
</tbody>
</table>

The survey included the Lysholm scale” (Table 2) and an additional short questionnaire designed by us to assess preinjury and postinjury activity levels and current pain and stability ratings during both daily activities and recreational activities (Table 3).

The preinjury activity level of this group was generally high. Of the 58 patients, 27 (46%) were level 5 or 4 (regular organized sport, training and/or competitive participation), 30 (52%) were level 3 or 2 (regular runner/walker/sport participant), and only 1 (2%) indicated that she engaged in absolutely no physical activity.

Postoperative data indicated that 41 patients (71%) returned to their preinjury activity level and 2 (3%) actually increased their activity. Of the 15 patients who indicated a decrease in activity, 8 dropped one level, 4 dropped two levels, and 3 dropped three levels.

The Lysholm knee function score had a mean of 87±11, (range, 55 to 100). Eighteen (31%) had an excellent function score (95 points), 22 (38%) had a good function score (84-94 points) and 18 (31%) had a score of less than 84 points with deficits resulting from primarily high intensity activity. The distribution of ratings across each Lysholm factor is presented in Table 4.

Pain ratings were low during both daily (2±1.4) and recreational activity (2.5±1.6). Stability ratings were good during both daily (1.9±1.6) and recreational (2.6±2) activities.

Patients had continued a regular strengthening program for an average of 8.5±3.5 months (range, 1 to 12) and were involved in a variety of activities at the time of the survey. Twenty (34%) had returned to team sports (11 on a competitive level), 36 (62%) were involved in such individual activities as racquetball, cycling, tennis, snow and water skiing, running, aerobics, and hiking. Only 2 (3%) individuals were not involved in any activity, and one of these patients had been inactive even prior to the injury.

As noted, the preinjury activity levels of this group were generally high, with all but one individual involved in some degree of recreational or competitive physical activity. Our 74% return to preinjury activity level is encouraging in light of Engebretsen et al’s report of a 64% return observed in a similar 1- to 2-year follow-up of the patellar tendon augmentation method. Our rehabilitation protocol, however, was much more aggressive than that used by Engebretsen et al, and this might have accounted for the difference. Other studies have reported return to preinjury activity rates of 18% to 77%, but the follow-up periods ranged from 5 to 16 days.
years, and the reconstruction and rehabilitation methods differed.\(^1\)\(^4\)\(^5\)

The majority of patients (69\%) rated their knee function good to excellent (84-100). The remaining 31\% reported scores that would be considered moderate to low function (<84), but the deficits were generally reflective of function during "severe exertion." Therefore, although these patients were reportedly symptomatic, they were symptomatic as a result of moderate to high intensity activities, eg, running, cycling, hiking, skiing, and team sports. The average score for our study population was 87. Other accounts of postoperative Lysholm scores report averages of 81-88 at a similar follow-up date.\(^1\)\(^6\) It is difficult to compare these reports because they represent different operative and rehabilitation methods; but, it does appear that our protocol resulted in an equal or better than average functional rating.

Our patients' subjective ratings of their pain and stability on the two different instruments were in agreement. On our instrument, pain ratings were low, averaging 2 and 2.5, respectively, during daily and recreational activities. Stability ratings were very good, averaging 1.9 and 2.6 during daily and recreational activities. Lysholm pain and stability ratings were consistent (pain: \(x=20\), "inconstant/slight"; stability: \(x=20\), "rarely with athletics or other severe exertion") and indicated that patients were functioning at a generally pain-free and stable level 1 to 1½ years following ACL reconstruction. More importantly, 35\% were participating in team sports (more than half at a competitive level), and 62\% were participating in individual sports, some of which would be considered moderate to high intensity (racquetball, snow and water skiing). Only 2 individuals (3\%) considered themselves inactive.

**Conclusion**

The rehabilitation protocol that this group of patients followed was designed to prepare them physically for an early return to normal activity levels. The intent of this survey was to determine whether or not they actually had returned to the rigors of sport and recreation. The information obtained indicates that the majority of these people have returned and are participating at levels of moderate to high intensity with little or no difficulty.

### Table 2.—Lysholm Knee Scoring Scale\(^9\)

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LIMP</strong></td>
<td>None</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Slight/periodical</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Severe/constant</td>
<td>0</td>
</tr>
<tr>
<td><strong>SUPPORT</strong></td>
<td>None</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Stick/crutch</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Unable to bear weight</td>
<td>0</td>
</tr>
<tr>
<td><strong>LOCKING</strong></td>
<td>No locking/catching</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Catching/no locking</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Lock occasionally</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Lock frequently</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Locked joint (exam)</td>
<td>0</td>
</tr>
<tr>
<td><strong>INSTABILITY</strong></td>
<td>Never gives way</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Rarely during athletics or other severe exertion</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Frequently during athletics or other severe exertion</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Occasionally in daily activities</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Often in daily activities</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Every step</td>
<td>0</td>
</tr>
<tr>
<td><strong>PAIN</strong></td>
<td>None</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Inconstant/slight during severe exertion</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Marked during severe exertion</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Marked on or after walking more than 1.5 miles</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Marked on or after walking less than 1.5 miles</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td>0</td>
</tr>
<tr>
<td><strong>SWELLING</strong></td>
<td>None</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>On severe exertion</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>On ordinary exertion</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td>0</td>
</tr>
<tr>
<td><strong>STAIR-CLIMBING</strong></td>
<td>No problem</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Slightly impaired</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>One step at a time</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Impossible</td>
<td>0</td>
</tr>
<tr>
<td><strong>SQUATTING</strong></td>
<td>No problems</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Slightly impaired</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Not beyond 90°</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Impossible</td>
<td>0</td>
</tr>
</tbody>
</table>
primarily, the most effective way to return to a physically active lifestyle. The clinician might determine postoperative progress and the ability to return to sport and play by measures of strength, range of motion, and ligament laxity. The patient, however, has the unique perspective of perception of function, and this too will be a factor in his/her decision to resume preinjury activity levels. Postoperative knee rehabilitation protocols continue to become more "accelerated," and patients are expected to progress quickly. Currently, we encourage full weight bearing at 2 to 3 weeks, off crutches as early as 4 weeks and return to sport as early as 4 months. In tracking the postoperative course, perhaps a periodic assessment of the patient's perception of joint function should accompany the traditional objective evaluations.

References

Table 3.—Activity level, pain and stability questionnaire

<table>
<thead>
<tr>
<th>1. Activity level before injury and surgery (circle one)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. I do not participate in any sport or recreational activity on a regular basis,</td>
</tr>
<tr>
<td>b. I participate regularly in recreational running and/or walking,</td>
</tr>
<tr>
<td>c. I participate regularly in recreational running and/or walking and individual sports,</td>
</tr>
<tr>
<td>d. I participate regularly in organized team sports and/or training,</td>
</tr>
<tr>
<td>e. I participate regularly as a competitive athlete.</td>
</tr>
</tbody>
</table>

| 2. Activity level now: (designate one of the above choices, ie, a-e) |  |
|---------------------------------------------------------------|
|  |

<table>
<thead>
<tr>
<th>3. Estimate the pain you presently experience during normal daily activities:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1—.2—.3—.4—.5—.6—.7—.8—.9—.10</td>
</tr>
<tr>
<td>no pain</td>
</tr>
<tr>
<td>unbearable pain</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. Estimate the pain you presently experience during recreational activities:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1—.2—.3—.4—.5—.6—.7—.8—.9—.10</td>
</tr>
<tr>
<td>no pain</td>
</tr>
<tr>
<td>unbearable pain</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5. Estimate how stable your knee feels during normal activity:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1—.2—.3—.4—.5—.6—.7—.8—.9—.10</td>
</tr>
<tr>
<td>very stable</td>
</tr>
<tr>
<td>very unstable</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6. Estimate how stable your knee feels during recreational activity:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1—.2—.3—.4—.5—.6—.7—.8—.9—.10</td>
</tr>
<tr>
<td>very stable</td>
</tr>
<tr>
<td>very unstable</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>7. How long did you continue a regular strengthening program following your surgery?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

| 8. List specific physical activities that you are now involved in on a regular basis. |

Table 4.—Distribution of responses to Lysholm Items (n=58)

<table>
<thead>
<tr>
<th>Response</th>
<th>Avg (possible)</th>
<th>Problems Indicated by Patient*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limp</td>
<td>4.5 (5)</td>
<td>None  18</td>
</tr>
<tr>
<td>Support</td>
<td>5.0 (5)</td>
<td>None  0</td>
</tr>
<tr>
<td>Catching/Locking</td>
<td>14.0 (15)</td>
<td>None  13</td>
</tr>
<tr>
<td>Instability</td>
<td>21.0 (25)</td>
<td>None  12</td>
</tr>
<tr>
<td>Pain</td>
<td>20.0 (25)</td>
<td>None  7</td>
</tr>
<tr>
<td>Swelling</td>
<td>8.0 (10)</td>
<td>None  17</td>
</tr>
<tr>
<td>Squat</td>
<td>4.2 (5)</td>
<td>None  20</td>
</tr>
<tr>
<td>Stairs</td>
<td>8.7 (10)</td>
<td>None  42</td>
</tr>
</tbody>
</table>

*Problems
None = patient indicated absolutely no deficiencies
Moderate = patient indicated rare or occasional problems during severe exertion or only slight impairments
Significant = patient indicated frequent problems, primarily during severe exertion

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- blocks harmful biomechanics
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Abstract: Certified athletic trainers (ATCs) in District 2 (n=187) of the National Athletic Trainers’ Association (NATA) were asked to complete a questionnaire that assessed the attitudes and judgments of ATCs concerning numerous factors presumed to influence sport injury rehabilitation. Gender and experience differences in ATCs’ attitudes and judgments about rehabilitation adherence were examined. Successful and unsuccessful adherence strategies also were reported. The questionnaire consisted of 60 statements that were categorized into seven scales: athletic trainer’s influence, environmental influences, athlete’s personality, pain tolerance, self-motivation, goals and incentives, and significant others. There were no significant differences for either gender or experience of ATCs on any of the seven scales. An analysis of questionnaire item responses revealed the following as factors ATCs deemed important to injury rehabilitation: a) good rapport and communication between the ATC and the injured athlete, b) explanation of the injury and rehabilitation regimen, c) convenience and accessibility of the rehabilitation facility, d) rehabilitation sessions planned around the athlete’s busy schedules, e) athletes’ beliefs that the program is worth pursuing, f) personal supervision and regular monitoring, g) need for injured athletes to see immediate results, and h) support from significant others. ATCs reported education, goal setting, encouragement, monitoring progress, and support systems as successful strategies.

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Patricia A. Frye is an associate professor in the Department of Health, Physical Education and Recreation at Western Michigan University in Kalamazoo, MI. She was employed at Ithaca College while this investigation was conducted.

Threats and rehabilitation without monitoring were reported as unsuccessful strategies.

Exercise rehabilitation programs are designed to return athletes to normal function after injuries have occurred. Certified athletic trainers (ATCs) are trained to evaluate and assist athletes with their rehabilitation. Success or failure of athletes to return to competition does not depend solely on the nature of the rehabilitation (ie, its type, intensity, frequency, duration). Arguably, the key factor influencing the effectiveness of the rehabilitation process is injured athletes’ commitment to their programs and the ability of ATCs to enhance that commitment.

Factors that enable or encourage athletes to maintain their rehabilitation programs are important to ATCs in making their rehabilitation programs effective. ATCs ponder why some injured athletes adhere, while others do not, and what they might do to maximize the necessary commitment. More important, however, is the frustration felt by ATCs when athletes under their supervision give less attention and effort to their rehabilitation than ATCs do.

In an excellent treatise on adherence across a multitude of domains, Meichenbaum and Turk11 revealed the complexity of the adherence issue.
Methods

In February 1988, we mailed the Athletic Injury Rehabilitation Adherence Questionnaire and a letter of explanation to 505 randomly selected certified ATCs in District 2 of the NATA. The questionnaire consisted of 60 statements to which the ATCs were asked to judge their agreement on a five-point Likert scale from "strongly agree" to "strongly disagree" and two open-ended questions that allowed ATCs to offer their most and least successful rehabilitation adherence strategies. The statements were categorized into seven scales derived from previous investigations and literature reviews: athletic trainer's influence, environmental influences, athlete's personality, pain tolerance, self-motivation, goals and incentives, and significant others. Examples of statements are shown in Table 1.

Descriptive statistics on the demographics of ATCs were assessed to provide information concerning gender, age, experience, and level of employment. An analysis of item responses was completed to assess what percentage of ATCs agreed with each statement. Scale differences by gender and experience were assessed by analysis of variance (ANOVA). Successful and unsuccessful rehabilitation adherence strategies were tabulated.

Results and Discussion

Of the 505 questionnaires mailed, 187 (37%) were returned. The sample revealed the following characteristics: 87 (47%) were females and 100 (54%) were males; mean age was 30.2 ± 7.4 years; 36 (19%) had 0-2 years post-bachelor's degree athletic training experience, 108 (58%) had more than two, but less than 10 years' experience, 42 (23%) had more than 10 years experience, and one (.5%) did not complete the experience category. Five (3%) were not employed in the athletic training field, 56 (30%) were employed in high schools, 76 (41%) in colleges/universities, 17 (9%) in sports medicine clinics, and 17 (9%) in other areas.

There were no gender (F[1,184] = 1.97, p > .05) or experience (F[1,183] = 4.57, p > .05) differences on any of the scales; therefore, the questionnaire results are independent of these variables and are presented for the entire sample.

Athletic Trainer's Influence

All respondents (100%) agreed that rapport between themselves and injured athletes is essential in getting the athletes to commit to their rehabilitation programs. When ATCs are open, honest, supportive, respectful, and considerate of injured athletes' feelings and needs, the likelihood of enhanced rehabilitation adherence is greater. There is so much uncertainty associated with an injury (eg, pain, recovery) that consideration of the athlete's frame of mind seems paramount, especially in the early stages of treatment.

Both explanation of the injury (170 [91%] in agreement) and the rehabilitation regimen (155 [83%] in agreement) were deemed important factors in getting the athlete's cooperation for the rehabilitation program. Injured athletes need to understand the nature and extent of the injury, the realities of the rehabilitation plan, and the prognosis for recovery (146 [78%] agreed that injured athletes need to be realistically apprised of the likelihood of pain; 133 [71%] agreed that rehabilitating athletes need to understand the effort needed). There is ample evidence that too little information and/or understanding of prescribed health care directions predispose limited treatment adherence. ATCs need to be mindful of the role they can play in disseminating important information and translating medical terminology to rehabilitating athletes.

Environmental Influences

Convenience and accessibility of the rehabilitation setting facilitates injured athletes' adherence in the minds of 178 (95%) of the ATCs. This supports evidence from previous research, which indicates reduced adherence is more likely for patients who find it difficult to be on time, who perceive the facility to be inconveniently located, and who encounter parking difficulties. Only 52 (28%) of the ATCs concurred that a businesslike atmosphere is necessary for the rehabilitation facility. On the other hand, crowded conditions appear to impact athletes' attendance at their

Table 1.—Sample Statements from the Athletic Injury Rehabilitation Adherence Questionnaire

<table>
<thead>
<tr>
<th>Scale</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Athletic Trainer's Influence</td>
<td>2. Athletes are likely to drop out of their rehabilitation programs if they are not given an explanation of their injuries.</td>
</tr>
<tr>
<td>B. Environmental Influences</td>
<td>15. If the training room is easily accessible, athletes' attendance at their rehabilitation sessions will be greater.</td>
</tr>
<tr>
<td>C. Athlete's Personality</td>
<td>20. Injured athletes who tend to display a general pessimism (ie, &quot;nothing goes right for me&quot;) are more apt to drop out of rehabilitation.</td>
</tr>
<tr>
<td>D. Pain Tolerance</td>
<td>31. Pain during the athlete's initial rehabilitation session decreases the chances of adherence.</td>
</tr>
<tr>
<td>E. Self-motivation</td>
<td>41. Adherence to exercise rehabilitation programs is related directly to the injured athlete's willpower.</td>
</tr>
<tr>
<td>F. Goals and Incentives</td>
<td>47. Athletes are more apt to adhere to rehabilitation programs when they see immediate results.</td>
</tr>
<tr>
<td>G. Significant Others</td>
<td>59. If coaches are supportive of their injured athletes' rehabilitation efforts, then athletes will more likely adhere to their programs.</td>
</tr>
</tbody>
</table>
rehabilitation sessions (112 [56%] agreed), but do not necessarily affect athletes' motivation to work at their rehabilitation (only 80 [43%] agreed).

Most ATCs agreed (172 [92%]) that it is crucial to plan rehabilitation sessions around injured athletes' schedules in order to ensure attendance. Student-athletes have extremely busy schedules; therefore, it is necessary to fit the program to the athlete, rather than the athlete to the program.4 Flexibility of both the ATC and the rehabilitation facility, when possible, seems warranted.

**Athlete's Personality**

Respondents offered conflicting judgments as to whether personality of the injured athlete is the most important factor in rehabilitation adherence (103 [55%] agreed; 67 [36%] disagreed; 17 [9%] were uncertain). Even with agreement or disagreement, the judgments did not represent strong feelings. Patient factors have not been useful predictors of adherence/nonadherence behavior in other domains, with the exception of patient satisfaction and beliefs.19 It is, therefore, not surprising that ATCs in this study agreed that injured athlete pessimism is disastrous (163 [87%] agreed), as is an unrealistic assessment about how much effort it will take to complete the rehabilitation program (144 [77%] agreed). Although it has been argued elsewhere that no default personality can be located to predict adherence or nonadherence,13 perhaps it might be more productive to look in the direction of self-efficacy, self-expectation, and self-appraisal.

**Pain Tolerance**

It is evident that pain and discomfort normally are associated with injury rehabilitation and, perhaps equally as obvious, that a certain magnitude of pain might cause an interruption or even cessation of the rehabilitation program. Less than half (86 [46%]) of the ATCs agreed that pain during the initial rehabilitation session decreases the likelihood of injured athletes adhering to their exercise prescription. Results were as mixed for the significance of the anticipation of pain as well. However, there was unanimous agreement that injured athletes need to understand the quantity and quality of pain to be expected during their rehabilitation if they are to adhere to their programs.

Athletic trainers need to assist rehabilitating athletes with their interpretation of pain in such areas as: a) when the onset of a certain level of pain signals the stoppage of an exercise, and b) when the pain has to be managed so as not to delay rehabilitation. Also, ATCs might devote more time and effort to pain reduction techniques during the initial phases of rehabilitation. Reducing pain through TENS or cryotherapy, thus making the rehabilitation a less painful experience, might well increase adherence to the rehabilitation program. Pain is such an individual process2 that each injured athlete must be considered separately, so that pain does not negatively interfere with the rehabilitation program.

**Self-motivation**

Self-motivation is the capacity to motivate oneself to perform a given task. Self-motivated individuals are better able to work toward their goals without external guidance and reinforcement.14 ATCs identified certain aspects of self-motivation as relevant to injury rehabilitation adherence.

Athletic trainers were unanimous in their agreement that rehabilitation would be enhanced if injured athletes believed they would benefit from their rehabilitation programs. That seems to be a significant precursor to the self-motivated state and has been reinforced in other health care areas.10,11 However, ATCs were not willing to concede that external motivators are wasted effort. Regular monitoring (178 [95%] agreed) and supervision (172 [92%] agreed) by ATCs seem to be essential to rehabilitation adherence. Even the mere presence of an ATC (159 [85%] agreed) assists the process.

And, although there is reasonably high agreement that rehabilitation adherence is related directly to injured athletes' wellpower (150 [80%] agreed), ATCs were split on whether athletes would comply with their prescribed rehabilitation exercises even if ATCs are not present. Furthermore, ATCs disagreed (150 [80%]) that, if injured athletes can perform their rehabilitation workouts on their own, they are more likely to adhere. This latter point seems to raise some concern about the practice of prescribing rehabilitation homework for injured athletes.

Much attention has been directed to the importance of self-motivation as an important factor in enhancing exercise adherence,3 but it seems apparent that ATCs feel that motivation can be given a boost through their efforts. The latter seems to be the more reasoned position, because not all injured athletes who come for rehabilitation will possess the degree of self-motivation necessary to perform the prescribed exercises either to ATCs' or their own satisfaction.

**Goals and Incentives**

Athletic trainers did not agree (67 [36%]) that long-term benefits are more important than short-term outcomes in promoting treatment adherence, although the knowledge of the long-term benefits certainly aids the adherence process (155 [83%] agreed). Injury rehabilitation is a difficult process in which athletes can be overwhelmed by the thought of long-term recovery.14 Some of the negative affect can be reduced by encouragement (168 [90%] agreed), focusing on positive aspects (161 [86%] agreed), and seeing immediate results (170 [91%] agreed). Setting and attaining short-term goals on the way to long-term goal realization can serve as a real confidence builder. We, along with others, strongly urge ATCs to consider the application of this motivational strategy to their treatment regimens.5,9

There seems to be a certain incentive value to the rehabilitation process because ATCs disagreed (133 [71%]) that injured athletes will search for reasons to miss their sessions and that they will attend only if nothing more pleasurable comes up (148 [79%] disagreed). It appears too simplistic to believe that treatment adherence hinges on whether the athlete will be able to return to competition that same season; only 99 (53%) of the ATCs supported that belief.

Threats and scare tactics (eg, "If you miss rehab, you don't play.") offer an interesting dichotomy because 71 (38%) agreed that they are effective, 80
(43%) disagreed that they work, and the remainder were not sure. Perhaps it is as simple as this: Threats and scare tactics work for some ATCs, and they use them, but they do not work for others because they either do not use them or they do not believe they are effective motivators.

**Significant Others**

ATCs were almost unanimous in their agreement that their support of their injured athletes’ rehabilitation efforts is essential. Likewise, coaches’ support and the feeling that injured athletes’ sense they are still part of the team received overwhelming agreement. However, not all ATCs agreed that teammates’ support was crucial (110 [59%] agreed, 47 [25%] disagreed, and 30 [16%] were not sure). The rehabilitation literature is replete with findings that reinforce the importance of social support.9,11,14

Recognition of this fact seems to point to an obvious conclusion. ATCs are in the unique position to orchestrate this place for creativity, or perhaps approaches that we had not considered yet, such was not the case. Perhaps the last part of a questionnaire is not the place for creativity, or perhaps strategies to enhance sport injury rehabilitation adherence are in their infancy stage of development.

Nonetheless, it is readily apparent that ATCs believe that education is an important phase of the rehabilitation process, probably an essential first step.7 ATCs recognize that they can be effective agents in the rehabilitation process by helping athletes set goals, encouraging them, and monitoring their progress.

Notice again the dichotomy surrounding threats. ATCs reported that threats are the least successful adherence strategy, yet the threat to withdraw sport participation appears on the list of successful strategies. There is certainly something individualistic about the use and effectiveness of threats that demands greater attention.

There is further reinforcement for the point made earlier about leaving injured athletes on their own to pursue their rehabilitation. More than 25% of the ATCs surveyed reported that unsupervised rehabilitation simply does not work. If unsupervised rehabilitation is deemed a necessary aspect of any athlete’s rehabilitation program, then it seems that more attention needs to be addressed to some of the motivational strategies mentioned elsewhere.7

**Conclusion**

Although the task of promoting greater rehabilitation adherence from injured athletes seems like an onerous task, we believe that ATCs have no alternative. Because your goal is to be effective sports medicine specialists and return injured athletes to normal function, we urge you to recognize the barriers that prevent rehabilitation adherence and try to eliminate as many of them as you can. On a more positive vein, we encourage you to create the kinds of rapport and implement the strategies that will increase your chances of being even more effective.

**Acknowledgements**

This study was supported by a grant from the Dean’s Research Fund, School of Health Sciences and Human Performance, at Ithaca College in Ithaca, NY. We appreciate the responses from the certified athletic trainers in District 2 of the NATA, who participated in this study, and Michael Matheny for comments on an earlier draft of this manuscript.

**References**


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In a study of 174 cases of humeral epicondylitis (tennis elbow), the Journal of the American Medical Association reported “A brace that limits extension and forearm rotary motion and supports the elbow gave relief in 80% of cases in which other conservative methods of treatment had failed.”

Quoted from the Journal of the American Medical Association January 10, 1966, vol. 195 pp. 67-70

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Injured Athletes’ Attitudes and Judgments Toward Rehabilitation Adherence

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Linda L. Hoisington, MS, ATC

Abstract: In a follow-up study to certified athletic trainers’ (ATCs’) attitudes and judgments toward injury rehabilitation adherence, previously injured and rehabilitated athletes (n=36) were administered the Athletic Injury Rehabilitation Adherence Questionnaire. The purpose of the study was to compare the results collected from athletes with those collected previously from ATCs. The questionnaire consisted of 60 statements, categorized into seven scales: athletic trainers’ influence, environmental influences, athlete’s personality, pain tolerance, self-motivation, goals and incentives, and significant others. Four additional open-ended questions dealing with successful and unsuccessful rehabilitation strategies also were completed. Athletes’ responses were generally similar to those of ATCs. Factors deemed significant to rehabilitation adherence were: (a) good rapport and communication between athletic trainers and injured athletes, (b) support from athletic trainers and coaches, (c) self-motivation on the part of athletes, and (d) convenience, accessibility, and flexibility of the rehabilitation facility and staff. The greatest deviations between athletes’ and ATCs’ responses were in the areas of self-motivation, pain tolerance, education about injury and rehabilitation exercises, and degree of realistic feedback. Analyses of open-ended question responses reinforced the aforementioned results. The strongest findings derived from these questions were the importance of rapport, communication, and support to rehabilitation adherence. Also, athletes’ distastes for threats and scare tactics were quite evident.

Adherence to treatment regimens, including injury rehabilitation, is an extremely complex issue. It has been argued elsewhere that there are more than 200 variables that influence commitment to prescribed treatments.11 Previous literature, focusing specifically on athletic injury rehabilitation, illustrates that rehabilitation adherence can be understood in terms of: (a) injured athletes’ characteristics (eg, self-motivation), (b) characteristics of the rehabilitation setting (eg, accessibility of the athletic training room), and (c) ATC-athlete interactions (eg, rapport).9,9

In two separate investigations,9,19 ATCs’ attitudes and judgments about a variety of rehabilitation strategies were revealed. ATCs emphasized the importance of rapport with injured athletes, social support, athletes’ self-motivation, and ATCs’ motivational outlook, to mention just a few of the findings. It is significant to point out that ATCs recognize the crucial importance of psychological variables in rehabilitation adherence.

Although important psychological skills and ATC-athlete interaction patterns helpful to treatment adherence have been identified previously, highlighting some of these will be of little value until ATCs consider the applicability of these suggestions to their treatment repertoires. Fortunately, more details about these suggested strategies are available in recent sports medicine literature.3,7,16-18

We propose the partnership idea, the dynamic interaction of ATCs and athletes, as the focus most suited for optimal injury rehabilitation. This, then, highlights the critical need to allow athletes to express their viewpoints concerning the most and least effective rehabilitation strategies.11 Athletes’ beliefs and expectations about such matters as treatment efficacy, athletic trainers’ supervision and motivational support, and their own attributions and motivation will lead to the framing of a very important, naive (not to mean simplistic, but natural and workable) model of injury treatment and rehabilitation. After all, injured athletes are the clients, and they are the ones going through the rehabilitation. To neglect their input is to negate an important source of information.

Although there are limits to self-report data,12 clients (ie, athletes) often can predict with some degree of accuracy their likelihood of adherence.11 It seems equally plausible that they are able to address the factors that personally predispose their adherence to their prescribed treatments.

In this study, we examined formerly injured and rehabilitated athletes’ (hereafter referred to as athletes) attitudes and judgments about factors presumed to influence sport injury rehabilitation adherence. Athletes’ findings then were compared and contrasted with those reported earlier in the injury rehabilitation literature.

Methods

In April 1992, we mailed the Athletic Injury Rehabilitation Adherence Questionnaire and a letter of explanation to...
all 108 athletes (103 males and 5 females) from mailing lists provided by ATCs at Colgate University, Cornell University, and Ithaca College. None of these institutions offer athletic scholarships. The criteria for subject selection were: the injury required at least 3 months of rehabilitation and the athlete must have graduated within the last 12 years.

The questionnaire consisted of 60 statements to which athletes were asked to judge their agreement on a five-point Likert scale from "strongly agree" to "strongly disagree." Also, four open-ended questions allowed athletes to indicate the rehabilitation strategies and types of interactions that enhanced and deterred their adherence to rehabilitation programs. The statements were categorized into seven scales derived from previous investigations and literature review. An analysis of item responses was completed to assess what percentage of athletes agreed with each statement. Successful and unsuccessful rehabilitation strategies and interactions were tabulated.

**Results and Discussion**

Of the 100 questionnaires that were deliverable, 36 were returned. Eight questionnaires were undeliverable, and follow-up attempts indicated that there were problems with the accuracy of the mailing lists and with the mail forwarding process. Therefore, the return rate of completed questionnaires was 36% (36/100). The sample consisted of 34 (94%) males and two (6%) females. Perhaps the low return is a result, in part, of the 12-year criterion measure used to generate the population of injured athletes. We chose this timeframe to create a larger population, but it might have allowed the inclusion of potential subjects who were far removed from their sport and injury days. Results and discussion are organized by questionnaire scales.

**Athletic Trainer’s Influence**

Athletes reinforced ATCs’ earlier findings about the significance of injured athlete/athletic trainer interactions; 32 (89%) reported that good rapport is essential for rehabilitation adherence. Across a variety of treatment domains, it seems clear that patients and clients need support, empathy, and special consideration to get them through their ordeals. Unless there is adequate psychological security, rehabilitation progress will be hindered.

As athletes enter the rehabilitation process, there are usually many questions (eg, nature of the injury; type, frequency, intensity, and duration of the rehabilitation regimen; and prognosis for recovery). ATCs, of course, are in a position to answer these questions, and ATCs have reported that explanation of the athlete’s injury and the proposed rehabilitation are crucial treatment adherence determinants. Athletes concurred with the importance of this educational phase, but placed more importance on knowledge of the rehabilitation regimen (36 [100%] agreed) than the details of the injury (24 [67%] agreed). ATCs, therefore, might well spend the majority of their educational efforts on what is to be done, rather than what has happened. However, this is not to suggest that all athletes will be less interested in the details of their injuries.

So as not to mislead you about the importance of education, we would be remiss if we did not echo Meichenbaum and Turk’s synthesis of literature on this topic: The educational phase is necessary, but clearly not guaranteed to increase adherence. But, without this important preliminary step, treatment adherence might well be undermined.

Accuracy of pain and effort appraisal was just as important to athletes as ATCs (26 [72%] agreed in each case). Athletes recognized that they need assistance with their interpretations of pain (eg, "good" pain vs. "bad" pain) and the degree of effort necessary to adhere to their rehabilitation.

There is an implication that ATCs might consider increasing workload demands on their rehabilitating athletes because 27 (75%) of the athletes reported that increased ATC demands facilitate adherence. In a previous study, ATCs recognized the importance of placing demands on athletes, but perhaps they underestimated the importance of their demands on treatment adherence.

**Environmental Influences**

The physical location of the athletic training room can either enhance or hinder treatment adherence. Athletes totally agreed that easy accessibility facilitates attendance, clearly a first important step in the rehabilitation process. Even though ATCs recognized this fact, athletes were even more convinced.

A substantial percentage of athletes (27 [74%]) indicated that crowded athletic training rooms reduce attendance at rehabilitation sessions. Not only that, crowded conditions seem to reduce adherence to the exercise workout, at least in the minds of more than one third (14) of the athletes. In a previous study, ATCs revealed similar findings, but not to the same degree (56% agreed that crowded conditions hinder attendance, and 43% indicated that rehabilitation efforts were reduced). At certain times of the day, it is probably an understatement to describe athletic training rooms as hectic. Notwithstanding this less-than-favorable atmosphere, neither athletes in the present study nor ATCs earlier judged that a businesslike setting is a training room necessity. Almost two thirds of each sample disagreed that a businesslike atmosphere is more conducive to treatment adherence. Perhaps that simply reflects the reality of athletic training rooms.

Not surprisingly, athletes were almost unanimous (34 [95%]) in supporting the expectation that rehabilitation sessions need to be planned around their schedules. It is necessary to fit programs to the athletes, rather than attempt to constrain athletes into competing timeframes. This was similar to earlier ATC responses (92% agreed).

To their credit, athletes were not as concerned with the length of their rehabilitation sessions as ATCs had indicated earlier. Only 13 (36%) of the athletes indicated that a rehabilitation session in excess of 30 minutes would deter adherence, whereas 56% of the ATCs surveyed earlier indicated that sessions longer than 30 minutes would predispose reduced adherence.
Athlete’s Personality

Adherence to injury rehabilitation programs is certainly dependent on injured athletes’ personalities, not solely, but operating in conjunction with the rehabilitation setting and the rapport that exists between athletes and ATCs. Evidently, that assertion seems reasonable because a moderately large segment of both athletes (21 [58%]) and ATCs (55%) acknowledged that the athlete’s personality is not the most important factor predisposing adherence. Adherence literature is replete with reports that person factors (ie, personality traits) are not in themselves useful predictors of adherence/nonadherence behavior. However, the one that holds promise as being most useful is athletes’ beliefs (eg, self-appraisal, self-expectancy, and self-efficacy). A majority of athletes (28 [78%]) revealed the importance of accurately appraising how hard they are working on their rehabilitation, exactly the level of agreement reported earlier by ATCs. Athletes recognized that a generally pessimistic belief or attitude about rehabilitation effectiveness predisposes treatment dropout (30 [83%]), a finding seen earlier in studies with ATCs and interpreted more fully by Hafen et al. On the other hand, the “depression” that results from being injured and/or not recuperating as hoped is not seen as a very significant adherence factor by either athletes (only 5 [14%] agreed) or by ATCs (15%). This finding in no way denigrates the application of the Kübler-Ross model of grief to injury rehabilitation, but it does suggest that athletes’ feelings (ie, personality states) are not as debilitating as their more permanent beliefs and expectancies.

Although it is expected that athletes will approach their rehabilitation cautiously to reduce the chance of reinjury, this likelihood does not play such an important part in the rehabilitation adherence equation as ATCs reported earlier. One quarter of ATCs surveyed indicated that fear of reinjury during rehabilitation is likely to cause treatment dropout; athletes, on the other hand, reported lesser agreement (4 [11%]).

Generalizations from the exercise adherence literature indicate or imply that self-motivated athletes will more likely adhere to their prescribed treatments. However, only approximately half of the athletes (20 [56%]) and the ATCs (49%) reported that those who initiate and pursue their rehabilitation with minimal directions adhere better. Rehabilitation requires participation from ATCs (eg, education, appraisal, and motivation) and support from others (eg, coaches), all very recognizable by athletes and ATCs. This reiterates the point made earlier about the dimensionality and complexity of the rehabilitation adherence issue.

Pain Tolerance

Pain and discomfort are associative characteristics of injury rehabilitation and are of interest because they have the capacity to interrupt or terminate treatment. Intuitively, we realize that pain must be dealt with and that athletes have different levels of pain tolerance. The puzzling question is how significant pain is to the rehabilitation process.

Both athletes (34 [94%]) and ATCs (97%) acknowledged the importance of accurate appraisal of pain (ie, quantity and quality expected). Athletes reported that pain is less of a deterrent to rehabilitation adherence than ATCs did. Specifically, pain expectancy, pain prior to the initiation of rehabilitation, pain at the onset of rehabilitation, and pain during rehabilitation exercises are all less powerful rehabilitation detractors for the athletes than ATCs had indicated earlier. Also, pain experienced during treatment was not reported by athletes to be a significant factor in causing cessation of the workout (only 1 [3%] agreed), whereas a substantial segment (39%) of ATCs reported that athletes generally stop their workout when they experience the onset of pain. Pain serves as a useful guide to gauge the intensity of the rehabilitation workout, and no efforts should be directed to cloud athletes’ awareness of pain. But, it seems clear that accurate pain appraisal and subsequent attentional focusing (eg, association or dissociation) are important ingredients in the rehabilitation adherence equation.

Self-Motivation

Self-motivation applied to injury rehabilitation reveals itself in athletes’ capacities to initiate and perform their workouts in the absence of any outside support. To that end, 33 (92%) of the athletes reported that rehabilitation adherence is related directly to their willpower (ie, strength of character, intrinsic motivation, and self-motivation). In an earlier study, ATCs supported this finding, but to a lesser degree (78% agreed).

On the surface, it might appear that athletes tended to undermine their position on the importance of self-motivation by indicating that: (a) regular monitoring by athletic trainers aids adherence (32 [89%] agreed), (b) athletic trainer supervision promotes greater effort (35 [97%] agreed), and (c) even the mere presence of an athletic trainer enhances the quality of the rehabilitation workout (35 [97%] agreed). Just because athletes recognize the very significant contributions athletic trainers make to the rehabilitation process (eg, education, scheduling, and supervision), that does not contradict their earlier assertions. It seems clear, however, that self-motivation is not powerful enough to carry athletes through the difficulties and complexities of rehabilitation (eg, negative affect, slow progress, and pain).

Self-motivated rehabilitative efforts seem to be based on a number of principles. Athletes need to feel that the rehabilitation will be successful (34 [95%] agreed). Also, the prescribed exercises must be perceived as justifiable (35 [97%] agreed). An effort orientation or attribution (ie, hard work accounts for success) is more salient than an ability attribution (ie, talent accounts for success) (31 [86%] agreed). Although there is some intuitive appeal to the belief that more successful athletes (eg, starters and star players) would adhere better to their prescribed treatments, a substantial segment of athletes (14 [39%]) disagreed with that premise. In an earlier study, ATCs reported a similar reservation (36% disagreed).

ATCs did not seem to give athletes quite enough credit for the amount of motivation they bring to the rehabilitation process. Only 40% of ATCs...
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agreed that athletes will initiate and pursue their prescribed treatment without athletic trainer supervision, contrasted to 22 (61%) of the athletes. Likewise, ATCs (76%) accentuated the significance of rehabilitation progress to prevent dropout, whereas only 22 (61%) of the athletes placed that much importance on progress. This does not at all mean that rehabilitation progress is unimportant, but simply that athletes are not all consumed with the necessity of progress.

Even in light of the degree of self-motivation athletes judged they possess, there are still a couple of cautionary notes for ATCs’ consideration. First, to assume that athletes will rehabilitate on their own once they know their rehabilitation regimens is apparently faulty. Few ATCs (14%) tended to believe this, and this was replicated by athletes themselves (5 [14%]). This fact supports a commonly held belief that homework assignments or unsupervised workouts are probably suspect as far as their effectiveness is concerned. Second, there is the issue of quantity vs. quality workouts. There was good consensus between ATCs and athletes on the difference between merely attending rehabilitation sessions and working hard. A substantial segment of ATCs (80%) agreed that attendance is no guarantee of workout effort, a finding reinforced by 25 (70%) of the athletes. These points merely reinforce the necessity of direct ATC involvement, regardless of the degree of athletes’ self-motivation.

**Goals and Incentives**

Neither athletes (13 [36%]) in this study nor ATCs (36%) in an earlier study agreed that long-term benefits are more important than short-term outcomes in promoting treatment adherence, but both groups recognized that the knowledge of long-term benefits enhances adherence. The latter finding was supported even more strongly by athletes (34 [94%] agreed) than by ATCs (83% agreed).

Long protracted rehabilitation (eg, following knee surgery) is a difficult process at best, and the questions and concerns of long-term recovery are omnipresent. ATCs can assist rehabilitat-

ing athletes by offering them encouragement, directing their attention to positive aspects and planning selected activities (eg, exercises and testing protocols) that demonstrate more immediate progress. Athletes indicated their agreement (30 [83%]) with the significance of seeing immediate results, but they did not agree (21 [58%]) to the extent ATCs did (86%) that positive feedback, regardless of actual progress, facilitates treatment adherence. Apparently realistic positive results are more salient to athletes than contrived positive results, even though the intent of both is to secure rehabilitation adherence.

Threats and scare tactics as motivators were not supported strongly by either ATCs or athletes, but athletes’ responses were even less favorable. ATCs were somewhat undecided about the effectiveness of threats (47% agreed; 35% disagreed) and scare tactics (30% agreed; 49% disagreed) in promoting treatment adherence. Athletes reported stronger disagreement about the effectiveness of both threats (21 [58%]) and scare tactics (20 [56%]). Of all the motivational strategies that are useful to enhance rehabilitation adherence, threats and scare tactics appear to be the choice of last resort, if a choice at all.

Athletes revealed the importance of their rehabilitation to them in the degree to which they prioritized their workout sessions. They reportedly do not look forward to exercises to miss their appointments (32 [88%] agreed). Only one (3%) athlete disagreed that rehabilitation was less than a high priority. Previously, ATCs revealed positive impressions of athletes’ incentive values for rehabilitation, but their responses did not reach the levels reported by athletes. The differences between the two groups are typified by their responses to the question of how faithful athletes will be to their rehabilitation if they are unable to return to competition for the remainder of the season. Only eight (22%) of the athletes judged return to competition to be an important precursor of rehabilitation, compared to 53% of the ATCs. Apparently, return to competition is not as significant to athletes as might be surmised.

**Significant Others**

Of all the variables that have been shown to impact treatment adherence, few parallel the importance of social support. Therefore, it is not surprising that both athletes and ATCs reported unanimous or nearly unanimous agreement that coaches and athletic trainers were essential for rehabilitation adherence. Somewhat surprisingly, however, was the reduced importance of teammate support. Only approximately 60% of the athletes in this study and ATCs in a previous study agreed that teammate support is essential to prevent dropout.

Complicating these findings are again almost unanimous agreement between athletes and ATCs that it is important for injured athletes to feel that they are still an integral part of their teams. Apparently, there are several possible dynamics at work here. Because coaches and ATCs are in leadership roles, athletes expect them to offer support as part of their responsibilities. Fortunately, ATCs seem prepared to deliver such support to athletes. Anecdotal evidence about support given by coaches to injured athletes is mixed; some coaches are quite interested in follow-up support, while others seem oblivious to the necessity. ATCs are in the unique position to orchestrate coach involvement with injured athletes’ rehabilitation progress. Social support strategies have been offered elsewhere, and we suggest ATCs consider their effectiveness to rehabilitative efforts.

It is equally possible that athletes do not expect teammates to offer support because: (a) teammates cannot understand the physical and psychological ramifications of the injury, (b) teammates typically shy away from or are hardened to others’ injuries, and (c) teammates do not even consider what an important supportive role they could play with their injured colleagues. Attitudinal shifts on the part of coaches and teammates might well encourage healthy athletes to offer motivational support for those athletes undergoing injury rehabilitation.

Table 1 reveals the athletic training techniques and interactional strategies that athletes judged most helpful with...
their rehabilitation. The rapport factor is clearly uppermost in athletes’ minds. Repeatedly, athletes referred to athletic trainers’ caring attitude for, honest approach to, and encouragement of all aspects of the rehabilitation. These findings very clearly reinforce those discussed earlier, and they parallel quite closely the results reported elsewhere by ATCs.9<19

Athletes were given the opportunity to propose the strategies and interactions they judged would enhance their rehabilitation adherence. As seen in Table 2, the largest response was “none” (16 [44%]). Some athletes, however, seemed to recognize the importance of education about rehabilitation details and athletic trainer attention and supervision. Relative to the partnership concept proposed earlier, these suggestions from athletes, if implemented, would enhance their participation in the rehabilitation process.

Athletes revealed a high degree of satisfaction with athletic trainers’ strategies and interactions because 28 (78%) of the athletes reported no unsatisfactory practices. Miscellaneous complaints were registered (lack of athletic trainer interaction, unknowledgeable athletic trainer, student athletic trainer given too much responsibility, no set schedule, inadequate monitoring of progress, negative feedback, and inadequate assistance with pain appraisal), but each of these was mentioned only once.

When athletes were asked to offer rehabilitation strategies that would not have worked for them, 21 (58%) indicated that threats and scare tactics are not effective. These results add further support to the problematic nature of negative motivation. Rehabilitation without direct athletic trainer supervision was mentioned by five (14%) of the athletes, again consolidating earlier discussion. Numerous other items were mentioned, but none that exceeded a single entry.

**Conclusion**

For the most part, athletes’ responses to various aspects of injury rehabilitation mirror those of ATCs. Athletic trainer-athlete rapport, with all that it encompasses, stands out as a primary factor in the treatment adherence equation. Athletes’ self-motivation is important and appears to be of greater magnitude than ATCs suspect, but it is not sufficient to ensure adherence by all athletes. Realistic pain appraisal by athletes, with ATCs’ help, is also important for adherence. Pain, however, does not interfere with the rehabilitation process as much as might be suspected.

Athletes have offered us a naive model of injury rehabilitation. The challenge is to eliminate the barriers to treatment adherence and accentuate those strategies and interactions that will promote enhanced injury rehabilitation adherence.

**Acknowledgements**

This study was supported by a small grant from the Dean’s Research Fund.

| Table 1.—Successful Rehabilitation Strategies or Athletic Trainer Interactions |
|-----------------------------|-----------------------------|-------------|
| Strategies/Interactions | # of Responses | |
| Caring Athletic Trainer Attitude | 15 (42%) | |
| Honest Approach (prognosis, pain) | 9 (25%) | |
| Encouragement | 7 (19%) | |
| Goal Setting | 7 (19%) | |
| Monitor Progress | 5 (14%) | |
| Athletic Trainer Personality | 2 (6%) | |
| Flexible Scheduling | 1 (3%) | |
| Fast Beginning | 1 (3%) | |
| Presence of Audience | 1 (3%) | |
| Trust in Athletic Trainer | 1 (3%) | |
| Explanation of Rehabilitation | 1 (3%) | |
| Personalize Treatment | 1 (3%) | |
| Set Specific Schedules | 1 (3%) | |
| Equipment Availability | 1 (3%) | |
| Convenient Rehabilitation Location | 1 (3%) | |
| Athletic Trainer Present During Rehabilitation | 1 (3%) | |

*Not all athletes offered a response; some offered multiple responses.*

| Table 2.—Rehabilitation Strategies or Athletic Trainer Interactions That Might Have Been Successful If Used |
|-----------------------------|-----------------------------|-------------|
| Strategies/Interactions | # of Responses | |
| None | 16 (44%) | |
| Detailed Explanations | 5 (14%) | |
| More Attention | 4 (11%) | |
| More Athletic Trainer Supervision | 3 (8%) | |
| Pain Appraisal | 2 (6%) | |
| More Motivation | 2 (6%) | |
| Outside Rehabilitation Arrangements | 2 (6%) | |
| Reinforce Adherence | 1 (3%) | |
| Recognize Time Demands | 1 (3%) | |
| Goal Setting | 1 (3%) | |
| Additional Rehabilitation Sessions | 1 (3%) | |
| Start Rehabilitation Earlier | 1 (3%) | |
| Better Equipment Availability | 1 (3%) | |

*Not all athletes offered a response; some offered multiple responses.*
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References
Abstract: Three strength measurement methods for determining muscle strength and imbalance ratios of the knee were compared in 41 (23 female, 18 male) NCAA Division I track and field athletes. Peak quadriceps extension and hamstring flexions were measured isotonically, isometrically, and isokinetically. Isokinetic measurements were performed on a Cybex II at 60°/s. Isometric extension and flexion measurements were performed using the Nicholas Manual Muscle Tester (Lafayette Instruments; Lafayette, Ind). Isotonic measurements were done on both Universal and Nautilus apparatuses. Testing order was randomized to avoid a treatment order effect. A repeated measures ANOVA and a post hoc Tukey test were used to compare the three methods of assessing strength and imbalance ratios of the knee. Absolute strength values were significantly different according to gender and mode of testing. Bilateral strength imbalance ratios for knee flexion were significantly lower for the Nautilus leg curl machine. Ipsilateral strength imbalance ratios were significantly greater for the Cybex II. Our results indicated that absolute strength values cannot be interchanged between testing modes. Except for Cybex II (ipsilateral) and Nautilus (bilateral knee flexion), strength imbalance ratios could be interchanged.

The term “muscular strength” usually refers to a measure describing an individual’s ability to exert maximal muscular force, either statically or dynamically. Traditionally, muscle strength is measured by three different methods: isometric, isotonic, and isokinetic. All three methods determine the amount of external load that is overcome as the muscle attempts to contract against resistance. In isometric strength testing, the muscle acts against an immovable resistance at a specific joint angle. Isotonic exercise allows for a complete range of motion, although maximal muscle demand occurs during only a small portion of the movement. Isokinetic strength testing does allow for full muscle tension throughout the range of motion, while holding the speed of movement constant. Because isometric, isotonic, and isokinetic strength testing requires a maximum muscle contraction, a strong relationship would be expected among these three modes of testing. However, while some studies have found moderate to high correlations, other studies have not produced the same results.

Although isometric and isotonic testing methods are being used, the isokinetic procedure is now the most widely accepted evaluation technique. Unfortunately, isokinetic equipment is expensive and not readily accessible to most athletes. Therefore, the purpose of this study was to compare the three methods of measuring strength to determine if absolute strength values and strength imbalance ratios could be interchanged between testing modes.

Methods
Forty-one NCAA Division I varsity track and field athletes (23 female, 18 male) volunteered to participate in this study. None of the athletes had sustained a knee injury. We informed the subjects of risks associated with the testing, and they gave informed consent prior to participation. One procedure was performed on each testing day, and no less than 3 days’ rest was given between testing sessions.

Isometric Testing Procedures
We used the Nicholas Manual Muscle Tester (Lafayette Instrument; Lafayette, Ind) to test maximal isometric knee extension and flexion. For knee extension, the subject sat in a Cybex chair. The angle between the back and the seat of the Cybex chair was 110°. The subject was secured with velcro straps across the chest, directly under each arm, across the pelvis, and over the thigh at a point 6 to 8 cm proximal to the superior aspect of the patella. Each strap was adjusted to ensure subject stability and to prevent extraneous movement. With the knee fully extended, the Manual Muscle tester was placed between the examiner’s hand and the subject’s leg, four to six cm proximal to the malleoli (Fig 1). We applied a downward force over 1 second to allow the subject to adjust and recruit the maximum amount of muscle fibers. Additional force was applied until the muscle contraction...
Fig 1.—Starting position for knee extension isometric testing using the Manual Muscle Tester.

Fig 2.—Ending position for knee extension isometric testing using the Manual Muscle Tester.

Fig 3.—Starting position for knee flexion isometric testing using the Manual Muscle Tester.

Fig 4.—Universal leg extension/curl machine.

Fig 5.—Nautilus leg extension machine.

Fig 6.—Nautilus leg curl machine.

began to break and the limb began to lower. Further force completely lowered the limb, and the test ended before the limb touched the Cybex chair (Fig 2). We instructed the subject that the test was over when the limb had been lowered. Testing lasted no longer than 3 seconds. The peak force achieved was recorded as the maximum strength effort for that motion.\textsuperscript{1,10}

To test maximal knee flexion, subjects lay prone on the Cybex II Upper Body Exercise and Testing Table. Velcro straps across the back, directly under each arm, across the pelvis, and over the thighs at a point 6 to 8 cm proximal to the superior aspect of the patella secured the subject. Each strap was adjusted to ensure subject stability and to prevent extraneous movement. With the knee fully flexed, we placed the Manual Muscle Tester between the examiner’s hand and the subject’s leg, 4 to 6 cm proximal to the malleoli (Fig 3). We applied a downward force using the same techniques described earlier and ending before the limb touched the testing table. The peak force achieved was recorded as the maximum strength effort for that motion.\textsuperscript{1,10}

**Isotonic Testing Procedures**

One repetition maximum (1RM) isotonic strength was measured with both Universal (Universal Gym Equipment, Inc; Cedar Rapids, Iowa) and Nautilus (Nautilus Sports/Medical Industries; Deland, Fla). Leg Extension and Leg Curl machines (Figs 4-6). The subjects warmed up for 5 minutes prior to testing. Leg order and movement were randomized to avoid a treatment order effect.

To measure quadriceps strength, the subject sat on the Leg Extension machine with the knee flexed at a 90° angle (full extension = 0°), with the lever arm of the device resting on the tibia of the lifting leg just proximal to the malleoli. To measure hamstring strength, the subject lay prone on the Leg Curl machine, with the lever arm across the Achilles tendon of the lifting leg. The maximum amount of weight
that could be moved through a 90° range of motion in 3 seconds and held for a duration of 2 seconds was recorded as the one repetition maximum (1RM).12

**Table 1.—Knee Flexion and Extension Strength Measures (Mean ± SD)**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Males* (lbs; n=18)</th>
<th>Females* (lbs; n=23)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>dominant</td>
<td>nondominant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dominant</td>
</tr>
<tr>
<td>Knee Extension (Quadriceps)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cybex II</td>
<td>190.0±34.1</td>
<td>188.3±36.9</td>
</tr>
<tr>
<td>Manual Muscle Tester</td>
<td>124.2±27.1</td>
<td>121.7±26.4</td>
</tr>
<tr>
<td>Nautilus</td>
<td>105.6±22.8</td>
<td>105.6±23.3</td>
</tr>
<tr>
<td>Universal</td>
<td>76.1±25.0</td>
<td>74.4±27.3</td>
</tr>
<tr>
<td>Knee Flexion (Hamstrings)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cybex II</td>
<td>117.3±22.0</td>
<td>115.4±21.8</td>
</tr>
<tr>
<td>Manual Muscle Tester</td>
<td>69.0±13.0</td>
<td>69.7±16.2</td>
</tr>
<tr>
<td>Nautilus</td>
<td>54.4±13.4</td>
<td>52.8±14.1</td>
</tr>
<tr>
<td>Universal</td>
<td>40.6±11.6</td>
<td>38.3±12.0</td>
</tr>
</tbody>
</table>

* males and females different (p<.05)

**Table 2.—Strength Imbalance Ratios of the Knee**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Knee Flexion Dominant vs nondominant (%)</th>
<th>Ham/quad (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual Muscle Tester</td>
<td>100.8</td>
<td>56.7</td>
</tr>
<tr>
<td>Cybex II</td>
<td>99.5</td>
<td>61.9*</td>
</tr>
<tr>
<td>Universal</td>
<td>96.1</td>
<td>54.0</td>
</tr>
<tr>
<td>Nautilus</td>
<td>93.2*</td>
<td>53.9</td>
</tr>
</tbody>
</table>

*Statistically different from other 3 (p<.05)

**Isokinetic Testing Procedures**

Isokinetic testing was conducted using a Cybex II. The angle between the back and the seat of the Cybex chair was 110°. The subject was secured by velcro straps across the chest, directly under each arm, across the pelvis, and over the thigh at a point 6 to 8 cm proximal to the superior aspect of the patella. We adjusted each strap to ensure subject stability and to prevent extraneous movement. The shin pad of the dynamometer was adjusted for leg length so that the lower edge of the pad was 4 to 6 cm proximal to the malleoli and secured to the tibia by a strap around

the lower leg. We aligned the rotational axis of the knee joint with the input shaft of the dynamometer. Subjects were asked to cross their arms over their chest (Fig 7).

Testing began after a 5-minute dynamic warm-up consisting of knee extension and flexion against minimal resistance. The speed selector was set at 60°/s. A damping setting of two and chart speed of 5 mm/s was used. Three maximal extension-flexion trials in succession were performed. The highest torque generated in each movement was recorded from the strip chart recording. We did not correct for the effect of gravity.12

A repeated measure ANOVA and a post hoc Tukey test were used to compare the three methods of assessing strength and imbalance ratios of the knee.

**Results**

Knee flexion strength of the dominant leg (x=56.6 lb) was significantly greater than the nondominant leg (x=55.4 lb; F[3,117]=5.39, p=.03). There was no difference in knee extension strength between dominant and nondominant legs (F[3,117]=0.01, p=.91). There was no interaction, however, between leg strength and either gender or testing technique for either knee flexion (F[3,117]=0.90, p=.44) or knee extension (F[3,117]=1.04, p=.38). Therefore, dominant and nondominant strength measurements were combined.

There was a significant interaction between gender and testing technique (mode); each mode was significantly different from each other, and males were significantly stronger than females (Table 1; Knee flexion, F[3,117]=16.29, p<.0001; Tukey p<.05). Knee extension strength of dominant and nondominant legs was not significantly different (F[3,117]=1.04, p=.38) with either gender and testing technique.

The bilateral strength imbalance ratios for knee extension were not different between testing devices (modes) (F[3,117]=1.42, p=.42) or gender (F[3,117]=0.35, p=.56). Knee flexion showed a significant difference be-
tween testing technique (mode); Nautilus recorded significantly lower values than the other three modes (Table 2; F[3,117]=3.40, p=.02; Tukey p<.05). The ipsilateral strength imbalance ratios for knee flexion/extension showed a significant difference between testing devices (mode); Cybex II produced significantly greater ratios than the other techniques (F[3,117]=7.65, p<.0001; Tukey p<.05) (Table 2). There was no significant difference (F[1,39]=0.15, p=.70) for gender.

Reliability for the Manual Muscle Tester and Cybex II were .96 and .97, respectively.

Discussion

Isometric, isotonic, and isokinetic strength testing methods have been studied extensively. A limited number of studies, however, have compared the three methods. These studies indicate that the absolute strength values of the three measurement techniques are unique in what they measure and should not be generalized from one method of strength assessment to another. Our results confirm this (Table 1). The higher absolute measures of both the Cybex II and the Manual Muscle tester might be attributed to what and how they measure strength. The Cybex II measurements of foot-pounds were not converted to pounds, and the Manual Muscle Tester measured an eccentric contraction instead of a concentric, as described by Nicholas. Eccentric contractions have been shown to record higher contractile strength than concentric. Further studies are indicated to compare these three absolute measurements.

Even though the absolute strength values between testing techniques were significantly different, the information gained from testing muscular strength can be used to assess an athlete’s muscular strength imbalance. The ratio of strength of the antagonist to agonist is used for determining an ipsilateral muscle imbalance, while the contralateral strength of the corresponding muscles is used to determine bilateral imbalance.

Except for Nunn and Mayhew, previous studies have compared the three methods of strength evaluation for computing muscle imbalance ratios. Reliability for the Manual Muscle Tester and Cybex II was determined by the test/retest method. The test was recorded 3 days prior to the initial test. We did not perform a retest for both the Nautilus and Universal leg machines. Therefore, reliability for these modes was not determined for this study. Even though the absolute strength values among the three methods might be different, if the proportion of strength between the hamstrings and quadriceps was constant, the bilateral and ipsilateral muscle strength ratios would be comparable. The various methods then could be used interchangeably in evaluating muscle strength imbalance in athletes. In the study by Nunn and Mayhew, none of the bilateral imbalance ratios were significantly different for the three methods tested, isometric (Cybex II), isotonic (Nautilus), and isokinetic (Cybex II).

Our study differs in that the Manual Muscle tester was used for isometric testing in place of the Cybex II, and that Universal isotonic measurements were also collected. Our results agree with Nunn and Mayhew that isometric, isotonic (Universal and Nautilus), and isokinetic (Cybex II) could be used interchangeably to evaluate the bilateral muscle strength imbalance for knee extension. However, the Nautilus showed a significantly lower bilateral ratio for knee flexion than the other methods tested (Table 2) and should not be used interchangeably. For ipsilateral strength ratios, however, the isokinetic (Cybex II) method produced significantly greater values of measurement than the other methods (Table 2). Nunn and Mayhew reported the same results for ipsilateral strength ratios. According to our results, the isokinetic (Cybex II) ipsilateral strength ratios should not be used interchangeably with other strength measurement techniques.

We conclude that:

1. bilateral strength imbalance ratios for knee extension can be determined using either isometric (Manual Muscle Tester), isotonic (Universal or Nautilus), or isokinetic (Cybex II) techniques interchangeably;
2. bilateral strength imbalance ratios for knee flexion can be determined using either isometric (Manual Muscle tester), isotonic (Universal), or isokinetic (Cybex II) techniques interchangeably; and
3. ipsilateral strength imbalance ratios of the knee can be determined using either isometric (Manual Muscle Tester) or isotonic (Universal or Nautilus) techniques interchangeably.

References

3. Clarke DH. Correlation between strength/mass ratio and speed of arm movement. Res Q. 1960;31:530-534
15. Smith LE, Whitley JD. Relation between muscular force of limb, under different starting conditions, and speed of movement. Res Q. 1963;34:489-496
Abstract: The purpose of this study was to dynamically examine various offset angles on the N-K table to determine which offset produces a torque pattern corresponding most closely to the isokinetic torque curve of the knee flexor musculature when tested at 60°/s. Subjects for the study were five college-age male volunteers (age=21.8±1.8 yrs, ht=181.9±4.3 cm, wt=88.4±12.6 kg). Mean peak isokinetic torque values for the five subjects were measured at 5° increments to represent the human knee flexor torque curve. These were converted to relative mean values by dividing each value by the maximum mean peak torque. Torque curves from four offset angles (90°, 110°, 135°, and 160°) for the N-K table were obtained by using the Kin Com in the passive mode at 20°/s to push the exercise arm of the N-K table through a range of motion of 0° to 90° while recording torque and angular position. The four torque curves were converted to relative values in a similar manner as for the subjects. Qualitative analysis reveals that the 160° offset angle most closely corresponded to the representative knee flexor isokinetic torque curve, while the 90° offset angle corresponded least. Although these findings would seem to support reconsideration of common clinical practice relative to the use of the N-K table for knee flexor strength development, the 160° offset angle is awkward because it has a tendency to force the user into hyperextension at the beginning phase of motion. As such, practical compromises might include the use of the 110° or 135° offset angle in lieu of the traditionally employed 90° offset angle, or the development of an extension stop that would prevent hyperextension of the knee.

Strength development is an important aspect of most rehabilitation programs. To optimize strength gains, many clinicians use several forms of training, including isometric, isotonic, and isokinetic exercises. Of these, isotonics might be the most widely employed strength training method. Lamb defines an isotonic exercise as one in which a constant load is moved through a range of motion. As such, practical compromises might include the use of the 110° or 135° offset angle in lieu of the traditionally employed 90° offset angle, or the development of an extension stop that would prevent hyperextension of the knee.

In 1954, Noland and Kuckhoff introduced an innovative isotonic resistance device known as the N-K table which still is used widely today. It was designed to make progressive resistance exercises for the quadriceps and hamstring muscle groups more convenient and efficient. The unique aspect of the N-K table is the adjustable lever arm that holds the weight and is, thus, termed the "resistance arm." This is separate from the "exercise arm," which is the arm that contacts the user. The resistance and exercise arms can be offset from one another at various angles by rotating the interface cam into position, where a pin connects the two arms. As the relationship of the two lever arms is altered, so is the point in the range of motion at which maximum resistance is realized. In terms of biomechanics, maximum resistance is reached when the resistance arm is horizontal to the floor. The question, then, is: "At what offset angle between the resistance and exercise arms does the maximum resistance most closely correspond to the strongest point in the human strength curve?" A thorough understanding of how torque patterns vary at different offset angles and how this relates to the torque curves for the knee flexor musculature is of obvious clinical significance.

Few studies have examined the torque patterns produced by various isotonic machines. Harman performed a torque analysis of five Nautilus machines and concluded that cam shapes would need considerable modification if they were to more closely match human strength curves as purported by the manufacturer. Lurvey et al. examined forces required to lift a weight through a range of motion on the N-K table, Nautilus and Universal knee extension machines. The N-K table was the only machine found to approximate the normal human strength curve for the knee extensors. Medvick and Stauber examined the N-K table to...
determine the optimal position of the resistance arm relative to the exercise arm to best match the knee extensor strength curve. They determined the optimal angle to be 55°. Only one study could be found that examined the optimal offset angle corresponding to the torque curve for the knee flexor musculature. Noland and Kuckhoff,9 in their article introducing the device, stated that they found an offset angle of 160° to "create a resistance curve" most closely paralleling the joint torque curves described by Clarke et al,1>2, but did not state how this was determined.

Clarke et al1>2 created isometric strength curves from tests of several subjects at various points throughout the range of motion. To our knowledge, the optimal offset angle corresponding to the strength curve for the knee flexor musculature has not been examined dynamically. The purpose of this study was to examine dynamically various offset angles to determine which offset produces a torque pattern most closely corresponding to the dynamic torque curve of the knee flexor musculature.

**Methods**

Subjects for this study included five college-age male volunteers (age=21.8±1.8 yrs, ht=181.9±4.3 cm, wt=88.4±12.6 kg). Subjects were free from history of knee injury, and each subject signed an informed consent document. The study was conducted according to institutional guidelines.

The instrumentation, procedures, and data analysis for this study were similar to that of Medvick and Stauber.8 Human torque curves for knee flexion were obtained on the Kinetic Communicator computer-controlled isokinetic dynamometer (Kin Com; Chattecx Corporation; Chattanooga, Tenn). The isokinetic mode was selected because it allows reliable quantification of human muscle performance.10 Subjects only participated in the isokinetic trial. Torque curves for the N-K table (N-K Products Co, Inc; Soquel, Calif) were obtained from two tests with four different offset angles. The Kin Com dynamometer’s passive mode was used to push the exercise arm through a range of motion of 0° to 90° of knee flexion, while recording the force and angular position with respect to time.

Reproducibility was measured by performing a test/retest comparison of the torque curves produced between the two trials for the N-K table. The difference in the torque curves produced between trials was calculated by the Kin Com to be 3% for the 90° offset angle, and 0% for the 110°, 135°, and 160° offset angles.

To obtain the isokinetic torque curves for knee flexion, each subject was seated on the Kin Com with his/her knee flexed to 90°. The axis of rotation of the mechanical arm of the dynamometer was set approximately 2 cm inferior and 2 cm posterior to the anatomical axis of the knee. The Kin Com lever arm was aligned with the shin pad and secured to the subject’s lower leg approximately 5 cm superior to the medial malleolus. Lever arm length was recorded for each subject. Subjects were stabilized by a strap over the anterior thigh just proximal to the patella and by a strap across the pelvis. Subjects performed the testing with their arms crossed over their chest, while viewing the monitor. Consistent verbal encouragement was provided to maximize effort. The interrupted concentric/concentric protocol was used with standard Kin Com overlay. For familiarization and warm-up, each subject performed five sub-maximal contractions for extension and flexion, followed by two maximal contractions for extension and flexion, respectively. Following a 1-minute rest, each subject performed five maximal test repetitions. A 5-second pause separated each movement of extension and flexion to allow the subject to rest between each effort. Only torque curves generated during the knee flexion contractions were used for this study.

To obtain torque curves for the N-K table, the exercise arm of the N-K table was secured to the lever arm of the Kin Com (Fig 1). It was necessary to reverse the orientation of the exercise arm relative to the resistance arm so that the resistance arm was on the inside. It was also necessary to remove the padded seat structures from both the N-K table and the Kin Com. Several 45-lb weights were placed on the base of the N-K table to stabilize it. The mechanical axes of rotation for the two machines were aligned. The resistance arm of the N-K table was loaded with 10 lbs. Trials were conducted with the Kin Com in the passive mode at 20°/s, moving the exercise arm through a range of motion of 0° to 90°. The 20°/s speed was used because it was determined in trial testing to be the fastest speed that did not compromise the stability of the set-up, and is consistent with the findings of Medvick and Stauber.8 The offset angles were 90°,
110°, 135°, and 160°. The Kin Com recorded the force and angular position with respect to time and calculated the values relative to torque and angle.

Mean isokinetic torque values were calculated by the Kin Com at 5° increments throughout the range of motion for each subject’s three repetition overlay. These values were used to calculate mean torque values for all subjects at 5° increments throughout the range of motion in order to create a representative torque curve for the knee flexor musculature. These values were converted to relative mean values by dividing each value by the mean peak torque. For example, the mean torque value at 50° of 53.2 Nm was divided by the mean peak torque of 66.6 Nm, resulting in a relative mean value of .8. This procedure allowed varying amounts of absolute torque to be compared in a torque-position relationship of the same magnitude.9 Torque curves for the N-K Table were obtained by recording the peak torque from one trial at each of the four offset angles at 5° increments throughout the range of motion. Four relative torque curves were generated for the N-K table in a manner similar to the isokinetic torque curves generated by the subjects. Torque values for the first and last five degrees of the 0° to 90° range of motion were excluded from comparison for two reasons. The first was to minimize the acceleration/deceleration artifact when testing the subjects isokinetically, and the second was the result of a delay in engagement between the resistance arm and exercise arm of the N-K table when testing it.

Results

The representative isokinetic torque curve for the five subjects was an ascending-descending shaped curve (ROM=0° to 90°) that was primarily descending in nature. Peak torque in this curve occurred at approximately 15° of knee flexion (Fig 2).

The N-K table’s offset angle of 90°, which is used often for knee flexion exercise clinically, produced an ascending curve which reached peak torque between 80° to 85° of knee flexion (Fig 2). The curve produced at the 110° offset angle was also primarily ascending in nature, reaching peak torque between 60° and 80° of knee flexion before descending slightly at 85° of knee flexion (Fig 2). When the lever arms of the N-K table offset one another by 135°, the resultant torque curve ascended to a peak torque at 30° of knee flexion, and maintained that peak torque through 55° of knee flexion before descending through the remainder of the range of motion (Fig 3). Finally, at the 160° offset angle, an ascending-descending torque curve was produced that was primarily descending in nature, reaching peak torque between 10° and 15° of knee flexion (Fig 3).

Discussion

Qualitative analysis suggested that the 160° offset angle most closely corresponded to the representative knee

Fig 2.—The isokinetic human knee flexor torque curve contrasted with the torque curves produced with 90° and 110° offset angles on the N-K table.

Fig 3.—The isokinetic human knee flexor torque curve contrasted with the torque curves produced with 135° and 160° offset angles on the N-K table.
flexor isokinetic torque curve. The 90° offset angle corresponded least to the representative torque curve. These findings are consistent with those of Noland and Kuckhoff, although it is not stated in their paper how they determined the optimal offset angle, and they compared offset angles to an isometrically derived torque curve in contrast to our dynamically derived representative knee flexor torque curve. Although the findings of this study seem to support our dynamically derived representative torque curve, the user into knee hyperextension at the beginning of the exercise motion. As such, our clinical impression is that a practical compromise might be to employ either the 110° or 135° offset angle in lieu of the traditionally employed 90° offset angle. Perhaps equipment modification in the form of a range of motion stop would eliminate the problem of forced hyperextension of the knee and would allow safe and effective use of the 160° offset angle.

Little information is available regarding seated knee flexion torque curves, particularly concerning the point in the range of motion at which peak torque is normally realized. The representative torque curve found in this study was derived from a small population of college-age male subjects and, therefore, might or might not be typical of the population at large. In addition, it is well documented in the literature that torque production varies widely as a function of test velocity. For this reason, further research is needed to establish normative data for torque curves and angles of peak torque production for seated knee flexion exercise at various test speeds. In terms of clinical importance, further research considerations also might include a training study to examine the differences between the offset angles and their effect on strength development.

The "play" in the mechanism between the resistance and exercise arms of the N-K table occurred because the N-K table used in this study was old and had some movement in the mechanism between the resistance and exercise arms. Thus, it was necessary for the Kin Com, in the passive mode, to pick up the slack in the system during the first few degrees of the motion before encountering resistance. It is interesting to note that the model of N-K table used in this study did not have consistent distances between offsets, with the first two offsets being 20° apart, and the distance between the second and third, and third and fourth offsets being 25° apart. This odd design was apparent in all three machines of the same model available to us and possibly might be attributed to wear-and-tear changes on the machines over time. Ideally, the two lever arms could offset one another at every 5° or 10°. This would allow for more flexibility in the use of the machine and more accurate testing to determine the offset which most closely approximates the knee flexor torque curve.

Torque curves for various offset angles of the N-K table for knee extension exercise have been established by the work of Medvick and Stauber. Our study documents the torque curves produced for various offset angles for knee flexion exercise, and supports alteration of the use of the N-K table for common clinical practice. Further research is needed to confirm this possibility.

References
Abstract: Clinicians commonly use electrical stimulation (ES) to control acute edema. But, except for anecdotal reports, there is little evidence to support that practice. We recently conducted a series of controlled, blinded studies on several nonhuman animal models to determine the efficacy of several forms of ES, but high-voltage pulsed current (HVPC) in particular, in controlling acute posttraumatic edema. We observed that acute posttraumatic edema is curbed by HVPC when certain protocols are used. Results of these studies suggest to us that wave form, polarity, treatment schedule, intensity and frequency of pulses all influence ES, and that clinical protocols need revision.

Athletic trainers and physical therapists are among those who frequently use various forms of electrical stimulation (ES) to control acute edema. High-voltage pulsed current (HVPC) probably has been advocated more than any other form of ES for this application, although to date little evidence has been reported from controlled studies of therapeutic effects for any form of ES for acute edema. Indeed, evidence to support use of ES for edema control is remarkably weak.

Historical Review

Licht\textsuperscript{19} attributed to Murat (1783) the observation that "electrification had been successful in such conditions as... edema of the limbs,..." Unfortunately, neither Licht nor Murat provided any support for this statement. More recently, Newton,\textsuperscript{25} in describing the first HVPC unit from 1945, ascribes to the DynaWave Neuromuscular Stimulator anecdotal evidence that it was useful in treating decubiti, burns, sprains, strains, and pain. Crisler, however, seems to have been the first to provide any clinical evidence that ES was useful for treating "sprains, strains, and charley horses." He claimed "complete relief," usually after only three or fewer treatments of 5 minutes or less on successive days. Crisler reported "vigorous muscular twitching," which he called "deep massage," and attributed the relief of signs and symptoms of sprains and strains to this activity. He also mentioned a vasomotor effect as being important, as well as "a direct nervous effect," but explained neither, nor did he provide references. Crisler used an ultrafaradic M-4 impulse generator, which was capable of generating up to 300V, had a frequency rate of 4-30 pps, and pulse duration of only a few microseconds. Crisler did not specify wave shape other than faradic, but other parameters are typical of high-voltage stimulators.

Newton\textsuperscript{25} suggested that common use of HVPC began in 1974 as a result of a national advertising campaign by Electro-Med Health Industries. It was not until 1981, however, that protocols and rationales for those protocols began to be published. Newton\textsuperscript{25} presented a paper on the theoretical physiological effects of HVPC at the Annual Conference of the American Physical Therapy Association. This paper later was expanded into a monograph\textsuperscript{24} by an HVPC supplier and was provided as part of the documentation with equipment. Alon\textsuperscript{1} also produced a seemingly influential monograph on HVPC that was published by a manufacturer of high-voltage stimulators.

Alon\textsuperscript{1} discussed a variety of applications of HVPC, but cited Crisler\textsuperscript{9} as the sole reference to support use of HVPC for edema control. Soon after Newton's and Alon's works came a series of papers that extolled the virtue of incorporating HVPC into existing regimens. Brown\textsuperscript{7} claimed that HVPC (and intermittent compression) "in conjunction with other rehabilitation techniques have proved very effective in reducing edema and speeding recovery," but cited only Alon,\textsuperscript{1} who in turn cited only Crisler.\textsuperscript{9} Brown,\textsuperscript{7} apparently unaware that he was working with two active electrodes of the same polarity, advocated reversing polarity for 15 minutes after an initial 15 minutes of stimulation to tolerance and concomitant intermittent pressure (from Jobst boot). He suggested that alternating polarity served to speed healing by moving interstitial fluid, thereby decreasing pooling, adhesions, and pain. The editor (Knight) noted that some of the points presented by Brown were only conjecture and that there were no "substantial data to indicate the effectiveness of these treatments;..." However, Knight went on to say that many respected clinicians claimed success in reducing edema with HVPC. Ross and Segal\textsuperscript{29} claimed "remarkable" results treating postoperative patients for pain, edema, and wound healing using HVPC. These authors concluded that HVPC is similar to galvanic current (ie, direct current) and attributed a variety of "polar effects" to HVPC. On the basis of these presumed attributes, Ross and Segal developed protocols that brought these reputed effects to bear. They provided two case histories. Finally, Quillen (1981 and 1982, cited in Alon and DeDomenico)
is stated by Alon to have resolved swelling of Grade I and II sprains in an average of 3 to 4 days using sensory-level stimulation.

Lamboni and Harris\textsuperscript{18} claimed that the effects of ice, elevation, and compression could be made "even more efficient" in reducing effusion with the addition of HVPC, but cited no references. They postulated that muscle contractions evoked by HVPC "... 'milks' the exudate from the area, increasing lymphatic drainage," and that the stimulation promotes production of "... enkephalins (sic), which is the body's natural anti-inflammatory agent." They provided no references to support this alleged action for enkephalins.

Newton and Karselis\textsuperscript{26} examined effects of HVPC on the pH of skin under electrodes and concluded that no polarizing effects were detectable at these sites after 30 minutes of continuous cathodal HVPC at 100V and 80-82 pps. Although not directly related to use of ES for control of edema, observations made by Newton and Karselis seemed to counter the belief that HVPC produced long-lasting polar effects, ie, produced electrical fields capable of inducing unidirectional migration of ions.

Santiesteban et al\textsuperscript{30} compared the efficacy of medium frequency interferential current with cold compression and contrast baths in reducing pain and swelling and increasing ROM in subacute ankle sprains. It is unclear how this experiment was executed, but it seems that there were only four people in each group. Treatment protocols for each group were unspecified, as were degree of injury and time elapsed since injury. The authors concluded, however, that medium frequency interferential current was at least as effective as cold compression and contrast baths.

Voight\textsuperscript{19} noted that use of HVPC for post-traumatic edema had been reported by many, citing Crisler, Alon, Brown, and Gieck,\textsuperscript{17} but characterized these reports as "subjective evaluations" and not based on thorough research. Seemingly on the basis of those subjective evaluations, however, Voight concluded that clinically, HVPC seemed to change capillary fluid dynamics, which resulted in reduction in edema. He then speculated that HVPC might retard blood flow into extracellular spaces by enhancing clotting, inducing vasoconstriction by stimulating sympathetics, and repelling negatively charged plasma proteins, thereby preventing them from leaving capillaries or dispersing them once they had escaped. Voight further speculated that positive polarity might facilitate thrombus formation, but enhance leakage of negatively charged plasma proteins. (Negative polarity might repulse plasma proteins, but prolong time for thrombus formation.) In other words, Voight assumed that HVPC had polarizing effects like direct current. His proposed protocol was to alternate positive and negative stimulation (to achieve benefits and minimize disadvantages of both) at 60-80 pps at tolerance or at submotor level "to ensure that no further aggravation of the tissues takes place" for 20 to 30 minutes, but conceded that the best time was unknown.

Ralston\textsuperscript{27} noted that little was published on the use of HVPC, so he conducted a survey of 19 athletic trainers to determine how and why HVPC was being applied. Most followed the instructions provided with their stimulators. Ralston concluded that, "There is very little, if any, 'state of the art' research published that gives definitive uses for high voltage galvanic stimulation." He then, mysteriously, went on to say, "A protocol for the most effective use of high voltage galvanic stimulation can, in fact, be synthesized from the knowledge we possess on the subject today." He proceeded to list various protocols.

Mohr et al\textsuperscript{21} were apparently the first to conduct controlled experiments to determine the effect of HVPC on existing edema. Specifically, they attempted to ascertain whether HVPC could accelerate resolution of already resolving edema. They traumatized one hind limb of a series of rats, and after 24, 48, and 72 hours, treated half the animals with cathodal HVPC at 80 pps, 40V for 20 minutes. Animals were unrestrained except during treatment so that muscle activity might have influenced outcomes, but they reported that volumes of treated limbs did not differ significantly from those of untreated limbs. This led them to conclude that more research was needed and that HVPC was at least not "contraindicated in the treatment of traumatic edema."\textsuperscript{22}

Alon and DeDomenico\textsuperscript{1} provided some physiological rationale for why HVPC might be applied to control edema, and then, after noting that this rationale was as yet unsubstantiated, suggested several provisional protocols. After reviewing the supporting literature (again Crisler and Quillen, 1981,1982), they concluded that: "Present data concerning the specific value of TENS in edema or joint effusion absorption are so limited that one must wait for future studies to confirm or refute the claims for its effectiveness."

Michlovitz et al\textsuperscript{21} compared ice and ice plus HVPC in the treatment of grade I and II acute lateral ankle sprains. Ankles of 10 subjects were elevated and received ice and wrap for 30 minutes on each of 3 consecutive days; ankles of 10 others were elevated and received ice and HVPC at submotor levels and 28 pps; ankles of 10 others received the same treatment as group II except their HVPC was administered at 80 pps. Volumes of ankles in each of the three groups were reported not to be significantly different after the first and third treatments. However, changes in volume following treatments were frequently less than the measurement error determined during reliability testing. Conclusions based on volume measurements are, therefore, suspect. Range of dorsiflexion and decreases in pain did not differ among groups.

Gieck and Saliba\textsuperscript{15} described various forms of ES and their reputed applications; only HVPC was listed among those forms of ES as a viable mode for edema modulation. They endorsed its use for this purpose by stating that they used it in their clinic, but included only Newton\textsuperscript{23,24} and a manufacturer's guide book\textsuperscript{17} in their references.

Griffin et al\textsuperscript{15} seem to have been the first to observe a "clinically significant," albeit not a statistically significant, treatment effect for HVPC in reducing chronic rather than acute edema. These investigators only examined 10 people in each of three test
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groups (intermittent pneumatic compression, HVPC, and sham-HVPC) and still just missed achieving a significant treatment effect for HVPC, ie, there were not significant differences between intermittent pneumatic compression and HVPC or between HVPC and placebo-HVPC, but differences were significant between intermittent pneumatic compression and placebo-HVPC. These results were promising, but not yet conclusive.

Finally, Cosgrove et al8 examined the effects on trauma-induced edema of monophasic pulsed current and symmetrical biphasic pulsed current relative to a control. Like Mohr et al,22 they examined the influence of ES on already resolving edema. They administered submotor stimulation or sham treatment to rat hind paws for one hour at 24, 48, and 72 hours post-trauma. They used submotor stimulation to "isolate effect of electokinetic influences on protein mobility," but let animals move about freely between treatments, ie, voluntarily induced muscle pump effects. Based on volume measurements performed before each treatment, they concluded that there were no significant differences between monophasic pulsed current and control groups or between monophasic pulsed current and symmetrical biphasic pulsed current groups in accelerating diminution of naturally resolving edema. They went on to proclaim that "...procedures currently used in the clinic do not significantly reduce existing edema caused by trauma in rat hind limbs."

Despite a lack of supporting evidence, HVPC continues to be promulgated in current texts, eg,2,3,13,25 as viable therapies for acute edema, although others are more cautious, eg,3,10,31

In summary, clinicians have been and continue to use ES, HVPC in particular, to control edema, although there were no controlled studies that clearly demonstrated the efficacy of this modality. An optimal protocol using HVPC for any edematous condition was, therefore, unknown.

Our Research

It was with this background in mind that we began a series of studies designed to determine if ES, and HVPC in particular, affect edema. Demonstration of clinical efficacy of any form of ES for control of acute edema requires control for such variables as age, sex, health, severity of injury, time from injury to treatment, site of injury, and differences in physiology from one individual to the next. Studies of animals permit much greater control of variables and, hence, require much smaller samples and far less time and expense. Use of these models requires the assumption that the physiology of the model specified is sufficiently similar to that of humans, that a therapeutic effect in the model is likely to be manifested in humans as well. With those caveats well in mind, we began our investigations. The remainder of this communication is a summary of those investigations using frogs and...
rats as models. We believe that results of these studies are potentially relevant to those who treat acute edema, and, at a minimum, provide a strong rationale for clinical trials.

Summary of Methods
The procedure for all studies was the same. We anesthetized the animals, painted lines on their legs, measured volume displacement of their feet and legs, and traumatized both feet of each animal using a uniform method (weight drop or hyperflexion). We then randomly selected one limb for treatment, usually beginning a series of 30-minute treatments interspersed with 30-minute or 60-minute rests. We measured limb volumes (using water displacement) immediately after trauma and after every treatment and rest, sometimes up to 24 hours postinjury. We statistically compared treated and untreated limb volume changes (mL/kg body weight).

We anesthetized frogs by immersion in aqueous solutions of MS222 (3 amino benzoic acid ethyl ester; 3 g/L water), and anesthetized rats with intraperitoneal injections of Inactin. Anesthesia could be maintained in frogs and anesthetized rats with in-water baths or 60-minute rests. We collected the water that subsequently spilled from the overflow chamber into a small beaker and weighed it on a microbalance. We determined the reliability of this volume measurement system by performing 30 repeated measurements on each of four untraumatized frog hind limbs. The coefficient of variation ranged from 0.79% to 1.01% (mean=0.88%), or an ANOVA-based intraclass correlation coefficient of 0.995. Measuring both limbs of a rat 20 times produced an intraclass correlation coefficient of 0.99.

Typically, we induced trauma by dropping a steel rod through a vertical tube from a uniform height onto the plantar aspect of a foot just distal to the malleoli. In one study, however, we induced sprains by hyperflexing ankle joints of frogs with a motor that forced feet through a uniform range of motion at a uniform rate.

We randomly assigned limbs to treatment or control. We then immersed hind limbs of an animal in water-filled beakers. We placed carbon-rubber electrodes in these beakers so that water in the beakers served as distal electrodes, ie, immersion technique. This technique circumvented problems in maintaining contact of surface electrodes on small, irregularly shaped body parts and difficulties in applying electrodes for long periods. Moreover, it allowed us to repeatedly immerse unencumbered limbs for measurement of limb volumes with no manipulation of those limbs. In all but one study,11 water in the immersion beakers served as the cathode (electrode with abundance of electrons and hence a negative charge).

Typically, we began a series of four, 30-minute treatments within 10 minutes after injury. Individual treatments were followed by either 30-minute or 60-minute rest periods. In one study,4 we delayed 4.5 hours post-trauma and then administered treatment for 6 continuous hours. In another study,32 we administered only a single 30-minute treatment immediately after trauma was induced. At commencement of each treatment, we immersed hind limbs in separate beakers and slowly increased voltage until we observed minimal limb movement in both limbs, ie, we determined grossly visible motor threshold. We randomly selected a limb to receive stimulation at 90% of motor threshold in all but one of our studies.33 In that one exception,9 we exceeded motor threshold to induce twitches. Having brought the control limb to motor threshold, we stimulated it no further.

We generally provided stimulation via Intelect 500S (Chattanooga Corp; P.O. Box 4287; Chattanooga, TN 37405) high-voltage stimulators. Output consisted of pulses, each comprised of two fast-rising phases of 5μs and 8μs duration separated by an intrapulse interval of 75μs. We delivered these pulses at 120 pps except in the study in which we exceeded motor threshold: in that investigation we delivered them at 1 pps. In the only instance in which we did not use HVPC,16 we used a low-voltage pulsed current (LVPC) machine (NTRON 8100; Henley International; 104 Industrial Blvd; Sugarland, TX
77478) capable of producing no more than approximately 100 V. This machine was modified by adding an internal bridge to produce double-peaked monophasic pulses of negative polarity (deviate in only negative direction from zero current baseline). Here, "effective" pulse duration was 620-630µs because interphase duration was virtually zero. We applied dispersive electrodes to the skin overlying hips or we placed them in the bottom of slings that supported the animals throughout data collection, ie, covered much of the belly.

As described earlier, we measured volumes before and after trauma, after each treatment and rest period, and in some cases, for up to 24 hours post-trauma. A person ignorant of limb assignment collected all data. We typically incised skin at ankles and feet just before killing the animals to confirm that volume changes were attributable to edema and not frank bleeding.

We always expressed data as changes from pre-trauma hind limb volumes per kilogram body weight (mL/kg). We used analysis of variance (ANOVA) with repeated measures to test the null hypotheses and we selected a 0.05 level of significance throughout. We also employed various post hoc tests in the different studies.

Summary of Results

Positively Curbed Edema Formation

1. Four, 30-minute treatments of cathodal HVPC, interspersed with 60-minute rests, applied via immersion technique immediately after injury at 120 pps and intensities 10% less than visible motor threshold significantly (F[1,8]=10.41, p=0.003) curbs edema formation following impact injury in frogs6 (Fig 1). Note that several hours after treatments ceased, treated limbs increased slightly in volume, whereas untreated limbs decreased slightly over that time.

2. Four, 30-minute treatments of cathodal HVPC, interspersed with 30-minute rests, applied via immersion technique immediately after injury at 120 pps and intensities 10% less than visible motor threshold significantly (F[11]=18.83, p=0.001) curbs edema formation following ankle injury in rats20 (Fig 2). Four, 30-minute treatments of cathodal HVPC, interspersed with 60-minute rests, applied via immersion technique immediately after injury at 120 pps and intensities 10% less than visible motor threshold significantly (F[1,11]=18.83, p=0.001) curbs edema formation following ankle injury in rats20 (Fig 2).
sprain for up to 24 hours in frogs\(^4\) (Fig 3).

4. A single 30-minute treatment of cathodal HVPC applied via immersion technique immediately after injury at 120 pps and intensities 10% less than visible motor threshold significantly \(F(1,8)=11.32, p=.003\) curbs edema formation following impact injury for more than four hours in frogs\(^12\) (Fig 4).

5. Cathodal HVPC initiated 4.5 hours after injury and applied via immersion technique for six continuous hours at 120 pps and intensities 10% less than visible motor threshold significantly \(F(1,10)=4.146, p=.05\) curbs edema formation following impact injury in frogs\(^5\) (Fig 5).

6. Four, 30-minute treatments of cathodal low voltage pulsed current (LVPC), interspersed with 30-minute rests, applied via immersion technique immediately after injury at 100 pps and intensities 10% less than visible motor threshold do not significantly \(F(1,11)=0.14, p=.71\) curb edema formation following impact injury in frogs\(^6\) (Fig 6).

7. Four, 30-minute treatments of cathodal HVPC, interspersed with 30-minute rests, applied via immersion technique immediately after impact injury at one pps and intensity sufficient to induce muscle twitches do not significantly \(F(1,11)=.04, p=.85\) curb edema formation in frogs\(^7\) (Fig 7).

8. Four, 30-minute treatments of anodal HVPC interspersed with 30-minute rests, applied via immersion technique immediately after injury at 120 pps and intensities 10% less than visible motor threshold fail \(F(1,8)=.02, p=.90\) to curb edema formation following impact injury in frogs\(^8\) (Fig 8).

**Discussion**

Before comparing our results with those of others and hypothesizing the physiologic mechanisms that might underlie our observations, we wish to discuss similarities and differences among our own studies that might be germane to interpreting information in our figures. In our figures, we plot results of individual studies on the composite results of all our studies. The legends contain a more comprehensive explanation. In our first three studies\(^9\) (Figs 1, 2, and 3), we observe a significant reduction in edema formation following impact injury in frogs\(^9\) (Fig 4).
we suspended frogs in slings during treatment and measurements with limbs in dependent position, but we placed them prone during rest periods between and after treatments. Prone positioning might be expected to influence total amount or rate of swelling. Indeed, in our third study, we placed frogs in prone position during the 4.5 hours between trauma and the treatment and again after treatment ceased. The values during the first 4.5 hours for treated and untreated limbs were nearly identical, and both sets of limbs were within the range of treated limbs in all studies in which a treatment effect was evident (Fig 5). This suggests that, at least under certain circumstances, HVPC is as effective in curbing edema as maintaining an edematous part at the level of the heart. Only after treatment began did rates of swelling between treated and untreated limbs begin to diverge. Because of the apparent treatment effect of prone positioning, we maintained animals in their slings with limbs in dependent position throughout all subsequent experiments, ie, Accent numbers of hematomas forced us to reduce the weight and height from which the weight was dropped in our last five studies. Amount and duration of edema among studies are, therefore, not strictly comparable.

In all but one (Fig 2) of our studies in which a treatment effect was evident, both treated and untreated limbs swelled. That is, only in rats did we observe an absolute reduction of edema in treated limbs. In the other studies, swelling was significantly less in treated limbs than in untreated limbs, but swelling was only curbed, not prohibited or reduced, in treated limbs. This curbing lasted varying amounts of time; a single 30-minute treatment significantly curbed edema in treated limbs for at least four hours. This residual effect seemed to be extended when multiple treatments were administered. Treatment effect was clearly finite. At varying times after treatments ceased, volumes of treated and untreated limbs converged.

We believe that clear evidence of a treatment effect in both frogs and rats reflects a common physiologic response to trauma and hence to treatment in these distantly related forms. Frogs and rats have long been studied and used as models for inflammatory response and wound healing in humans. This is not to say that the physiology of frogs and rats does not differ in significant ways from that of humans; thus, results of studies of frogs and rats cannot be applied directly to humans (see for a more complete rationale for nonhuman models and limitations of those models). At a minimum, however, evidence of a treatment effect in both frogs and rats is likely to be predictive of similar effects in humans and, we believe, provide adequate justification for clinical trials.

We believe that our studies are important because, as far as we know, they
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are the first to show, under controlled conditions, a clear treatment effect for sensory-level (i.e., below visible motor threshold) HVPC, or any other form of ES, on acute edema, at least during and for a short time after treatment(s). Others, have only provided testimonials to the efficacy of HVPC in controlling edema. Newton observed increased ROM, but no reduction in edema after HVPC in an uncontrolled study. Mohr et al observed no treatment effect, and Michlovitz et al reported none beyond that of ice. Cosgrove et al observed that neither monophasic pulsed current nor symmetrical biphasic pulsed current reduced existing edema relative to controls. Only Griffin et al observed a "clinically significant" reduction in chronic edema using HVPC at intensities sufficient to induce muscle contractions.

As noted, our studies provide, perhaps for the first time, some justification for using HVPC for treating acute edema. But others, namely Mohr et al and Cosgrove et al, conducted controlled studies and observed no treatment effect for HVPC. We speculate that time of intervention is critical. If Reed is correct in suggesting that HVPC reduces permeability of microvessels, then it might be necessary to reduce that permeability at a time when proteins (with attendant fluids) are escaping the vascular system. That is, HVPC might need to be applied during the acute stage, while proteins and fluids are still being lost from vascular to extravascular spaces. Reducing permeability after proteins and fluids have escaped vascular spaces (i.e., in subacute stage) might even slow resolution of edema by retarding movement of escaped fluid into blood vessels. We typically initiated treatment within minutes, but no more than 4.5 hours, after trauma, whereas Mohr et al and Cosgrove et al waited 24 hours to begin. By this time, edema had reached its peak and might even have been resolving. Unfortunately, Mohr et al and Cosgrove et al measured limb volumes at 24-hour intervals, immediately before treatments. Consequently, we do not know if the ES they administered altered limb volumes during or shortly after treatments. They observed only that no treatment effect was discernible nearly 24 hours after treatment. It is noteworthy that Cosgrove et al reported that mean limb volumes for control rats were less than those for symmetrical biphasic current-treated rats, significantly so at 96 hours post-trauma. The authors note that symmetrical biphasic pulsed current might have had an "adverse effect on edema reduction" and suggest that this effect might result from a lack of residual net charge. In our view, it is also possible that either or both forms of ES administered by Cosgrove et al might have reduced vascular permeability during and for some time after treatments and thereby retarded uptake of fluids back into the vasculature. Hence, limb volumes of treated rats might be expected to exceed those of untreated animals when such treatments are applied in the subacute stage.

Results of some of our studies call into question the protocols commonly used in clinics. None of those protocols have been derived from well-controlled, blinded studies. Several of our studies strongly suggest efficacy, but only begin to suggest guidelines for protocols. However, contrary to recommendations from some sources, polarity seems to be an important variable in the context of using "sensory-level" HVPC for controlling acute edema. Seemingly, not all forms of ES are capable of curbing acute edema, although only one HVPC generator and one non-high voltage application have been examined thus far. If responses of frogs and rats are at all indicative of human responses, then treatment once a day for 30 minutes to an hour is probably not adequate to achieve meaningful benefits.

**Tentative Protocol**

Results from our series of experiments lead us to suggest the following tentative protocol for management of acute edema: Cathodal HVPC at 120 pps at 90% of visible motor threshold delivered via immersion technique. We suggest that 30-minute treatments be applied every 4 hours beginning as soon after injury as possible, or as long as edema is still likely to be forming. We further suggest that treatments continue only as long as edema is likely to be forming. We are just beginning to test this suggested protocol in clinics. Its efficacy in treating humans is, therefore, unknown. Its efficacy relative to other modalities is equally unknown, as is its applicability to chronic edema.

None of our studies provide solid clues to how HVPC might work. Because of the exceedingly short duty cycle of HVPC (less than 1%) and/or because anodal HVPC did not exacerbate edema formation, we doubt that the "electrical field effect" postulated by others is a significant factor in edema control. Further, strong sensory stimulation (10% less than visible motor threshold) does not by itself seem to produce a treatment effect because this level of stimulation produced by a low-voltage stimulator and anodal HVPC failed to curb edema formation. Even stronger stimulation, producing low-level muscle activity (one twitch per second), did not produce a treatment effect. When we increased intensity to evoke low-level muscle activity, it was still unlikely that we depolarized small-diameter myelinated or unmyelinated fibers; therefore, we probably did not directly activate sympathetics or C-afferents. Thus, we speculate that whatever HVPC is doing to curb edema is induced by non-neurological factors. We further speculate, following Reed, that HVPC might be affecting microvessel permeability, which could in turn, affect both fluid and protein loss to interstitial spaces. Recent, and yet unpublished, work from our laboratories shows that anodal HVPC decreases diameters of histamine-dilated arterioles, whereas cathodal HVPC has no significant effect. One of our studies found no treatment effect on edema when using anodal HVPC. These observations suggest that blood flow to capillaries can be altered by HVPC, but is not critical to edema control. Another study by others also suggests that edema is not affected by dimensions of arterioles.

**Conclusions**

Clinicians have long used forms of ES, HVPC in particular, to regulate edema. This practice has some theoretical bases, but little objective evidence...
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of efficacy. Anecdotal reports and unsupported claims of manufacturers seemingly have been cobbled together to form a pseudo rationale for using this modality for this clinical problem. Because current clinical protocols are not based on sound empirical evidence, published protocols are of little value. Acute edema typically is treated with ice, elevation, and compression; sometimes ES is added to those interventions. But, to date, no evidence is available that indicates that ES enhances the therapeutic effects of these other modalities.

Recent controlled, blinded studies on nonhuman animal models provide evidence, perhaps for the first time, that nonhuman animal models provide evidence, perhaps for the first time, that nonhuman animal models provide compelling rationale for clinical trials.

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References
**Abstract:** While the high school setting holds the best promise of employment for the recently certified athletic trainer, most student athletic trainers do not spend time working with the secondary school athlete. The athletic trainer must be aware of the stages of adolescent psychological maturity and be sensitive to the athlete’s psychological needs. It is important that the athletic trainer develops strategies for dealing with both the athlete and his/her parents.

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**Working with Adolescents in a High School Setting**

Stephen J. Straub, MEd, ATC

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**Psychological Development Theories**

While the onset of puberty and adolescence usually coincide, they are two mutually exclusive events. Puberty is a physical change during which the reproductive organs become functional. Adolescence is a biopsychosocial process that might start before the onset of puberty. During adolescence, there is a formation of identity, an achievement of independence, and the evolution of a personal value system. In order to become an adult, a teenager must achieve independence within the family and have identity formation in intellectual, sexual, and functional modes.

Hall, who practiced psychology during the early 20th century, was one of the first psychologists to make scientific studies of the adolescent. The stage he associated with adolescence was termed “puberty” and encompassed the years from 12 to 24. Hall felt that adolescence was a period of great emotional trauma, rising from the conflict between biologically controlled puberty and society’s demand for social and emotional maturity, a period he labeled as one of “Storm and Stress.” Later, psychologists refuted this idea of constant turmoil. More recent studies have shown that 80% of adolescents cope well during the teenage years.

Freud designed a theory of psychosexual stages of development and placed the adolescent in the genital stage. The genital stage can bring the reawakening of the Oedipal/Electra conflict, which could give rise to rebellion against parents and other authority figures. However, Freud did not place much emphasis on this stage because he felt the first 6 years were most critical in personality development. Erikson modified Freud’s theory of psychosexual development to include birth through later adulthood. Erikson designed eight stages that focus around a conflict having two possible outcomes, one positive and one negative. Adolescence is marked by the identity vs. identity diffusion conflict. Erikson felt that adolescence provides a time out from adult responsibilities to ask, “Who am I?” and “What will I do with my life?” If the adolescent stays in a state of identity diffusion (not knowing who he is in relation to society), he cannot progress to the intimacy associated with young adulthood.

Piaget developed a theory focusing on cognitive development. It was Piaget’s idea that thinking becomes more complex as the individual matures. At age 6 or 7 the child enters a stage of concrete operations. In this stage, logic emerges in association with tangible items. The child still does not have the ability to think of the hypothetical scenario or about abstract concepts. In the stage of formal operations, ages 11 through 15, abstract thinking is developed. The transition from concrete to formal operations occurs on a continuum and it might never be fully achieved by some adults. Based on these development theories, adolescence usually is broken down into the following three phases:

1. Early adolescence - ages 11 to 15 years
2. Mid-adolescence - ages 15 to 17 years

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*Stephen Straub* is an assistant athletic trainer at Kean College of New Jersey in Union, NJ 07083.
3. Late adolescence - ages 17 to 21 years

The most outstanding characteristics of the individual stages are presented in the Table.

When dealing with the individual athlete, it might be helpful to consider his/her developmental stage and plan strategies accordingly.

**Early Adolescence**

The early adolescent often is overly concerned with body image and the comparison of one’s self with others. These “body comparisons” can be the beginning of eating disorders, and the athletic trainer should be sensitive to the uncertainty regarding appearance that the young athlete might have. Bedevilment will not make the “late bloomer” grow any faster and should be avoided.

The early adolescent will test authority, and the training room can be one of the “proving grounds.” Often, the athlete will test the “no cleats in training room” rule or the sign-in policy just to see what he or she can get away with. It becomes important for the athletic trainer to set the ground rules and enforce them at the beginning of the season. It is always easier to loosen up on the rules, than to become more stringent. For the nonconformer, a few days without injury treatment has longlasting results.

The tendency to magnify one’s personal situation is quite common in the freshman athlete. Recently, a freshman cheerleader subluxed her patella 2 days before a competition. When informed she would not be able to participate in the competition, she began to sob uncontrollably. The athlete was convinced that she was letting the team down, and it would be her fault if they lost. In this situation, it is essential that the athletic trainer not belittle the athlete’s fears. Instead, the athletic trainer should reassure the athlete that the injury sustained was not her fault and, with hard work, she possibly could cheer in the next competition, or else another achievable goal could be outlined.

In the younger athlete, concrete thoughts tend to dominate. Because most thought is not abstract, it is hard for these athletes to see the potential consequences of their acts. Often, even when the long-term ramifications have been explained to them, their lack of impulse control causes them to jump into situations they were told to avoid. Many times, we will return a senior athlete to practice with the instructions: “You can participate at an intensity level that doesn’t provoke pain.” This athlete is capable of formal operational thought and enough impulse control to get a limited practice in without doing further damage. Younger athletes with the same instruction often practice full tilt until they can no longer walk. Then they do not understand why you are annoyed with them. These athletes might do better with a very specific list of do’s and don’ts presented to them and their coach.

**Midadolescence**

Midadolescence usually is marked by competency in the abstract thought process, although it is estimated that 30% of the normal populace never will become abstract thinkers. Teenagers who are capable of formal thought are better able to appreciate the consequences of their acts and consider delaying immediate pleasures for a more worthwhile but distant goal. The stress of competition often can return the midadolescent to concrete operational thought.

In this age group, the peer group is a dominant force. The peer group defines behavioral and dress codes, as well as a value system. The soccer team is easily differentiated from the basketball team because each group chooses its own style of shoes or haircut. A part of the athlete’s choice of sports appears to be that individual’s desire to be associated with a specific group.

It is common for the athlete to choose uniforms, safety equipment, and athletic shoes based on what the others are wearing. It is usually possible to find a happy medium between what is biomechanically correct and what is socially correct. The athlete also might comply poorly with wearing knee immobilizers, using crutches or wearing supportive shoe wear because this also is “socially incorrect.” These athletes must be reassured continually that the world really isn’t staring at them and that the appliances they have been fitted with are necessary to expedite return to play.

**Late Adolescence**

While the age bracket for late adolescence is 17 to 21 years, inclusion in this group cannot be based on age alone. The true late adolescent will have estab-
Injury and the Adolescent Alienation

Following injury, the athlete often suffers from feelings of alienation. Two of the biggest components of alienation are powerlessness and isolation. Powerlessness is the inability to control one’s own destiny. Isolation is the feeling of being apart from the team.

The powerlessness that the adolescent feels can be in direct conflict with the independence sought. The athletic trainer should return some control to the athlete as soon as possible. When feasible, he/she should provide rehabilitation alternatives such as a preferred piece of equipment or sequence of events. This allows the athlete to take an active part in rehabilitation progressions.

The isolation brought on by injury can remove the athlete from his/her peer group. It becomes important to return the athlete to a position of being part of the team as soon as possible. The athlete should be encouraged to participate in team weight-training sessions, strategy meetings, and all team meals. Some athletes are willing to keep the score book or play ballboy in order to help the team; others feel that this is a derogatory request and feel more isolated than ever. This should be handled on an individual basis.

Athletics in Perspective

In addition to sidelining the athlete, injury and pain sometimes play secondary roles. Injury can offer a socially acceptable way for the adolescent to avoid the pressures of competition, while saving face. Some athletes, especially those in such individual sports as wrestling, seem to come up with a minor injury just before the big matches. This injury can give the athlete something to fall back on in case of a loss. This athlete possibly is receiving too much pressure to win, either self-imposed or through the school or family environment. When this is suspected, the athlete should be reminded subtly to keep athletics in perspective.
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NAME: 
INJURY: 
SPORT: 
DATE: 
EXERCISE: 

Fig 1.—Personalized rehabilitation card to facilitate compliance.

Fig 2.—The adult athlete, the athletic trainer acts as an intermediary, facilitating communication between the athlete, coach and doctor.

lished abstract thought, a true sense of perspective and pragmatic goals. There are some athletes who will present with these characteristics. In being consistent with the independence and level of maturity these individuals have attained, it is best to let them be a big part of the decision-making process concerning their health care. These athletes usually can be counted on to make the proper decisions when provided with all the alternatives and potential consequences of their actions. It is important to remember that these athletes might be mature young adults, but, legally, they still are minors. The parents should be well-informed and consulted in all major decisions.

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Compliance

The adolescent is noted for having a high rate of noncompliance with medical advice. Home exercise programs are forgotten and 20-minute ice applications turn into hot showers. One way to combat the "lost instruction ritual" is to have the athlete demonstrate his/her program immediately following the athletic trainer’s instructions. In a conversation with J. Gieck, Professor of Athletic Training, University of Virginia, (February 1991), he encouraged a method of "tell them what they need to know; then have them show you what they know." This is effective for reinforcing proper exercise technique and duration.

An effective exercise program also can be facilitated by using personalized exercise cards (Fig 1). As the individual exercises are performed, they are checked off. In this manner, it is difficult for an athlete to "forget" an exercise. As the athletic trainer reviews these cards each day, he/she can monitor progress and is provided with a permanent written record of the rehabilitation administered. In the instance of an athlete marking an exercise complete without having done it, disciplinary actions should be handled in conjunction with the coach. This helps the athlete realize that rehabilitation is an integral part of sports participation. Athletes also should be treated with the expectation that they are capable of complying fully with the treatment. High expectations will lead to high results.

Parents

Parents are the backbone of the high school establishment. They run the booster club and the PTA. It is their tax dollars that pay secondary school athletic trainers, and their children whom we teach. Ultimately, they are the true employer. This is not to say that parents are always right, but rather a reminder that all important decisions should be made in conjunction with the parents and they should stay well-informed.

Figure 2 represents the scenario that occurs when an adult athlete is injured. The athlete has direct contact with the athletic trainer, the doctor, and the coach. The coach and the doctor interact through the athletic trainer, who can act as an intermediary between all parties. All pertinent decisions can be made quickly with a maximum amount of participation.

The ideal high school athlete/parent scenario is represented in Figure 3. It is similar to Figure 2, with the addition of the parent in an equal position with the athlete. This is a well-informed parent who does not attempt to fulfill a role for which he/she is not suited. The parent knows what the athlete knows, and the athletic trainer continues to act as the
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Frank Shorter
Olympic Gold Medalist
In Figure 4, the parent is portrayed as a distant figure. When decisions concerning his/her child’s health care must be made, this parent has to be sought actively. Often, parents don’t know about the injury, even if it has been a long-standing chronic problem. The athletic trainer should not hesitate to telephone the parents, even for minor injuries, because this is an opportunity to open the lines of communication. Parent/coaching staff meetings are also an opportune time for the athletic trainer to meet parents and inform them of what is expected of their child, as well as the treatment the athlete can expect to receive in return.

Figure 5 depicts the parent who believes that he/she knows it all. In this figure, the parent is placed above the athletic trainer, attempting to do the athletic trainer’s job. One way to deal with this parent is through selective listening. Allow this parent to talk all about “the good old days” (when they played ball) to their heart’s content, as long as he/she doesn’t try to teach the child spear tackling. Another effective strategy is to allow this parent to win some battles. The athlete could be allowed to soak in epsom salts, as long as cold water is used. The parent believes the epsom salts work; the athletic trainer believes the cold water works. Either way, the athlete gets better, and that is what is important.

**Conclusion**

A review of adolescent psychology helps the athletic trainer to understand the thought patterns of secondary school athletes and can be helpful in dealing with this age group. The athletic trainer should remember that the athlete matures on a continuum and might not display the same characteristics from day to day. We must be careful when evaluating athletes for participation in the decision-making process, and sometimes it is better just to say “no”. Finally, the athletic trainer must be sensitive to the needs of the human being inside the uniform and try to keep the role of athletics in perspective.

**Acknowledgements**

Special thanks to the staffs of the Sports Medicine Department at the University of Virginia and the Athletics Department at Albemarle County High School for their time and patience.

**References**

Treating friction blisters can be tedious but simple. Athletic training texts suggest various treatment methods, for example, applying Bacitracin or Neosporin, or antiseptics and second skin. None of the texts mentions toughening the area, however. To treat effectively a newly exposed dermal skin layer, a toughening technique must be employed. The method described below is a comprehensive treatment plan for blisters that includes readying the area for unprotected full-weight-bearing function.

Remember to adhere always to standard infection controls (ie, OSHA regulations) when handling bodily tissues and fluids. With this in mind, remove the remainder of the epidermal layer. It is of primary importance that the loose skin be trimmed closely, so that a further shearing action of the loose skin adjacent to the intact skin will not occur during weight-bearing activities (Fig 1). You should consult with your physician concerning the removal of this layer of skin to ensure that proper procedures are followed.

After you have removed the loose skin, clean the tender exposed dermal layer with either hydrogen peroxide, benzalkonium chloride nf, or a combination with a betadine solution (Fig 2). Completely cover the blister site and adjacent area with an abundant amount of either a germicidal wound care product or a benzoin tincture compound (Fig 3). This could cause a burning sensation in the affected area, but the pain should diminish rapidly.

Perhaps a sterile dressing with a non-adhering "Telfa-like" surface to prevent the dressing from sticking to the open wound, particularly if you use benzoin, should be used to cover the affected area (Fig 4). Place the medicated compress over the blister and secure it, if necessary, with adhesive and/or elastic tape (Fig 5). If the athlete prefers more cushion, a padded donut may be placed over the area.

The athlete should have the blister cleaned and the dressing changed before and after activity. Depending on the level of pain tolerance of the individual athlete, shoes may be worn during the initial toughening stage of the treatment.

The compress should be worn continuously for 2 to 3 days until the new skin is toughened enough to permit weight-bearing.

**Tip from the Field**

Medicated Compress for Blister Treatment

Spence B. Fletcher, MA, ATC, NREMT
William R. Whitehill, EdD, ATC
Kenneth E. Wright, DA, ATC

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Fig 1.—Trimming of the blistered area

Fig 2.—Cleansing of affected area

Fig 3.—Solution application
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skin is tough enough to handle friction with minimal padding. Additional tape might be necessary to secure the compress during high levels of activity, and

you might have to repeat the dressing/protection procedure during intense workouts. Still, the basic procedure is similar for the practice and nonpractice settings.

This treatment procedure has been used successfully on blistered feet and hands.

References

Two public health problems involving tryptophan associated eosinophilia-myalgia syndrome and adverse effects associated with the use of y-hydroxybutric acid highlighted the widespread use of legal and illegal food supplement products and the potential hazards involved. Although consumers might use these products for their pharmaceutical properties, they might not consider food supplements as drugs, and physicians might not routinely elicit a history of their use. A hypothesis that these products might be popular among health-conscious persons or those who purchase health and bodybuilding magazines was made. As a preliminary step to qualifying the types of food supplement products available and to identify potential areas for future research, health and bodybuilding magazines were surveyed to determine the extent of advertising for these products, as well as the number and types of ingredients used in these products. A single issue of each of 12 health or bodybuilding magazines, published during June, July, or August 1991, were purchased at Atlanta-area supermarkets, bookstores, and card shops. Each magazine was reviewed page by page for advertisements for food supplement products, and a tabulation was made as to those advertised as tablets, capsules, or powders. No liquid supplements were included. Using this information, a determination was made as to the number of unique ingredients in all advertised products and the number of times any ingredient was mentioned in any advertisement. The data was categorized into major groups of ingredients and products and also as to the purported health benefits or effects of the products. Eighty-nine companies, 311 products, and 235 unique ingredients were counted in the 12 magazines, and specific ingredients were mentioned 914 times. The survey found that amino acids were the most frequently mentioned. Many products were promoted for muscle growth and enhanced strength, and steroid-type ingredients were advertised as being in 28 of 311 products. No health effect was mentioned for 90 products. The findings on nutritional supplements products, their ingredients and availability are intended to serve as a preliminary assessment of a problem that is poorly documented in the medical literature. The emphasis to practitioners is: 1) the food supplement items are readily available to the public; 2) judging by the quantity of advertisements, the types of supplement items listed here, as well as many others, are consumed by a sizeable number of patients; 3) many ingredients are not readily identifiable, and even for those that are, all potential effects and side effects might not be known; 4) supplement users might combine two or more products and set their own dosage regimen; 5) unanticipated effects might occur as happened in the case of tryptophan associated eosinophilia-myalgia syndrome.

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The purpose of this paper is to report the effect of a specific rehabilitation program for the shoulder on a group of patients who had traumatic or atraumatic and multidirectional instability of the shoulder. The cases of 115 patients (140 shoulders) were available for review. In addition to the hospital charts, the preoperative and postoperative radiographs were available. The diagnosis and classification of the shoulders into the traumatic and atraumatic groups were based on a carefully taken history, a physical examination and evaluation of radiographs.

After the cause of the instability had been evaluated and classified, the patients began performing a specific set of exercises designed to strengthen the deltoid and the muscles of the rotator cuff. The fact that exercises improve the dynamic stability of the shoulder and often can obviate the need for operative intervention is not a new concept. We found a substantial difference in the number of satisfactory responses between patients who had traumatic and atraumatic instability. Of the shoulders that had traumatic instability, 15% had good or excellent results; of the shoulders that had atraumatic subluxations, 83% had good or excellent results. Information from this study has helped us in the care of our patients. Patients who have a clear-cut history of a traumatic anterior injury and have the telltale osseous changes on the glenoid rim or humeral head are told that the proposed rehabilitation program has only an 18% chance of success. Patients who have a history and physical findings that are indicative of an atraumatic problem and who have no radiographic abnormalities in the shoulder joint are thrilled to learn that an operation is not imminent and that the rehabilitation program has a success rate of 83%. Because of the high rate of complications associated with a routine reconstructive procedure on a shoulder that has atraumatic and multidirectional subluxation, and because of the high success rate of rehabilitation exercises for these problems, we recommend a trial of specific resistance exercises before reconstruction of the shoulder is considered. In addition, during the exercise program, the physician has ample time to determine if the patient has any additional complicating factors, for example, psychological or psychiatric dis-
orders that could compromise the results even if the best reconstructive procedure is performed.


We did a retrospective review and follow-up examination to investigate the incidence, risk factors, and outcomes of patients who developed loss of motion after arthroscopic anterior cruciate ligament reconstruction. Two hundred forty-four patients with a minimum follow-up of one year were reviewed. Loss of motion (defined as a loss of extension of more than 10° or flexion of less than 125°) was identified in 27 patients for an overall incidence of 11.1%. Factors associated with loss of motion included acute reconstruction (less than one month from initial injury) and concomitant medical collateral ligament repair or posterior oblique ligament refection or botl. Twenty-one patients required surgery to regain their motion; three patients required a second procedure.

Twenty-one of 27 patients with loss of motion underwent a detailed follow-up and were compared with 24 randomly chosen controls, who had a normal range of motion after anterior cruciate ligament reconstruction. At follow-up, patients who experienced loss of motion had a significant decrease in noninvolvement involved knee extension and flexion compared to the control patients. There was no difference between our patients and the controls regarding patellofemoral problems, anterior knee laxity, and functional strength. Sixty-seven percent of the patients with loss of motion had good or excellent results in comparison to 80% of the control group.

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The purposes of this study were to: 1) determine normal values for cervical active range of motion (AROM) obtained with a "cervical-range-of-motion" (CROM) instrument on healthy subjects whose ages spanned 9 decades, 2) determine whether age or gender affects six cervical AROMS, and 3) examine the intratester and intertester reliability of measurements obtained. Measurements were made on 337 subjects (171 females and 166 males) whose ages ranged from 11 to 97 years. Measurements were taken by five physical therapists with 7 to 30 years of clinical and teaching experience. Among male and female subjects of the age, females had a greater AROM than did males for all AROMS except neck flexion. Among both males and females, each of the six cervical AROMS decreased significantly with age. From two pilot studies separate from the acquisition of the normal database, we determined our intratester and intertester reliabilities for making neck AROM measurements with the CROM instrument. We concluded that AROM measurements on the cervical spine with the CROM instrument demonstrated good intratester and intertester reliability because the intraclass correlations coefficients were generally .80.

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Chronic tendinitis is a common and debilitating musculoskeletal pathology that can be particularly recalcitrant to treatment. Details of the composition and structure of the tendon are presented, enabling clinicians to understand the mechanical function of the tendon under different loading conditions and the various mechanisms of tendinitis injury. The effects of exercise, disuse, the incidence of injury, and tendinitis terminology are discussed. Other purposes of this paper are to describe the natural course of tendon healing, the clinical assessment of tendinitis, and suggested treatments for chronic tendinitis. The paper concludes with two case studies. Information in the paper should assist the clinician in treating chronic tendinitis more successfully.


The use of thermal modalities to enhance stretching procedures is not well-documented clinically. This study documented the effectiveness of applying superficial heat and cold in conjunction with a low-load prolonged stretch (LLPS) for increasing shoulder flexibility. Ninety-two healthy males were randomly assigned to one of five groups: 1) an LLPS alone, 2) heat applied in the initial phase of an LLPS, 3) cold applied in the final phase of stretch, 4) a combination of heat initially followed by cold, and 5) no intervention. Subjects received three, 40-minute treatments across a 5-day period. A follow-up measurement was taken 3 days later. Results demonstrated that an LLPS associated with the use of heat, ice, or a combination of both facilitated greater long-term improvements in flexibility compared to controls. However, only subjects receiving heat in the initial phase of an LLPS showed significant gains when compared with those who received stretching alone (p<.05). We concluded that applying heat in conjunction with an LLPS to a nonpathologic shoulder is a clinically
The combination of heat and the dependent position, as experienced with a standard lower extremity whirlpool treatment, has the potential of encouraging lower extremity swelling. This study examined the effects of whirlpool and the dependent position on lower extremity swelling in 40 healthy physical therapy students and therapists (12 males, 28 females) between the ages of 20 and 40 (avg=24.3 yrs). Volumetric measurements were taken before and after three experimental conditions. Condition number 1 involved a 29-minute treatment in a leg whirlpool at 40°C (104°F). The second condition involved sitting for 20 minutes with the foot resting on the bottom of an empty leg whirlpool. The third condition involved a 20-minute rest in a supine position. A one-way ANOVA and Tukey’s post hoc test were used to analyze the data. Analysis revealed the greatest increase in limb volume following the whirlpool treatment (avg=44 ml±30.5). The second greatest increase (avg=20.5±32.5) occurred when the extremity was maintained in the dependent position. When placed in the supine position, subjects experienced a decrease in limb volume (avg=16 ml±15.2). The findings were statistically significant at the .01 level. The results indicated that while lower extremity swelling does occur from treatment in a whirlpool or by placing the extremity in a dependent position, the changes seen are not as dramatic as those reported in the upper extremity. The variations were hypothesized to result from physiological and anatomical differences between the upper and lower extremities. Caution is advised, however, when using the whirlpool to treat lower extremity injuries in the presence of significant musculoskeletal or vascular pathology because marked swelling could result.


Anterior knee pain syndrome (AKPS) represents a significant challenge for patients and clinicians. The purposes of this study were to: 1) determine the reliability of the Q-angle measurement, 2) quantify Q-angle changes that occur with knee flexion, and 3) determine if subjects with AKPS (n=52) have a significantly different Q-angle than subjects without AKPS (n=50).

With the knee in an extended position, intratester Q-angle intraclass correlation coefficients (ICC) ranged from .84 to .90, and standard error of measurement (SEM) values ranged from 2.01° to 2.33°. Intertester Q-angle ICC was .83, and the SEM was 2.49°. With the knee flexed, the intratester ICC was .83 for both testers, and SEM values ranged from .68° to 2.45°. Intertester ICC and SEM were .65 and 3.50°, respectively. No significant difference was found in intratester Q-angle values between the extended and flexed knee positions (p>.05). No significant difference in Q-angle was found between asymptomatic subjects (11.1±5.5°) and symptomatic subjects (9.12.4±5.1°) (p=.07). Increased Q-angles were not responsible for AKPS in this group of patients. Other factors were hypothesized to be responsible for their symptoms.


Increased use of athletic trainers in sports medicine clinics has created a need for information about ideal use of these professionals in these settings. The purposes of this study were to: 1) describe the characteristics of sports medicine clinics and their personnel, 2) determine whether there were differences between opinions of certified athletic trainers (ATCs), physical therapists (PTs), and professionals with dual credentials (PT/ATCs), about the ideal role of the ATC in sports medicine clinics, and 3) determine whether there were differences in actual usage of ATCs between states with and without athletic training laws. Subjects include 46 PTs, 43 PT/ATCs and 73 ATCs from six different states. A questionnaire ascertained opinions about ideal ATC use and about current practice of ATCs with respect to 28 different clinical procedures. For 27 of the 28 procedures, there were significant differences of opinion about ideal ATC use between individuals with the three credentials. No significant differences in actual athletic trainer use in sports medicine clinics were found between states with and without athletic training laws.

The NATA Board of Certification accepts this continuing education offering for .5 hours of prescribed CEU credit in the program of the National Athletic Trainers’ Association, Inc., provided that the test is used and completed as designed.

To participate in this program, read the material carefully, photocopy the test, and answer the test questions. Mark your answer by circling the correct letter. Then fill in your name, address, and other information and mail with $15 for processing to the address below. FOR CREDIT, the form must be postmarked by May 20, 1993.

A passing score is 70%. We will notify the NATA Board of Certification of all persons who score 70% or better, and the NATA will enter .5 CEU credit on those persons' records. Participation is confidential.

This CEU Credit Quiz contains questions drawn from the following articles:

Bunton, et al: The role of limb torque, muscle action, and proprioception during closed kinetic chain rehabilitation of the . . .
Draper/Ladd: Subjective evaluation of function following moderately accelerated rehabilitation of anterior cruciate . . .
Fisher/Hoisington: Injured athletes’ attitudes and judgments toward rehabilitation adherence
Hoffman: A progressive ankle disk system
LaPlaca, et al: Comparison of N-K table offset angles with the human knee flexor torque curve
Mendel/Fish: New perspectives in edema control via electrical stimulation
O’Neil, et al: Squat Board
Stone, et al: Closed kinetic chain rehabilitation for the glenohumeral joint
Straub: Working with adolescents in a high school setting

**CEU CREDIT QUIZ**

Name (Dr., Mr., Mrs., or Ms.) __________________________
Institution or Team ________________________________
Mailing Address __________________________________
City __________________ State ______ Zip ________
Social Security Number ____________________________
NATA Membership Number _________________________

Please indicate below the setting in which you work:

- [ ] High School  [ ] Junior College  [ ] College
- [ ] University  [ ] Sports Medicine Center
- [ ] Other (please specify) _______________________

**Answers to Winter CEU Credit Quiz**

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**Instructions**

1. Photocopy these pages and write on the copy.
2. Read the articles listed above.
3. Answer the questions.
4. Mail with $15 fee (checks made payable to Indiana State University) prior to May 7, 1993, to:

**JAT - CEU Quiz**

Physical Education Department
Indiana State University
Terre Haute, IN 47809

86  Volume 28 • Number 1 • 1993
Circle the correct answer.

1. ATCs deemed the following to be important to injury rehabilitation:
   a. good rapport between the ATC and the injured athlete.
   b. a need for the injured athlete to see immediate results.
   c. support from individuals of the same gender.
   d. All of the above.
   e. a and b only

2. A more aggressive approach to ACL rehabilitation and return to sport should probably take into consideration:
   a. measures of strength and range of motion.
   b. ligament laxity.
   c. the patient's perception of function.
   d. All of the above.
   e. a and c only

3. Historically, criteria for returning an athlete to activity have been peak torque values and muscle girth. These criteria:
   a. may neglect proprioception.
   b. do not relate to returning an athlete to previous functional levels.
   c. are of little help in determining how a patient will perform a multisegmental movement.
   d. All of the above.
   e. a and c only

4. When dealing with the high school athlete, which of the following tactics might the athletic trainer find useful?
   a. A specific list of "do's" and "don'ts" might be important due to a teenager's limited ability for abstract thought.
   b. Understanding of the complex process of growing up may be more beneficial than chastisement in many cases.
   c. Set ground rules at the beginning.
   d. Keep parents well-informed and consulted in all major decisions.
   e. All of the above.

5. The Squat Board:
   a. uses various belts and rubber tubing.
   b. is not intended to be a daily training tool.
   c. allows a regular overload resistance progression.
   d. is potentially as problematic as closed kinetic chain exercises using other devices.
   e. b and c.

6. Closed kinetic chain exercises have an advantage over open kinetic chain exercises in that they:
   a. enhance proprioception.
   b. provide inherent joint stability through increased weight bearing.
   c. allow for sport-specific adaptation.
   d. All of the above.
   e. a and c only

7. If full ROM is the selection criteria of a rehabilitation exercise, which of the following exercises should be considered?
   1) lateral step-ups; 2) leg extensions; 3) Stairmaster; 4) slideboard; 5) Fitter
   a. all 5 exercises d. 1 and 2 only
   b. all except #5 e. 3 and 4 only
   c. 1, 2, and 3

8. Rehabilitation should focus on reeducating proprioceptors in a manner that reestablishes the functional movements found in athletic performance in addition to developing muscle girth and strength.
   a. True
   b. False

9. Closed kinetic chain rehabilitation:
   a. should be confined to the lower extremity.
   b. should be used in rehabilitation programs for athletes using the upper extremity in a weight-bearing manner.
   c. is of little help for swimmers, but could benefit gymnasts.
   d. a and c.
   e. b and c.

10. Errors commonly made by athletes when using ankle disks include:
    a. conducting the exercise with slight flexion (10° to 20°) of the knee.
    b. too limited motion at the hip to rotate the system.
    c. excessive motion at the pelvis, preventing the ankle from moving through its complete range of motion.
    d. a and b.
    e. b and c

11. ATCs can assist rehabilitating athletes by:
    a. offering encouragement.
    b. planning selected activities.
    c. directing athletes’ attention to contrived positive aspects.
    d. All of the above.
    e. a and b only

12. Results of the study of electrical stimulation on rats and frogs:
    a. call into question protocols commonly used in clinics.
    b. suggest efficacy and the beginning of guidelines for protocols.
    c. suggest the following tentative protocol for management of acute edema: Cathodal HVPC at 120 pps at 90% of visible motor threshold delivered via immersion technique.
    d. All of the above.
    e. b and c only

13. The comparison of N-K table offset angles with the knee flexor torque curve lends support to which of the following statements?
    a. The traditionally employed 90° offset angle should be changed to 160°.
    b. The 110° angle might be awkward to use.
    c. Common clinical practice relative to the use of the N-K table for knee flexor strength development may need to be reconsidered.
    d. The 135° angle may tend to force the user into knee hyperextension.
    e. None of the above.

14. Which of the following are reported to be successful strategies by ATCs in athletes’ rehabilitation adherence?
    a. threats.
    b. rehabilitation without monitoring.
    c. goal setting and encouragement.
    d. All of the above.
    e. b and c only

15. The studies of electrical stimulation on frogs and rats are important in that:
    a. the results can be applied directly to humans.
    b. they show a clear treatment effect for sensory level HVPC on acute edema, both during and for a short time after treatment.
    c. others have only provided testimonials to the efficacy of HVPC in controlling edema.
    d. a and c only.
    e. b and c only
Aircast’s Latest Innovation is a Strap
(But not an ordinary strap)

In 1978 Aircast® introduced the Air-Stirrup® brace—the first off-the-shelf ankle stirrup. Since then, dozens of improvements have been made. Eight of these were worthy of patents.* Swivel-Strap™ is the latest. This is not an ordinary strap. Its molded hook Velcro® is smoother to the touch but holds even better. Lab tests show attachment to the shell is stronger. And clinical trials show patient preference is universal.

Swivel-Strap swivels. So it wraps anatomically and permits counter rotation. Narrowed hook Velcro® is always covered by the strap. No more snags.

*Aircast innovations in ankle brace design:

*The scope and validity of this patent was affirmed in a U.S. District Court in January, 1992.
In the preface of this text, Dr. Allan J. Ryan states that Sports Medicine encompasses many disciplines and professions. Included, of course, are those involved directly in health promotion and services, for example, physicians, physical therapists, athletic trainers, exercise physiologists, nutritionists, psychologists, and those conducting research in the areas of biomechanics, kinesiology, and the epidemiology of sports injury. Also included are those involved in sports management, members of sports governing bodies and rules committees, athletic directors, coaches, and suppliers of sports equipment and facilities.

The first thing that came to mind after reading this statement was how much our profession has grown and the vast number of allied health professionals involved. In 1958, when I started as a student trainer in North Carolina, the Sports Medicine team consisted of the part-time head athletic trainer, a game night team physician, and myself. Our equipment consisted of an old porcelain-covered whirlpool, a four-pack hydrocollator, a homemade training table, and a water-circulating coke box.

Prevention of Athletic Injuries: The Role of the Sports Medicine Team

Chapter 1 describes the complex field that has developed over the past two millennia to help athletes perform more effectively, to prevent illness and injury, and to restore the injured athlete to participation. Allan J. Ryan, MD, using his lifetime experience in Sports Medicine (more than 50 years), gives the reader a glance at the past and at present research, showing the interrelationships that have made safety a central concern at all levels of sports and the development of Sports Medicine Centers.

In Chapter 2, John W. Powell, PhD, ATC, points out the value of gathering accurate data on sports-related injury and illness, following a carefully designed plan to distinguish causative factors from chance associations. This chapter demonstrates how careful epidemiologic study can make all members of the Sports Medicine team more effective in promoting safety, and how vital such information is in establishing safety priorities and evaluating the success of interventions intended to protect the athlete. Similarly, in Chapter 3, Frederick O. Mueller, PhD, describes the system of collecting and analyzing data on the most serious injuries in some commonly practiced sports. Such findings clarify the level of danger present and help participants and sponsors determine whether changes in rules and techniques have been or can be effective in making these sports safer, or perhaps whether the sport should be discontinued, for example, boxing, in some countries.

Chapter 4 deals with the legal aspects of Sports Medicine and is co-authored by Jerald D. Hawkins, EdD, ATC, and Herbert T. Appenzeller, EdD (a prime pioneer who is published widely in this area). This is by far one of the more enlightening chapters, spelling out the seven principles to reduce the threat of litigation, and describing standard defenses to charges of negligence, including assumption of risk and contributory negligence.

In chapter 5, Voight R. Hodgson, PhD, details principles of protective equipment construction, development of standards between manufacturers, and interactions between equipment standards and the legal system. In chapter 6, David M. Nelson demonstrates how carefully formulated rules can be instrumental in sharply reducing unacceptable injury rates, while maintaining the basic character and excitement of the sport. The role of the Sports Medicine practitioner in rules and changes is discussed also.

Chapter 7 should help all members of the Sports Medicine team to better understand the many ways the National Federation of State High School Associations (NFSHSA) works to improve the safety of sports competition, while chapter 8 discusses the responsibilities of the athletic director for hiring, evaluating and training staff, financing equipment, facilities, and insurance, and directly impacting the safety of athletes through the establishment of policies for the sports program at his/her institution.

My favorite chapter is chapter 9, written by "Mr. Sports Medicine," Donald L. Cooper, MD. Dr. Cooper was one of the first true team physicians and has assisted and guided many trainers during his tenure of more than 30 years. A former student trainer turned physician, Dr. Cooper seems to be the one who always is reminding us of our roots and pointing us towards the future. His contribution to this text is a common sense approach to the relationship of the physician with the athletic trainer and other members of the sports medicine team. He also gives specific guidelines for participation, physical evaluation, and principles of organizing the medical care of athletes.

The aim of Chapter 10 is to assist other members of the sports medicine team to understand the athletic trainer's skills and the role of athletic trainers in caring for athletes. This chapter emphasizes professional relationships at various levels of sport. In chapter 11, desirable qualifications for the role of a sport psychologist are described. Ways that athletes can be helped by such a professional, including the develop-
ment of healthy attitudes, the recognition of such stresses as overtraining, and the improvement of coping skills after an injury are discussed.

Chapters 12 and 13 deal with physiological differences between the sexes in their response to exercise, special injury considerations in the areas of gymnastics and dance, and the need for special protective equipment for women. The relationship of menstruation and exercise, amenorrhea, sports in pregnancy, and the differences between the sexes in optimal training practices is also discussed. Chapter 14 deals with sports involvement of the disabled, as well as their unique requirements for safe sports participation.

The remaining five chapters concern areas of prevention of serious and even catastrophic injury that cut across all issues discussed in the previous chapters and are critical to sports performance and, in some cases, to survival. Topics include head and neck injuries (Robert C. Cantu, MD), heat stress (Dr. Allan Ryan), drug use (James C. Puffer, MD), nutrition (John J.B. Anderson, PhD), and sudden death (Steven P. Van Camp, MD).

Other scholarly authors not previously mentioned include Richard D. Schindler, Homer C. Rice, PhD, William E. Prentice, PhD, PT, ATC, John M. Silva III, PhD, Charles J. Hardy, PhD, Carol C. Teitz, MD, Christine E. Haycock, MD, and B. Cairbre McCann, MD.

Overall, this is an excellent text and does an outstanding job of covering the prime sports medicine issue facing our profession today.
Current Literature

ACCIDENT-PRONE ATHLETES


AIDS


Goldsmith MF. When sports and HIV share the bill, smart money goes on common sense [news]. JAMA. March 1992;267:1311-1314.


ACHILLES TENDON


ANKLE BIOMECHANICS


Soderberg GL, Cook TM, Rider SC, Stephenitch BL. Electromyographic activity of selected leg musculature in sub-


**EFFECTS OF TRAVEL**


**GENERAL**


### OPTP Introduces PT Board

Orthopedic Physical Therapy Products of Minneapolis has introduced a new device for controlled movement and rehabilitation. The PT Board has a swivel base, allowing not only 360° of movement, but controlled side-to-side or front-to-back movement, as well as varying degrees of movement in-between.

The PT Board, adaptable to a variety of treatments, can provide consistent, controlled movement for rehabilitation of the wrist, ankle, foot, shoulder, and pelvis. It also provides proprioception awareness and feedback. The PT Board can be used for pelvic training. It helps strengthen abdominal muscles and facilitates anterior, posterior, and lateral pelvic tilt exercises, as well as static and dynamic stretching of paraspinal soft tissues.

Therapists can use the PT Board in the clinic and can provide patients with their own boards to use at home.

For more information about the PT Board or any other OPTP product, contact OPTP, PO Box 47009, Minneapolis, MN 55447-0009, or call (800) 367-7393.

### CT Offers PulseMeter Watch

Country Technology, Inc has unveiled the PulseMeter Watch, a device that monitors heart rate using a photonic sensor, which fits on the fingertip. The watch has settable upper and lower limit alarms (high tone/low tone) for keeping in a safe training range.

The watch operates as a standard digital watch, stopwatch, and interval timer. It can be used for aerobics, running, jogging, or any activity that could overtax the cardiovascular system. For more information, contact Country Technology, Inc, PO Box 87, Gays Mills, WI 54631, or call (608) 735-4718.

### Rich-Mar Announces 3MHz Option

The Rich-Mar Corporation has introduced the Model "25 Multi-Hz" unit offering a 2cm² 3MHz soundhead and a 5cm² soundhead that is 1MHz. The Multi-Hz design allows use of either the 1MHz or 3MHz simply by picking up the corresponding soundhead; there are no heads or cables to change. The 25 Multi-Hz uses a true 3MHz crystal to produce a 3MHz frequency, rather than harmonizing a crystal.

When using the unit for smaller, superficial injuries, the 2cm² 3MHz soundhead allows treatment of these areas with the smaller transducer. For larger and deeper areas, use the 5cm² soundhead. The 25 Multi-Hz features the ergonomically designed Rich-Mar transducers for therapist comfort. Because the heads do not detach, they are safe for underwater treatment.

For additional information, contact Rich-Mar at (800) 762-4665.

### Thera-Kinetics Unveils Wrist Therapy Unit

Thera-Kinetics, Inc has introduced the new portable JACE W550 Wrist Continuous Passive Motion (CPM) Device. The JACE W550 provides axis to axis alignment, a "Zero Set" feature enabling goniometric setting of range of motion, and a "floating" hand support to prevent compression and distraction of the joint.

A microprocessor permits step-by-step prompted operation and provides for the presetting of up to three therapy regimes. The W550 incorporates a warm-up phase, gradually increasing the patient to 100% of programmed motion. The JACE W550 provides 2 to 20 lb of force (average), flexion/tension and radial/ulnar movements with a full 135° of motion. Dual rechargeable battery packs provide a minimum of 8 hours of use at full power. The W550
also interfaces with neuromuscular stimulators.

For additional information, contact Thera-Kinetics at (800) 234-0900.

Tsumura Reformulates Wart Remover

Tsumura Medical has announced that TRANS-PLANTAR Plantar Wart Remover has been reformulated to improve stability and comply with the US Food and Drug Administration OTC Monograph.

The new TRANS-PLANTAR formulation features 15% salicylic acid in a karaya gum hydrogel base. The formulation extends the shelf life of the previous TRANS-PLANTAR formulation by 9 months. The new formulation continues to incorporate the only drug delivery vehicle that allows overnight dosing and concomitant therapy with an emery file to expedite sloughing of verrucous tissue.

TRANS-PLANTAR’s hydrating, occlusive dermal patches maintain a continuously solubilized supply of salicylic acid for continuous drug delivery to the wart. The hydrating property of the patches eliminates the need to soak the wart.

TRANS-PLANTAR Plantar Wart Remover System is available nationally and dispensed only through pharmacies. Doctors and other qualified health care professionals can obtain clinical information and patient samples by calling (800) 345-8084 (in Minnesota, call 612/496-4750).

Carapace Introduces Plaster Alternative

Carapace is offering the new Duracast Plaster of Paris as an alternative to traditional plaster. Duracast plaster bandages have low wet and dry plaster loss and they reach a high green strength quickly, adding security and preventing distortion of the cast during the curing phase.

Duracast is packaged in a heat-sealed, foil wrapper that provides a moisture barrier for stable performance and extended shelf life. For additional information, contact Gary W. Silvers, RN/OTC, Marketing Manager, Carapace, Incorporated, at (800) 223-5463.

3M Produces New Soft Cast

3M Health Care has introduced the Scotchcast brand soft cast, a fiberglass cast designed for use where support, but not rigid immobilization, is necessary. The Scotchbrand soft cast allows the person who applies the cast to determine the proper amount of support or protection by varying the number of layers.

The soft cast has soft, pliable edges and is comfortable for the patient. It is easy to apply and remove because it can be unwrapped or cut with bandage scissors. The cast can be univalved and overwrapped for re-use.

For additional information on the Scotchcast soft cast, write 3M Health Care, 3M Center, Bldg 275-4W, St. Paul, MN 55144-1000, or call the 3M Health Care Customer Helpline at (800) 228-3957.
The Journal of Athletic Training welcomes the submission of manuscripts that are of interest to persons engaged in or concerned with the progress of the athletic training profession; injury prevention, evaluation, management, and rehabilitation; administration of athletic training facilities and programs; and athletic health care counseling and education. Manuscripts should conform to the following:

SUBMISSION POLICIES
1. Submit one original and three copies of the entire manuscript (including photographs, artwork, and tables) to the editor.
2. All manuscripts must be accompanied by a letter signed by each author, and must contain the statements below. By signing the letter, the author(s) agrees to comply with all statements. Manuscripts that are not accompanied by such a letter will not be reviewed. "This manuscript contains original unpublished material that has been submitted solely to the Journal of Athletic Training, is not under simultaneous review by any other publication, and 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 (our) submission, the author(s) undersigned hereby transfers, assigns, or otherwise conveys all copyright ownership to the NATA, in the event that such work is published by the NATA."
3. Materials taken from other sources, including text, illustrations, or tables, must be accompanied by a written statement giving the Journal of Athletic Training permission to reproduce the material. Photographs of individuals must be accompanied by a signed photograph release form. Accepted manuscripts become the property of the National Athletic Trainers' Association, Inc.
4. The Journal of Athletic Training uses a double blind review process. Authors should not be identified in any way except on the title page.
5. Manuscripts are edited to improve the effectiveness of communication between the author and the readers, and to aid the author in a presenting work that is compatible with the style policies found in the AMA Manual of Style, 8th ed. (Williams & Wilkins) 1989. The author agrees to accept any minor corrections of the manuscript made by the editors.
6. Published manuscripts and accompanying work cannot be returned. Unused manuscripts will be returned when submitted with a stamped, self-addressed envelope.

STYLE POLICIES
7. The active voice is preferred. Use the third person for describing what happened. "I" or "we" (if more than one author) for describing what you did, and "you" or the imperative for instruction.
8. Each page must be typewritten on one side of 8½" x 11" inch plain paper, double spaced, with one-inch margins. Do not right justify pages.
9. Manuscripts should contain the following, organized in the order listed below, with each section beginning on a separate page:
   a. Title page
   b. Acknowledgements
   c. Abstract and Key Words (first numbered page)
   d. Text (body of manuscript)
   e. References
   f. Tables—each on a separate page
   g. Legends for illustrations
10. Beginning numbering of pages of your manuscript with the abstract page(s) #1; then, consecutively number all successive pages.
11. Titles should be brief within descriptive limits (a 16-word maximum is recommended). The name of the disability treated should be included in the title if it is the relevant factor; if the technique or type of treatment used is the principle reason for the report, it should be in the title. Case studies are to be directed.
12. The title page should also include the names, titles, and affiliations of each author, and the name, address, phone number, and fax number of the author to whom correspondence is to be directed.
13. A comprehensive abstract of 75 to 200 words must accompany all manuscripts except tips from the field. Number this page one, type the complete title (but not the author's name(s)) on the top, skip two lines, and begin the abstract. It should be a single paragraph and succinctly summarize the major intent of the manuscript, the major points of the body, and the author's summary and/or conclusions. It is unacceptable to state in the abstract words to the effect that "the significance of the information is discussed in the article". Also, do not confuse the abstract with the introduction.
14. List three to four keywords that can be used in a subject index to refer to your paper. These should be on the same page as, and following your abstract. For tips from the field, the key words should follow immediately after the title on the first numbered page.
15. Begin the text of the manuscript with an introductory paragraph or two in which the purpose or hypothesis of the article is clearly developed and stated. Tell who the study needed to be done or the article written, and culminate 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 the one to two paragraph review of the literature, identify and develop the magnitude and significance of the controversy, pointing out differences between other's 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.
16. 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 experimental report consists of a methodology section—a presentation of the results, and a discussion of the results. The methodology 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 review of the literature 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.
17. The body of a case study 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 a review of the relevant literature) (example: "Physical findings relevant to the rehabilitation program were..."), medical history (surgery, laboratory results, exam, etc.), diagnosis, treatment and clinical course (rehabilitation until and after return to competition), criteria for return to competition, and deviation from the expected (what makes this case unique).

NOTE: It is mandatory that the Journal of Athletic Training receive, with the manuscript, a release form signed by the individual being discussed in the case study. Case studies cannot be reviewed if the release is not included.

d. The body of a technique 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 why the technique should be used. The discussion of why should review similar techniques, point out how the new technique differs, the advantages and disadvantages of the technique in comparison to other techniques.

e. A tip from the field is similar to a technique article but much shorter. The tip should be presented and its significance briefly discussed and related to other similar techniques.

f. 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.

g. Citations in the text of the manuscript take the form of a superscripted number, which indicates the number assigned to the citation. It is placed directly after the reference or the name of the author being cited. 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.

h. The Reference page(s) accompanying a manuscript should list authors numerically and in alphabetical order, and should be in the following form: a) articles: author(s) (list all) with the family names then initials, title of article, journal title with abbreviations as per Index Medicus (italicized or underlined), volume, year, inclusive pages; b) books: author(s), title of book (underlined), editor(s), place of publication, publisher, year, inclusive pages of citation. Examples of references to a journal, book, and presentation at a meeting are illustrated below. See the AMA Manual of Style for other examples.


m. Tables must be typed. Type legends to illustrations on a separate page. See references cited in #5 or #19a for table formatting.

n. Photographs should be glossy black and white prints. Graphs, charts, or figures should be of good quality and clearly presented on white paper with black ink in a format that can be legally released for publication. Do not use paper clips, write on photos, or attach photos to sheets of paper. Carefully attach a write-on label to the back of each photograph so that the photograph is not damaged.

21. Photographs should be glossy black and white prints. Graphs, charts, or figures should be of good quality and clearly presented on white paper with black ink in a format that can be legally released for publication. Do not use paper clips, write on photos, or attach photos to sheets of paper. Carefully attach a write-on label to the back of each photograph so that the photograph is not damaged.

22. All artwork to be reproduced should be submitted as camera-ready black and white line art. If artwork is to be reproduced in black, plus a second (or more) color, it should be submitted as color tips from the field. Black and white line art. Clearly mark each area of color, or areas of shading or screening (a percent or tint of black or color), on a separate photocopy. Author pay for color.
## ADVERTISING INDEX

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