Antipronation Taping and Temporary Orthoses

Effects on Tibial Rotation Position After Exercise

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Abnormal lower-limb biomechanics—in particular, abnormal pronation of the subtalar joint with concomitant increased internal rotation of the tibia—is one of the major causes of overuse injuries of the lower limb. A randomized, controlled, within-subjects research design (N = 14) was used to investigate the effect of a temporary felt orthosis and an antipronation taping technique to control the transverse tibial rotation position immediately after application and after each of two 10-minute periods of exercise. The results showed that the taping technique was superior to both the orthosis and no intervention in controlling tibial rotation position immediately after application and after 10 minutes of exercise. After 20 minutes of exercise, neither the tape nor the orthosis was significantly superior to the control; however, the trends suggested that some residual control was maintained. Future studies are needed to determine the amount of foot pronation control required to relieve symptoms in a symptomatic population in order to determine the clinical effectiveness of these treatment methods. (J Am Podiatr Med Assoc 89(3): 118-123, 1999)

Overuse injuries of the lower limb are prevalent and severely interfere with sports and recreational activities, thereby having a significant impact on society. These injuries can be attributed to either extrinsic factors (eg, training errors, running surfaces, and shoes), intrinsic factors, or a combination of both.[1] Intrinsic factors include abnormal lower-limb biomechanics as a result of malalignment syndromes, limb-length discrepancies, and muscle dysfunction.[2, 3] In particular, abnormal pronation of the subtalar joint during the stance phase of gait is often reported as a contributing factor in these overuse injuries.[4-7]

Approximately 25% of all running injuries are knee injuries,[8] the majority of which are overload injuries involving the patellofemoral joint.[9] Malalignment due to structural deviations in the foot and lower leg are frequently observed in the population with symptomatic patellofemoral pain.[10, 11] The forces experienced during the stance phase of gait are considered to be largely responsible for these injuries.

The stance phase of gait is a closed-chain activity that requires coordinated movement of the proximal and distal joints of the lower limb.[7, 12] Closed-kinetic-chain subtalar joint pronation, which is a triplanar motion involving eversion of the calcaneus and adduction and plantarflexion of the talus, occurs during the initial contact phases of the gait cycle.[13] Adduction of the talus produces an obligatory internal rota-

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tion of the leg.[14] This coincides with a flexing moment at the knee and conjunct internal rotation of the tibia. During the mid- and late-stance phases, the subtalar joint supinates, the tibia externally rotates, and the knee extends.[14] These synchronous actions of the knee, tibia, and subtalar joint during the stance phase of gait are interdependent motions.[7] Alterations in any of these synchronous actions will influence these interdependent motions. For example, in the circumstance of favorable subtalar joint axis inclination, excessive or prolonged subtalar joint pronation during the stance phase of gait results in increased internal rotation of the tibia and flexion of the knee. This leads to increased torsional stresses on the lower extremity and a delay or reduction in tibiofemoral extension.[15] Disturbances in normal patellofemoral mechanics due to alteration in tibial rotation will yield an uneven distribution of shearing and compressive forces acting at the patellofemoral articulation,[16] potentially predisposing the knee joint complex to patellofemoral pain and dysfunction.[11,17]

Physiotherapeutic management of overuse injuries related to increased pronation frequently involves the use of taping techniques and temporary orthoses to address abnormal biomechanics. These techniques are based on the concepts outlined in the tissue stress model of McPoil and Hunt,[18] in which tissues being abnormally stressed are identified and subsequently unloaded. A concurrent reduction or abolition of symptoms associated with a reduction in pronation confirms the link between pain and abnormal biomechanics and provides guidelines for treatment.[19]

A reduction in abnormal pronation and symptoms in the lower limb in groups of runners using an assortment of orthotic devices has been demonstrated.[20-22] Tape and orthoses may have the ability to reduce the internal rotation during the stance phase of the gait cycle in conditions in which the increased internal rotation of the tibia is associated with abnormal pronation. In a study of 20 recreational runners, Nawoczenski et al[23] demonstrated that a semirigid orthosis significantly decreased the magnitude of rotation occurring from heel contact to peak tibial internal rotation. A similar reduction in maximal tibial internal rotation has also been demonstrated in two single-case studies.[24] In a study of 20 adolescent females with patellofemoral pain, Eng and Pierrynowski[17] found a significantly greater reduction in pain in a group prescribed soft orthoses in conjunction with an exercise program compared with a group prescribed an exercise program alone. The effect of temporary felt orthoses and taping on tibial rotation has not been investigated.

The effect of adhesive strapping during activity has been the focus of numerous research studies.[19,25-27] Ator et al[25] demonstrated that two commonly used techniques (low-Dye and double X) were able to reduce pronation immediately after their application; however, this effect was not maintained after 10 minutes of jogging. Vicenzino et al[19] demonstrated that augmenting the low-Dye technique with taping techniques that extended up the distal leg provided for better antipronation control immediately after application and after a 20-minute period of exercise.

The purpose of the present study was to investigate the effects of an augmented low-Dye taping technique and the use of temporary felt orthoses on tibial position in the transverse plane immediately following application and after exercise.

Methods

Subjects

Fourteen subjects (3 women and 11 men) with a mean (±SD) age of 23.9±3.5 years (range, 18 to 30 years) participated in the study. Volunteers were accepted on the basis of a difference in vertical navicular height of 10 mm or more between a relaxed calcaneal stance position and subtalar neutral position as determined by the palpation method. A Vernier height gauge (Mitutoyo Corp, Tokyo, Japan) calibrated to 0.02 mm was used to measure vertical navicular height. A drop of 10 mm has been considered abnormal by Mueller et al.[28] Criteria for exclusion included any current injuries to the lower extremities that had required a reduction in activity levels and/or treatment by a health-care practitioner, severe orthopedic or neurologic conditions, and a known allergy to sports tape. Prior to participation, each subject signed an informed consent form that was approved by the University of Queensland Medical Research Ethics Committee. All subjects participated in some form of regular aerobic exercise and were capable of completing the necessary controlled exercise program.

Transverse Tibial Rotation Position

Tibial rotation position in the transverse plane (TTR) was measured using a technique modified from the method described by Cornwall and McPoil.[24] A tibial pointer device consisting of a 25 × 25 × 25-mm block with 2 × 110-mm rods positioned orthogonally to one another was attached to the subject's tibia with Velcro straps (Velcro USA Inc, Manchester, New Hampshire). It was positioned on the medial tibial plateau just medial to the tibial tuberosity. A T ruler with 1-mm increments was used to measure the perpendicular distance from the tip of each rod to a standardized datum point fixed onto a wall.

To ensure that foot position was standardized between trials and between conditions, a template of the subject's foot position was made. This template consisted of a tracing of both feet when the subject stood in a standardized position with the posterior aspects of the heel counters aligned, and the feet positioned parallel to each other with 20 cm between the calcaneal bisectors.

Treatment Conditions

This study investigated the effect of three treatment conditions (tape, orthosis, and no intervention) on TTR. A temporary orthosis was fabricated from 7-mm orthopedic felt. The orthosis consisted of two parts, a medial longitudinal buttress and a navicular/sustentaculum tali pad. The medial longitudinal buttress extended from the posterior calcaneus to the first metatarsal head and from the medial border of the foot to the bisection of the calcaneus and had a calcaneal recess cut out. A navicular/sustentaculum tali pad extended from the sustentaculum tali to the cuneiform (Fig. 1).

The augmented low-Dye technique, which has previously been described in detail by Vicenzino et al,[19] was used in this study. The technique involves applying a device consisting of a spur and mini-stirrups to the foot and then adding reverse sixes and calcaneal slings to an anchor on the distal one-third of the leg. A rigid 38-mm sports tape with zinc oxide adhesive was used for all of the taping procedures. A control condition in which no tape or orthosis was applied was also used to allow for control of the effect of exercise over time on TTR.

Experimental Protocol

Subjects attended three separate testing sessions and a standardized protocol was followed at each session. Subjects were randomly assigned to the order of treatment conditions of taping, orthosis, and control. The subject stood on his or her template while the TTR pointer was attached to the medial tibial plateau of the right leg using a Velcro strap. An outline of the position of the device on the tibial plateau was drawn onto the skin with an indelible ink pen to allow for accurate relocation between all trials. TTR was measured in relaxed calcaneal stance while the subject wore shoes. An investigator who was blinded to the intervention read the measurements and then recorded them onto a data-collection sheet. Each measurement was performed twice.

The subject then had either the tape applied or the

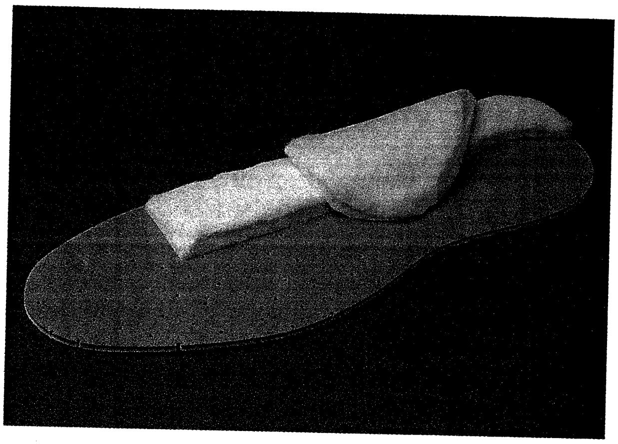

Figure 1. Temporary felt orthosis illustrating the medial longitudinal buttress and the navicular/sustentaculum tali pad.

orthosis inserted into the shoe; in the control trial, the subject wore shoes only. An experienced therapist applied the tape and made and applied the orthosis. The subjects wore the same shoes, which were their own, at each testing session. All shoes were visually assessed by the therapist to ensure that they did not induce pronation or internal rotation. Prior to application of the tape, any hair in the region was shaved and the foot and leg were washed with soap and warm water to remove any dirt or oils that might decrease the adhesion of the tape. The TTR measurements were repeated following application of either tape, orthosis, or nothing (ie, preexercise).

The subject then jogged for two 10-minute periods around a 35-m figure-8 track on a flat, smooth surface at the Department of Physiotherapy, University of Queensland, at a self-determined pace. Subjects completed the same number of circuits between the two 10-minute exercise periods and between the testing sessions. The TTR measurements were repeated after each 10-minute exercise period. On completion of the testing, the tape was removed with blunt-nosed scissors or the orthosis was removed from the shoe. Subjects returned for two more sessions in which the only change in the protocol was the treatment condition.

Data Analysis

Tibial position in the transverse plane was calculated using an algorithm similar to that used by Cornwall and McPoil.[24] This involved the trigonometric comparison of the known actual distance between the two limbs of the pointer device with a perceived distance between the two limbs of the pointer in the frontal plane. Figure 2 illustrates the algorithm used.

Two TTR measurements were recorded and the average was used in the analyses. Prior to the application of the three conditions, the tibial position in the transverse plane during relaxed calcaneal stance was attained. All postapplication data were then expressed as a percentage of the preapplication TTR measurement. This was the dependent variable. The independent variables were treatment method and measurement time, each of which had three levels. The three levels of treatment method were tape, orthosis, and control. The three levels of exercise time were 0 minutes (immediately after application), after 10 minutes, and after 20 minutes of exercise.

The comparisons of interest in the present study were between tape and orthosis, tape and control, and orthosis and control for the treatment method variable and between 0 and 10 minutes, 10 and 20 minutes, and 0 and 20 minutes for the exercise time. Within subjects, planned contrasts were used under the SPSS multivariate analysis of variance procedure (SPSS for the MacIntosh 4.0 [Apple Computer, Cupertino, California]). Such comparisons required a Bonferroni adjustment to the family-wise α (0.05) for multiple comparisons. In this circumstance, the corrected α_{pc} was 0.025 ($k = 3$, $\alpha_{FW} = 0.05$).

Results

The means (±SEM) for TTR for the tape, orthosis, and control conditions before exercise (0 minutes) and after 10 and 20 minutes of exercise are shown in Figure 3.

Effect of Exercise on Each Treatment Condition

The antipronation tape produced its greatest change in TTR immediately after application (16.9% change into external rotation). This change represents an actual change in tibial position in the frontal plane of 4.6°. There was a significant reduction in this change to 7.2% (2°) after 10 minutes of exercise ($F_{1,13} = 9.97$, $P = .008$) and 1.3% (0.4%) after 20 minutes ($F_{1,13} = 15.89$, $P = .002$). The change noted over the second 10-minute exercise period was not significant ($F_{1,13} = 3.99$, $P = .07$).

The orthosis showed a trend similar to that of the taping technique in that there was a significant percent change in TTR between the preexercise measure (0 minutes) and after 10 and 20 minutes of exercise ($F_{1,13} = 23.19$, $P < .001$ and $F_{1,13} = 6.45$, $P = .03$, respectively) and no significant difference between

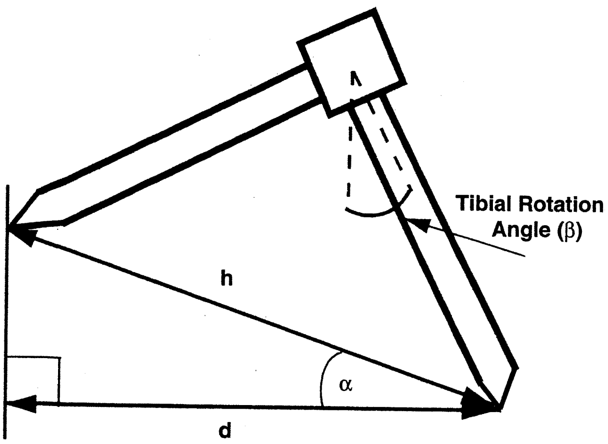

Figure 2. Diagram illustrating the measurement of transverse tibial rotation with the tibial pointer device, where d = the perceived distance between the two limbs of the pointer device as calculated with the T ruler (see text for explanation); h = the known distance between the two limbs of the tibial pointer device; α = the angle defined by the relationship between the known and perceived distance [$\alpha = \cos^{-1}(d/h)$]; and β = the angle of transverse tibial rotation ($\beta = 45 - \alpha$). (Adapted with permission from Cornwall and McPoil.[24])

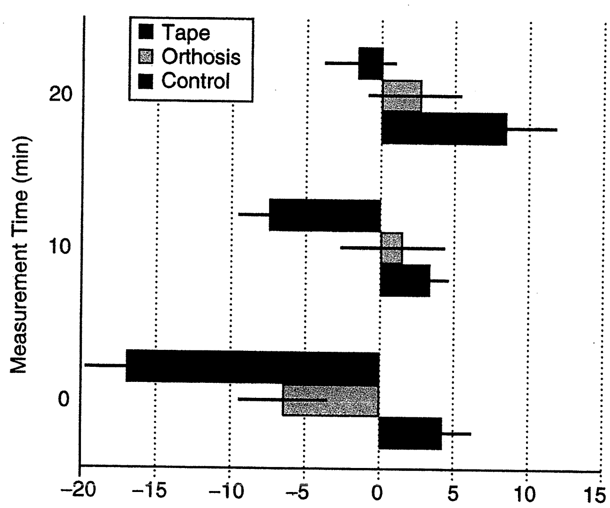

Figure 3. Mean (±SEM) percent change in tibial rotation position in the transverse plane for the three treatment conditions (tape, orthosis, and control) at the three measurement times. Positive values represent a *relative* increase in internal rotation from the relaxed calcaneal stance position and negative values represent *relative* external rotation.

10 and 20 minutes ($F_{1,13}$ = 0.14, P = .72). Immediately after application, the tibial position in the frontal plane was 6.6% relative external rotation, which represents an actual change of 1.8°. After 10 minutes, the effect had significantly decreased so that the tibia was relatively internally rotated 1.1% (0.3°) compared with preapplication. The relative internal rotation increased further to 2.3% (0.6°) after 20 minutes.

The control condition demonstrated no significant difference between preexercise and 10 minutes ($F_{1,13}$ = 0.50, P = .49), between preexercise and 20 minutes ($F_{1,13}$ = 2.29, P = .15), and between 10 and 20 minutes ($F_{1,13}$ = 3.87, P = .07), although there was an overall trend for an increased relative internal rotation from 4% to 8%. This represents an approximate 1° change in overall tibial position.

Differences Between Treatment Methods at Each Measurement Time

Immediately following application, both the tape and the orthosis produced a relative external rotation of the tibia in the frontal plane that was superior to the control ($F_{1,13}$ = 52.03, P < .001 and $F_{1,13}$ = 7.69, P = .02, respectively). Tape performed significantly better than the orthosis ($F_{1,13}$ = 7.98, P = .01). After 10 minutes of exercise, tape was significantly better than the control ($F_{1,13}$ = 14.5, P = .002); however, the differences between tape and orthosis and between orthosis and control were not significant ($F_{1,13}$ = 4.01, P = .07 and $F_{1,13}$ = 0.22, P = .65, respectively). There was no significant difference between any of the three methods after the second 10-minute period of exercise (between control and tape [$F_{1,13}$ = 4.62, P = .05], between control and orthosis [$F_{1,13}$ = 1.96, P = .19], and between tape and orthosis [$F_{1,13}$ = 1.35, P = .27]).

Discussion

The findings of this study demonstrate that applying an augmented antipronation taping technique or inserting a temporary felt orthosis into a shoe can provide control of tibial rotation in the transverse plane immediately after application, and that the taping technique was significantly more effective than the orthosis. The change in tibial position of approximately 2° after insertion of the orthosis is similar to that in the study by Nawoczenski et al,[23] who reported a reduction of 2° of internal rotation from heel contact to maximum internal rotation during gait. A possible explanation for the improved control demonstrated by the tape is that the taping extends up the lower leg and therefore exerts a direct controlling force on the tibia. The orthosis, like the unaugmented low-Dye technique, exerts no direct leverage on the tibia and appears to exert less of an influence on lower-limb alignment in comparison with the taping technique used in this and previous studies.[19]

The effect of both the orthosis and the tape diminished after 10 minutes of exercise; however, the taping technique remained significantly better than the control condition. The tibial position in the frontal plane was still relatively externally rotated compared with the preapplication measure (2°). The reduction in efficacy of the tape following a period of exercise has been well documented.[19, 25, 26, 29, 30] Vicenzino et al[19] showed that although the effect of the augmented antipronation technique had significantly decreased over the exercise period, it was still superior to the control.

The temporary orthosis was significantly reduced in its effectiveness after 10 minutes of exercise, showing a small relative internal rotation compared with preapplication, but showed little further deterioration. The statistically significant reduction in the effectiveness of the temporary orthosis over the first 10-minute exercise period can be explained in part by the compressibility of the felt under repetitive load. A previous study[24] has suggested that this may be partially influenced by body mass, a factor that was not considered in the present study but should be addressed in future research.

The results of this study demonstrate no significant control of tibial rotation at the completion of exercise for both tape and orthosis compared with a control condition. Although not statistically significant, there is a trend for an increase in the amount of internal tibial rotation of the control condition over time. This may provide evidence of a warming-up effect of the contributing muscles that control pronation and internal rotation because activity produces increases in elasticity of muscular tissue,[31] which may be due to increased local tissue temperature.[32]

Diagnostically, a reduction in symptoms following the application of tape or orthosis that corrects tibial rotation indicates that there is an association between altered foot biomechanics and the condition producing the symptoms. The amount of biomechanical correction required to relieve symptoms is unknown. Thus the trend for tape and orthoses to provide better control of TTR than the control, although not statistically significant, does not discount their effectiveness clinically. In addition, this study used only 14 subjects and a measurement procedure of tibial position that was highly variable, and consequently it may not have overcome the risk of a type II error. Future studies with less variable measurement procedures and greater subject numbers are required. Patient populations should also be investigated.

Transverse tibial rotation should be developed further as a clinical measurement tool because it demonstrates the effect of techniques applied to the foot on proximal tibial mechanics. The tibial pointer device can be easily viewed and measured by the clinician. Furthermore, analysis can occur during both static and dynamic activities.

Conclusion

Temporary felt orthoses and an antipronation taping technique appeared to be effective in changing TTR following application and after 10 and 20 minutes of exercise, when compared with a control condition in which nothing was used. However, statistically significant differences between tape, orthosis, and control were not evident at 20 minutes, and evident only between tape and control at 10 minutes, and between all conditions before exercise. This study investigated only static TTR, and further research is needed to determine the effect of these treatments (tape and orthosis) on dynamic TTR and pain in order to understand their clinical effects.

References

1. Lysens RJ, Ostyn MS, Vanden Auweele Y, et al: The accident-prone and overuse-prone profiles of the young athlete. Am J Sports Med **17:** 612, 1989.
2. Greenfield B: "Evaluation of Overuse Syndromes," in *The Biomechanics of the Foot and Ankle*, ed by R Donatelli, p 153, FA Davis, Philadelphia, 1990.
3. James SL, Bates BT, Osternig LR: Injuries to runners. Am J Sports Med **6:** 40, 1978.
4. DeLacerda FG: A study of anatomical factors involved in shinsplints. J Orthop Sports Phys Ther **2:** 55, 1980.
5. Gross MT: Lower quarter screening for skeletal malalignment: suggestions for orthotics and shoewear. J Orthop Sports Phys Ther **21:** 389, 1995.
6. Moss CL, Gorton B, Deters S: A comparison of prescribed rigid orthotic devices and athletic taping support used to modify pronation in runners. J Sport Rehab **2:** 179, 1993.
7. Tiberio D: Pathomechanics of structural foot deformities. Phys Ther **68:** 1840, 1988.
8. van Mechelen W: Running injuries: a review of the epidemiological literature. Sports Med **14:** 320, 1992.
9. O'Toole ML: Prevention and treatment of injuries to runners. Med Sci Sports Exerc **24** (suppl 9): 360, 1992.
10. Buchbinder MR, Napora NJ, Biggs EW: The relationship of abnormal pronation to chondromalacia of the patella in distance runners. JAPA **69:** 159, 1979.
11. Klingam RE, Liaos SM, Hardin KM: The effect of subtalar joint posting on patellar glide position in subjects with excessive rearfoot pronation. J Orthop Sports Phys Ther **25:** 185, 1997.
12. Donatelli R: Abnormal biomechanics of the foot and ankle. J Orthop Sports Phys Ther **9:** 11, 1987.
13. Sell KE, Verity TM, Worrell TW, et al: Two measurement techniques for assessing subtalar joint position: a reliability study. J Orthop Sports Phys Ther **19:** 162, 1994.
14. Inmam VT, Ralston HJ, Todd F: *Human Walking*, Williams & Wilkins, Baltimore, 1981.
15. McCulloch MU, Brunt D, Vander Linden D: The effect of foot orthotics and gait velocity on lower limb kinematics and temporal events of stance. J Orthop Sports Phys Ther **17:** 2, 1993.
16. Biloff C: Patellofemoral malalignment. J Manual Manipulative Ther **3:** 39, 1995.
17. Eng JJ, Pierrynowski MR: Evaluation of soft foot orthotics in the treatment of patellofemoral pain syndrome. Phys Ther **73:** 62, 1993.
18. McPoil TG, Hunt GC: Evaluation and management of foot and ankle disorders: present problems and future directions. J Orthop Sports Phys Ther **21:** 381, 1995.
19. Vicenzino B, Feilding J, Howard R, et al: An investigation of the anti-pronation effect of two taping methods after application and exercise. Gait Posture **5:** 1, 1997.
20. Bates BT, Osternig LR, Mason B, et al: Foot orthotic devices to modify selected aspects of lower extremity mechanics. Am J Sports Med **7:** 338, 1979.
21. Donatelli R, Hurlbert C, Conway D, et al: Biomechanical foot orthotics: a retrospective study. J Orthop Sports Phys Ther **10:** 205, 1988.
22. Smith LS, Clarke TE, Hamill CL, et al: The effects of soft and semi-rigid orthoses upon rearfoot movement in running. JAPMA **76:** 227, 1986.
23. Nawoczenski DA, Cook TM, Saltzman CL: The effect of foot orthotics on three-dimensional kinematics of the leg and rearfoot during running. J Orthop Sports Phys Ther **21:** 317, 1995.
24. Cornwall MW, McPoil TG: Footwear and foot orthotic effectiveness: a new approach. J Orthop Sports Phys Ther **21:** 337, 1995.
25. Ator R, Gunn K, McPoil TG, et al: The effect of adhesive strapping on medial longitudinal arch support before and after exercise. J Orthop Sports Phys Ther **14:** 18, 1991.
26. Fumich RM, Ellison AE, Guerin GJ, et al: The measured effect of taping on combined foot and ankle motion before and after exercise. Am J Sports Med **9:** 165, 1981.
27. Tweedy R, Carson T, Vicenzino B: Leuko and Nessa ankle braces: effectiveness before and after exercise. Aust J Sci Med Sport **26:** 62, 1994.
28. Mueller MJ, Host JV, Norton BJ: Navicular drop as a composite measure of excessive pronation. JAPMA **83:** 198, 1993.
29. Gross MT, Batten AM, Lamm AL, et al: Comparison of DonJoy ankle ligament protector and subtalar sling ankle taping in restricting foot and ankle motion before and after exercise. J Orthop Sports Phys Ther **19:** 33, 1994.
30. Shapiro MS, Kabo JM, Mitchell PW, et al: Ankle sprain prophylaxis: an analysis of the stabilizing effects of braces and tape. Am J Sports Med **22:** 78, 1994.
31. Safran MR: Warm-up and muscular injury prevention: an update. Sports Med **8:** 239, 1989.
32. Lehmann JF, Masock AJ, Warren CG, et al: Effect of therapeutic temperatures on tendon extensibility. Arch Phys Med **51:** 481, 1970.