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Predictive Factors for Lateral Ankle Sprains: A Literature Review

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Objective: To review the prospective studies of ankle-ligament-injury risk factors.

Data Sources: We searched MEDLINE from 1978 to 2001 using the terms *ankle, ligament, injury, risk factor,* and *epidemiology.*

Data Synthesis: The results included many studies on the treatment and prevention of ankle injuries. There were, however, very few prospective studies focusing on identifying the risk factors that predispose an athlete to ankle-ligament trauma.

Conclusions/Recommendations: There is some agreement among authors with regard to the risk factors for ankle-ligament injury; however, considerable controversy remains. Although female athletes are at significantly greater risk of suffering a serious knee sprain, such as disruption of the anterior cruciate ligament, this does not appear to be the case for ankle-ligament sprains. Therefore, sex does not appear to be a risk factor for suffering an ankle-ligament sprain. Athletes who have suffered a previous sprain have a decreased risk of reinjury if a brace is worn, and the consensus is that generalized joint laxity and anatomical foot type are not risk factors for ankle sprains. However, the literature is divided with regard to whether or not height, weight, limb dominance, ankle-joint laxity, anatomical alignment, muscle strength, muscle-reaction time, and postural sway are risk factors for ankle sprains. Future research is needed on this topic to develop a consensus on all ankle-injury risk factors. This will allow future intervention studies to be designed that will reduce the incidence and severity of this common injury.

Key Words: ligament, injury, risk factor

Garrick was one of the first to identify the lateral ligaments of the ankle as the most commonly injured structures in athletes,[1] and subsequent reports support this finding. As a result, retrospective and prospective studies have been performed to focus on the risk factors for lower extremity injuries and ankle-ligament sprains. In this review, we made an important distinction between retrospective and prospective studies. Only prospective studies can control the multiple variables that are difficult to reliably obtain and evaluate in a population of athletes at risk for suffering an ankle injury. For example, exposure data can only be documented through a prospective investigation, while variables such as baseline ankle laxity cannot be measured after the injury has occurred. There were too few well-designed studies available in the literature to perform a systematic review and, therefore, the purpose of our paper was to review prospective investigations of ankle-ligament-injury risk factors. We did not include studies of lower extremity injuries as a group, nor did we include retrospective studies. Our study was organized according to intrinsic (those from within the body) and extrinsic (those from outside the body) risk factors based on the classification system introduced by Williams.[2] This review is important because the risk factors that predispose an athlete to ankle-ligament trauma should be understood before an intervention study designed to reduce the incidence of these debilitating injuries is implemented.

INTRINSIC RISK FACTORS

The intrinsic risk factors for sprains of the lateral ankle ligaments investigated through prospective studies include the following: previous sprain; sex; height and weight; limb dominance; anatomic foot type and foot size; generalized joint laxity; anatomic alignment, ankle-joint laxity, and range of motion of the ankle-foot complex; muscle strength; muscle reaction time; and postural sway.

Previous Sprain

Perhaps the most frequently studied risk factor for lateral ankle-ligament sprains is a previous sprain of this complex. This is based on the fact that disruption of a ligament compromises an important biomechanical stabilizer and creates partial deafferentation of the ankle. The literature is divided with regard to whether or not a previous sprain has an influence on the risk for a future sprain. One of the original prospective risk-factor studies is the work of Ekstrand and Gillquist,[3] who enrolled 124 soccer athletes, examined each player at the beginning of the year, and then followed them for 1 year while documenting exposure to practices and games. They reported an increased risk for lateral ankle-ligament injury in athletes who had suffered a prior ankle-ligament sprain. Subsequent studies of soccer and basketball athletes and military recruits undergoing basic training found that they were at increased risk for lateral ankle-ligament injury after suffering a prior ankle injury.[4–8] In contrast, studies of athletes participating in similar sports have revealed no increased risk for lateral ankle-ligament injury after suffering a prior ankle injury.[9–12] One explanation for the divergent findings may be

that the condition of the joint after injury not only depends on the index injury and the associated damage to the ligaments, muscles, and deafferentation of the joint but also on what type of rehabilitation was administered, whether or not the subject complied with the rehabilitation program, and the quality of recovery that was achieved.

Sex

The incidence of knee injuries, particularly disruption of the anterior cruciate ligament, is considerably greater for female athletes in comparison with male athletes[13–19]; in contrast, the disparity of ankle-ligament sprains between the sexes appears to be much smaller.[20] Hosea et al[20] performed a comprehensive, prospective study on high school and collegiate basketball players. Female athletes were at 25% increased risk of suffering a grade I ankle sprain compared with male athletes; however, the relative risk between the sexes for the more serious grade II and III sprains, ankle fractures, and syndesmotic sprains was not significantly different. In addition, for both male and female athletes, the relative risk of suffering an ankle sprain doubled as the level of competition increased from high school to the collegiate level. This interesting finding is in contrast to anterior cruciate ligament tears, which increase substantially with increasing levels of competition for female athletes but not for males.[21]

Our group has recently completed a prospective study of Division I collegiate athletes who participated in soccer, lacrosse, or field hockey.[22] Before the athletic season started, subjects without a history of lower extremity trauma were identified and suspected ankle-injury risk factors were measured. During the season, subjects were continuously monitored and all ankle-ligament injuries were evaluated and graded by the same investigator. Men and women differed substantially in terms of many of the preseason risk factors (eg, height, weight, isokinetic strength, muscle-reaction time, and range of motion of the foot and ankle), and this led us to analyze the risk factor data separately for each sex. The number of ankle injuries per 1000 person-days of exposure to sport was 1.6 for men and 2.2 for women, rates that were not significantly different.

Height and Weight

Height and weight have been implicated as risk factors: when an athlete is in an at-risk position for inversion ankle trauma, an increase in either height or weight proportionally increases the magnitude of inversion torque that must be resisted by the ligaments and muscles that span the ankle complex. The investigation of collegiate athletes by our group[22] demonstrated that height and weight were not independent risk factors for ankle sprains. Similar findings were reported by Sitler et al.[11] In contrast, Watson[23] found that male soccer athletes who sustained ankle sprains had greater height than those who did not. Milgrom et al[6] reported that during basic training, male military recruits who were taller and heavier were at increased risk of suffering an ankle injury.

Limb Dominance

Limb dominance has been implicated as a risk factor for lower extremity trauma because most athletes place a greater demand on their dominant limb. Therefore, they produce increased frequency and magnitude of moments about the knee and ankle, particularly during high-demand activities that place the ankle and knee at risk. The literature is divided with regard to limb dominance as a risk factor for suffering an ankle-ligament sprain. In our investigation,[22] limb dominance was unrelated to risk of ankle injury for male and female athletes participating in soccer and lacrosse and female athletes participating in field hockey. Similarly, Surve et al[7] found that soccer athletes reported no difference in the incidence of ankle injuries between dominant and nondominant ankles. In contrast, Ekstrand and Gillquist[3] noted that the dominant leg sustained significantly more ankle injuries in male soccer players, with 92% of ankle injuries affecting the dominant leg. These contrasting findings may have been the result of different study designs or the methods used for data analysis.

Anatomic Foot Type and Foot Size

Anatomic foot type (pronated, supinated, or neutral) does not appear to be a risk factor for ankle sprains[9,22,24]; however, the classification system that characterizes anatomic foot type as pronated, supinated, or neutral may be inadequate for identifying abnormalities in foot biomechanics. This approach has not been related to musculoskeletal abnormalities, it lacks the specificity and sensitivity to identify abnormalities in foot biomechanics, and it is evaluated while a subject is standing barefoot and not during a situation when the lower extremity is at risk for injury. Therefore, specific and sensitive measurements of foot-contact mechanics that can be used during dynamic, at-risk activity need to be developed and used to determine if they are capable of identifying an ankle at risk for an inversion sprain. Kaufman et al[25] were the first to use such an approach. Dynamic measurements of arch contact in Navy Sea, Air, and Land trainees were collected while they walked barefoot and in military footwear. Dynamic pes planus, pes cavus, and increased hindfoot inversion were risk factors that predisposed trainees to lower extremity overuse injury. Similar studies of ankle- and knee-ligament injuries are needed in athletes who take part in high-risk sports.

Milgrom et al[6] showed that increased foot width is associated with an increased risk of suffering a sprain of the lateral ankle ligaments. This finding can be explained, at least in part, by the fact that during an inversion injury, an increased foot width is associated with an increased moment arm and corresponding inversion moment in comparison with a narrow foot.

Generalized Joint Laxity, Ankle-Joint Laxity, Anatomic Alignment, and Range of Motion of the Ankle-Foot Complex

Generalized joint laxity has no predictive value for ankle sprains[10,22,26] when considering all athletes as a group[10,26] and men and women as separate groups.[22] To most professionals involved with the diagnosis and treatment of ankle injuries, increased joint laxity is considered a ''sure bet'' risk factor for an ankle injury because it indicates that a soft tissue restraint and its contribution to stability and neural intervention of the ankle complex may have been compromised. However, the literature presents conflicting findings. Barrett et al[9] demonstrated that ankle laxity, measured with the standard anterior drawer and talar tilt clinical examinations, did not predict ankle sprains.[9] In our initial work on this subject,[10] measurement

of ankle laxity with the anterior drawer test showed a trend in which increased laxity was associated with an increased risk of ankle injury, while the talar tilt test was not associated with injury. In our most recent study of collegiate athletes,[22] the same trend was observed among women, and increased talar tilt was associated with increased risk of injury among men. This finding is supported by the earlier work of Glick et al,[27] who reported a higher incidence of lateral ankle-ligament sprains in American football athletes with an excessive talar tilt (defined as greater than 5°) in comparison with those whose talar tilt was less than 5°. Likewise, Chomiak et al[28] reported a higher incidence of noncontact ankle sprains among soccer players with an excessive anterior drawer and talar tilt. The discrepancy among these previous studies may derive from the use of the clinical examination and a grading system to evaluate joint laxity, which are not sensitive means of evaluating joint laxity, or from an inadequate sample size, which may not have included a sufficient number of subjects with increased ankle laxity.

Our recent study[22] of collegiate soccer, lacrosse, and field hockey athletes revealed that ankle injuries were more common among women with increased tibial varum and calcaneal eversion range of motion, while no such relationship was found for men. Thus, alignment of the hindfoot in combination with the lower extremity is important when evaluating risk factors for inversion injury of the ankle.

Ankle dorsiflexion and plantar-flexion range of motion does not appear to be related to the risk of suffering an ankle sprain among collegiate soccer, lacrosse, and field hockey athletes.[22] Ankle range of motion is also not associated with injury in ballet and modern dancers.[29]

Muscle Strength

Although most would consider it intuitive that lower extremity strength is related to the risk of suffering an ankle-ligament sprain, only our group has investigated this with a prospective study design, and the findings from these studies differ.[10,22] In our earlier study[10] of collegiate athletes participating in soccer, lacrosse, and field hockey, ankle sprains were associated with higher ratios between ankle inversion and eversion peak torques, higher peak torques produced by plantar flexion, and a lower ratio between dorsiflexion and plantar-flexion peak torques. In contrast, our recent study[22] of the same level of athletes participating in the same sports did not reveal differences in peak-torque values between injured and uninjured athletes for dorsiflexion, plantar-flexion, inversion, and eversion motions. In addition, the ratios between ankle eversion and inversion peak torques and between dorsiflexion and plantar-flexion peak-torque values were not related to the risk of suffering an ankle sprain. The differences between these studies may be explained by the differences in the methods that were used to analyze the data. In the initial study, women and men were analyzed as a group, while in the most recent study, women and men were considered separately. This is important because peak torque is sex dependent, as are other risk factors, and the analysis used combined data from men and women. Even risk factors having similar effects in men and women may not be detected in analysis of combined data if high values for women correspond with low values for men. Conversely, variables whose values differ greatly between the sexes may falsely appear to have an effect on risk if women are inherently at higher risk. In addition, in the initial study, we did not document exposure data and used the Student *t* test to analyze the data without adjustment for different sports, which may have been associated with different baseline risk values. In the recent investigation, we evaluated exposure data and performed data analysis using the Cox regression model to take into account both time at risk for injury and differences in risk associated with different sports.

Muscle-Reaction Time

Although previous studies have measured the peak torque developed during isokinetic dorsiflexion-plantar-flexion and inversion-eversion motions, it is unclear how to interpret these outcomes because most ankle injuries occur within a time interval that is much faster than that required to develop peak torque and at much higher velocities that those used to measure peak torque. From this perspective, both the force and temporal response of the muscles that span the ankle are important to consider. Therefore, in our most recent study[22] of ankle-ligament injury risk factors, muscle-reaction time, or the time lag between joint perturbation and muscle activation (sometimes called the closed-loop efferent reflex response), was measured for dorsiflexion and inversion motions of the foot. Muscle-reaction times for both modes of perturbation were not predictive of injury in men; however, an interesting trend occurred in women. Compared with uninjured female athletes, the gastrocnemius muscle of female athletes with ankle sprains required less time to react, while the anterior tibialis muscle required more time to react in response to dorsiflexion perturbation. This combination introduces the hypothesis that the protective effect of the leg muscles on maintaining joint stiffness and stability through cocontraction may be compromised and suggests that a neuromuscular deficit may exist in those athletes who are injured.

Postural Sway

Recognizing that an athlete's center of gravity changes during upright posture and that this is under control of both the central and peripheral nervous systems, Tropp et al[12] used a forceplate to characterize the change in an athlete's center of gravity (eg, postural sway) and related it to the risk of suffering an ankle injury. Postural sway was measured during the preseason in soccer players who were then followed for a complete season. An elevated postural-sway value identified an athlete at increased risk of suffering an ankle sprain. Watson[23] characterized postural sway with a practical approach that involved measurement of the duration of time a subject could maintain a single-leg stance without touching down to recover balance. Those who could maintain a single-leg stance for at least 15 seconds were considered to have normal posture, while those who touched down to regain balance within the 15-second test were considered to have abnormal posture. Ankle sprains affected more subjects with abnormal posture than with normal posture. Similarly, McGuine et al[30] used the NeuroCom Balance Master (NeuroCom International Inc, Clackamas, OR) to measure postural sway among a cohort of high school basketball players and demonstrated that subjects with increased sway scores suffered a 7-fold increase in ankle sprains compared with those with normal sway. We[22] also used the NeuroCom system to measure postural sway, but we studied collegiate soccer, lacrosse, and field hockey players who had not suffered prior injury to their lower extremities. We did

not find a relationship between sway score and risk of ankle sprain.

EXTRINSIC RISK FACTORS

Extrinsic risk factors that have been investigated through prospective studies include bracing and taping, shoe type, and the duration and intensity of competition and player position.

Ankle Bracing and Taping

Review of the prospective studies of the effect of bracing on reduction in ankle sprains revealed a consistent finding: athletes with a history of ankle sprains who use a brace or tape experienced a lower incidence of ankle sprains.[5,7,8,11] Tropp et al[8] were the first to investigate the effect of a brace on soccer players. Three groups of athletes, each with a history of ankle sprain, were studied. The first group received no intervention (eg, control group), the second used a brace, and the third performed ankle-disk training throughout their season. Athletes who wore a brace or underwent ankle-disk training experienced a significant decrease in the incidence of ankle sprains in comparison with the control group. The protective mechanisms of the 2 interventions were thought to be different: the brace was hypothesized to provide mechanical support, while the protection imparted by disk training was attributed to a decrease in the functional instability of the ankle. Using a prospective study design, Surve et al[7] also studied the effect of braces on the incidence of ankle-ligament injury among soccer players. Athletes were divided into 2 groups: those with no prior ankle sprain and those with a history of ankle sprain. Subjects in each group were then randomly assigned to the semirigid brace or unbraced group. Those with prior ankle sprains who used the brace had a reduced incidence of ankle sprains, but there was no difference in the severity of ankle sprains with or without the use of the brace. These observations led the investigators to suggest that the protection provided by a brace was not accomplished through mechanical support of the joint but through an improvement in proprioception. Using a similar study design, Sitler et al[11] performed the most comprehensive prospective study of the effect of bracing on reducing ankle sprains among collegiate basketball athletes. Athletes were divided into groups according to the presence or absence of previous ankle sprains and were then randomly assigned to a group that wore a brace or a group that received no brace or tape. All athletes wore the same high-top basketball shoes, which provided an important control of this ankle-support variable. The incidence of ankle sprains was lower in athletes with a history of ankle sprains who wore a brace, but there was no difference in the severity of ankle sprains between the groups. McKay et al[5] also studied basketball players and reported that using ankle tape for support decreased the risk of reinjury in athletes with a history of ankle-ligament sprains.

Shoe Type

Another extrinsic risk factor that has undergone investigation is shoe type. One of the first studies revealed that the incidence and severity of knee and ankle injuries in high school football players were reduced when the length of the shoe cleats was reduced.[31] In contrast, 2 prospective studies have shown no correlation between shoe type and ankle sprains for military trainees and basketball players.[6,9] Milgrom et al[6] performed a well-controlled study that followed male military trainees during basic training. Half of the trainees used three-quarter-height basketball shoes (approximately 11 cm high) to train, while the other half used lightweight infantry boots (approximately 22 cm high). The incidence of ankle sprains between the trainees using the basketball shoes and those using the infantry boots was no different. Barrett et al[9] also performed a well-controlled study of basketball players who were randomly assigned to groups wearing low-top shoes, high-top shoes, or high-top shoes with an inflatable air chamber. No difference in the incidence of ankle sprains among the shoe types was noted. Although this study was well controlled, the authors stated that the low number of ankle sprains limited their findings. This is a concern because shoe type might have been shown to reduce the incidence of ankle injury if a larger sample size had been used. In the McKay et al[5] study of basketball players, athletes who wore shoes with air cells in the heel-cup portion were at significantly greater risk of injuring the ankle than those who wore shoes without air cells. Although most would agree that current athletic shoes offer limited support to an ankle in response to inversion trauma, it is important to recognize that specific characteristics of the shoe may either reduce the risk of injury (eg, certain design characteristics may provide increased proprioceptive input) or increase the risk of injury (eg, restricted ankle range of motion, abnormal foot-shoe and shoe-surface traction, or increased inversion moment arm about the ankle complex). We did not find information about the effect of different characteristics of athletic shoes on the risk of ankle injury.

Duration and Intensity of Competition and Player Position

Although several prospective studies have recorded exposure data,[5,9,11,22,30] only Ekstrand et al[3,32] and Arnason et al[33] have separated their data by practices and games. Ekstrand et al[3,32] found that twice as many injuries occurred in soccer games as in practice, and there was no difference in risk of ankle injury among player positions. Arnason et al[33] reported 4.4 ankle sprains per 1000 hours of participation in soccer games and only 0.1 sprains per 1000 hours of practice. Similar to Ekstrand et al,[3,32] Sitler et al[11] noted no difference in risk of ankle injury among basketball player positions.

CONCLUSIONS

Most professionals involved in the care of athletes would agree that prevention of injury is important. However, when one considers the most common injury experienced in sport, ankle-ligament sprains, a dilemma arises because there is very little consensus in the literature with regard to the risk factors for ankle injury derived from well-controlled, prospective investigations. Our review of the available prospective studies found some consensus: (1) sex does not appear to be a risk factor for suffering an ankle sprain, (2) the use of a brace is effective for reducing the risk of reinjuring the ankle, and (3) foot type (classified as supinated, neutral, or pronated) and generalized joint laxity are not ankle-injury risk factors. At this point, there is little consensus in the literature with regard to whether or not height, weight, limb dominance, ankle-joint laxity, anatomical alignment, muscle strength, muscle-reaction time, and postural sway are risk factors for ankle sprains.

Most proposed risk factors for lateral ankle sprains remain controversial and require further investigation. For example, our prior work on this subject revealed differences in many of the intrinsic factors between male and female athletes. This led us to perform separate analyses for each sex[22]; however, very few researchers have taken this approach, and most studies have focused only on male athletes.

The recent literature has provided important advances with regard to identifying ankle-injury risk factors through well-controlled, prospective studies, yet much work is needed to properly identify ankle-injury risk factors. Future studies must be prospective in design, provide an equal distribution of male and female athletes when the sport under investigation involves both sexes, evaluate men and women separately if the risk factors are sex dependent, include the collection of exposure data (accounting for both practices and games), use a well-accepted system to classify and grade the type of ankle injuries encountered, and consider analysis such as the Cox regression model, which takes into account both time at risk and differences in risk associated with different sports.

Once the risk factors for ankle-ligament sprains are determined, future intervention studies can be performed to reduce the incidence and severity of ankle-ligament trauma.

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