

Ankle Injuries and Ankle Strength, Flexibility, and Proprioception in College Basketball Players

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Objective: To determine if ankle muscular strength, flexibility, and proprioception can predict ankle injury in college basketball players and to compare ankle injury rates in female and male players.

Design and Setting: In this prospective, correlational study, subjects were tested at the start of the competitive season for ankle joint muscle strength, flexibility, and proprioception. The first ankle injury for each subject was recorded on an injury report form, and the data were analyzed to determine if any of these preseason measurements predicted future injury. The setting was a competitive 9-week season for four women's and four men's college basketball teams.

Subjects: A convenience sample of 31 female and 11 male college basketball players.

Measurements: Subjects were tested for ankle dorsiflexion range of motion, various measures of ankle proprioception, and

isokinetic peak torque of ankle dorsiflexion-plantar flexion and eversion-inversion at 30°/sec and 180°/sec before the start of the conference basketball seasons. Data were analyzed using a series of multiple regression equations to determine the variance in ankle injury attributed to each variable.

Results: Various measures of proprioception predicted left ankle injury in all subjects ($p < .05$), while ankle strength and flexibility measures failed to account for additional variance. There was no statistically significant difference in ankle injury rate between women and men.

Conclusions: Ankle joint proprioceptive deficits can be used to predict ankle injury, but further research is needed to identify other sources of variance. In our study, ankle injury rate was similar in female and male college basketball players.

Key Words: athletic injuries, college athletes, range of motion

Injuries to the ankle joint are among the most common of all sport-related injuries. Figures range from 10% to 30% of all injuries and from 5% to 20% of all time-loss injuries.¹⁻⁹ Athletes participating in sports such as football, soccer, basketball, and volleyball are especially at risk for this type of injury, largely because of the running and jumping involved. In 1977, Garrick³ reported that during any single year of a 6-year period at the University of Washington, at least 16% of all time-loss injuries for all sports involved ankle sprains.

Although ankle injuries are suffered by athletes in many sports, ankle sprains are most prevalent in basketball. Many authors describe ankle sprains as being "de rigueur" for basketball participation.^{3,10} Ankle sprains are not only the most common injury in basketball, but some studies cite basketball playing as being the most common cause of ankle sprains.¹¹

Prophylactic ankle protection techniques (primarily adhesive taping) are the most readily available and easiest methods used by athletic trainers and coaches to prevent ankle injuries caused by the external stresses inherent in sport. These methods theoretically provide external mechanical support to the ankle joint; however, it would be of interest to identify internal risk factors that might predispose an athlete to ankle injury. Several intrinsic factors may be involved, including lower leg muscle weakness, poor limb proprioception, and tight heel cords.^{1,12,13}

Flexibility and strength have frequently been studied to determine their role in athletic injury prevention, but few

conclusions have been drawn. Although proprioception has not been studied as thoroughly, there is speculation as to whether proprioceptive deficits predispose an individual to injury. Proprioception training, along with strength and flexibility training, is believed to be essential to the success of most rehabilitation programs.^{9,14-16}

Few studies have investigated athletic injuries in a prospective manner. Researchers who have done so have made few conclusive findings, and their methods vary greatly, making it difficult to draw conclusions or make comparisons. Also, strength, flexibility, and proprioception have largely been investigated in isolation, while no studies have inspected the interrelationship of several variables, and most studies focused on athletes of a single sex. Therefore, the main purpose of this study was to determine the variance in ankle joint injury explained by muscle strength, flexibility, and proprioception. A secondary purpose was to compare ankle injury rates in male and female college basketball players. The study is considered exploratory because of the relatively small sample and short duration.

METHODS

Thirty-one female and 11 male members of the University of Nebraska at Omaha, Creighton University, Dana College, and Midland Lutheran College women's and men's varsity basketball teams ranging in age from 18 to 22 years (women's mean, 20 ± 1.3 yr; men's mean, 20 ± 1.1 yr) participated in this study. Subjects were not randomly sampled but were members of an available subject pool. Each was training and participating in basketball prior to the start of the conference season.

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This training included daily organized practice sessions for 10 to 12 weeks, as well as competition in several preseason games.

Each team member who volunteered to participate in the study completed a questionnaire before testing to determine if he or she qualified for the study. All qualified subjects had an absence of significant history of ankle injury for both ankles. This was defined as an absence of (1) ankle injury in the past 6 months requiring complete immobilization (ie, use of a walking cast); (2) functional instability (a feeling of "giving way"); and (3) previous reconstructive ankle surgery.

We informed subjects of testing procedures and protocol before participation, as well as the possible risks and benefits associated with the treatment as outlined by the informed consent form approved by the University of Nebraska Institutional Review Board.

Design

We tested all subjects for ankle joint muscle strength, flexibility, and proprioception at the start of their conference basketball season. A season lasted 9 weeks (postseason competition was not included), during which the incidence of ankle injury was assessed. For each subject, data were recorded only for an initial injury, while any further injury, either reinjury to the same ankle or injury to the opposite ankle, was not used in the analysis. The reason for using only the first injury was that any ankle injury may have predisposed the athlete to further ankle injury. Since we could not control for possible predisposition to future ankle injury, we reported only the initial injury. An NATABOC-certified athletic trainer at each school recorded all injuries by completing the injury report form provided.

This study defined injury as any ankle injury that (1) occurred as a result of participation in an organized intercollegiate practice, contest, or conditioning activity; (2) required medical assistance by a team athletic trainer or physician; and (3) resulted in any alteration of normal routine by that athlete. All three criteria had to be met for the incident to be reported.

The dependent variable in this study was ankle injury. Independent variables were ankle joint strength, flexibility, and proprioception. We determined the amount of variance explained by each variable and compared the rate of ankle injury in women and men.

Measurements

Before testing, each subject warmed up for 5 minutes on an exercise cycle at a self-selected intensity. The order of testing for each independent variable was randomized. All subjects wore low-cut athletic court shoes, and each researcher collected all measurements at his or her site.

The experimental procedure for measuring each variable was as follows:

Flexibility. For each subject, active ankle dorsiflexion in degrees was measured bilaterally. Subjects sat upright with both the knee and hip flexed to approximately 100° and the foot in neutral position. Each measurement was recorded on a

Biodex (Biodex Medical Systems, Inc, Shirley, NY) equipped with an electric goniometer (ELGON). Once the subject's foot was securely fastened to the Biodex foot pedal, each subject was asked to actively dorsiflex the foot.

A perpendicular relationship of the foot to the leg was considered the neutral position of the ankle, and active dorsiflexion from this position resulted in a positive value. One measurement was taken for each ankle, with investigators verbally encouraging subjects to achieve maximal dorsiflexion. The investigators' tones and words were similar with each subject.

Proprioception. Proprioception was defined as the ability to match reference joint angles without visual feedback. The ELGON on the Biodex was again used, this time to record ankle joint position in two planes: dorsiflexion-plantar flexion and eversion-inversion.

Subjects sat upright with knee and hip flexion as described previously. They were asked to close their eyes during testing to eliminate visual input.^{17,18} The score obtained from the proprioception measurement was the deviation from the referenced joint position and was recorded as absolute error.

Subjects completed two or three smooth, continuous warm-up repetitions of each motion just before the respective test to familiarize themselves with the apparatus and movement and to promote relaxation. When they felt comfortable, we told them to hold their ankles in a neutral position. Neutral position was achieved when 0° registered on the ELGON. At this time, having asked subjects to close their eyes, the investigators then manually moved the apparatus to a predetermined reference position for each motion. The experimenter then instructed the subject to hold the foot in that position and to remember that position for future reference. After approximately 3 to 5 seconds, the investigator manually returned the foot to the neutral position. The subject was then asked to match the referenced position.

Each subject completed 12 trials, three each at preselected joint angles of 15° for inversion and 20° for eversion in the sagittal plane and 10° for dorsiflexion and 15° for plantar flexion in the frontal plane. Midrange angles were selected in an attempt to maximize sensory input from muscle proprioceptors.¹⁹ The order of angle assessment was randomized within each plane.

Strength. We measured concentric and eccentric torque for both dorsiflexion-plantar flexion and eversion-inversion at speeds of 30°/sec and at 180°/sec on a Biodex isokinetic dynamometer. We positioned the subjects in the same manner as previously described. Subjects' feet were securely strapped to the foot pedals, and the subjects were also strapped at the calf, thigh, and waist in an attempt to isolate the ankle joint. Subjects also crossed their arms in a relaxed position across their chests to eliminate the possibility of substituting other muscles to improve peak torque.

Subjects warmed up with two full repetitions before testing at each speed for each movement. Experimenters verbally encouraged subjects to give a maximal effort as they performed four consecutive repetitions for each ankle, at each speed, and for each movement. Concentric measurements were performed subsequently on each ankle at each movement. Subjects were

allowed recovery periods of at least 1 minute between speeds for each ankle and at least 2 minutes between movements, minimizing the effects of fatigue.

RESULTS

We calculated means and standard deviations for flexibility, strength, and proprioception measurements (Table 1), as well as physical characteristics of subjects (Table 2). For all summary data, women and men are presented separately. Several multiple regression analyses were used to develop equations to predict the incidence of ankle injury from the variables being measured. We dummy-coded injuries, with 1 denoting injury and 0 denoting no injury. A 2×2 chi-square analysis was performed to determine differences between male and female injury rates. A significance level of $p \leq .05$ was used for all analyses.

Data from all 42 subjects initially tested were included in the analyses. Eight subjects (19%) suffered an ankle injury over the course of the season: seven women (23%) and one man (9%). Since limbs were analyzed separately, as well as together, it is of interest to mention that four of the injuries were to the left ankle and four to the right.

We performed a series of stepwise multiple regression analyses, with injury as the dependent variable and several independent variables. Analyses were performed with all data combined, as well as individually, for women and men for injury of the left and right ankle, respectively.

Proprioception was a predictor of left ankle injury in all subjects, and two variables, both measures of proprioception, were predictors for each left and right ankle injury in the female subjects ($p \leq .05$). Specifically, left inversion (mean deficit, 1.4° ; range, 0.0° to 7.0°), right dorsiflexion (mean deficit, 1.0° ; range, 0.0° to 5.0°), right eversion (mean deficit, 3.0° ; range, 0.0° to 9.0°), and right inversion (mean deficit, 1.6° ; range, 0.0° to 13°) proprioception were identified ($r = 0.99$ for test-retest reliability of first and second efforts). The

Table 2. Physical Characteristics of Subjects ($n = 42$)

	Mean \pm SD*	Range
Women ($n = 31$)		
Age (yr)	20.0 \pm 1.32	18.0 to 22.0
Height (cm)	176.9 \pm 7.22	162.6 to 193.0
Weight (kg)	70.4 \pm 7.95	54.5 to 90.9
Men ($n = 11$)		
Age (yr)	20.0 \pm 1.10	19.0 to 22.0
Height (cm)	190.0 \pm 4.52	182.9 to 195.6
Weight (kg)	84.4 \pm 7.24	71.4 to 93.2

* SD, standard deviation.

regression equations and related statistics are presented in Tables 3 through 5.

A 2×2 chi-square analysis found no significant difference in ankle injury rate between women and men ($\chi^2 = 0.959$; $p \leq .05$).

DISCUSSION

Our results indicate that various proprioceptive deficits at the ankle joint are predictors of ankle injury. This supports the finding of Tropp et al,²⁰ who found subjects with functional instability, as prospectively measured by stabilometry, more likely to suffer an ankle injury than normal subjects. These results also agree with recent reports supporting the relationship of injury and proprioceptive deficits,^{16,21} which may begin to answer the question posed by many authors as to whether a proprioceptive deficit is a predisposing factor or a result of injury.¹³

Specifically, left inversion proprioception was the lone predictor of left ankle injury in all subjects, explaining 14.59% of the variance (standard error of estimate, or SEE, 0.278). Left inversion and right dorsiflexion proprioception were predictors of left ankle injury in the female subjects only. It is of interest to note that the contralateral limb explained variance in the involved limb. However, this finding is not surprising when

Table 1. Flexibility, Proprioception, and Strength Measures for the Left and Right Ankles ($n = 42$) (mean \pm SD*)

Variable	Women ($n = 31$)		Men ($n = 11$)	
	Left Ankle	Right Ankle	Left Ankle	Right Ankle
Flexibility (degrees)				
Heel cord	30.1 \pm 8.5	27.4 \pm 7.6	27.9 \pm 7.3	27.2 \pm 5.1
Proprioception (degrees) \pm absolute error				
Inversion	2.7 \pm 3.8	2.7 \pm 2.4	0.9 \pm 1.2	2.1 \pm 1.8
Eversion	2.8 \pm 2.7	2.7 \pm 2.8	5.0 \pm 2.6	5.4 \pm 2.6
Dorsiflexion	2.2 \pm 1.9	2.1 \pm 1.4	1.9 \pm 1.8	2.6 \pm 1.5
Plantar flexion	3.0 \pm 3.1	2.6 \pm 2.4	3.3 \pm 3.0	3.4 \pm 3.0
Strength (Nm)				
Inversion 30°/sec	23.2 \pm 6.1	24.9 \pm 5.6	30.2 \pm 8.1	31.4 \pm 6.0
Inversion 180°/sec	12.1 \pm 3.8	20.0 \pm 3.0	15.2 \pm 4.2	14.8 \pm 6.4
Eversion 30°/sec	25.5 \pm 4.5	26.0 \pm 4.5	29.0 \pm 3.3	31.4 \pm 6.0
Eversion 180°/sec	14.9 \pm 2.2	15.3 \pm 2.4	18.8 \pm 3.9	19.0 \pm 5.1
Dorsiflexion 30°/sec	30.2 \pm 5.6	32.4 \pm 4.7	38.6 \pm 5.4	41.3 \pm 6.5
Dorsiflexion 180°/sec	14.4 \pm 4.5	13.8 \pm 3.0	18.2 \pm 3.9	17.1 \pm 4.1
Plantar flexion 30°/sec	59.5 \pm 12.7	64.8 \pm 11.7	74.0 \pm 24.5	76.0 \pm 28.2
Plantar flexion 180°/sec	25.1 \pm 8.7	24.2 \pm 5.5	27.5 \pm 13.0	26.0 \pm 10.2

* SD, standard deviation.

Table 3. Regression Predicting Left Ankle Injury (n = 42)*

Step	Variable	R	R ² × 100	SEE
1	L inversion proprioception	0.382	14.59	0.278

$$* Y' = 1.981 - 0.046 (X_1).$$

Table 4. Stepwise Regression Predicting Left Ankle Injury in Women (n = 31)*

Step	Variable	R	R ² × 100	SEE
1	L inversion proprioception	0.447	20.02	0.273
2	R dorsiflexion proprioception	0.614	37.71	0.246

$$* Y' = 1.999 - 0.049 (X_1) - 0.125 (X_2).$$

Table 5. Stepwise Regression Predicting Right Ankle Injury in Women (n = 31)*

Step	Variable	R	R ² × 100	SEE
1	R eversion proprioception	0.469	22.03	0.306
2	R inversion proprioception	0.572	32.68	0.289

$$* Y' = 2.029 - 0.078 (X_1) + 0.063 (X_2).$$

considering that proprioception affects balance. One unstable limb might affect how the athlete reacts to situations and cause stress on the opposite limb in an effort to avoid use of the unstable limb. These variables explained 37.71% of the variance and had an SEE of 0.246.

Finally, right eversion proprioception was identified with right inversion as a predictor of right ankle injury in the women, explaining 32.68% of the variance (SEE, 0.289). However, right inversion proprioception was negatively correlated with ankle injury, which indicates that the injured subjects had better proprioception of this motion than the noninjured subjects. Other factors not assessed here may explain much of the variance in ankle injuries.

The results of this study explained relatively small portions of the variance causing ankle injury. This was not surprising, however, because many other factors involved in the occurrence of injury may also explain variance. These factors may include fatigue, skill level, footwear, type of prophylactic protection, playing surface, psychological factors, other physiological characteristics, accident, and chance. Researchers have had to select variables to focus on and then try to explain how those individual factors contribute to injury, which may explain the overall lack of prospective injury studies.

Another finding in our study is that ankle injury rates did not significantly differ between women and men. This finding is in agreement with Garrick,³ who reported that rates of ankle injury between sexes are similar in the same sport. However, the low number of men ($n = 11$), especially when compared with the women ($n = 31$), makes a Type II error quite likely. Therefore, these results are tenuous due to the small sample size and should be interpreted with caution.

Results did not identify ankle joint muscle strength and heel cord flexibility as predictors of ankle injury. The lack of

significance for strength was in agreement with Cowan et al,²² who found the risk of injury to be similar in both strong and weak subjects in terms of absolute strength. Knapik et al²³ also reported no relationship between absolute strength and injuries, but did find specific strength imbalances to be a factor in injury incidence. However, we found no studies that specifically measured ankle joint muscle strength and its relationship to ankle injury, which prevents comparison.

A possible rationale as to why absolute strength has not consistently been correlated with injury rate might be explained simply by the inherent nature of sport. An athlete participating in a sport such as basketball encounters forces that exceed the power of human muscle, as well as the structural integrity of connective tissue. Athletes are subjected to unpredictable and rapid changes in body posture and position that place undue stresses on tissue, at times causing injury.

This same rationale may also explain why flexibility did not explain any of the variance in this study. No studies have investigated heel cord flexibility and its relation to ankle sprains, so direct comparisons cannot be made. Most prospective studies on flexibility and injury have focused on larger muscle groups and other types of injuries, such as muscle strains. Knapik et al²³ found women athletes 2.6 times more likely to be injured if they had a 15% or greater hip extensor range of motion imbalance. Nicholas²⁴ looked at hypermobility and found a relationship that indicated a greater chance of injury in those who are more hypermobile, but his findings have not been replicated using similar methods.²⁵ However, comparison of injuries across studies is difficult due to differences in the types of sports examined, the types of injuries examined, the various definitions of injuries, and differences in the methods of data collection and reduction.

The results from our study identified specific proprioception deficits as predictors in ankle injury. Although few studies have assessed proprioception, some researchers agree that proprioception training is a critical component of rehabilitation programs.^{14,16} Proprioception training as part of preseason conditioning, though not as common as other types of training, is used in some programs. Authors such as Tomaszewski²⁶ have already presented simple ankle proprioception programs that could potentially be used by all athletes in a preventive fashion.

There are several recommendations for future prospective injury research. Most importantly, a greater number of subjects over a longer duration will provide more injuries for study and perhaps improve the likelihood of finding more predictors. Also, other variables may be considered in addition to those used in this study. These may include, but are not limited to, strength, flexibility, and proprioceptive imbalances; strength tests at speeds higher than 180°/sec; proprioception measurements using a weight-bearing method (typical of the injured condition); stabilometric measurements; body composition; and nonphysiological variables, such as shoe type and prophylactic protection used.

From this study, we concluded that proprioceptive deficits at the ankle joint can be used as a predictor of ankle joint injury. This information is beneficial to athletic trainers, coaches, and

athletes because proprioception training may be justified as a preventive measure, rather than simply a rehabilitative measure.

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