Identification of Ankle Injury Risk Factors in Professional Soccer Players Through a Preseason Functional Assessment

Lucas Sartori Manoel,*[†] PhD, Marcela Godoy Xixirry,[†] BSc, Thabata Pasquini Soeira,[†] MSc, Marcelo Camargo Saad,[†] PhD, and Marcelo Riberto,[†] MD, PhD
Investigation performed at the Department of Biomechanics, Medicine and Rehabilitation of the Locomotor Apparatus, Ribeirão Preto School of Medicine, University of São Paulo, São Paulo, Brazil

Background: Etiologically, the risk of an ankle injury depends on extrinsic and intrinsic factors, such as muscle strength asymmetry, decreased flexibility, and decreased proprioception, as well as patient age and history of injuries.

Purpose/Hypothesis: The purpose of this study was to identify risk factors present in the preseason assessment that may predispose professional soccer players to ankle injuries. We hypothesized that analysis of these parameters could relate the incidence of injuries to the deficits found during the preseason period, enabling the identification of risk factors to predict the occurrence of injuries.

Study Design: Cohort study; Level of evidence, 2.

Methods: A total of 89 professional soccer athletes were evaluated in the preseason period; the evaluation included athlete history and anthropometric data collection, an isokinetic ankle evaluation, and functional tests: the Dorsiflexion Lunge Test and Y-Balance Test (YBT). The athletes were monitored during the competitive period, and the incidence of injuries was surveyed. The association of quantitative variables and injury outcomes was analyzed using the Student t test for independent samples, with $P < .05$. For the association of categorical variables and injury outcomes, the chi-square test was performed, with $P < .05$.

Results: A higher incidence of ankle injuries was associated with lower YBT scores in the dominant ($P = .04$) and nondominant ($P = .01$) limbs. A higher body mass index was also associated with a higher injury occurrence ($P = .01$).

Conclusion: Functional tests, such as the YBT, are indicated tools for assessing the physical capacities and possible risks of ankle sprains, as they can evaluate the ankle functional capacity in a complex way, identifying athletes more prone to ankle injuries. Athletes' body mass index should also be taken into account to prevent such injuries.

Keywords: ankle; soccer; risk factor; injury

*Address correspondence to Lucas Sartori Manoel, PhD, Department of Biomechanics, Medicine and Rehabilitation of the Locomotor Apparatus, Ribeirão Preto School of Medicine, University of São Paulo, Avenida Bandeirantes, 3900 - Ribeirão Preto - SP, 14040-900, Brazil (email: lucas.sartori.fisio@gmail.com).

[†]Department of Biomechanics, Medicine and Rehabilitation of the Locomotor Apparatus, Ribeirão Preto School of Medicine, University of São Paulo, São Paulo, Brazil.

Soccer is the most practiced sport in the world and has a high incidence of injuries. Compared with other team sports, such as volleyball, basketball, and handball, soccer has higher injury rates,[5,36] with 68% to 88% being lower limb injuries.[5,17] Epidemiological studies[7,10,26] have shown a high incidence of soccer injuries, with rates ranging from 1.5 to 15.4 injuries per 1000 training hours and 7.4 to 47.5 injuries per 1000 hours of games.[17,35] The most injured body part in soccer is the ankle, composing 17% to 20% of the injuries.[13]

According to Fousekis et al,[12] the ankle is the body part responsible for absorbing the mechanical load imposed by the interaction between the player and the ground, as well as contact with the opponent. Such situations make the joint susceptible to injuries, such as sprains and ligament injuries. Sprains, when neglected or poorly rehabilitated, have an 80% chance of recurrence and 72% of progression to chronic instability[20] and may contribute directly to longer times of athlete absence because of either the number of sprains in a given period or the severity of the lesions.

Etiologically, the risk of soccer injuries depends on extrinsic factors, such as direct contact with the opponent,[1] inadequate field,[25] inadequate warm-up, and type of footwear.[23] Intrinsic factors related to injury incidence are muscle strength asymmetry,[1,6] decreased flexibility,[16] and decreased proprioception.[22] Other intrinsic factors that may be related to injury incidence are age[1] and previous injuries.[8] Studies have proven that previous ankle injuries induce intrinsic changes, such as ankle muscle strength deficits,[18] neuromuscular control deficits,[19] and delayed response times.[32] These deficiencies are directly related to the increased risk of sport injuries, which may explain the increased chance of sprain relapse after the first episode.

To assess muscle strength performance, isokinetic dynamometry is considered the gold standard, providing reliable data on strength measurements and their variables and making it a tool of great applicability in sport.[9] Studies that have correlated muscle strength with the incidence of soccer injuries have found a significant correlation in knee injuries,[6] muscle injuries,[4] and ankle sprains.[12] The study by Fousekis et al[12] included a sample of 100 athletes to evaluate different risk factors associated with ankle sprains, performing isokinetic dynamometry of plantarflexors and dorsiflexors. Among the results found, there was a significant correlation between ankle injuries with peak torque asymmetry >15% between muscle groups, with an increased odds ratio of 8.88.

In addition to isokinetic dynamometry, functional tests are widely described in the literature and are used to assess the functional capacity of the lower limbs, enabling analysis of postural control, dynamic stability of body segments, balance, flexibility, and strength.[11] Thus, it is possible to analyze the complexity of the tasks required in sport and identify changes that may compromise limb function, such as strength asymmetry, flexibility deficits, postural changes, and balance deficits.[3] Among the tests used to evaluate lower limb function, the Y-Balance Test (YBT) is one of the most described and has the best reliability.[29] Another test that may complement a functional assessment aimed at preventing the risk of ankle injuries is the Dorsiflexion Lunge Test (DLT). It has good reliability[2] and is superior to an amplitude evaluation by traditional goniometry[33] in which deficits are related to a higher risk of ankle injuries, especially in soccer players.[28]

In addition to the intrinsic factors analyzed using physical assessments, other parameters, such as anthropometric data and the athlete's history, should also be taken into account to examine the risk of injuries. Fousekis et al[12] identified that a higher body mass index (BMI) and body weight are directly related to a higher risk of injuries. A history of injuries should also be taken into consideration when assessing athletes, as higher injury rates are related to athletes with previous injuries.[20]

Considering the intrinsic risk factors related to the increased incidence of ankle injuries in soccer, it is expected that analysis of such parameters through a functional assessment could relate the incidence of injuries to the deficits found during the preseason period, thus making it possible to identify risk factors and consequently to predict the occurrence of injuries. The aim of this study was to identify risk factors present in the preseason assessment that may predispose professional soccer players to ankle injuries.

METHODS

Sample

This study was approved by a research ethics committee. It was a prospective study. The participants signed the Free and Informed Consent Form after explanation of the research objectives and analysis of the inclusion criteria.

Participants of this research were selected professional soccer athletes linked to football clubs that played in the Brazilian Football Championship of 2017, 2018, and 2019. They were male, aged between 18 and 30 years, and did not have musculoskeletal disorders at the time of evaluation.

Athletes were included if they were football players who were participating at a competitive level with a professional training load, consisting of 3 to 5 hours of training daily 5 days a week for at least 2 years, and who had a professional contract with football clubs that were part of the Brazilian Football Confederation. Patients who had acute musculoskeletal disorders at the time of evaluation, such as muscle, ligament, and soft tissue injuries; swelling; pain; or recent surgery, were excluded from the study.

The participants were recruited by an invitation sent to the club's technical committee or medical department. Athletes who expressed interest in participating in the survey were invited to the rehabilitation center of Hospital das Clínicas of the Ribeirão Preto School of Medicine on a scheduled date for an examination, and the assessment was performed in the preseason period before the start of the competition calendar.

Sample Calculation

The sample size was calculated based on the prospective study by Fousekis et al,[12] who assessed the risk of ankle sprains in 100 professional soccer athletes, with the isokinetic evaluation showing asymmetries between muscle forces in the ankle joint and an increased risk of sprains (odds ratio, 8.88 [95% CI, 1.95-40.36]; $P = .005$). Considering a significance level of .05, study power of 0.80, relative risk of 4 times, and incidence of ankle sprain injuries of about 12% in noncontact situations, the sample size calculated was 44 participants. Because of the high demand of participants to enroll in the study and the number of participants presented by the study of Fousekis et al, 89 professional soccer athletes were included.

Assessments

Performance evaluations were conducted in the preseason before the start of the championship season in 2017, 2018, and 2019, which constitutes the training period before the start of the first official championship match, and applied by physical therapists from soccer clubs who were trained to maintain the scientific rigor of data collection. The

Figure 1. Ankle isokinetic evaluation.

athletes participating in the research initially underwent a history evaluation and physical examination to rule out possible dysfunctions that would exclude them from the study. The Foot and Ankle Outcome Score questionnaire was also administered for a subjective assessment of the foot and ankle; it consists of 44 questions, with a score from 0 to 100, in which 100 indicates no symptoms and 0 indicates extreme symptoms. Thus, athletes with scores >80 were considered clinically fit to participate in muscle performance tests.

Anthropometric data were collected, as well as measurements of the length of the lower limb, which was measured as the distance from the anterior superior iliac spine to the lateral malleolus. Limb dominance was assessed as the most used limb for kicks or jumps. Additionally, a 5-minute warm-up on a stationary bicycle was performed. The functional assessment consisted of patient history, isokinetic ankle dynamometry, and functional tests: the DLT and YBT.

Isokinetic Dynamometry

Isokinetic dynamometry of the ankle dorsiflexor and plantarflexor groups was performed. Positioning orientations were according to the manufacturer's specifications: supine position with the chair inclination at 25°; thorax, abdomen, and distal third-thigh cross straps; dynamometer perpendicular to the chair and parallel to the floor; and ankle initially positioned in neutral position, keeping the tibia parallel to the floor and the foot fixed at 90°, forming a right angle (Figure 1). Testing was performed at 2 angular speeds, 30 (slow) and 120 deg/s (fast), in the concentric mode, with 5 repetitions at 30 deg/s, followed by 15 repetitions at 120 deg/s and 60 seconds of recovery between tests. The evaluation was always initiated by the dominant foot to facilitate the athlete's familiarization with the isokinetic dynamometer. The participant performed a series of 5 submaximal repetitions before each test to familiarize himself with the movement. During the test, the participant was asked to perform the maximal voluntary isometric contraction, with verbal stimulation during the execution of the movement. The absolute isokinetic parameters evaluated

Figure 2. Dorsiflexion Lunge Test.

were peak torque (N·m), peak torque normalized by body weight (N·m//kg), total work (J), and average power (W). Relative parameters were the dorsiflexion/plantarflexion ratio at 30 and 120 deg/s, and this last parameter is widely used to analyze the balance of forces between agonist and antagonist muscles of a target joint. The values were considered normalized and expressed as a percentage in relation to the patient's body weight.

Functional Tests

Dorsiflexion Lunge Test. The DLT was performed while weightbearing, placing the foot perpendicularly in contact with the wall and the knee equally supported on the wall. The participant was then asked to move the foot off the wall by sliding it backward so that the knee did not lose contact with the wall and the heel of the tested foot did not lose contact with the floor. Then, the maximum distance between the foot and the wall was measured. Distances <9 to 10 cm suggested the restriction of dorsiflexion. This test is predictive of future football injuries[3] (Figure 2).

Y-Balance Test. The YBT assesses unipodal balance and dynamic lower limb neuromuscular control and is an adaptation of the Star Excursion Balance Test in which only the anterior, posteromedial, and posterolateral components are evaluated.[14] This test was performed in the single-leg position in which the participant aimed to keep a fixed foot on the ground in the center of the axis of a demarcated Y-shaped figure on the floor while trying to reach the farthest point of the lines in the anterior, posterolateral, and posteromedial directions with the nonfixed toe (Figure 3). The athlete touched the line at maximum range and returned to the starting position.[14] He received verbal and
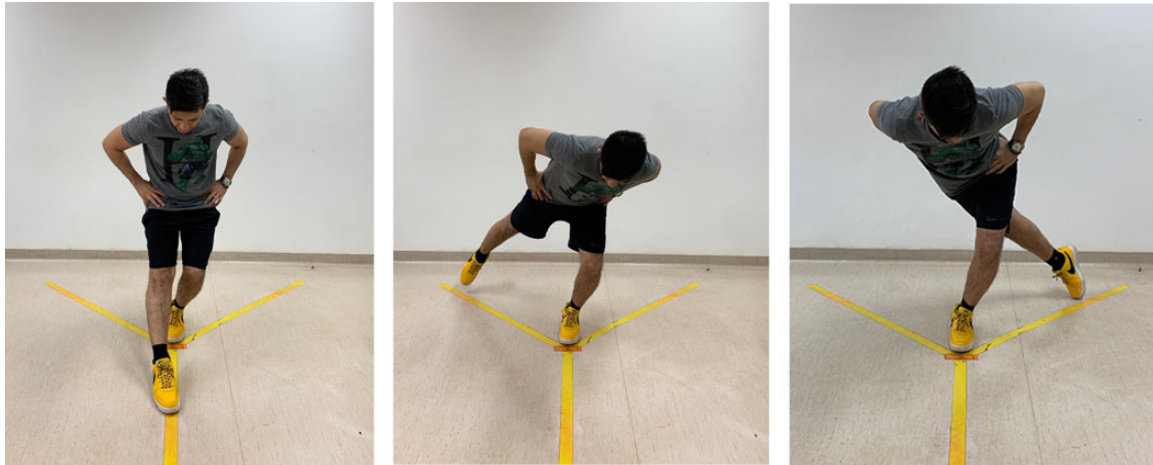
Figure 3. Y-Balance Test in anterior, posteromedial, and posterolateral directions.

visual guidance for the test. The athlete was instructed to perform 6 repetitions of the learning test, alternating among the 3 directions and between the support feet. If he removed the support foot from the initial position or supported the nonfixed foot to regain balance, the repetition was disregarded. A total of 3 consecutive repetitions were performed in each direction, repeating them in all 3 directions, and the test was performed bilaterally, starting with the dominant limb as a fixed foot. The largest distance (in cm) reached by the participant was considered the final score.

According to Gribble et al,[14] in addition to the maximum range achieved, a normalized sum of the limbs' range can also be calculated and is called the composite score. The composite score is the sum of the 3 distances divided by 3 times the limb length (in cm) and multiplied by 100. This normalized score is also used to determine injury risk. A difference in anterior range of $\geq$4 cm from the contralateral limb and/or a composite score of $\leq$94% of limb length on the YBT indicates a risk of injuries.[14]

Assessment of Injury Incidence

During the competitive period, the participants were evaluated directly by the respective medical team of each club. The team was instructed to examine the injuries and their characteristics, such as the location of the injury by body part, clinical or radiological diagnosis (if any), contact or noncontact injury, situation where the injury occurred (game or training), and severity of the injury (by time away from games and training), which was classified as follows: mild = 0-3 days; moderate = 4-21 days; and severe $\geq$22 days.

The definition of a sport injury used for standardization during the collection period was proposed by Junge et al[17] as a sport-related traumatic event that resulted in a period of absence from matches or training. All teams participating in the study received an injury incidence form and were instructed to complete it. At the end of the competitive period, the medical teams of the respective participating clubs submitted the forms, and the data were compiled; the medical team was available to consult or solve any doubts of the researchers regarding the athletes and their respective injuries. Also, the medical department or technical committee of the participating clubs was contacted monthly to collect information regarding the incidence of injuries in athletes during the competitive period.

Statistical Analysis

Quantitative variables were evaluated for normal distribution and summarized with central tendency and dispersion measures. Categorical variables were expressed as a percentage of each category.

The outcome of the study was the occurrence of atraumatic ankle injuries not caused by contact, such as sprains, fractures, muscle injuries, and ligament injuries, among others. The association of quantitative variables and injury outcomes was analyzed using the Student t test for independent samples. For the association of categorical variables and injury outcomes, the chi-square test was performed. Statistical analysis was performed using SPSS statistical software (Version 17; IBM Corp). The significance level used was .05.

RESULTS

The results of the preseason evaluation were described in terms of quantitative and categorical variables of the sample. A total of 89 athletes were assessed, and there were no athletes excluded from the study by exclusion criteria. The quantitative analysis (Table 1) showed a homogeneous sample in terms of age, weight, and height. The categorical analysis (Table 2) showed a higher prevalence of right side–dominant athletes (76%), and 21% of the sample reported a history of injuries. As recruitment was conducted by inviting all athletes competing for their referral clubs, a homogeneous concentration of athletes in each participating club was expected, as well as a higher concentration of midfielder players.

TABLE 1
Patient Quantitative Data

	Mean ± SD
Age, y	26.25 ± 4.43
Weight, kg	78.70 ± 8.80
Height, m	1.79 ± 0.08
Body mass index, kg/m^2	24.44 ± 1.64

TABLE 2
Patient Categorical Data (n = 89)

	n (%)
Position	
Goalkeeper	11 (12.4)
Defender	15 (16.9)
Midfielder	35 (39.3)
Side player	11 (12.4)
Striker	17 (19.1)
Limb dominance	
Right	68 (76.4)
Left	21 (23.6)
Previous injury	
No	70 (78.7)
Yes	19 (21.3)

TABLE 3
Injury Characteristics (n = 45)

	n (%)
Atraumatic ankle injury	16 (35.6)
Position	
Goalkeeper	3 (6.6)
Defender	8 (17.7)
Midfielder	19 (42.2)
Side player	4 (8.9)
Striker	11 (24.0)
Injury location	
Ankle	20 (44.4)
Knee	8 (17.7)
Thigh	15 (33.3)
Hip	1 (2.2)
Shoulder	1 (2.2)
Injury setting	
Training	13 (28.9)
Match	32 (71.1)
Contact	
Atraumatic	36 (80.0)
Traumatic	9 (20.0)
Severity	
Mild	17 (37.8)
Moderate	17 (37.8)
Severe	11 (24.4)

Description of Injury Incidence

The characterization of injuries occurring during the competitive period (Table 3) was specified according to the occurrence of injuries. A total of 45 injuries occurred, of

TABLE 4
Patient Categorical Data by Injury Occurrence[a]

	No Atraumatic Ankle Injury (n = 73)	Atraumatic Ankle Injury (n = 16)	P Value
Limb dominance			.26
Right	58 (79.5)	10 (62.5)	
Left	15 (20.5)	6 (37.5)	
Previous injury			.95
No	58 (79.5)	12 (75.0)	
Yes	15 (20.5)	4 (25.0)	

[a]Data are presented as n (%).

which 16 were specifically atraumatic ankle injuries, composing 36% of the total injuries.

There was a higher incidence of ankle injuries (44%), followed by thigh injuries (33%). Most injuries occurred during matches (71%), with atraumatic contact (80%). Injury severity ranged from mild to moderate (38% each).

Description of Association Between Variables and Outcomes

The association between categorical variables and injury outcomes was assessed using the chi-square test (Table 4). Limb dominance and injury history showed no significant differences.

The difference between quantitative variables and injury outcomes was assessed using the Student t test (Table 5). Athletes with a higher BMI had a higher incidence of injuries ($P = 0.01$).

Isokinetic variables at velocities of 30 (Table 6) and 120 deg/s (Table 7) showed no significant association with the occurrence of an injury. Moreover, by analyzing the composite score in both the dominant and the nondominant limbs, the relationship between functional test results (Table 8) and injury outcomes was significant on the YBT.

DISCUSSION

The preseason period is crucial in preparing athletes for better performance during the competition season. During this period, a functional examination was conducted to analyze the athlete's physical abilities and possible risk factors that may lead to an increased risk of injuries during the season. It is possible that at this time, preventive training, aimed at correcting the dysfunctional parameters observed by the functional evaluation of the preseason period, could be implemented. The aim of this study was to analyze the preseason physical, psychological, and functional variables of professional soccer athletes and to correlate these variables with injury-related outcomes, especially ankle injuries.

There were 45 injuries during the competitive period, 16 of them specifically atraumatic ankle injuries (36% of injuries). Consideration should be given to relate risk factors to injury outcomes that involve only atraumatic ankle injuries, as the ability to predict injuries arising from traumatic

TABLE 5
Differences Between Patient Quantitative Data[a]

	No Atraumatic Ankle Injury	Atraumatic Ankle Injury	Difference (95% CI)	*P* Value
Age, y	25.75 ± 4.01	26.36 ± 4.54	−0.61 (−2.95 to 1.73)	.59
Weight, kg	77.63 ± 6.21	78.90 ± 9.29	−1.27 (−5.17 to 2.56)	.49
Height, m	1.82 ± 0.07	1.79 ± 0.08	0.03 (−0.01 to 0.07)	.16
Body mass index, kg/m^2	23.54 ± 1.52	24.64 ± 1.61	−1.10 (−1.97 to −0.22)	.01[b]

[a]Data are presented as mean ± SD unless otherwise specified.
[b]$P < .05$.

TABLE 6
Differences Between Isokinetic Variables of Ankle Plantarflexion and Dorsiflexion at 30 deg/s[a]

	No Atraumatic Ankle Injury	Atraumatic Ankle Injury	Difference (95% CI)	*P* Value
Plantarflexion				
Peak torque, N·m				
Dominant limb	142.87 ± 19.20	139.79 ± 24.26	3.08 (−8.59 to 14.76)	.59
Nondominant limb	137.57 ± 18.63	134.64 ± 24.44	2.93 (−8.50 to 14.36)	.60
Deficit	3.51 ± 6.22	3.11 ± 11.07	0.40 (−3.83 to 4.63)	.84
Total work, J				
Dominant limb	164.44 ± 41.16	150.93 ± 44.36	13.51 (−10.65 to 37.69)	.26
Nondominant limb	139.76 ± 32.20	131.20 ± 38.90	8.56 (−10.80 to 27.92)	.37
Deficit	14.01 ± 10.86	9.49 ± 22.48	4.52 (−3.39 to 12.43)	.25
Average power, W				
Dominant limb	39.81 ± 6.28	38.18 ± 9.26	1.63 (−2.36 to 5.62)	.41
Nondominant limb	38.48 ± 6.39	37.69 ± 9.44	0.79 (−3.26 to 4.86)	.69
Deficit	2.94 ± 9.81	−0.67 ± 20.50	3.61 (−3.57 to 10.79)	.31
Dorsiflexion				
Peak torque, N·m				
Dominant limb	33.87 ± 6.13	33.15 ± 6.84	0.72 (−2.91 to 4.35)	.68
Nondominant limb	33.85 ± 7.20	33.74 ± 7.35	0.11 (−4.08 to 4.30)	.95
Deficit	−0.38 ± 14.02	−3.37 ± 19.07	2.99 (−5.72 to 11.70)	.48
Total work, J				
Dominant limb	42.75 ± 10.66	39.98 ± 12.47	2.77 (−3.61 to 9.15)	.38
Nondominant limb	40.39 ± 13.40	37.40 ± 10.94	2.99 (−4.57 to 10.55)	.41
Deficit	3.95 ± 24.75	3.44 ± 26.62	0.51 (−14.04 to 15.07)	.94
Average power, W				
Dominant limb	11.19 ± 2.64	10.79 ± 2.34	0.40 (−1.10 to 1.91)	.58
Nondominant limb	11.40 ± 3.10	11.07 ± 2.91	0.33 (−1.45 to 2.11)	.70
Deficit	−2.28 ± 17.77	−1.77 ± 25.89	−0.51 (−11.78 to 10.76)	.92
Agonist/antagonist ratio, %				
Dominant limb	24.31 ± 6.43	24.09 ± 4.33	0.22 (−3.33 to 3.79)	.89
Nondominant limb	24.96 ± 6.70	25.60 ± 7.38	−0.64 (−4.59 to 3.31)	.74

[a]Data are presented as mean ± SD unless otherwise specified.

events related to contact between opponents is very unlikely. The ankle was the most injured joint in the sample, with 20 injuries in the sample. These data are in agreement with the literature,[13] followed by thigh injuries, also described in the literature as another body part with higher rates of soccer injuries.[21] Most injuries occurred during games, establishing a relationship between the level of physical demands and the highest incidence of injuries.

Analyzing the general data of the sample and their relationship with the incidence of injuries, a statistically significant relationship was observed between the athletes' BMI and the risk of injuries. Apparently, athletes with a lower BMI had lower injury rates. In a study with similar characteristics, Fousekis et al[12] concluded that a higher BMI in soccer athletes increased the susceptibility of ankle sprains, with a relative risk of 8.16. This increased risk is associated with increased ligament overloading during the support phase in complex movements typically performed in football, such as spinning and pivoting.[12]

Muscle strength analysis, considered the gold standard, is performed using an isokinetic evaluation, especially in sport, when the objective is to observe possible asymmetries

TABLE 7
Differences Between Isokinetic Variables of Ankle Plantarflexion and Dorsiflexion at 120 deg/s[a]

	No Atraumatic Ankle Injury	Atraumatic Ankle Injury	Difference (95% CI)	*P* Value
Plantarflexion				
Peak torque, N·m				
Dominant limb	100.98 ± 15.50	97.42 ± 20.03	3.56 (−5.91 to 13.04)	.44
Nondominant limb	93.58 ± 14.22	92.50 ± 19.66	1.08 (−7.77 to 9.93)	.80
Deficit	6.98 ± 8.15	3.75 ± 14.58	3.23 (−2.33 to 8.78)	.24
Total work, J				
Dominant limb	343.73 ± 94.58	345.41 ± 101.50	−1.68 (−57.17 to 53.82)	.95
Nondominant limb	319.01 ± 77.42	327.91 ± 102.13	−8.90 (−56.48 to 38.68)	.70
Deficit	4.44 ± 21.11	2.35 ± 26.31	2.09 (−10.70 to 14.88)	.74
Average power, W				
Dominant limb	47.48 ± 16.89	48.39 ± 17.95	−0.91 (−10.80 to 8.98)	.85
Nondominant limb	44.59 ± 13.85	47.03 ± 18.19	−2.44 (−10.95 to 6.06)	.56
Deficit	0.86 ± 26.52	−2.10 ± 35.98	2.96 (−13.47 to 19.38)	.71
Dorsiflexion				
Peak torque, N·m				
Dominant limb	23.47 ± 4.92	23.99 ± 8.07	−0.52 (−3.83 to 2.80)	.75
Nondominant limb	23.89 ± 4.46	23.44 ± 4.92	0.45 (−2.27 to 3.16)	.73
Deficit	−2.78 ± 13.13	−2.41 ± 2.69	−0.37 (−8.80 to 9.53)	.93
Total work, J				
Dominant limb	100.28 ± 24.55	87.96 ± 2.23	12.32 (−1.53 to 26.18)	.07
Nondominant limb	100.14 ± 26.31	93.22 ± 26.68	6.92 (−8.37 to 22.20)	.35
Deficit	−2.09 ± 25.43	−9.09 ± 31.15	7.00 (−8.35 to 22.34)	.35
Average power, W				
Dominant limb	17.89 ± 3.99	15.99 ± 4.28	1.90 (−0.43 to 4.25)	.10
Nondominant limb	18.41 ± 5.43	16.96 ± 5.05	1.45 (−1.66 to 4.57)	.34
Deficit	−2.03 ± 22.05	−9.50 ± 33.23	7.47 (−6.63 to 21.56)	.28
Agonist/antagonist ratio, %				
Dominant limb	23.97 ± 6.54	24.99 ± 6.62	−1.02 (−4.93 to 2.91)	.59
Nondominant limb	25.66 ± 5.13	26.87 ± 10.82	−1.21 (−4.98 to 2.56)	.52

[a]Data are presented as mean ± SD unless otherwise specified.

TABLE 8
Differences Between Functional Test Variables[a]

	No Atraumatic Ankle Injury	Atraumatic Ankle Injury	Difference (95% CI)	*P* Value
Y-Balance Test				
Anterior reach, cm	0.20 ± 3.43	1.15 ± 4.27	−0.95 (−3.47 to 0.77)	.20
Posteromedial reach, cm	0.73 ± 5.40	0.21 ± 5.73	0.52 (−2.72 to 3.77)	.74
Posterolateral reach, cm	1.87 ± 5.62	0.59 ± 5.59	1.28 (−2.06 to 4.62)	.43
Composite score, %				
Dominant limb	92.39 ± 6.75	88.23 ± 6.59	4.16 (0.15 to 8.15)	.04[b]
Nondominant limb	93.18 ± 6.03	88.66 ± 6.72	4.52 (0.87 to 8.17)	.01[b]
Dorsiflexion Lunge Test, cm				
Dominant limb	10.13 ± 3.11	9.82 ± 3.71	0.31 (−1.53 to 2.14)	.73
Nondominant limb	10.16 ± 2.55	9.93 ± 3.33	0.23 (−1.31 to 1.76)	.76

[a]Data are presented as mean ± SD unless otherwise specified.
[b]$P < .05$.

of muscle strength. The relationship between strength asymmetry and an increased incidence of injuries is very clear in knee injury studies, but this relationship is not evident in other joints, such as the ankle. In this study, there was no correlation between any isokinetic muscle strength variable and the incidence of injuries. This study analyzed several isokinetic variables, such as peak torque, work, power, and agonist/antagonist ratio, at 2 different velocities, thus having more reliable force analysis than most studies in the literature using an isokinetic evaluation for examining only muscle peak torque. Fousekis et al[12] observed a relationship between eccentric force asymmetry

at 60 deg/s and the risk of injuries; other variables were not correlated with risk of injuries. Namazi et al,[24] in their prospective study, correlated several isokinetic variables of different body parts with the incidence of injuries. No significant relationship was found between strength asymmetry and injury outcomes. These results bring into question the individual role that muscle strength plays in ankle injuries.

Apparently, the key to preventing ankle injuries lies in multifactorial analysis of physical parameters rather than isolated parameters, such as strength or range of motion. Functional tests, such as the YBT, are used to analyze ankle function from a functional perspective, correlating various parameters, such as muscle strength, neuromuscular control, range of motion, balance, and psychological aspects.[14] Such tests include objective, valid, and reliable measurements of sport-specific movements and are used in athletes because of their ability to assess dynamic tasks, such as jumping, reaching, or running, among other soccer-targeted functions.[30]

Comparing the findings of the functional tests with the incidence of ankle injuries throughout the season, a statistically significant relationship between YBT scores and injury outcomes was observed. The YBT was superior in identifying athletes at a higher risk of injuries because it is a functional test that encompasses several motor skills rather than analyzing them separately, such as an isokinetic assessment that analyzes muscle strength in isolation from any other physical parameter that may influence ankle function. The YBT has been widely used in clinical practice with satisfactory results in identifying sport-related risk factors.[27,30] Limb asymmetries on the YBT are associated with an increased risk of lower limb injuries. Static balance changes assessed by the YBT are related to an increased risk of injuries to the lower limbs in school-aged athletes and those involved in physical activity by up to 2.5 times.[31,34]

In a 2018 study, Hartley et al[16] analyzed the relationship of YBT scores with the incidence of ankle sprains in young soccer athletes. The authors observed a direct relationship between lower YBT scores and a higher incidence of ankle sprains. In addition, they also observed a relationship between an increase in BMI of the participants and a higher occurrence of injuries. These results also match those from a study by Gribble et al,[15] who evaluated the same parameters in a population of high school soccer athletes, totaling 606 participants. The authors reported a higher incidence of ankle sprains in athletes who had lower YBT scores during the preseason. A higher BMI was also related to a higher incidence of sprains in their study.[15]

This study has some limitations. The period analyzed after the preseason evaluation lasted about 3 months, including the state championship in which each team participated. Because of the high turnover of the athletes in the clubs between competitions, it was impossible to follow these athletes for a longer period than a competition; as the athletes usually change clubs frequently, these changes made it impossible for the research team to keep up the monitoring of athletes in the long term. The medical team was advised on the process of examining the injuries that

occurred during the competitive period and was supported by material provided by the research team itself; thus, data collection regarding the incidence of injuries was performed exclusively by the club's medical team. Data were provided to the research team according to the medical team's database of the respective clubs. Meetings were held between the medical team and the research team at the end of the competitive period to discuss the obtained data.

This study presents the applicability of a preseason functional assessment aimed at predicting future ankle injuries in sport because functional testing using the YBT obtained better results in identifying possible risks. In addition, the YBT provides a multifactorial analysis of the ankle function, compared to other tests, such as isokinetic evaluation, which evaluates only the strength parameter. The health professional can use this as a preventive assessment, analyzing possible ankle dysfunctions, performing preventive work, and thus minimizing the incidence of ankle sprains.

CONCLUSION

During the competitive period, there was a high incidence of injuries, with the ankle being the most involved joint. Further, 36% of the injuries during the season were atraumatic ankle injuries, which could be prevented. A higher BMI was related to a higher risk of ankle injuries. No isokinetic variable at either speed was related to ankle injuries during the competitive period. Athletes with lower scores on the YBT had a higher incidence of ankle injuries. These data suggest that the risk of ankle injuries depends on multifactorial analysis of physical parameters and not on isolated parameters, such as strength or range of motion.

REFERENCES

1. Árnason Á. Risk factors for injuries in football. *Am J Sports Med*. 2004; 32(1)(suppl):5S-16S.
2. Bennell K, Talbot R, Wajswelner H, Techovanich W, Kelly D, Hall A. Intra-rater and inter-rater reliability of a weight-bearing lunge measure of ankle dorsiflexion. *Aust J Physiother*. 1998;44:175-180.
3. Clanton T, Lauren M, Matheny B. Return to play in athletes following ankle injuries. *Sports Health*. 2012;4(6):471-474.
4. Croisier J, Ganteaume S, Binet J, Genty M, Ferret J. Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. *Am J Sports Med*. 2008;36: 1469-1475.
5. De Loes M. Epidemiology of sports injuries in the Swiss organization "Youth and Sports" 1987-1989: injuries, exposure and risks of main diagnoses. *Int J Sports Med*. 1995;16:134-138.
6. Devan MR, Pescatello L, Faghri P, Anderson J. A prospective study of overuse knee injuries among female athletes with muscle imbalances and structural abnormalities. *J Athl Train*. 2004;39:263-267.
7. Dvorak J, Junge A. Football injuries and physical symptoms: a review of the literature. *Am J Sports Med*. 2000;28(5)(suppl):S3-S9.
8. Ekstrand J, Gillquist J. Football injuries and their mechanisms: a prospective study. *Med Sci Sports Exerc*. 1983;15:267-270.
9. Ekstrand J, Hägglund M, Waldén M. Epidemiology of muscle injuries in professional football (soccer). *Am J Sports Med*. 2011;39(6): 1226-1232.
10. Ekstrand J, Tropp H. The incidence of ankle sprains in soccer. *Foot Ankle*. 1990;11(1):41-44.

11. Filipa A, Byrnes R, Paterno MV, et al. Neuromuscular training improves performance on the Star Excursion Balance Test in young female athletes. *J Orthop Sports Phys Ther*. 2010;40(9):551-558.

12. Fousekis K, Tsepis E, Vagenas G. Intrinsic risk factors of noncontact ankle sprains in soccer: a prospective study on 100 professional players. *Am J Sports Med*. 2012;40(8):1842-1845.

13. Gabbe BJ, Finch CF, Wajswelner H, Bennell KL. Predictors of lower extremity injuries at the community level of Australian football. *Clin J Sport Med*. 2004;14:56-63.

14. Gribble PA, Hertel J, Plisky P. Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. *J Athl Train*. 2012; 47(3):339-357.

15. Gribble PA, Terada M, Beard MQ, et al. Prediction of lateral ankle sprains in football players based on clinical tests and body mass index. *Am J Sports Med*. 2016;44(2):460-467.

16. Hartley EM, Hoch MC, Boling MC. Y-Balance Test performance and BMI are associated with ankle sprain injury in collegiate male athletes. *J Sci Med Sport*. 2018;21(7):676-680.

17. Junge A, Dvorak J, Graf-Baumann T. Football injuries during the World Cup 2002. *Am J Sports Med*. 2004;32(1)(suppl):23S-27S.

18. Kaminski TW, Hartsell HD. Factors contributing to chronic ankle instability: a strength perspective. *J Athl Train*. 2002;37(4):394-405.

19. Konradsen L. Factors contributing to chronic ankle instability: kinaesthesia and joint position sense. *J Athl Train*. 2002;37(4): 381-385.

20. Lentell G, Katzmann LL, Walters MR. The relationship between muscle function and ankle stability. *J Orthop Sports Phys Ther*. 1990;11: 605-611.

21. Liporaci RF, Saad MC, Belilaqua-Grossi D, Riberto M. Preseason intrinsic risk factors-associated odds estimate the exposure to proximal lower limb injury throughout the season among professional football players. *BMJ Open Sport Exerc Med*. 2018;4(1): e000334.

22. Mandelbaum BR, Silvers HJ, Watanabe DS, et al. Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. *Am J Sports Med*. 2005;33:1003-1010.

23. Mckay GD, Goldie P, Payne W, Oakes B. Ankle injuries in basketball: injury rate and risk factors. *Br J Sports Med*. 2001;35:103-110.

24. Namazi P, Zarei M, Hovanloo F, Abbasi H. The association between the isokinetic muscle strength and lower extremity injuries in young male football players. *Phys Ther Sport*. 2019;39:76-81.

25. Orchard JW, Powell JW. Risk of knee and ankle sprains under various weather conditions in American football. *Med Sci Sports Exerc*. 2003; 35:1118-1123.

26. Peterson L, Junge A, Chomiak J, Graf-Baumann T, Dvorak J. Incidence of football injuries and complaints in different age groups and skill-level groups. *Am J Sports Med*. 2000;28(5)(suppl):S51-S57.

27. Plisky PJ, Rauh MJ, Kaminski TW, Underwood FB. Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. *J Orthop Sports Phys Ther*. 2006;36(12):911-919.

28. Ross SE, Guskiewicz KM, Gross MT, Yu B. Balance measures for discriminating between functionally unstable and stable ankles. *Med Sci Sports Exerc*. 2009;41:399-407.

29. Shaffer SW, Teyhen DS, Lorenson CL, et al. Y-Balance Test: a reliability study involving multiple raters. *Mil Med*. 2013;178(11): 1264-1270.

30. Stiffler MR, Bell DR, Sanfilippo JL, Hetzel SJ, Pickett KA, Heiderscheit B. Star Excursion Balance Test anterior asymmetry is associated with injury status in Division I collegiate athletes. *J Orthop Sports Phys Ther*. 2017;47(5):339-346.

31. Trojian TH, Mckeag DB. Single leg balance test to identify risk of ankle sprains. *Br J Sports Med*. 2006;40(7):610-613.

32. Vaes P, Duquet W, Van Gheluwe B. Peroneal reaction times and eversion motor response in healthy and unstable ankles. *J Athl Train*. 2002;37(4):475-480.

33. Venturini C, Ituassú NT, Teixeira LM, Deus CVO. Intrarater and interrater reliability of two methods for measuring the active range of motion for ankle dorsiflexion in healthy subjects. *Braz J Phys Ther*. 2006;10(4):407-411.

34. Willems TM, Witvrouw E, Delbaere K, Mahieu N, Bourdeaudhuij I, De Clercq D. Intrinsic risk factors for inversion ankle sprains in male subjects. *Am J Sports Med*. 2005;33(3):415-418.

35. Woods C, Hawkins RD, Maltby S, et al. The Football Association Medical Research Programme: an audit of injuries in professional football. Analysis of hamstring injuries. *Br J Sports Med*. 2004;38(1): 36-41.

36. Yde J, Nielsen AB. Sports injuries in adolescents' ball games: soccer, handball and basketball. *Br J Sports Med*. 1990;24:51-54.