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Reliability of a Functional Test Battery Evaluating Functionality, Proprioception and Strength of the Ankle Joint

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Aim: In contrast to the one-sided evaluation methods used in the past, combining multiple tests allows one to obtain a global assessment of the ankle joint.

Materials and Methods: Twenty healthy male volunteers participated in this study. One component of the test battery included five different functional ability tests, which included: single limb hopping course, one-legged and triple-legged hop for distance, and six-meter (6-m) and cross 6-m hop for time. Ankle joint position sense and one leg standing test were used for proprioceptive evaluation. Isokinetic strength of the ankle invertor and evertor muscles were evaluated at a velocity of 120°/sec. Reliability of the test battery was assessed by calculating the intraclass correlation coefficient (ICC).

Results: The ICCs for ankle functional and proprioceptive ability showed good to high reliability (ICC ranging from 0.89 to 0.98). Furthermore, isokinetic ankle joint inversion and eversion strength measurements represented good reliability (ICCs between 0.86-0.89).

Conclusions: The functional test battery investigated in this study proved to be a reliable tool in the assessment of the ankle joints of healthy recreational athletes. Clinicians may use the information of the functional test battery to detect changes in ankle joint performance as a component of a screening evaluation.

Key Words: Reliability, clinical functional test battery, functional ability, proprioception, strength, ankle joint

Ayak Bileği Ekleminin Fonksiyonelliğini, Propriosepsiyonunu ve Kuvvetini Değerlendiren Fonksiyonel Test Bataryasının Güvenirliği

Amaç: Geçmişte kullanılan tek yönlü değerlendirme yöntemlerinin aksine birden fazla testin birleştirilmesi ayak bileği eklemi için daha geniş çaplı bir değerlendirme yapılmasına olanak sağlayacaktır.

Yöntem ve Gereç: Çalışmaya 20 sağlıklı erkek denek katıldı. Kullanılan test bataryasının bir bölümü beş farklı fonksiyonel testi kapsadı. Bunlar arasında parkur testi, tek adım ve üç adım sıçrama mesafesinin ve altı metreyi düz ve çapraz sıçrama zamanının ölçümü vardı. Ayak bileği propriosepsiyonu eklem pozisyon hissi ve tek bacak durma testi ile değerlendirildi. Ayak bileği invertör ve evertör kaslarının izokinetik kuvveti 120°/sn'lik açısal hız ile ölçüldü. Test bataryasının güvenirliği sınıf içi korelasyon katsayısının (ICC) hesaplanması ile değerlendirildi.

Bulgular: Ayak bileğinin fonksiyonel ve proprioseptif becerisi için elde edilen ICC değerleri iyi ve yüksek bir güvenirliğe işaret etti (0.89-0.98 arasında değişim göstermiştir). Bunun yanısıra, ayak bileği izokinetik invertör ve evertör kuvvet ölçümleri de iyi düzeyde bir güvenirliği yansıttı (0.86-0.89 arasında değişim göstermiştir).

Sonuç: Bu çalışmada incelenen fonksiyonel test bataryası sağlıklı rekreasyonel sporcuların ayak bileği eklemlerinin değerlendirilmesinde güvenilir bir yöntem olduğunu kanıtlamıştır. Klinisyenler fonksiyonel test bataryasından elde edecekleri bilgileri tarama muayeneleri kapsamında ayak bileği performansındaki değişiklikleri tespit etmek için kullanabilirler.

Anahtar Sözcükler: Güvenirlik; fonksiyonel test bataryası; fonksiyonel beceri; propriosepsiyon; kuvvet; ayak bileği eklemi

Introduction

Ankle injuries are one of the most common injuries encountered in sport activities. Eighty-five percent of ankle injuries are sprains, and of these, 85% are inversion sprains of the lateral ligaments (1). It has been shown that repetitive ankle joint injuries cause evertor and invertor muscle strength deficits, and neurosensorial, proprioceptive and mechanical impairments (2,3). The ultimate goal of management is firstly to identify proprioceptive, functional, and strength deficits among these patients with ankle injury and thereafter to return the athlete to the highest functional level in the most efficient manner. Therefore, exercises that increase proprioception, balance and functional capacity are routinely performed after an ankle joint injury in addition to strengthening the invertor and evertor muscles.

Isokinetic dynamometer, using various commercially available equipments, is a frequently applied method to assess muscle performance (4) and proprioception (5), both in laboratory settings and clinical practice when the athlete can safely resume unrestricted sporting activities. Many isokinetic reliability assessments have targeted ankle plantarflexion and dorsiflexion muscle groups, and have indicated the different isokinetic dynamometers to be highly reliable in various patient populations (6-9). On the contrary, few studies have addressed the ankle invertor and evertor muscles (10,11), and to our knowledge, no study has investigated the reliability of testing these muscles using the Cybex Norm dynamometer.

The proprioceptive mechanism is essential for proper function of the joint in sports, for activities in daily life, and for some occupational tasks. Proprioception contributes to the motor programming for neuromuscular control required for precision movements and also contributes to muscle reflex, providing dynamic stability. Objective quantification of proprioception may improve early detection of proprioceptive loss and help quantify this loss with injury. Difficulty in detecting minimal, but potentially important, alterations in proprioception may be partly because of the lack of reliable and valid methods of quantifying joint position and movement sense. However, proprioception is frequently evaluated following ankle injuries using different methods and equipment (12). Although there are studies that have investigated the reliability of one leg standing test, kinesthesia and joint position sense for ankle plantarflexion and dorsiflexion direction, which found high reliability (13,14), with respect to ankle invertor and evertor strength measurements, no study has evaluated the reliability of ankle joint position sense testing in the inversion-eversion direction using the Cybex Norm dynamometer.

Functional performance tests are dynamic measures used to assess general lower body function. Clinicians use functional performance testing during the latter stages of rehabilitation and as a criterion to determine return to participation status after ankle joint injuries (15). Therefore, the reliability of these tests is essential for appropriate data analysis. Studies investigating the reliability of single leg hop for distance, triple leg hop for distance and one-legged 6-m hop for time demonstrated highly reliable values (16,17). Additionally, we developed a single limb hopping course test to document the function of the ankle on an uneven surface; the reliability of this jumping course has not been evaluated yet.

In contrast to the one-sided evaluation methods used in the past, combining multiple tests allows one to obtain a global assessment during the return to sport activity phase for each athlete. In the present study, different clinical tests were chosen based on the components of functionality, proprioception and strength, which are important diagnostic markers for the ankle joint following injuries. Thus, the purpose of the study was to examine the repeatability of the different tests of a clinical test battery that evaluates 1) functional ability of the ankle joint using five different tests, 2) proprioception using joint position sense and one leg standing test, and 3) ankle invertor and evertor muscle strength measurements, using the Cybex Norm dynamometer.

Materials and Methods

Subjects

Twenty male recreational athletes with no history of lower extremity dysfunction (mean age 21.1 ± 1.8 years; mean height 173.8 ± 4.8 cm; mean body mass 65.3±5.3 kg; mean body fat percent 13.8±1.7%) participated in this study. Any individual with a history of low-back or lower extremity injury, complaints of pain, swelling, or functional limitations in the ankles, or who had undertaken any therapeutic exercise programs for the ankle joint within 12 months before testing was excluded from this study. The test procedure took place in 13 right-limb and 7 left-limb dominant ankles, since strength and proprioception of the lower extremity does not appear to be influenced by limb dominance (18). Limb dominance was determined by asking subjects which leg they would use to naturally kick a ball. All 20 subjects enrolled in this study participated regularly in recreational sports like running, soccer or basketball 1-2 times a week for durations of 30-90 minutes. Written consent was obtained from each subject before testing, and all subjects were screened to ensure that there were no lower extremity neuromuscular or musculoskeletal problems or contraindications for isokinetic testing. After being informed about the study and test procedures, and any possible risks and discomfort that might ensue, their written informed consent to participate was obtained in accordance with the Helsinki Declaration (19).

Experimental Procedure

The same clinician (YY) evaluated all 20 subjects twice, with a 3-5 day interval between the test sessions. In order to prevent the tests negatively affecting each other, test sessions were separated and completed in two days. Isokinetic strength and functional test measurements were made on the first day. On the second day, balance and proprioceptive ability of the ankle joint were evaluated. All tests were performed at the same time each day.

Isokinetic Strength Measurement

Isokinetic testing of the ankle invertor and evertor muscles was performed at a velocity of 120°/s for eccentric and concentric contractions of the ankles. Subjects performed a 10-minute warm-up of general range of motion and stretching exercises for joint movements of inversion/eversion and dorsiflexion/plantarflexion. After the warm-up, they were appropriately positioned on the isokinetic dynamometer (Cybex Norm, USA), which was calibrated before testing each subject. The ankle was positioned so that the subtalar joint became neutral, which was the start position (0°) (20). The talocrural joint was positioned in 10°-15° plantarflexion as a consequence of the low-cut lace-up shoe worn by each subject that simulated a position for inversion injury. Two straps, which crossed to the dorsum of the foot, were attached to the footplate. The knee of the test leg was positioned in 80°-110° flexion and the lower leg was parallel to the floor. The thigh stabilizer pad and strap secured the distal aspect of the thigh for the test leg and a seatbelt placed around the abdomen secured the torso. All the tests were performed with the subjects wearing shoes.

The range of motion stop angles from eversion to inversion direction were set at 20º of eversion and 30º of inversion, and vice versa from inversion to eversion. Three submaximal trials for familiarization with the isokinetic testing procedure and to perform warm-up were followed by five maximal concentric and eccentric invertor and evertor trials. Evertor and invertor muscle strength was obtained by measuring maximal force moments (torque) during isokinetic ankle inversion and eversion movements. To ensure that a maximal effort was attained, all subjects received positive verbal encouragement during testing. The same investigator performed all the tests to ensure standardization. A two-minute rest was permitted between the test for inversion and eversion to prevent the build-up of fatigue.

Proprioceptive Ability of the Ankle Joint

In order to evaluate the proprioceptive ability and balance of the ankle joint, the measurement of ankle joint position sense and one leg standing test were used.

Ankle joint position sensibility: Passive joint position sense (PJPS) was measured by the continuous passive motion (CPM) mode of the isokinetic dynamometer (Cybex NORM^{TM}) at 1°/s angular speed. The tested foot was placed on the footplate of the Cybex, according to the manufacturer's instructions for isolating inversion-eversion and plantar flexion-dorsiflexion, and was secured with Velcro straps. Prior to testing, the Cybex dynamometer was calibrated as a part of the regular schedule for maintenance of equipment used for this testing device.

To initiate the test, the foot was placed in the neutral (0º) position. All subjects were blindfolded to eliminate the contribution of visual cues during the repositioning of the joint. For familiarization with the testing device, subjects were instructed to perform three active repetitions of ankle movement ranging from maximal ankle inversion to maximal eversion. The test began with the tester passively moving the tested ankle into the testing position of 10º of inversion and maintaining that position for 10 s. After 10 s of static positioning, the ankle was moved back passively from the presented angle to the reference angle (neutral position). When the testing device moved continuously from the neutral position to inversion at 1°/s angular speed, the subject was asked to passively reproduce the previously presented test angle of 10º of inversion by stopping the device using the handheld on-off switch when he thought the test angle had been reached. Two trials were performed. Following the first reference angle, the same testing protocol was used for 20º of inversion angle from the beginning of the starting angle (neutral position). Angular displacement was recorded as the error in degrees between the reference angle and the repositioned angle. The mean of the two trials for each tested condition was calculated, to determine an average error in scores (18).

One leg standing test: This test evaluates the subject's ability to maintain balance while standing on one leg. We performed this test not on a hard surface but on a medium-density polyfoam mat and with eyes closed to increase the failure rate. The subjects stood on the test side limb with their stance foot centered on the mat with their knees slightly flexed. They were instructed to lift the limb that was not being tested by bending the knee, and holding it in approximately 90° of knee flexion. Once the subjects were in this position with eyes closed, and said that they were ready, data collection was started. The one leg standing test measurement was performed for one minute. During the test period, each surface contact with the contralateral leg, moving of the test foot, or swaying the body excessively out from midline in any direction to obtain a balanced stance was counted as one failure point. The subjects performed the tests without shoes and socks to negate any extraneous skin sensation from clothing touching the foot area. The outcome measure was averaged over two trials.

Functional Ability of the Ankle Joint

We evaluated the functional ability of the ankle using five different tests. The tests performed were: the single limb hopping course, the one-legged hop for distance, the triple- legged hop for distance, the six-meter (6-m) hop for time (s) and the cross 6-m hop for time (s).

Single limb hopping course: This test is especially useful to document the function of the ankle on an uneven surface, and was previously described by Aydin et al. (18). The jumping course consists of eight squares: four of them are even, one has a 15º increase, one has a 15º decrease, and two show a 15º lateral inclination (Figure 1). The volunteers are asked to jump across this course on one leg by touching each area once as fast as possible without leaving the course. The test result is quantified by seconds used to pass the course. Each failure adds an extra second to the time taken to complete the course.

One-legged and triple-legged hop for distance: Patients were asked to make one and three forceful hopping movements forward as large as they could. The distance between the starting point and the end point was measured. Two tests were performed and the average distance was measured for each test.

Figure 1. Single limb hopping course.

6-m and cross 6-m hop for time: This is a timed test performed over a distance of 6 m. Each subject was encouraged to use linear, large, forceful one-legged hopping motions and crosswise, large, forceful one-legged hopping motions across a line with a 10 cm width to propel his body toward the measured distance as quickly as possible. Two tests were performed and the average time was measured for each test.

Data Analysis

Statistical analysis was performed using SPSS version 10.0 (SPSS, SPSS Inc, Chicago, IL, USA) software. Mean and standard deviations were used to describe all variables. Test-retest reliability of the tests was determined by intraclass correlation coefficients (ICC). The ICCs were classified as follows: 0.90-0.99, high reliability; 0.80-0.89, good reliability; 0.70-0.79, fair reliability; and <0.69, poor reliability (21). To objectively identify reliability, it is suggested to combine ICC calculations (which represent a relative measure of reliability) with the standard error of the measurement (SEM) (which quantifies the precision of individual scores on a test reported by the tester and is referred to as the typical error) (22). The SEM possesses the unit of measure and calculates a range where the subject's true score is located and is equal to the standard deviation of the measurements multiplied by the square root of one minus the reliability coefficient [SEM = SD*$(1\text{-ICC})^{0.5}$] (22). Paired-samples T test was used to determine the stability of all the measurements. Level of significance was set at $P < 0.05$.

Results

Figures 2, 3, and 4 show the graphical representation created from the means and standard deviations (SD) of muscle strength, proprioceptive ability, and functional performance test scores, respectively, of the ankles of the two testing sessions. There were no significant differences between the two testing sessions for all measured parameters ($P > 0.05$). ICCs and SEMs for these mean scores of muscle strength, proprioceptive ability, and functional performance are presented in Tables 1, 2, and 3, respectively. The ICC values for muscle strength of the ankle invertors and evertors in the concentric and eccentric mode demonstrated "good" reliability (ICC range: 0.86 to 0.89). On the other hand, proprioceptive ability evaluated with ankle joint position sense and one leg standing test indicated "high" reliability

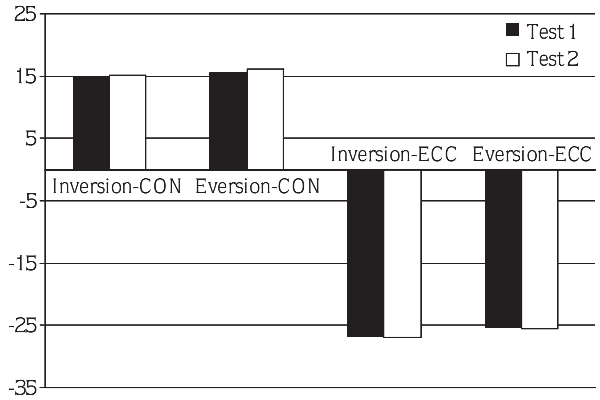

Figure 2. Muscle strength values of the ankle joint for both testing sessions (*CON: Concentric. ECC: Eccentric*).

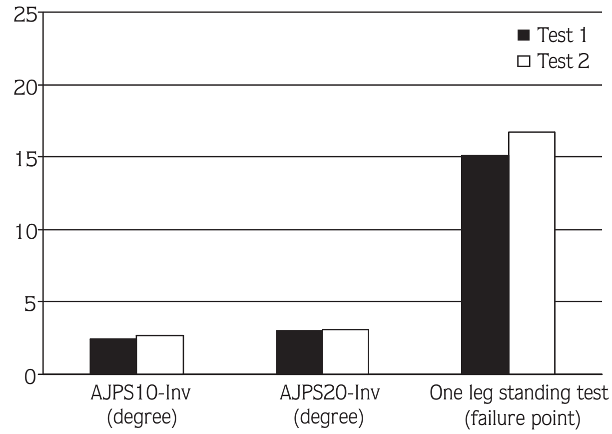

Figure 3. Proprioceptive ability scores of the ankle joint for both testing sessions (*AJPS10-Inv: Ankle joint position sense at 10° of inversion angle. AJPS20-Inv: Ankle joint position sense at 20° of inversion angle*).

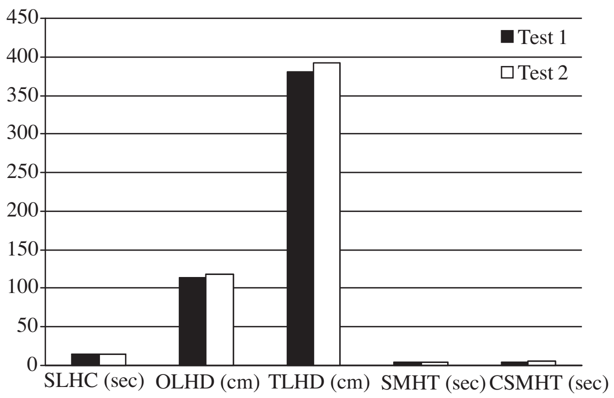

Figure 4. Functional performance test scores of the ankle joint for both testing sessions (*SLHC: Single limb hopping course. OLHD: One-legged hop for distance. TLHD: Triple-legged hop for distance. SMHT: Six-meter hop for time. CSMHT: Cross six-meter hop for time*).

Table 1. Reliability data for the muscle strength values of the ankle joint.

Measure	ICC	SEM
Ankle inversion, concentric	0.88	±0.6 Nm
Ankle eversion, concentric	0.89	±0.9 Nm
Ankle inversion, eccentric	0.88	±1.8 Nm
Ankle eversion, eccentric	0.86	±1.0 Nm

ICC: Intraclass correlation coefficient.
SEM: Standard error of measurement.
Nm: Newton-meter.

Table 2. Reliability data for the proprioceptive ability scores of the ankle joint.

Measure	ICC	SEM
AJPS at 10° of inversion	0.90	±0.22°
AJPS at 20° of inversion	0.94	±0.24°
One leg standing test	0.92	±1.04

ICC: Intraclass correlation coefficient.
SEM: Standard error of measurement.
AJPS: Ankle joint position sense.

Table 3. Reliability data for the functional performance test scores of the ankle joint.

Measure	ICC	SEM
Single limb hopping course	0.91	±0.88 sec
One-legged hop for distance	0.97	±2.9 cm
Triple-legged hop for distance	0.98	±15.5 cm
Six-meter hop for time	0.91	±0.30 sec
Cross six-meter hop for time	0.89	±0.23 sec

ICC: Intraclass correlation coefficient.
SEM: Standard error of measurement.

(ICC range: 0.90 to 0.94). Except for the cross 6-m hop for time test, the ICC value of which displayed "good" reliability (0.89), the other four functional performance test measurements exhibited "high" reliable results (ICCs ranged from 0.91 to 0.98).

Discussion

Ankle sprain is the most common sports injury, predominantly (85-90%) affecting the lateral ligaments of the ankle (1). In connection with this, sport medicine clinicians commonly see athletes who have sustained an ankle injury. The ultimate goal of management is firstly to identify proprioceptive, functional, and strength deficits among these patients and thereafter to return the athlete to the highest functional level in the most efficient manner. Tasks that better mimic circumstances encountered during sporting activities may be more appropriate when assessing athletic individuals. To evaluate functional performance, we chose tests that imposed sport-specific and ankle inversion-specific movements and loads on the ankle joint and required the balance, coordination, and multiplanar muscular stabilization necessary for high-intensity athletic activity. Therefore, we combined functional and proprioceptive ability tests with strength tests, which are commonly used separately in the evaluation of the ankle. To establish the potential clinical utility of these measures, information regarding the test-retest reliability of this testing protocol is necessary, yet such information is not presently available. The purpose of the present study was to examine the reliability of the different tests of a clinical test battery evaluating strength of the ankle invertor and evertor muscles, ankle joint position sense, and functional performance. When assessing test-retest reliability, in which the same measurements are made of the same property in the same units on two or more occasions, ICC is the preferred measure. There are no universally accepted standards as to what constitutes poor, fair, good or high reliability, and various methods to classify the magnitude of ICC are used (21,23). To interpret reliability measures, we used the recommendations of Currier (21) that ICC values above 0.90 represent high reliability while values between 0.70 and 0.89 represent fair to good reliability. However, the decision of whether a method is sufficiently reliable depends upon the specific application: for example, an ICC of 0.80 may be acceptable if the method is going to detect large differences as a result of an intervention, whereas a higher ICC may be required to detect very small differences. To address the inherent variability within the method, measurement errors need to be calculated. The most common measurement errors reported are the SEM (22). Since the ICC is reflective of the ability of a test to differentiate between different individuals, it does not provide an index of the expected trial to trial noise in the data, which would be useful to clinicians (22). Unlike the ICC, which is a relative measure of reliability, the SEM provides an absolute index of reliability. For an observed score, the SEM quantifies the range in which the true score might be expected to vary as a result of measurement error, and therefore provides information to help evaluate change in an individual's performance more confidently (22). According to the ICC and SEM values observed in the present study, ankle inversion and eversion strength parameters evaluated with the Cybex Norm isokinetic dynamometer showed good reliability (ICC: 0.86-0.89), and proprioceptive and functional ability scores showed good to high reliability (ICC: 0.89-0.98). Furthermore, no significant differences existed between testing trials for any of the tests of the clinical test battery. Therefore, we believe that the clinical test battery examined in the present study offers sports medicine clinicians a reliable method to assess ankle joint performance and can be used with great reliability by a single examiner.

Ankle strength: Measurements collected using dynamometers play an important role in patient assessment and research studies. Isokinetic dynamometers have enabled the rapid quantification of strength parameters of muscle function, and the measurements with these devices can be made isometrically at various angular positions and isokinetically (concentrically or eccentrically) with a large scale of angular speeds. Since strength deficits of the ankle evertor and invertor muscles are mostly encountered after ankle injuries (2), we used the isokinetic dynamometer to evaluate the strength of these muscles. The usefulness of isokinetic computerized methods as well as other assessment methods depends upon the ability to control factors that influence the measurement. These include the accuracy of the dynamometer, the test protocol, the reproducibility of the measurement, and factors related to the subject and the person performing the test (6). Suboptimal securing of the subject to the dynamometer can produce different values, due to agonistic coactivation. Together with a short lever arm and a small cross-sectional muscle area, as is the case in the ankle joint, this makes careful fixation and adjustment important, as small differences between test sessions lead to large effects in torque production. Rigorous standardization was used in this study in order to minimize the influence of these factors. Many isokinetic reliability assessments have focused on ankle dorsiflexion and plantarflexion strength and have shown the different isokinetic dynamometers like Kin-Com 500H (8), Cybex II (9), Cybex 6000 (7) and Biodex (6) to be highly reliable for these muscle groups in healthy subjects and post-stroke patients. However, there are few studies that have investigated the reliability of testing isokinetic inversion and eversion in healthy subjects (10). Aydog et al. (10) showed high reliability (ICC ranging between 0.87 and 0.96) for concentric ankle inversion and eversion strength using the Biodex dynamometer in healthy subjects. Similar to these investigations, our study also showed good reliability for the ankle invertor and evertor muscles using the Cybex Norm dynamometer in healthy recreational athletes.

Proprioception: It is widely believed that the tendency for ankle sprains to recur is due to a proprioceptive deficit caused by deafferentation during the original trauma (24). Many methods have been devised to assess ankle proprioception (25,26), and most of these techniques do not isolate variations in performance to the ankle region and may involve other factors such as visual and vestibular cues, neuromuscular control, and the influence of other joints (27). Although visual and vestibular inputs contribute to proprioception, the peripheral mechanoreceptors are most important from a clinical orthopedic perspective. The neural input provided by these mechanoreceptors and the visual and vestibular receptors are all integrated by the central nervous system to generate a motor response. These motor responses generally may be categorized within three levels of motor control: spinal reflexes, brain stem activity, and cognitive programming. Quantifying the reproduction of joint position (either active or passive) and the detection of changes in joint position is processed at the highest level of organization: the somatosensory cortex. These methods can objectively isolate the measurement of joint position at the ankle, although in a non-weight-bearing position. Since lateral ankle sprain occurs in the inversion direction, proprioceptive abilities during the ankle inversion movement have gained in interest. In relation to this, studies have used different isokinetic dynamometers to evaluate joint position sense of the ankle joint in the inversion direction (18,28). Although some studies have investigated reliability of the one leg standing test, kinesthesia, and joint position sense for ankle plantarflexion and dorsiflexion direction and have reported high reliability (13, 14), with respect to ankle invertor and evertor strength measurements, no study has evaluated the reliability of ankle joint position sense testing in the inversion-eversion direction using the Cybex Norm dynamometer. The results of our study demonstrated high ICC values for the joint position sense at 10° (0.90) and 20° (0.94) of inversion and for the one leg standing test (0.92). To our knowledge, the present study is the first to investigate reliability for ankle joint position sense at 10° and 20° of inversion using the Cybex Norm isokinetic dynamometer.

Functional performance: In an attempt to quantify function, various functional performance tests that simulate the stresses around the knee and ankle encountered during athletic activities have been designed (15,29). Functional performance tests cannot detect specific abnormalities; however, they are dynamic measures used to assess lower limb function. These tests are helpful because they combine multiple components, such as muscular strength, neuromuscular coordination, and joint stability, which could be affected after joint injury. Furthermore, functional performance tests are fast, simple to perform, require minimal staff training, and can be conducted in any clinical setting. Consequently, these tests are mostly used by clinicians as an assessment tool; therefore, the reliability of them is essential for appropriate data analysis. Although there are several studies investigating functional performance tests after ankle or knee injuries, they did not address the reliability of the tests used. Conversely, Booher et al. (30) developed three functional performance tests (single-leg hop for distance, single-leg 6-m hop for time and 30-m single-leg agility hop) and estimated the test-retest reliability of these tests in 18 healthy subjects (4 M, 14 F). They reported ICCs ranging from 0.77 to 0.97 when analyzing mean scores between test sessions. Bolgla and Keskula (16) explored the reliability of the functional performance tests (single hop for distance, triple hop for distance, 6-m hop for time, and cross-over hop for distance) described by Noyes et al. (29) in 20 subjects (5 M, 15 F) with no history of lower extremity dysfunction. Except for the results for the 6-m hop for time (ICC: 0.66), the other test results indicated high reliability (ICC: 0.95 to 0.96). In contrast, Ross et al. (17) determined the test-retest reliability of the same four single-leg horizontal hop tests with a time interval of approximately four weeks between the two testing sessions in 18 healthy and athletic men. They also reported high test-retest reliability coefficients for each of the four single-leg horizontal hop tests (ICC ranged from 0.92 to 0.97). We performed the same three horizontal hop tests (one-legged hop for distance, triple-legged hop for distance, and 6-m hop for time) as in the previous studies in healthy recreational athletes and also found high ICC values, ranging between 0.91 and 0.98, pointing to the reliability of these tests. The two functional performance test measures (single limb hopping course and cross 6-m hop for time), the test-retest reliability of which was demonstrated for the first time in the present study, also showed good to high reliability (ICC: 0.91 for single limb hopping course and 0.89 for cross 6-m hop for time).

In conclusion, the functional clinical test battery used in the present study and based on the different components of functional performance, muscle strength and proprioceptive ability was shown to be a reliable tool in the evaluation of ankles of recreational athletes. Thus, this study showed that invertor and evertor muscle strength and proprioceptive measures of the ankle joint in recreational athletes can be quantitatively assessed with the Cybex Norm system. Additionally, the single leg hop and agility tests offer clinicians a reliable method to assess ankle joint performance in recreational athletes. Given these quantitative and reliable measures, we recommend that clinicians may use the information of the functional test battery to detect changes in ankle joint performance in such athletes as a component of a screening evaluation. Further analysis of the reliability of these variables in athletes after ankle joint injuries seems appropriate.

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