The Validity and Reliability of Knee Proprioception Measurement Performed With Inclinometer in Different Positions

Sinem Suner-Keklik, Gamze Cobanoglu-Seven, Nihan Kafa, Mustafa Ugurlu, and Nevin Atalay Guzel

Context: Proprioception is the basic element of the spontaneous control of movement, balance and joint stability. Therefore, it is necessary for the execution of walking and daily and sport activities. Loss of proprioception of the knee, which may cause a new injury, is important to evaluate the position sense of the joint during the rehabilitation period. However, the evaluation methods that are used are very expensive, complicated, and nonportable, or the measuring method is difficult to implement. Objective: We demonstrated the validity and reliability of knee proprioception measurements performed in the open kinetic chain position and closed kinetic chain position with a dual inclinometer. Design: We assessed the validity and intratester reliability of a digital inclinometer for measuring the knee joint position sense in different positions. Setting: Clinical laboratory. Participants: We enrolled 22 participants (age = 21.8 ± 0.95 y, height = 172 ± 9.1 cm, weight = 64.9 ± 14 kg) into the study. Intervention: The same investigator used an inclinometer to take knee proprioception measurements in open and closed kinetic chain positions. Main Outcome Measures: The relative angular error was calculated by taking the arithmetic average of the difference between the target angle and reproduced angle and was the main outcome measure. Results: We found that the dynamometer-inclinometer had a moderate ICC value (ICC = 0.594, SEM = 1.60, \(P = .005\)), whereas inclinometer t1 vs inclinometer t2 (ICC = 0.778, SEM = 0.62, \(P < .001\)) and closed kinetic chain position t1 and closed kinetic chain position t2 (ICC = 0.888, SEM = 0.63, \(P < .001\)) had high ICC values. Conclusion: Knee proprioception measurements performed with a dual inclinometer were reliable in the closed kinetic chain position in healthy, sedentary individuals and were valid and reliable in the open kinetic chain position.

Keywords: knee joint, position sense, isokinetic dynamometer

Proprioception is defined as the sense of the movement and position of various parts of the body in space.\(^1\) It is an important component of neuromuscular performance.\(^2\) It is the basic element of the spontaneous control of movement, balance, and joint stability. Therefore, it is necessary for the execution of walking and daily and sport activities.\(^3\)

Knee proprioception, which plays a key role in the accurate and efficient execution of movements during sport performance, is related to several sport injuries.\(^4\) Position sense in the knee joint is affected by central and peripheral mechanisms, such as muscles, tendons, and articular, cutaneous, and anterior cruciate ligament (ACL) receptors.\(^2\) With ACL damage or degenerative processes, such as osteoarthritis, the impact on proprioceptive sense may cause errors in normal muscular coordination patterns and, consequently, impairment in functional stability. Hence, impaired muscular function aggravates the progression and severity of the disease.\(^5\)

To prevent severe loss in knee proprioception, which may cause a new injury, it is important to evaluate the position sense of the joint during the rehabilitation period.\(^4\) In studies focused on evaluating the knee joint position sense, evaluations were performed with an isokinetic dynamometer or video analysis system. However, these devices are very expensive, complicated and nonportable, or the measuring method is difficult to implement.\(^4\)

Devices, such as an inclinometer, that are cheaper and easier to use can be used to measure the joint position. For this purpose, some studies have been conducted to evaluate the validity and reliability of an inclinometer for the shoulder\(^6\) and hip joints\(^7\) in the open kinetic chain position. In one study, an inclinometer was used to evaluate the knee joint position sense, and it was concluded that an inclinometer is a portable, affordable, and practical device in respect to joint examinations.\(^4\)

In recent years, more investigators have recommended that the joint position or movement sense should be investigated in load-bearing positions.\(^8\) It is thought...
that these positions are more functional and that all of the cutaneous, joint, and muscle proprioceptors that work during normal daily activities are active. It has also been stated that evaluation of proprioception in a standing load-bearing position has greater clinical importance regarding falling, chronic ankle sprain, and other pathological conditions related to excessive joint load. In light of this information, we think that measurements that are taken in the standing closed kinetic chain position are more functional.

The validity and reliability of the knee joint position sensation was previously tested in athletes using a nondual inclinometer in the closed kinetic chain position. An angle of 50° was chosen as the proprioception evaluation angle. However, this angle is greater than the knee flexion angle values observed during normal walking and daily routine activities. While enrolment of only healthy athletes and execution of the test only in the closed kinetic chain position were considered to be the limiting factors in this study, it was emphasized that further studies evaluating the validity and reliability of an inclinometer in nonathletes or the open kinetic chain position were necessary.

Based on this information, the objective of the current study was to demonstrate the validity and reliability of knee proprioception measurements performed in different positions with a dual inclinometer.

### Methods

#### Participants

We enrolled 22 participants (age = 21.8 ± 0.95 y, height = 172 ± 9.1 cm, weight = 64.9 ± 14 kg) into the study. Subjects who had injuries or surgical interventions in a lower limb within 6 months before the assessment were excluded from the study. The study was approved by the ethics committee of our university.

#### Procedures

All subjects wore comfortable shoes and shorts during the study to standardize proprioceptive input.

The same investigator took all measurements from the dominant extremity, which was determined by questioning individuals about their preferred kicking leg. To prevent visual input, all subjects wore eye masks during the measurements. We defined 30° as the proprioception evaluation angle because it is within the angular interval of 20° and 40°, which has shown a strong correlation with proprioceptive feedback along with normal walking and seems to be more accurate regarding functional measurement. We took 5 measurements: 1 to test reliability with the isokinetic system, 2 with the inclinometer in the open kinetic chain position, and 2 with the inclinometer in the closed kinetic chain position (Figure 1). We performed the measurements every 3 days.

We started the proprioception evaluation with the active joint reposition test using the isokinetic system (Cybex Norm, Humac, CA, USA). Subjects sat up straight on the chair in the isokinetic test system, and the tested knee was brought to the same level as the dynamometer axis. We fixed the thigh with a band. We fixed the tibia with a band 3 cm superior to the lateral malleolus. We used 90° flexion as the starting position because 90° of knee flexion was chosen as the starting position in studies that measured proprioception using an isokinetic system. We asked participants to extend their knee from the starting position (90° knee flexion) until the knee reached the target angle of 30°. Participants returned to their starting position after 5 seconds in this position. We demonstrated the target angle in the same way 3 times. After this process, we asked participants to reproduce the sensed angle as accurately as possible and recorded the reproduced angles. We repeated this step 3 times.

Three days after the isokinetic evaluation, we carried out measurements in the same open kinetic chain position with a Dualer IQ Digital Inclinometer (J-Tech Medical, Midvale, UT, USA). Participants were in the same position as they were in the isokinetic system, and we fixed one part of the inclinometer to the lower one-third section part of the lateral face of the femur along the joint line with a strap. We fixed the other part of the inclinometer to the lower one-third lateral section of the leg along the joint line. Similar to the isokinetic procedure, we asked participants to extend their knee from the starting position (90° knee flexion) until the knee reached the target angle of 30°. We demonstrated the 30° target angle 3 times; then, we asked participants to reproduce this angle 3 times and recorded the angles. To control the validity of the test, 3 days later we repeated this procedure in the same position.

We conducted an active measurement of knee joint position sense in the closed kinetic chain position 3 days after the second evaluation, which was carried out with an inclinometer in a standing position. We placed the inclinometer in the open kinetic chain position. The test started when the knee was in extension, and we asked participants to squat until they reached the target angle of 30°. We allowed participants to grab the wall bar with 1 hand to maintain their balance while squatting with a single leg. When they reached the target angle, we asked them to stay in this position for 5 seconds and then to return to the starting position (complete knee extension). After the target angle was sensed 3 times by the participants, we asked them to reproduce the target angle as accurately as they could. We repeated this procedure 3 times and recorded the angles. To evaluate the validity, we repeated the procedure after 3 days.

We recorded the difference between the angle sensed by the participants and their reproduced angle as the absolute angular error. We calculated the relative angular error (RAE) as the arithmetic mean of the absolute angular error.
Statistical Analysis

We present each measurement as the mean and standard deviation. We analyzed the normal distribution of the variables with the Kolmogorov-Smirnov test.

We evaluated the interrater reliabilities (inclinometer t1-t2, closed kinetic chain t1-t2 and isokinetic vs inclinometer t1) with the intraclass correlation coefficient (ICC) and determined the “limit of agreement” values with Bland-Altman analysis. ICC was determined according to the randomization model of the 2-way variance analysis for absolute concordance of the measurements (ICC2,1). ICC values greater than 0.75 were defined as “good concordance,” values between 0.50–0.74 were defined as “moderate concordance,” and values smaller than 0.50 were defined as “poor concordance.”

The Bland-Altman plots were structured as the mean of the difference between 2 measurements. The mean values of the differences between consecutive measurements were reported as “bias.” The “limit of agreement” was calculated according to the following formula.

\[
\text{Limit of Agreement} = \text{Bias} \pm \text{the reliability coefficient (standard deviation} \times 1.96)
\]

Measurement errors were referred to as the “standard error of measurement” (SEM). The following formula was used for the calculations:

\[
\text{SEM} = SD \times \sqrt{1-\text{ICC}}
\]

Responsiveness was calculated with the “minimal detectable change” (MDC). For this calculation, the following formula was used (95% confidence intervals):

\[
\text{MDC} = \text{SEM} \times \sqrt{2 \times 1.96}
\]

Results

We show the demographic characteristics of the participants and data related to the measurement results in Table 1. Before the ICC calculations, a Kolmogorov-Smirnov test showed that all 5 measurements had a normal distribution (P > .05). Although the dynamometer-inclinometer had a moderate ICC value (ICC = 0.594, SEM = 1.60, P = .005), the inclinometer t1 vs inclinometer t2 (ICC = 0.778, SEM = 0.62, P < .001) and closed kinetic chain position t1 and closed kinetic chain position t2 (ICC = 0.888, SEM = 0.63, P < .001) had high ICC values. We list the ICC, SEM, and MDC values of the measurements in Table 2. In addition, we present the mean values of the difference between the measurements with Bland-Altman plots as a graph (Figure 2).

Figure 1 — Respectively: inclinometer measurements of closed kinetic chain position, inclinometer measurements of open kinetic chain position, and isokinetic measurements of open kinetic chain position.

Discussion

Proprioception is important for sensorimotor control, regulation of muscle stiffness, movement acuity, joint stability, coordination, and balance. It is based on the execution of walking and daily and sport activities.
Decreased proprioception can cause injury and recurrence of injuries. Approaches for the development of proprioception reduce the risk of injury. For this reason, rehabilitation approaches and training programs targeting the development of proprioception are important in the treatment and prevention of musculoskeletal problems. Proprioception has to be evaluated periodically to assess the effectiveness of training or to improve rehabilitation programs.

However, proprioception assessments are often made with expensive equipment or in a laboratory environment. Therefore, their use in the clinical setting is impractical. Inclinometers are affordable and easy-to-use in a clinical context. Proprioceptive measurements made with an inclinometer can be used as a practical and inexpensive method to promote rehabilitation and training programs and to demonstrate their effectiveness.
Since it has been reported in the literature that dominant and nondominant extremity proprioception are comparable and considering the high number of repeated measurements, we decided to carry out all measurements only on the dominant extremity.

There are no studies in the literature that focused on the validity and reliability of a dual inclinometer for knee proprioception in the open kinetic chain position. In their study, Romero-France et al mentioned this as a drawback. As validity analyses of proprioception measurements are rather difficult to perform, there is no globally accepted, golden-standard measurement method. Nevertheless, the same open kinetic chain position that is used for isokinetic system measurements is used for inclinometer measurements. Therefore, we used the isokinetic system evaluation for comparison regarding the validity. The results of our study showed that measurements performed in the open kinetic chain position with the knee in 30° flexion had moderate validity. Analysis of the repeated measurement results after 3 days revealed that the measurements were highly reliable. The isokinetic system is rather expensive, complicated, and nonportable. The weight of the dynamometer and the straps used to fix the extremity cause additional sensory input. Furthermore, the necessity to carry the heavy dynamometer during the active repositioning test causes difficulties in finding the correct angle, leading to conflicting results in the proprioception evaluation. On the other hand, as the inclinometer is light and easy-to-use, it does not cause additional sensory input and can be easily used to make proprioception measurements.

It has been shown in the literature that muscle fatigue might change the results of the proprioception examination. The change of the activation pattern of the muscle spindle and, correspondingly, the decrease of proprioceptive afferent nerve sensitivity have been indicated as additional reasons along with fatigue. The heavy weight of the isokinetic system dynamometer might cause fatigue during repeated measurements and affect the results. Therefore, the moderate reliability demonstrated by comparison of the inclinometer and isokinetic system in the open kinetic chain position might be influenced by this mechanism. During measurements with the inclinometer, participants stated that they did not sense any feedback and had difficulty reproducing the target angle. The heavy weight of the dynamometer, tension in the straps occurring with movement and sound of the dynamometer provided feedback to participants. Taking the comments of the participants into consideration, we suggest that the measurements performed with the inclinometer in the open kinetic chain position accurately reflected the proprioceptive sense.

Previous studies have shown the reliability of an inclinometer for knee proprioception measurements in different positions. Garsden et al used an inclinometer for knee proprioception measurements in patients with osteoarthritis, but they used a partial load-bearing position for testing. Regarding the literature, several investigators have reported that the evaluation of proprioception measurements in joint load-bearing positions was more functional and that all cutaneous, articular and muscular proprioceptors, which function during normal daily activities, were activated in these positions. In our study, we observed that the knee proprioception measurement with full (not partial) joint load-bearing in the closed kinetic chain position was reliable.

Romero-France et al compared a nondual inclinometer with a video analysis system for proprioception examination in athletes using 50° knee flexion. They concluded that the inclinometer was a valid and reliable method and stated the necessity for demonstrating similar results in sedentary individuals. As all participants were healthy, sedentary individuals, our study covered this gap in the literature. Moreover, as the target angle of 30° used in our study is within the angular interval of 20° and 40°, which has shown a strong correlation with proprioceptive feedback along with normal walking, it seems to be more accurate regarding functional measurement. Romero-France et al placed a wedge under the heel to reduce tension in the triceps surae muscle during measurements. Although several mechanisms, such as articular and cutaneous receptors, play a role in proprioception, sensing of position and movement is carried out primarily by the muscle spindle. It has been reported in the literature that the hip and ankle positions on the same side and co-contraction of the lower extremity muscles might affect the results of the reposition test in weight-bearing positions. Therefore, the wedge placed under the foot might change the sensitivity of the muscle spindle, which plays an important role in proprioception, as well as knee proprioception values with relaxation of the triceps surae muscle. In addition, considering that the purpose of the examination in closed kinetic chain position is to evaluate proprioception in positions that occur in daily activities, we suggest that more accurate results are obtained without a wedge placed under the foot. In the same study, a 20-cm high step placed under the foot, which was not involved in the examination, caused sensory input from the other side; therefore, the values obtained were the result of proprioceptive information coming from both extremities. Because of these reasons, our study might provide more reliable results regarding both the positioning of participants and measuring the proprioceptive sense of a single extremity in a full-loading closed kinetic chain position.

As the positions used for the isokinetic system and closed kinetic chain position measurements were not the same, we did not assess reliability. However, previous studies have shown the validity of the inclinometer in knee proprioception examinations in different positions. Nevertheless, in our study, we were also able to demonstrate the reliability of using an inclinometer for proprioception examinations in closed kinetic chain position with healthy, sedentary participants.
As there is not another measurement method (like the video analysis system) that can be used in the same closed kinetic chain position, a validity study could not be performed. We considered this drawback as a limitation of our study.

Conclusion

We believe that the results of our study make an important contribution to the literature with respect to proprioception evaluation. It was shown that knee proprioception measurements performed with a dual inclinometer were reliable in the closed kinetic chain position in healthy, sedentary individuals and were valid and reliable in the open kinetic chain position. These results showed that the inclinometer, which is an easy-to-use, inexpensive, and portable device for evaluating patients and monitoring the efficacy of treatment, can also be used for evaluation of knee proprioception.

References

24. Mohammad Baznesshin M, Amiri A, Jamshidi AA, Vasaghi-Gharamaleki B. Quadriceps muscle fatigue and knee...

