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RESEARCH ARTICLE

THE CONCURRENT VALIDITY AND RELIABILITY OF THE SMARTPHONE MEASUREMENT APPLICATION TO EVALUATE ILIOTIBIAL BAND TIGHTNESS: A CROSS-SECTIONAL STUDY

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ABSTRACT

Purpose: In recent years, the medical use of smartphones has increased with the development of hardware. The study aims to evaluate the reliability and concurrent validity of iPhone® measurement application to measure iliotibial band tightness.
Materials and Methods: This was a cross-sectional study. Thirty athletes with iliotibial band tightness (17 males, 13 females) between 20 and 45 years old were included and assessed in this study. The iliotibial band tightness was measured with Ober test using a bubble inclinometer and iPhone® measurement application and evaluated by two experienced physiotherapists. Three measurements were taken for both extremities using both the bubble inclinometer and the iPhone® measurement application by the researchers. The intraclass correlation coefficient (ICC) was used to evaluate the reliability of each smartphone measurement, and Bland–Altman analysis was used to examine measurement errors.
Results: The iPhone® measurement application has strong inter-rater (ICC=0.941) and intra-rater (ICC=0.986) reliability and concurrent validity (r=0.945) in measuring iliotibial band tightness.
Conclusion: From the cross-sectional study's results, it can be concluded that the iPhone® measurement application possesses strong intra-rater and inter-rater reliability and concurrent validity and can be used for measuring iliotibial band tightness.

Keywords: Assessment, iliotibial band tightness, musculoskeletal abnormalities, smartphone

INTRODUCTION

A longitudinal fibrous sheath running along the lateral thigh is the iliotibial band (ITB) tract, an essential structure involved in the lower limb motion. The ITB derives fascial inputs from the deep thigh fascia, gluteus maximus, and tensor fascia lata proximally in the thigh and implants them distally around the leg, including on the proximal tibia (1,2). Therefore, limitations in sports activities occur due to ITB tightness, which increases the incidence of overuse knee injuries in different sports branches (3,4).

The direct association between ITB tightness and limitations in sports activities supports the preference for using the Ober or modified Ober tests in measuring ITB tightness (5). The initial Ober test was identified to investigate the relationship between tightness in the ITB and sciatica and low back pain (6). Today, this measure is not only used to measure ITB flexibility for those with low back pain but also to examine ITB flexibility in all people (5). Due to the increase in ITB tightness, the movement of the extremity measured with the Ober test in the horizontal plane is limited and the adduction movement of the hip joint decreases (7).

The ITB tightness measure may be conducted through visual inspection or by using a variety of measuring methods, including observation, goniometer, tape measurement, and inclinometer (5,8). Bubble inclinometers are compact, lightweight, and affordable. The inclinometer drawbacks include usability, as many clinics do not have them, and the clinicians' experience with the unique measuring techniques for these methods (9). A body of evidence reported good reliability of a gravity-based bubble inclinometer for calculating ITB tightness in symptomatic and asymptomatic individuals (10). A study by Samo et al. (11) found that the investigator and/or technological errors could be responsible for causing great measurement uncertainties. Procedural and technological errors result in inaccurate measurements. So, smartphones can be a realistic solution to inclinometer from an accessibility viewpoint.

Using sensors embedded in standard smartphones, this technology has the potential to provide clinicians and sports professionals with easy access to more accurate and precise measurements. Its development has not been studied as a clinical instrument for measuring ITB tightness, despite smartphones' increasing popularity in recent years. To the authors' knowledge, there is no study in the literature investigating the Concurrent Validity and Reliability of a Smartphone Measurement Application to Evaluate Iliotibial Band Tightness. To use smartphone applications such as bubble inclinometers in a clinical setting, its effectiveness must be evaluated. Therefore, the aim of this cross-sectional observational study was to determine the inter-observer and intra-observer reliability of a smartphone application iPhone® Measurement Application and determine the correlation between iPhone® Measurement Application and bubble inclinometer regarding active ITB tightness in athletes. In addition, for the two measuring instruments, we tried to analyze the concurrent validity and 95% consensus rate. We hypothesizes that the iPhone® measurement application will exhibit strong concurrent validity and reliability when assessing iliotibial band (ITB) tightness, demonstrating a robust correlation with the bubble inclinometer measurements in athletes.

MATERIALS AND METHODS

Study design and participants

This cross-sectional study was conducted across two sessions at KTO Karatay University Physical Therapy Laboratory between March 2021 and April 2021. This study was approved by KTO Karatay University Faculty of Medicine Drug and Non-Medical Device Research Ethics Committee (Decision Date: 27.12.2019, Number 2019/012) and prospectively registered at www.clinicaltrials.gov (NCT04787900).

A priori power analysis suggests a minimum enrollment of 16 or more athletes for a correlation of 0.7, an α level of 0.05, and a power of 95% (12). Inclusion criteria for this study were being between the ages of 20 and 45, having an ITB inclination angle below 24.59 degrees (10) and consenting to participate. Exclusion criteria included a history of hip or knee surgery and a history of lower extremity trauma within the last three months. Thirty athletes with ITB tightness between 20 and 45 years old were included in this study. The study protocol complied with the Declaration of Helsinki for human experimentation. All athletes provided written informed consent.

Procedure

This study employed a concurrent validity and reliability design to assess the iPhone® measurement app's reliability and accuracy in evaluating ITB tightness. The bubble inclinometer, recognized for its validity and reliability in OBER test assessments, was chosen for comparison. Athletes underwent a standardized 2-minutes warm-up with a cycle ergometer before the measurements (13). Additionally, prior to data collection, all athletes were introduced to the testing procedures and equipment. This familiarization process aimed to ensure athletes' comfort and understanding of the tests and devices, potentially enhancing the reliability of the collected data. The ITB flexibilities of both the dominant and nondominant limbs were evaluated by two independent blinded researchers, each in a separate room. One researcher used the iPhone® measurement application, while the other utilized a bubble inclinometer for measurements. The assessments were conducted sequentially by the first

Figure 1. A) Measurement procedure for the Ober test with a bubble inclinometer. B) Measurement procedure for the Ober test with iPhone® measurement application

investigator followed by the second investigator, ensuring consistency and comparability in the evaluation process. All measurement values were recorded by a third investigator to maintain impartiality and accuracy in data collection. For each extremity of the athletes, three measurements were taken, with a 5-minutes passive rest period provided between each measurement. This practice aimed to minimize any potential fatigue effects and ensure reliable and consistent assessments. Following data collection, a rigorous comparative analysis was performed utilizing statistical methods established in prior studies (14,15). This analysis involved a comprehensive examination of the data obtained from both devices to determine their validity and reliability in assessing ITB tightness.

Before the initial measurement, the athlete warmed up for 2 minutes. After warming up, the athlete lay on his side and flexed his knee to 90°. The researcher stabilized the patient from the pelvis with one hand and, with the other hand, brought the athlete's flexed leg to adduct and extend. The non-measured extremity was stabilized with the aid of a belt. Bubble inclinometer was first used for measurement. Researcher 3 recorded the result by placing the device to be measured on the lateral projection of the midpoint of the femur with a 90-degree angle (Figure 1a).

After the first bubble inclinometer measurement, the second and third measurements were taken with 5-minutes passive intervals.

Following the completion of the first researcher's evaluation, the athletes moved to the second researcher's room. The protocol applied for the bubble inclinometer was used for the measurements of the athletes (Figure 1b). The primary outcome of this study was concurrent validity, and the secondary outcome was reliability.

Instruments

We used two devices to measure ITB tightness, namely, bubble inclinometer (Baseline, Fabrication Enterprises Inc., New York) and iPhone® measurement applications (Apple Inc., California). The iPhone® measurement application measurements were made with the iPhone 6s plus running in IOS 13.3.1 (Apple Inc., California).

Statistical analysis

The SPSS 25 (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, version 25.0. Armonk, NY: IBM Corp.) software was used to evaluate the data and the Shapiro-Wilk test to examine the conformity

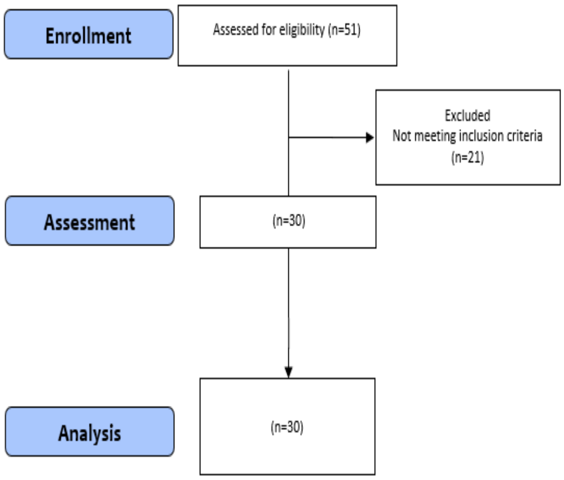

Figure 2. Flow diagram

of variables to normal distribution. All data were normally distributed. We analyzed using the mean ± standard deviation for the demographic data of the athletes. Descriptive data (mean ± standard deviation) were determined for the measuring angles of both devices.

The criterion and concurrent validity of the bubble inclinometer and iPhone® measurement applications were compared with the reference standard and were calculated using the Pearson product-moment correlation coefficient (r, two-tailed). The correlations were interpreted as weak (0.1–0.39), moderate (0.4–0.69), or strong (0.7– 0.99) (16).

The reliability of all measurements was tested using the ICC models (3, k and 2, k, respectively) for the intra-rater and inter-rater analyses. Using the SPSS software, the ICC model (2, k) was computed by selecting the options two-way random, average measure, and absolute agreement and the ICC model (3, k) the options two-way mixed and average measure (17).

The Bland-Altman plots were used to visually assess the mean differences and 95% limits of agreement between the bubble inclinometer and iPhone® measurement applications (18). A standard measurement error (SEM) calculated in the SD X √(1-ICC) form was used to examine the instruments' precision (19). The minimum detectable change (MDC95) representing the magnitude of the change required to provide confidence that a change is not caused by a random variation or measurement error was calculated with the formula form √2 X 1.96 X SEM at 95% confidence level. The level of significance was set at 0.05 (20).

RESULTS

The demographic information of 30 athletes with ITB tightness between the ages of 20 and 45 in this study was given in Table 1. (N = 30; 17 males, 13 females; age = 26.3 ± 4.6 years; body mass index = 23.5 ± 1.6 kg/m2). The flow diagram is shown in Figure 2. The measuring angles for each device by two researchers are given in Table 2.

Concurrent validity

One of the outcomes of this study is concurrent validity. The analysis of the whole dataset showed a strong correlation between the bubble inclinometer and iPhone® measurement application for ITB tightness measurement (r = 0.945, 95% CI = 0.058–0.575).

The Bland-Altman plot illustrated the agreement between the iPhone® measurement application and bubble inclinometer, with most values falling within the 95% limits of agreement (Figure 3). The mean difference between the iPhone® measurement application and bubble inclinometer measurement angle were −0.310.

Reliability

Another of the outcomes of this study was reliability, which was analyzed both inter-rater and intra-rater.

Intra-rater reliability

A strong intra-rater reliability was found with both the bubble inclinometer (ICC:0.983, %95CI:0.960–0.992) and iPhone® measurement application (ICC: 0.986, %95CI: 0.971–0.993) (Table 3).

Inter-rater reliability

A strong inter-rater reliability was found with both the bubble inclinometer (ICC:0.992, %95CI:0.987–0.995) and iPhone® measurement application (ICC: 0.941, %95CI: 0.902–0.965). (Table 4).

DISCUSSION

This is the first study that investigated the intra-rater and inter-rater reliability and concurrent validity of iPhone® measurement applications in measuring ITB tightness in individuals without ITB-related pathology The iPhone® measurement application was found to be highly valid, reliable, and accurate in measuring ITB tightness compared to a bubble inclinometer. The concurrent validity for ITB tightness between the bubble inclinometer and iPhone® measurement application was strong. These results are consistent

Table 1. Demographic characteristics of the participants

	Mean	SD
Age (year)	26.36	4.62
Height (m)	1.77	.05
Weight (kg)	71.30	7.38
BMI (kg/m^2)	23.52	1.68
Gender	n	%
Male	17	56.67
Female	13	43.33

n, number of participants; SD, standard deviation; BMI, body mass index; kg, kilogram, m:meter %, percentage

Table 2. Measurements of iliotibial band tightness for each device

	Right		Left	
	Mean	SD	Mean	SD
Bubble inclinometer (degree) Researcher 1	18.96	3.14	18.93	3.03
Bubble inclinometer (degree) Researcher 2	18.93	3.21	19.1	3.17
iPhone® measurement applications (degree) Researcher 1	19.23	2.93	19.36	2.67
iPhone® measurement applications (degree) Researcher 2	19.26	2.91	19.6	3.99

SD, Standard deviation

Table 3. Intra-rater reliability

Intra-rater	Bubble inclinometer	iPhone® measurement application
ICC (95% CI)	0.983 (0.96–0.992)	0.986 (0.971–0.993)
SEM	0.797	0.680
MDC_{95}	2.098	1.884

ICC, intraclass correlation coefficient; CI, confidence interval; SEM, standard error of measurement; MDC95, minimum detectable change

Table 4. Inter-rater reliability

Inter-rater	Bubble inclinometer	iPhone® measurement application
ICC (95% CI)	0.992 (0.987–0.995)	0.941 (0.902–0.965)
SEM	0.555	1.445
MDC_{95}	1.538	4.005

ICC, intraclass correlation coefficient; CI, confidence interval; SEM, standard error of measurement; MDC95, minimum detectable change

with various studies showing similar levels of correlation between smartphone applications and inclinometers and goniometers for measuring different ranges of motion (21,22).

Stresses from the daily living activities and sports, traumas, and pathologies can affect ITB mechanics and function. ITB tightness causes sports injuries, especially in the knee and hip joints. Measuring ITB tightness using valid and reliable tools can help clinicians and physiotherapists to provide an accurate clinical evaluation of athletes with knee and hip injuries occurring during competition or training (23,24). In the literature, the intra-rater and inter-rater reliability values of the bubble inclinometer used to measure ITB tightness have been reported to be strong (5,8). In this study, the ICC values for intra-rater and inter-rater reliability of measuring ITB tightness using the bubble inclinometer were 0.983 and 0.992, respectively. The reliability of the bubble inclinometer in this study aligns with prior research, showing consistently strong ICC values.

Several studies have evaluated the reliability and validity of smartphone ROM applications (25–27). Charlton et al. (28) evaluated the reliability and validity of a Smartphone for the assessment of hip ROM and found that intra-rater reliability ranged from 0.63 to 0.94. When compared to bubble inclinometer and motion analysis system, concurrent validity was 0.71 to 0.98. In another study of smartphone validity and reliability for the assessment of hip ROM, concurrent validity was excellent (r = 0.91-0.93). In addition, it showed excellent intra-rater and inter-rater reliability (ICC > 0.90) for all hip movements (29). The validity and reliability of the smartphone for the assessment of hip ROM were generally found to be valid and reliable in studies. We think that smartphones can be used in the evaluation of ROM of the hip joint due to the low compensation in the movements of the hip joint during measurement.

According to the results of the Ober test conducted by Reese and Bandy (5) the ITB tightness measured with the bubble inclinometer was 18.9°. In this study, the bubble inclinometer angle varied between 18.93° and 18.96°, and the tilt angle measured with iPhone® measurement applications was between 19.23° and 19.26°. The angular values obtained from this study are similar to the literature. The mean measurement values obtained from both devices used in this study were comparable. The results also revealed that both raters had a strong intra-rater reliability. In this study, the bubble inclinometer mean values were slightly

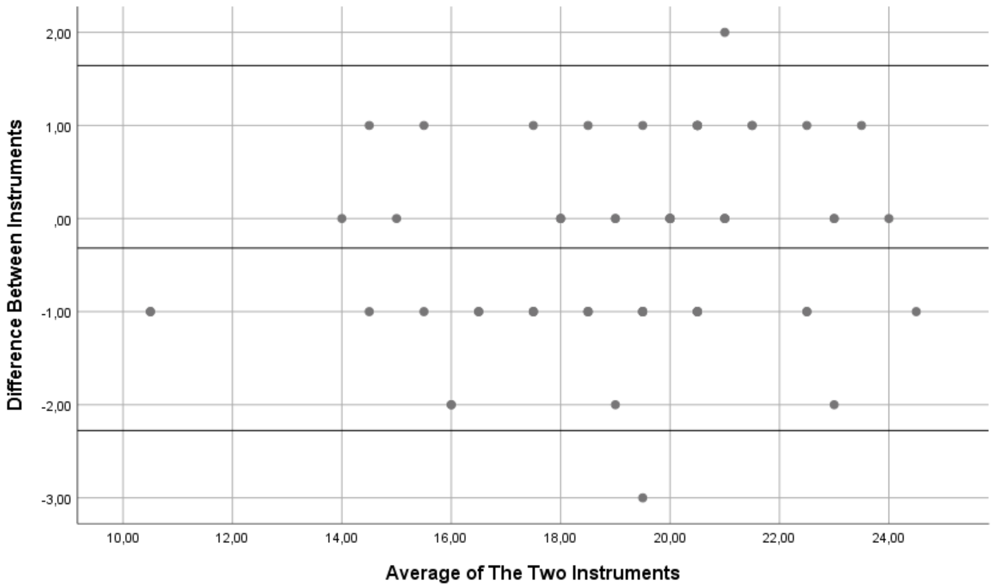

Figure 3. Bland-Altman plot for the iPhone® measurement application and bubble inclinometer

lower than that with the iPhone® measurement application. The distinct device structures and potential challenges in maintaining constant skin contact with the smartphone during measurement might explain the variance in average values obtained. We think that the high surface area of the smartphone and full contact make measurement easier. These results could have potential practical applications for physicians and physiotherapists wanting to simply monitor their patients' ITB tightness using their smartphones. Another reason for the high reliability may be due to more than 10 years of clinical experience of the investigators making the assessments. However, more research is needed in investigating the reliability of the existing iPhone® measurement applications for inexperienced examiner where reliability values cannot be predicted. Before the evaluations, the athletes were shown how to perform the application. To get more reliable results, we performed all measurements for three times. The averages of these measurements were analyzed. There are validity and reliability studies on the use of the iPhone® measurement application for range of motion evaluation, but there are no studies on the use of the application in ITB tightness (9,14,21,30,31). The findings of this study align with existing literature (9,17). The ICC values for the intra-rater and inter-rater reliability of measuring ITB tightness using the iPhone® were 0.986 and 0.941, respectively.

The intra-rater (0.971-0.993) and inter-rater (0.902-0.965) reliability of the iPhone® measurement applications were strong. The reliability achieved with the iPhone® measurement applications was comparable to that of the gravity-based inclinometer, partly owing to the absence of a smartphone case, a snug fit, and familiarity. The advantages of using the iPhone® measurement applications over the bubble inclinometer are being not limited in time and space and being a standard and free application of an iPhone®. It should be noted that millions of people can easily access the iPhone® measurement application from Apple's AppStore. Conversely, the limitations of using smartphones should be considered. Examiners may not want to use their smartphone for evaluation, as there will be direct contact between the smartphone and the individual's skin (9). Additionally, software and hardware problems may be encountered in smartphones regardless of the examiner. Depending on the increase in smartphone usage, the use of a valid and reliable application other than the medical devices used for clinical ROM measurement may make the evaluation easier and cheaper. Thus, based on this information, the iPhone® measurement application can be used validly and reliably for ITB tightness measurement without the need for additional medical equipment.

The strength of this study is that it reached a sufficient sample size, and it was a double-blind study. Despite its strengths, this study encountered several limitations. Firstly, the iPhone Measurement application used for assessment was limited to the iOS operating system, restricting its application on other platforms like Android or HarmonyOS. Additionally, the expertise level of the examiners could potentially impact the study outcomes, raising uncertainties about whether less experienced raters would produce similar results. Furthermore, the study faced an imbalance in gender representation, with a larger number of male athletes compared to females. This disparity might have influenced the generalizability of the findings, considering potential anatomical and biomechanical variations between genders. While the study aimed to focus on ITB tightness regardless of gender-specific variations, future research should consider a more balanced gender representation for a comprehensive understanding of potential impacts on measurement outcomes.

Evaluation is important in the field of physiotherapy and sports. Before and after a problem occurs, the problem source is understood with a good evaluation, wherein many devices can be used (e.g., goniometers, inclinometers, measuring tapes, etc.) (10,22). Recently, the use of smartphone technology has become widespread due to its practicality and the large number of people using it. Thus, measurements can be made easily without the need for medical equipment. This study demonstrated that the iPhone® measurement applications in a ready-to-use smartphone are valid and reliable for measuring ITB tightness.

CONCLUSION

The study's hypothesis positing the strong concurrent validity and reliability of the iPhone® measurement application in evaluating ITB tightness has been confirmed. Our findings demonstrate a robust correlation between measurements obtained via the iPhone® application and the bubble inclinometer, supporting its effectiveness as a valid and reliable tool for assessing ITB tightness among athletes with ITB-tightness pathology. Therefore, the study's objectives have been met, affirming the utility of the iPhone® measurement application as a feasible alternative to traditional medical devices, offering clinicians and physiotherapists a convenient and reliable means of evaluating ITB tightness.

We recommend the incorporation of the iPhone® measurement application as a complementary assessment tool in clinical settings. Its accessibility, accuracy, and reliability make it a valuable addition to the array of traditional measurement devices. However, practitioners should consider the need for standardization in its usage and ensure familiarity with the application's methodology to optimize results. Additionally, future research should explore its efficacy in diverse populations and validate its use by practitioners with varying levels of experience.

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Author contributions:
Conflict of interest: The authors have no conflict of interest to declare related to the present manuscript.
Ethical approval: This study was approved by KTO Karatay University Faculty of Medicine Drug and Non-Medical Device Research Ethics Committee (Decision Date: 27.12.2019, Number 2019/012) and prospectively registered at www.clinicaltrials.gov (NCT04787900). Informed consent was obtained from all patients for being included in the study.
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