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Research Article / Araştırma Makalesi

Interrater and intrarater reliability of a handheld myotonometer in measuring mechanical properties of the iliotibial band

İliotibial bant mekanik özelliklerinin değerlendirilmesinde myotonometrik ölçümün güvenilirliğinin araştırılması

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ABSTRACT

Objective: The aim of this study is to investigate the intra-rater and inter-rater reliability of the MyotonPRO device in measuring the mechanical properties of the iliotibial band in healthy individuals.

Materials and Methods: Thirty-two healthy participants (20 males, 12 females) aged between 19 and 27 years were included in the study. The mechanical properties of the iliotibial band (tone, stiffness, elasticity) were measured using the MyotonPRO device (Mumeetria Ltd, Tallinn, Estonia). To determine the reliability of the device, measurements were performed by two independent researchers. After the initial measurements, a second round of measurements was repeated by the same two researchers after 48 hours.

Results: The MyotonPRO provided very high intra- and inter-rater reliability in measuring the mechanical properties of the iliotibial band (intraclass correlation coefficients 2.1>0.81). The standard measurement error was calculated as 0.8 to 0.5 Hz for tone, 40.3 to 27.9 N/m for stiffness, and 0.1 log for elasticity for both raters. For inter-rater values, tone was 0.7 to 0.6 Hz, stiffness was 17.8 to 25.1 N/m, and elasticity was 0.04 to 0.1 log. The minimum detectable change for intra-rater measurements was found to be 2.3 to 1.5 Hz for tone, 111.7 to 77.3 N/m for stiffness, and 0.2 log for elasticity for both raters. For inter-rater measurements, tone was 1.9 to 1.6 Hz, stiffness was 49.4 to 69.6 N/m, and elasticity was 0.1 to 0.2 log. The coefficient of variation for all parameters was below 9.8%.

Conclusion: The results indicate that the MyotonPRO device is a reliable tool for measuring the tone, stiffness, and elasticity of the iliotibial band in healthy individuals.

Keywords: *Iliotibial band, MyotonPRO, reliability*

ÖZ

Amaç: Bu çalışmanın amacı, MyotonPRO cihazının sağlıklı bireylerde iliotibial bant mekanik özelliklerini ölçmede değerlendirici içi ve değerlendiriciler arası güvenilirliğini araştırmaktır.

Gereç ve Yöntemler: Çalışmaya yaşları 19-27 arasında 32 sağlıklı birey (20 erkek, 12 kadın) dâhil edildi. İliotibial bantın mekanik özellikleri (tonus, sertlik, elastikiyet) MyotonPRO (Mumeetria Ltd, Tallinn, Estonya) ile ölçüldü. Cihazın güvenilirliğinin belirlenmesi için iki bağımsız araştırmacı tarafından ölçümler gerçekleştirildi. İlk ölçümlerin ardından 48 saat sonra ikinci ölçümler iki araştırmacı tarafından tekrarlandı.

Bulgular: İliotibial bant mekanik özelliklerinin ölçülmesinde MyotonPRO değerlendirici içi ve değerlendiriciler arası çok yüksek güvenirliğe sahip bulundu (sınıf içi korrelasyon katsayıları 2.1>0.81). Standart ölçüm hatası tonus için değerlendirici içi 0.8 ile 0.5 Hz, sertlik 40.3 ile 27.9 N/m ve elastikiyet her iki değerlendirici için 0.1 log olarak hesaplandı. Değerlendiriciler arası değerlere bakıldığında tonus 0.7 ile 0.6 Hz, sertlik 17.8 ile 25.1 N/m ve elastikiyet 0.04 ile 0.1 log olarak bulundu. Saptanan minimum değişiklik değerlendirici içi tonus için 2.3 ile 1.5 Hz, sertlik için 111.7 ile 77.3 N/m ve elastikiyet her iki değerlendirici için 0.2 log olarak bulundu. Değerlendiriciler arası tonus için 1.9 ile 1.6 Hz, sertlik için 49.4 ile 69.6 N/m ve elastikiyet 0.1 ile 0.2 log olarak bulundu. Değerlendirilen tüm parametreler için varyasyon katsayıları %9.8'in altındaydı.

Sonuç: Elde edilen sonuçlar, MyotonPRO cihazının sağlıklı bireylerde iliotibial bantın tonus, sertlik ve elastikiyetini ölçmek için güvenilir bir araç olduğunu göstermektedir.

Anahtar Sözcükler: *İliotibial bant, MyotonPRO, güvenilirlik*

INTRODUCTION

The iliotibial band (ITB) or tract is a lateral thickening of the tensor fascia lata (TFL). It surrounds the TFL and attaches to the iliac crest by separating into superficial and deep layers proximally. The ITB is generally seen as a dense fibrous connective tissue that passes over the lateral femoral epicondyle and attaches to the anterolateral

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surface of the tibia (1). It functions as a lateral stabilizer of the knee by transmitting forces from the hip to the knee. It also plays a role in postural functions (2). Injuries resulting from the overuse of the lateral knee due to repetitive lower extremity movements are referred to as ITB syndrome (3). Changes in its viscoelastic properties are observed with frequent repetitive knee flexion and extension movements. The function of the ITB can be assessed during passive or active movements. The assessment of ITB tension is often based on the clinical Ober test, which is also used to evaluate the flexibility of the iliotibial band (4).

Various methods such as shear wave elastography, ultrasound combined with a dynamometer, and magnetic resonance elastography are utilized to assess the mechanical properties of the ITB. However, these methods have certain disadvantages: magnetic resonance elastography requires the use of expensive equipment, increasing costs, and is more time-consuming. Standard ultrasonography provides only indirect information about muscle stiffness, while shear wave elastography is costly and its results depend on the skill and experience of the operator. Palpation or manual muscle tests, although cost-effective, yield subjective results. In contrast, myotonometric measurements offer several advantages. The Myoton device is a portable tool that allows measurements in various settings. Additionally, unlike other methods that only assess soft tissue stiffness, myotonometric measurements can evaluate stiffness, tone, and elasticity simultaneously (5,6).

One of its key advantages is its ability to deliver measurement results within seconds and maintain high consistency across repeated measurements. This feature ensures reliable assessments of structures such as the ITB, which is thin, long, and rigid. High reproducibility is particularly valuable in monitoring progress during rehabilitation processes. Furthermore, myotonometric measurements provide objective data for evaluating the efficacy of treatment protocols targeting the iliotibial band. This facilitates rapid and practical assessments (7).

In recent years, the mechanical properties of muscles and tendons (stiffness, tone, elasticity) have also been evaluated through non-invasive, pain-free myotometric measurements (8). This measurement, based on free oscillation theory, involves a short mechanical stimulus applied to the skin using a polyurethane probe, providing a non-invasive and painless method (9). The test-retest validity and reliability of MyotonPRO (Mumeetria Ltd, Tallinn, Estonia) have been reported for various muscle and tendon groups (10,11). Aird et al. demonstrated that MyotonPRO is a valid and reliable assessment tool for evaluating the mechanical properties of the quadriceps muscle (12). The validity and reliability of MyotonPRO for evaluating the mechanical properties of the patellar tendon and Achilles tendon have also been established (13), and studies have assessed the mechanical properties of these tendons using the myotometric measurement method (14). To our knowledge, no study has evaluated the mechanical properties of the ITB using myotometric measurements. Therefore, the aim of our study is to investigate the reliability of myotometric measurements in evaluating the mechanical properties of the iliotibial band.

MATERIAL and METHODS

Participants

This cross-sectional study was conducted at the Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Hasan Kalyoncu University. Ethical approval for the study was obtained from the Hasan Kalyoncu University Health Sciences Noninvasive Research Ethics Committee under decision number 2022/116. The study was conducted in accordance with the principles outlined in the Helsinki Declaration. Participants were given detailed information about the purpose, duration, and potential risks of the study, and informed consent was obtained from those who voluntarily participated.

The study included 32 healthy individuals aged between 19 and 27 years, with right-sided dominance, with moderate-intensity physical activity level (≥3000 MET-min/week, moderate- intensity activity of at least one hour or more per day) according to the International Physical Activity Questionnaire (IPAQ) short form (15), a body mass index (BMI) between 18.5-24.9 kg/m^2, who voluntarily participated in the study. Individuals with neurological or systemic diseases, those with a history of lower extremity surgery in the past year, and those with chronic knee and ankle injuries within the last three months were excluded from the study.

Assessments

The tone and viscoelastic properties of the ITB were assessed using the MyotonPRO device by two independent researchers (SU, TG). After the initial measurements, the same measurements were repeated 48 hours later at the same time of day (10). Prior to data collection, participants were instructed to refrain from physical activity for 24 hours. Measurements were taken in a side-lying position with the dominant extremity (right) on top and the knee in semi-flexion. Participants were instructed to relax in this position for 10 minutes before the measurement. During this time, the reference point for the ITB was marked 5 cm above the lateral femoral condyle. After the rest period, the

(Figure 1) (16). Only measurements with a coefficient of variation (CV) of less than 3% were considered. After the final measurement, a second researcher performed the same measurements three times at the marked reference point, and the averages were recorded 30 seconds later.

Figure 1. MyotonPRO measurement technique. (A) Resting position; (B) Determination of the measurement site; (C) Measurement with MyotonPRO.

Myoton® PRO Device

The MyotonPRO is a portable, non-invasive device designed to measure the viscoelastic properties of soft tissues (17). This device is widely recognized for being cost-effective, user-friendly, and reliable, making it an excellent tool for the mechanical evaluation of the musculo-skeletal system. The measurement technique employed by the MyotonPRO is based on the free oscillation method (18,19). To begin the assessment, the probe is positioned perpendicular to the skin, applying pressure to compress the underlying soft tissue. A brief mechanical stimulus is then introduced, prompting the tissue to oscillate. These oscillations are captured by an accelerometer, and the raw signal is processed to filter out frequencies that are not characteristic of the tissue's natural oscillations. This analysis provides data on the tissue's oscillation frequency [N], its logarithmic decay (elasticity), and stiffness [N/m]. In this context, resting muscle tone refers to the stiffness of the muscle in its elastic and/or viscoelastic state when there is no active contraction. Elasticity is defined as a material's ability to return to its original shape after the removal of a load. Stiffness is a biomechanical property that indicates the muscle's resistance to external forces that may deform it or disturb its resting state (20).

Statistical Analysis

The statistical analysis was conducted using IBM SPSS Statistics version 21.0 (IBM Corp.). Normality of data was assessed via the Kolmogorov-Smirnov test alongside frequency histograms. Significance threshold was set at $p<0.05$. To evaluate the mechanical properties of the ITB, means and standard deviations (SD) were computed for two different raters and two separate time points. The reliability of the MyotonPRO device was measured using intraclass correlation coefficients (ICC) with a 95% confidence interval.

For inter-rater reliability, $ICC_{(2,1)}$ (two-way mixed model, consistency) was employed, while for intra-rater reliability, $ICC_{(2,2)}$ (two-way random effect model, absolute agreement) was used. Bland-Altman statistics were applied for each comparison, with the mean difference (d) and the 95% limits of agreement calculated as the mean ± (1.96 × SD) (21). The coefficient of variation (CV) for each comparison was determined using the formula:

$$\mathrm{CV} = \frac{\mathrm{SEM}}{\mathrm{mean}} \times 100\%$$

The standard error of measurement (SEM) was calculated with the formula:

$$\mathrm{SEM} = \mathrm{SD} \times \sqrt{1 - \mathrm{ICC}}$$

The minimum detectable change (MDC) was computed using:

$$\mathrm{MDC} = \mathrm{SEM} \times 1.96 \times \sqrt{2}$$

Correlation strength was classified as follows: 0.00-0.20 (weak), 0.21-0.40 (low), 0.41-0.60 (moderate), 0.61-0.80 (high), and 0.81-1.00 (very high) (22).

RESULTS

A total of 32 participants (20 males, 62.5% and 12 females, 37.5%) with an average age of 22 years participated in the study. There were no significant differences in room and skin temperature across test sessions on the ITB. All data passed the Kolmogorov-Smirnov statistical test for normal distribution, supporting the use of parametric statistical

Table 1. Physical characteristics of the participants		
Parameters (n=32)	**Min-Max**	**X±SD**
Age (yrs)	19-27	22.2±2.2
Height (m)	1.58-1.90	1.75±0.09
Weight (kg)	53-90	74.5±11.1
Body Mass Index (kg/m²)	16.1-24.3	24.3±2.9

Intra-Rater Reliability

When examining the test-retest reliability for the first and second raters, the tone, stiffness, and elasticity of the iliotibial band were found to have very high reliability (ICC 2.1>0.81). Among the measurements over different days, tone showed the highest reliability (ICC 0.96-0.98), followed by stiffness (ICC 0.94-0.97), and then elasticity (ICC 0.83-0.84). SEM values were calculated as 0.8-0.5 Hz for tone, 40.3-27.9 N/m for stiffness, and 0.1 log for elasticity for both raters. MDC values for frequency ranged from 2.3 to 1.5 Hz, 111.7 to 77.3 N/m for stiffness, and 0.2 log for elasticity for both raters. The CV values for all parameters were below 9.8% (Table 2).

Table 2. Intra-rater reliability of MyotonPRO measurement of ITB mechanical properties

Parameter	R	Time 1	Time 2	ICC	%95GA	CV %	SEM	MDC
Tone (Hz)	R1	17.6±4.5	17.9±4.3	0.97	0.93-0.98	4.5	0.8	2.3
	R2	18.3±4.6	17.8±4.3	0.99	0.97-0.99	2.8	0.5	1.5
Stiffness(N/m)	R1	419.6±178.5	409.3±169.4	0.95	0.89-0.98	9.8	40.3	111.7
	R2	432.9±176.5	416.8±160.9	0.98	0.95-0.99	6.7	27.9	77.3
Elasticity (log)	R1	1.04±0.19	1.05±0.18	0.83	0.65-0.92	9.5	0.1	0.2
	R2	1.01±0.16	1.03±0.16	0.84	0.67-0.92	9.7	0.1	0.2

ITB: iliotibial band, R1: researcher 1, R2: researcher 2, ICC: intraclass correlation coefficient, CI: confidence interval, CV: coefficient of variation, SEM: mean standard error of the mean, MDC: minimum detectable change

Inter-Rater Reliability

Inter-rater reliability for the first and second measurements, within a 95% confidence interval, showed very high reliability for tone, stiffness, and elasticity (ICC 2.1>0.81). SEM values for inter-rater measurements were found to be 0.7-0.6 Hz for tone, 17.8-25.1 N/m for stiffness, and 0.04-0.1 log for elasticity. MDC values for frequency ranged from 1.9 to 1.6 Hz, for stiffness 49.4 to 69.6 N/m, and for elasticity 0.1 to 0.2 log. The CV values for all parameters were below 6.0% (Table 3).

Table 3. Inter-rater reliability of Myoton Pro measurement of ITB mechanical properties

Parameter	Time	R1	R2	ICC	%95GA	CV %	SEM	MDC
Tone	T1	17.6±4.5	18.3±4.6	0.98	0.95-0.99	3.8	0.7	1.9
(Hz)	T2	17.9±4.3	17.8±4.3	0.98	0.96-0.99	3.4	0.6	1.6
Stiffness	T1	419.6±178.5	432.9±176.5	0.99	0.98-0.99	4.1	17.8	49.4
(N/m)	T2	409.3±169.4	416.8±160.9	0.98	0.95-0.99	6.0	25.1	69.6
Elasticity	T1	1.04±0.19	1.05±0.18	0.93	0.86-0.97	3.8	0.04	0.1
(log)	T2	1.05±0.18	1.03±0.16	0.88	0.75-0.94	4.7	0.1	0.2

ITB: iliotibial band, T1: 1st measurement, T2: 2nd measurement, ICC: intraclass correlation coefficient, CI: confidence interval, CV: coefficient of variation, SEM: mean standard error of the mean, MDC: minimum detectable change

The Bland-Altman statistics in Table 4 illustrate the level of agreement between measurements taken on the first and second days across two different raters, as well as the consistency of measurements between the raters. All graphs revealed a symmetrical distribution of data around the mean difference, indicating minimal systematic bias (Table 4, Figure 2).

Table 4. Bland-Altman statistics for mechanical properties of the iliotibial band

Measurement of reliability	**Mean difference** (95% limits of agreement)		
	Tone	Stiffness	Elasticity
Between researchers[a]	0.65 (-0.46 to 1.01)	0.29 (-18.1 to 17.1)	0.12 (-0.14 to 0.90)
Between researchers[b]	0.95 (-0.04 to 0.92)	0.33 (-23.9 to 24.4)	0.24 (-0.15 to 0.13)
Between measurements[1]	0.38 (-1.11 to 1.25)	0.68 (-15.4 to 37.2)	0.76 (-0.04 to 0.16)
Between measurements[2]	0.22 (-0.95 to 0.77)	0.34 (-24.0 to 25.2)	0.79 (-0.04 to 0.15)

a, b: at time 1 and 2 for researchers; 1, 2: for Researcher 1 (SU) and Researcher 2 (TG) for measurements

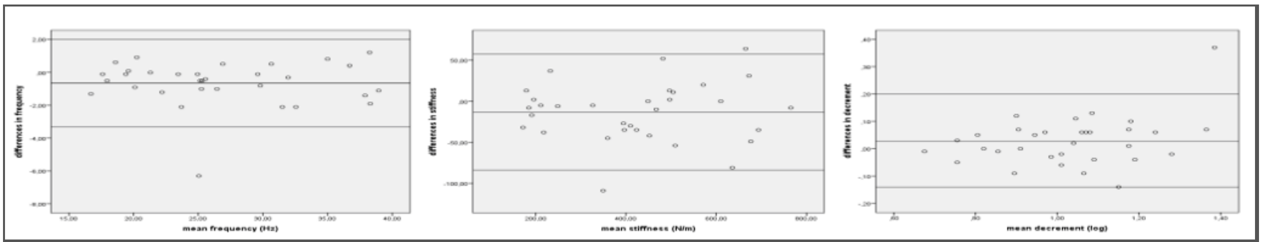

Figure 2. Examples of Bland-Altman graphs for the evaluation of the dominant side iliotibial band mechanical properties of healty individuals with MyotonPRO

DISCUSSION

Our study is the first to investigate the reliability of the MyotonPRO device in measuring the mechanical properties of the iliotibial band. The results show that the MyotonPRO device has very high intra-rater (ICC 0.96-0.98) and inter-rater (ICC 0.97-0.98) reliability in assessing the tone, stiffness, and elasticity of the ITB. Our findings are consistent with those of Aird et al., who investigated the mechanical properties of the quadriceps muscle in 20 healthy individuals, and found very high intra-rater reliability for MyotonPRO measurements (ICC 3,1 >0.90) (12). Similarly, a study examining the tone, stiffness, and elasticity of the rectus femoris and vastus medialis muscles in 94 athletes from different disciplines reported high inter-rater reliability (ICC 0.74-0.99) (23). Liu et al. found excellent intra-rater and inter-rater reliability (ICC: 0.88-0.95) when measuring Achilles tendon stiffness, with CV below 11%, SEM below 18.2 N/m, and MDC below 44.4 N/m (13). MyotonPRO's intra-rater and inter-rater reliability for assessing the mechanical properties of the cervical and orofacial muscles has been reported as moderate to high (ICC: 0.50-0.95). SEM values for tone were below 0.8 Hz, stiffness below 20.9 N/m, and elasticity below 0.2 log. CVs were consistently under 9.1%, aligning with our results (24).

Kurashino et al. (25) found excellent intra-rater and inter-rater reliability (ICC≥0.9) when measuring the stiffness of the deltoid, pectoralis major, and latissimus dorsi muscle groups in patients with adhesive capsulitis. Similarly, a study examining the tone and stiffness of the quadriceps femoris and patellar tendon across different knee flexion angles in 30 healthy participants yielded excellent inter-rater reliability (ICC>0.78) and good to excellent intra-rater reliability (ICC>0.41). The SEM values for inter-rater measurements were found to be below 0.9 Hz and 37.9 N/m, while intra-rater SEM values were below 1.3 Hz and 52.0 N/m (26). In our study, both intra-rater correlation coefficients were excellent, with SEM values for tone and stiffness below 0.8 Hz, and MDC values below 111.7 N/m.

The high ICC values in our study are consistent with those found in the literature, suggesting that our sample size and homogeneity were adequate. SEM values comparable to or lower than those in the literature suggest minimal error and high measurement agreement. The higher MDC values observed for stiffness may be attributed to the dense fibrous structure of the ITB, which could result in slightly larger variations, comparing to other muscles and tendons.

While many studies have easily demonstrated MyotonPRO's reliability based on ICC values (27-29), recent literature suggests that results based on CV provide more precise information (30). Studies that include CV values are relatively few. Our study proved that CV values were well below the 15% threshold commonly accepted for biological materials (31), with intra-rater CV at 9.8% and inter-rater CV at 4.7%. This indicates the high robustness of measurements.

Limitations

Our study focused only on healthy participants when assessing the reliability of the MyotonPRO device for measuring the ITB. Further reliability studies should be conducted in clinical populations, such as those with ITB syndrome, to expand the findings. Also, measurements were taken only from the dominant limb. Future studies comparing mechanical properties of both dominant and non-dominant limbs may add valuable information to the device's reliability.

To conclude; our study demonstrates that MyotonPRO has very high intra-rater and inter-rater reliability for measuring the mechanical properties of the iliotibial band in healthy individuals. Furthermore, the inter-rater variation coefficients were under 6%, which is significantly lower than the accepted threshold for biological measurements. The findings suggest that MyotonPRO is a reliable and reproducible tool for measuring the tone, stiffness, and elasticity of the ITB.

Ethics Committee Approval / Etik Komite Onayı

The approval for this study was obtained from Hasan Kalyoncu University Health Sciences Noninvasive Research Ethics Committee (Approval number: 2022/116, Date: 02.12.2022).

Conflict of Interest / Çıkar Çatışması

The authors declared no conflicts of interest with respect to authorship and/or publication of the article.

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Author Contributions / Yazar Katkıları

Concept: SU; design: TG; supervision: SU; materials: SU; data collection and processing: SU, TG; analysis and interpretation: SU, TG; literature review: SU, TG; writing manuscript: TG; critical reviews: SU. All authors contributed to the final version of the manuscript and discussed the results and contributed to the final manuscript.

Additional information

All methods were carried out in accordance with relevant guidelines and regulations.

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