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Validity and reliability of the KFORCE Sens® electrogoniometer in the evaluation of ankle, knee, and hip range of motion

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Abstract

Background: Range of motion (ROM) is essential for diagnosing limitations from musculoskeletal issues, developing treatment plans, and monitoring treatment progress. ROM assessments commonly involve tools like universal goniometers, evaluation scales, inclinometers, and smartphone applications.

Objective: This study aimed to test the validity of the KFORCE Sens® electrogoniometer in evaluating lower extremity ROM by comparing it with the universal goniometer and examining the inter-rater and test-retest reliability.

Methods: Fifty-one healthy volunteers (aged 18 - 25 years) were included in this study. The lower extremity ROM values of each participant were assessed by two assessors separately using a KFORCE Sens® electrogoniometer. The same assessors repeated the KFORCE Sens® electrogoniometer measurements once to examine test-retest reliability. Lower extremity ROM values were also assessed by one assessor using a universal goniometer.

Results: According to the study findings, both the inter-rater and test-retest reliability of the KFORCE Sens® electrogoniometer device in all ROMs of the lower extremities were excellent (ICC > 0.80). In addition, the ROM values of the KFORCE Sens® electrogoniometer device and the ROM values of the universal goniometer in the same joint were highly correlated ($r > 0.80$, $p < 0.05$).

Conclusion: The KFORCE Sens® electrogoniometer is a valid and reliable device for evaluating lower extremity ROM.

Keywords: Range of motion, electrogoniometers, reliability, lower extremity

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INTRODUCTION

Range of motion (ROM) plays a very important role in the diagnosis of limitations caused by musculoskeletal problems. This is useful in the establishment of the treatment programme and in monitoring the course of treatment. The evaluation of ROMs often uses universal goniometers, evaluation scales, inclinometers, and smartphone applications [1]. With the advancement of technology, the use of electrogoniometers for ROM measurements is becoming widespread [2]. Many joint, validity and reliability studies of electrogoniometers have been carried out in the evaluation of ROMs [3,4]. Studies have often concluded that electrogoniometers are valid and reliable in the knee and ankle joints [5,6]. However, there are limited studies reporting the validity and reliability of an electrogoniometer on the entire lower limb (hip, knee and ankle). In addition, the measurement results may vary due to the different shapes, sizes, attachments, ergonomics, and weights of the electrogoniometers. It is necessary to examine the validity and reliability of each of these technological devices

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separately in order to make accurate measurements and to demonstrate their usability.

KFORCE Sens® is an electrogoniometer or inertial sensor developed by KinventTM (Montpellier, France) engineers to evaluate joint ROM. KFORCE Sens® offers real-time biofeedback by measuring the difference between the starting position and the end point of the movement based on measurement sensors. According to the instructions of the device, the measurement accuracy is 1°, while the device deviation is about 3°. Data obtained from the device can be transferred to smartphones and computers via Bluetooth® connections [7]. Although it is known that universal goniometers are frequently used in ROM evaluations, the measurement error rate of these goniometers is quite high due to factors relating to both the evaluator and the participant. Therefore, the widespread use of electrogoniometers developed in line with technological advances will reduce the margin of error. However, before an electrogoniometer can be used, its validity and reliability must be examined. To the best of our knowledge, the reliability and validity of the KFORCE Sens® electrogoniometer for the assessment of ROM in the major joints in the lower limb (hip, knee and ankle) has not been investigated. The aim of this study was to determine the test-retest reliability, inter-rater reliability, and validity of the KFORCE Sens® electrogoniometer in the lower extremity ROM assessment.

MATERIALS AND METHODS

Study design and participants

This study was a cross-sectional study. This study was carried out on 51 healthy young adults aged between 18 - 25. This study was approved by the Kırşehir Ahi Evran University Ethics Committee, the participating research institutions (Number: 2022-21/182, Date: 22/11/2022). The study was conducted in accordance with the Declaration of Helsinki, and verbal and written consent was obtained from all individuals. Volunteers and healthy young adults were included in the study. Exclusion criteria were lower extremity deformity that may prevent joint movement, lower extremity pain, trauma, surgical history, neurological disease, and rheumatologic disease.

Data collection procedure

Lower extremity ROM was evaluated with both the Baseline® 360° universal goniometer and the KFORCE Sens® electrogoniometer. To examine the construct validity of KFORCE Sens®, its relationship with Baseline® 360° universal goniometer values was examined. In addition, KFORCE Sens® evaluations for both inter-rater and test-retest reliability of KFORCE Sens® were repeated by two physiotherapists. Before starting the evaluation, the protocol was explained to the individuals, and the device was introduced. Evaluations were made in a quiet room on the examination bed so that participants would not be distracted. In the study, the dominant sides of the participants were evaluated for ROM. Since there is no standard time and repetition in the instructions for the use of the device or in the literature, these times and repetitions were determined in line with the consensus of the authors.

Instruments for data collection

For hip joint movement measurement, the goniometer was positioned on the lateral side of the leg for flexion-extension movements. Participants were laid in the supine (for flexion) and prone (for extension) positions. The pivot point was the trochanter major, the fixed arm was parallel to the columna vertebralis, and the movable arm followed the lateral midline of the femur (Figure 1). In the evaluation of hip internal-external rotation, subjects were seated with the legs hanging over the edge of the bed; the pivot point was tuberositas to the tibia; the fixed arm was parallel to the opposite knee; and the movable arm followed the crista of the tibia. A knee flexion measurement was performed in the prone position. The goniometer was positioned laterally; the fixed arm followed the axis of the femur, the pivot point followed the lateral condyle of the femur, and the movable arm followed the fibula. Finally, in the ankle dorsiflexion-plantarflexion measurement, the subject was seated with the knees extended, the pivot point was in the lateral malleolus, the fixed arm was in the fibula, and the movable arm followed the axis of the fifth metatarsal bone. After the Baseline® 360° universal goniometer evaluations, the KFORCE Sens® evaluations started 5 minutes later.

The participants' positioning was the same as in the 360° universal goniometer evaluations. The device was attached to the anterior aspect of the distal femur for hip flexion-extension, to the anterior surface of the distal tibia for hip internal-external rotation, to the posterior aspect of the distal tibia for knee flexion, and the dorsal aspect of the metatarsal heads for ankle dorsi-plantar flexion (Figure 1). The assessment was started by pressing the "start" button on the mobile device, and then the previous protocol was followed. The device saved the active ROM values. The gadget features a gyroscopic inertial sensor that allows for joint range of motion measurement, monitoring, and therapy. It calculates the angle with regard to the limb's initial position in a specified anatomic plane. All assessments with the device were performed by two physiotherapists. To assess the test-retest reliability of the electrogoniometer, the physiotherapists then repeated the measurements once. A period of 30 seconds was given between each measurement. Test-retest evaluations were performed after a 5-minute rest break after the first measurements were completed. Figure 1 summarises the evaluation using the KFORCE electrogoniometer.

Data analysis

All statistical analyses were conducted using IBM SPSS Statistics for Windows, version 24 (IBM Corp., Armonk, N.Y., USA). For the evaluation of normal distribution in variables, a combination of visual methods and analytical techniques was employed (histogram and Shapiro–Wilk test). Assessment of the reliability of the electrogoniometer was conducted using the intraclass correlation coefficient

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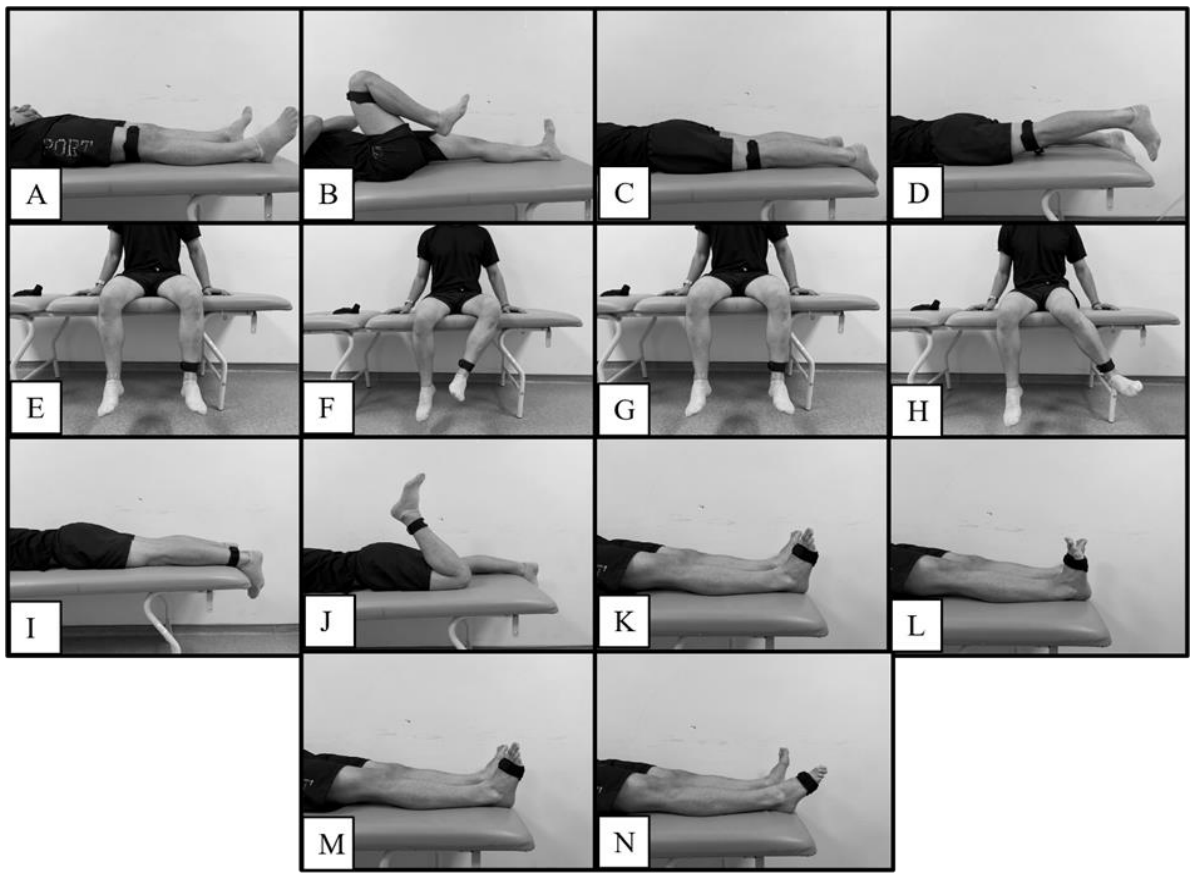

Figure 1. Evaluation of range of motion with KFORCE Sens® electrogoniometer. A: Hip flexion initial position, B: Hip flexion final position, C: Hip extension initial position, D: Hip extension final position, E: Hip external rotation initial position, F: Hip external rotation final position, G: Hip internal rotation initial position, H: Hip internal rotation final position, I: Knee flexion initial position, J: Knee flexion final position, K: Ankle dorsi flexion initial position, L: Ankle dorsiflexion final position M: Ankle plantarflexion initial position, N: Ankle plantarflexion final position.

(ICC). The ICC values were categorised as poor (< 0.40), fair (0.40 - 0.59), good (0.60 - 0.79), and excellent (> 0.80) reliability, respectively [8]. The relationship between the electrogoniometer and the secondary measurements was analysed using Pearson correlation analysis since it fits the normal distribution. A correlation coefficient was considered poor (less than 0.30), moderate (between 0.30 and 0.60), and strong (greater than 0.60) [9]. Calculation of the standard error of measurement (SEM) value for the electrogoniometer scores employed the formula SEM = Standard deviation x √(1 - ICC). The determination of the minimal detectable change at a 95% confidence interval (MDC95) involved the formula MDC95 = 1.96 x SEM x √2 [10]. The established level of statistical significance was set at $p < 0.05$.

RESULTS

The demographic information indicated the mean age of participants to be 20.88 ± 1.67 years (Table 1). Male participants were more than females (52.9%, n = 27). The mean clinical measurement values are summarised in Table 2.

The first rater's test-retest ICC values for KFORCE Sens® electrogoniometers for hip flexion, hip extension, hip internal rotation, hip external rotation, knee flexion, ankle plantar flexion, and ankle dorsiflexion were 0.97, 0.89, 0.89, 0.88, 0.94, 0.94, and 0.91, respectively. This result demonstrates excellent test-retest validity in the lower extremity ROM evaluation of the KFORCE Sens® electrogoniometer among the study participants. Regarding the inter-rater reliability of KFORCESens® electrogoniometers between the first and second raters for hip flexion, hip extension, hip internal rotation, hip external rotation, knee flexion, ankle plantar flexion, and ankle dorsiflexion angles, the ICC values were 0.96, 0.87, 0.86, 0.87, 0.93, 0.90, and 0.90, respectively. Thus, the interrater reliability of the KFORCE Sens® electrogoniometer was also found to be excellent Table 3).The correlation results of the KFORCE Sens® electrogoniometer with the universal goniometric measurements, which are frequently

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Table 1. Participants' demographic features

		Mean	SD	Min	Max
Age (years)		20.88	1.67	18	25
Height (cm)		167.88	10.73	150	196
Weight (kg)		63.67	17.06	40	118
BMI (kg/m^2)		22.37	4.38	16.43	43.34
		n		(%)	
Gender	Male	27		52.9	
	Female	24		7.1	

Table 2. The mean values of the measurements of the ROM

			Mean	SD	Minimum	Maximum
Baseline® 360° universal goniometer		Hip flexion	103.00	7.66	88	120
		Hip extension	15.10	2.95	10	20
		Hip internal rotation	37.61	3.38	30	45
		Hip external rotation	37.14	3.11	29	44
		Knee flexion	123.16	5.84	111	134
		Ankle plantar flexion	38.59	4.35	30	48
		Ankle dorsi flexion	14.08	2.95	9	20
KFORCE Sens®	Hip flexion (1)	Test	104.57	7.40	90	120
		Retest	103.94	7.20	91	120
	Hip flexion (2)	Test	104.63	6.93	91	118
		Retest	103.29	6.42	92	115
	Hip extension (1)	Test	15.57	3.32	9	20
		Retest	15.33	3.02	9	20
	Hip extension (2)	Test	15.22	2.40	11	19
		Retest	15.20	1.82	12	20
	Hip internal rotation (1)	Test	37.94	3.48	30	45
		Retest	38.02	3.23	31	45
	Hip internal rotation (2)	Test	37.35	3.29	30	45
		Retest	37.25	3.25	30	44
	Hip external rotation (1)	Test	37.98	3.45	30	45
		Retest	37.96	3.07	31	44
	Hip external rotation (2)	Test	37.31	3.30	30	45
		Retest	37.14	3.35	30	45
	Knee flexion (1)	Test	124.06	6.06	113	134
		Retest	124.00	6.53	110	135
	Knee flexion (2)	Test	124.20	6.14	111	135
		Retest	124.33	5.40	115	135
	Ankle plantar flexion (1)	Test	39.94	5.30	30	50
		Retest	39.61	4.95	30	50
	Ankle plantar flexion (2)	Test	39.37	4.86	30	50
		Retest	39.12	4.74	30	50
	Ankle dorsi flexion (1)	Test	14.57	3.45	9	20
		Retest	14.06	3.11	9	20
	Ankle dorsi flexion (2)	Test	14.47	3.10	10	20
		Retest	14.20	2.84	10	20

Table 3. Inter-rater (ICC) and test-retest (ICC) reliability of the KFORCE Sens®

n = 51	Difference (Mean ± SD)	Inter-rater (ICC $_{1,2}$) (95% CI)	Test-retest (ICC $_{1,1}$) (95% CI)	SEM	MDC$_{95}$
Hip flexion	-0.62 ± 1.67	0.96 (0.94-0.98)	0.97 (0.95-0.98)	0.19	0.52
Hip extension	-0.23 ± 1.49	0.87 (0.79-0.93)	0.89 (0.81-0.94)	0.49	1.34
Hip internal rotation	0.07 ± 1.59	0.86 (0.77-0.92)	0.89 (0.81-0.94)	0.52	1.42
Hip external rotation	-0.01 ± 1.61	0.87 (0.78-0.92)	0.88 (0.79-0.93)	0.18	0.49
Knee flexion	-0.05 ± 2.15	0.93 (0.89-0.96)	0.94 (0.90-0.97)	0.51	1.39
Ankle plantar flexion	-0.33 ± 1.82	0.90 (0.83-0.94)	0.94 (0.89-0.96)	0.43	1.17
Ankle dorsi flexion	-0.50 ± 1.40	0.98 (0.96-0.99)	0.91 (0.85-0.96)	0.42	1.15

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Table 4. Relationship between KFORCE Sens® and Baseline® 360° universal goniometer ROM evaluations

		Baseline® 360° universal goniometer						
		Hip flexion	Hip extension	Hip internal rotation	Hip external rotation	Knee flexion	Ankle plantar flexion	Ankle dorsi flexion
KFORCE Sens®	r	0.890	0.912	0.882	0.900	0.921	0.916	0.925
	p	< 0.001	< .001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

used in the clinic to determine the concurrent validity of hip flexion, hip extension, hip internal rotation, hip external rotation, knee flexion, ankle plantar flexion, and ankle dorsiflexion of healthy individuals, included in the study, are summarised in Table 4. According to our results, a statistically significant correlation was found between the lower extremity ROM values of the KFORCE Sens® electrogoniometer and all the same joint ROM values of the universal goniometer ($p < 0.001$).

DISCUSSION

To the best of our knowledge, this is the first study to examine the validity and reliability of the KFORCE Sens® electrogoniometer for lower extremity ROM assessment. Based on the results of the current study, the test-retest reliability of the KFORCE Sens® electrogoniometer in healthy young adults was excellent. The results also showed that it is valid in the assessment of lower extremity ROM because of the significant relationship between the KFORCE Sens® electrogoniometer and the Baseline® 360° universal goniometer. Also, in this study, we present the MDC and SEM values of the KFORCE Sens® electrogoniometer for the first time on lower extremity ROM assessment in healthy young adults.

Electrogoniometers are a practical tool to identify functional limitations, guide treatment programs, and provide evidence of treatment efficacy. Electrogoniometers are a practical tool to identify functional limitations, guide treatment programs, and provide evidence of treatment efficacy. Available literature indicates that practical and reliable alternative goniometer types have been developed [7]. In this study, we investigated the reliability of the KFORCE Sens® electrogoniometer, which is a portable device that transmits data to smartphones and computers via Bluetooth® connections in the lower extremity range of motion. In a previous study, the reliability of the KFORCE Sens® electrogoniometer in the wrist joint was investigated and concluded that the ICC value was 0.94 for flexion/extension movement and 0.96 for ulnar/radial deviation [7]. Morales et al. observed excellent reliability in evaluating the ankle ROM of the electrogoniometer (ICC > 0.90) [11]. Derhon et al. similarly demonstrated that the reliability of the electrogoniometer application in the evaluation of knee joint flexion ROM was excellent (ICC > 0.80) [12]. In another study, Saraç et al. evaluated the hip joint ROM with the electrogoniometer application and stated that the reliability of the electrogoniometer application in the evaluation of the hip joint was excellent (ICC > 0.90) [13]. In our study, the test-retest reliability of the KFORCE Sens® electrogoniometer was found to be excellent (ICC > 0.80).

In this study, we used a universal goniometer for the concurrent validity of the KFORCE Sens® electrogoniometer. When the results of our study were examined, we observed a strong correlation between the KFORCE Sens® electrogoniometer and the universal goniometer in all lower extremity ROM values ($r > 0.88$, $p < 0.001$). We noted a dearth of literature comparing universal goniometer and electrogoniometer is limited. However, electrogoniometer is similar to each other in terms of smart sensor structures, and many studies have been conducted comparing the two goniometers in this regard. Vohralik et al. found a strong correlation between universal goniometer and smartphone goniometer application in ankle ROM assessment [14]. In a study examining the flexion ROM of the knee joint, Hambly et al. stated that the smartphone goniometer application and the universal goniometer were correlated [15]. In another study, Saraç et al. concluded that smartphone goniometer applications and universal goniometers were correlated to the evaluation of hip joint ROM [13]. Results from our present study are consistent with literature, thus suggesting that KFORCE Sens® electrogoniometer is a valid tool for the evaluation of lower extremity ROM.

Our study examined the SEM95 and MDC95 values of the KFORCE Sens® electrogoniometer for each lower extremity movement. In the previous study, the validity and reliability of the KFORCE Sens® electrogoniometer in the wrist joint were examined, but the SEM95 value was not given [7]. Tekin et al. did not examine the MDC95 value in the validity and reliability study of the KFORCE Sens® electrogoniometer [7]. This study had some limitations. First, the study population consisted of healthy young adults. Further, the validity and reliability study of the KFORCE Sens® electrogoniometer was conducted only in the evaluation of proprioception sense, making it difficult to discuss our study by comparing it with the literature. We recommend that KFORCE Sens® electrogoniometer should be examined in specific pathologies, age groups and different extremities in future studies.

Conclusion

Test-retest and inter-rater reliability are excellent in evaluating the KFORCE Sens® electrogoniometer's lower

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extremity ROM, and its concurrent validity with the universal goniometer is strong.

DECLARATIONS

Ethical consideration
Written informed consent was obtained from all study participants, and ethical approval (Number: 2022-21/182, Date: 22/11/2022) for the study was obtained from the Kırşehir Ahi Evran University Ethics Committee.

Consent to publish
All authors agreed on the content of the final paper.

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Competing Interest
The authors declare that there is no conflict of interest regarding the publication of this article.

Author contributions
İC conceived the research idea and designed the study with MC. ŞK and MC participated in data collection. FT and HA contributed to the data analysis and interpretation. GKAA wrote the initial draft of the manuscript. İC, ŞK, MC and AÖ provided critical revision of the manuscript. All authors contributed to and approved the final version to be published.

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Availability of data
Data is available upon request to the corresponding author.

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