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Comparison of Smartphone Applications with Traditional Tools in the Assessment of Patellofemoral Pain: Validity and Reliability Study

Patellofemoral Ağrının Değerlendirilmesinde Akıllı Telefon Uygulamalarının Geleneksel Araçlarla Karşılaştırılması: Geçerlilik ve Güvenirlik Çalışması

[1]Musa ÇANKAYA, [1]Aleyna BEKAROĞLU

[1]Seydişehir Vocational School of Health Services, Department of Physiotherapy and Rehabilitation, Necmettin Erbakan University, Konya, Türkiye

Musa Çankaya: http://orcid.org/0000-0002-2093-5036
Aleyna Bekaroğlu: http://orcid.org/0009-0001-3369-6361

ABSTRACT

Objectives: Patellofemoral pain (PFP) is one of the most confusing and clinically challenging chronic diseases. The aim of this study was to determine the validity and reliability of the smartphone goniometer application in patients with PFP by comparing it with a universal and digital inclinometer.

Materials and Methods: Twenty-seven patients with PFP were included in this study. Flexion range of motion for the knee joint and flexion/extension, abduction, and internal/external rotation range of motion for the hip joint were measured by two examiners using a smartphone application, a digital inclinometer, and a universal goniometer. To assess inter-rater reliability, the two measurements made by the first observer were evaluated at 24-48 hour intervals. To assess intra-rater reliability, the measurements of both observers were compared.

Results: With all three methods, active knee and hip range of motion measurements in PSS patients showed high intra-rater and inter-rater reliability (ICC = 0.69-0.97). Concurrent validity analysis also showed statistically significant, moderate to strong correlations between the three methods (r = 0.562-0.993). SEM and MDC were highest in the goniometer measurement and were intra-observer (3.77-7.94° and 10.44-21.99°, respectively) and inter-observer (2.61-9.45° and 7.23-27.54°, respectively).

Conclusions: The smartphone app, inclinometer, and universal goniometer are valid and reliable for measuring lower limb ROM in PFA patients. They can be used in the clinic.

Keywords: Lower extremity, anterior knee pain syndrome, range of motion, mobile application, test-retest reliability

ÖZ

Amaç: Patellofemoral ağrı (PFA) en kafa karıştırıcı ve klinik olarak zorlayıcı kronik hastalıklardan biridir. Akıllı telefon gonyometre uygulamasının PFA hastalarda geçerlilik ve güvenilirliğinin universal gonyometre ve dijital inklinometre ile karşılaştırılarak belirlenmesi planlanmıştır.

Materyal ve Metot: Bu çalışmaya PFA yirmi yedi hasta dahil edildi. Diz eklemi için fleksiyon hareket açıklığı ve kalça eklemi için fleksiyon/ekstansiyon, abdüksiyon, iç/dış rotasyon hareket açıklığı akıllı telefon uygulaması, dijital inklinometre ve üniversal gonyometre kullanılarak iki denetçi tarafından ölçüldü. Değerlendiriciler arası güvenilirliği değerlendirmek için, ilk gözlemci tarafından yapılan iki ölçüm 24-48 saat aralıklarla değerlendirilmiştir. Değerlendirici içi güvenilirliği değerlendirmek için her iki gözlemcinin ölçümleri karşılaştırılmıştır.

Bulgular: Her üç yöntemle de, PFA hastalarında aktif diz ve kalça hareket açıklığı ölçümleri yüksek gözlemci içi ve gözlemciler arası güvenilirlik göstermiştir (ICC = 0,69-0,97). Eşzamanlı geçerlilik analizi de üç yöntem arasında istatistiksel olarak anlamlı, orta ila güçlü korelasyonlar gösterdi (r = 0,562-0,993). SEM ve MDC en yüksek gonyometre ölçümünde olduğu ve gözlemciler içi (sırasıyla, 3,77-7,94° ve 10,44-21,99°), gözlemciler arasında (sırasıyla, 2,61-9,45° ve 7,23-27,54°) olduğu belirlenmiştir

Sonuç: PFA hastalarında alt ekstremite ROM'ların ölçmek için akıllı telefon uygulaması, inclinometre ve universal gonyometre geçerli ve güvenirdir. Klinikte kullanılabilinir.

Anahtar Kelimeler: Alt ekstremite, diz önü ağrı sendromu, hareket açıklığı, mobil uygulama, test-tekrar test güvenilirliği

Sorumlu Yazar / Corresponding Author:
Musa Çankaya
Seydişehir Vocational School of Health Services, Anabağlar District, Prof. Dr. Necmettin Erbakan Street No:19/3, Seydişehir/Konya -Türkiye
Tel.: +090 506 295 73 82
E-mail: musa-cankaya@hotmail.com

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INTRODUCTION

Patellofemoral pain (PFP) is one of the most common knee disorders that impair function and daily activities.[1] Symptoms usually arise from the anterior aspect of the patella and along the medial aspect of the knee.[2] The symptoms of PFP may develop slowly or suddenly, and pain tends to worsen with activities such as squatting, prolonged sitting, climbing stairs, jumping, and running.[3,4]

Measurements of range of motion (ROM) are widely used in the evaluation of PFP.[1] When the literature is examined, it is seen that the reliability and validity of universal goniometers (UGs) and smartphone applications (SAs) have been verified in samples of healthy individuals.[5,6] Goniometer obtaining accurate and consistent measurements of joint ROM is extremely difficult due to anatomical complexity and associated movements.[7] Tools, including electro goniometers, HALO digital goniometers, photogrammetry software, Hawk goniometers, and Sas, are currently used.[7,8]

Digital inclinometers (DIs) are handheld devices placed on the body's surface to measure the angular position relative to the vertical or horizontal plane.[9] DIs can help in stabilizing the limb and performing the measurements.[10] With the development of smartphone technology and software applications, phone applications with evaluation purposes are increasing alongside the widespread ownership of smartphones. SAs are similar to UGs in that they are easy to use, relatively inexpensive, and highly accessible.[8,11] With the use of SA downloadable data, such as that obtained by electrogoniometry, these measurements can be converted into meaningful assessment data, such as data on joint motion. Therefore, the emergence of smartphone-based goniometer apps offers clinical practitioners a new set of tools to incorporate into clinical practice.[11] Smartphone application needs to be developed further due to its advantages such as portability, low energy requirement, user-friendliness, wide instrumentation possibilities, cost, ease of use and easy applicability in daily rehabilitation. Existing smartphone applications have a great advantage in terms of quality and ease of use.

When the literature was examined, it was found that there were studies examining the validity of UGs and SAs.[12,13] However, the validity and reliability analyses conducted to date were conducted for healthy individuals and no research has been conducted on unhealthy individuals. Research on unhealthy individuals would most likely yield different measurement results due to pain and limitation of movement among unhealthy individuals; thus, the results obtained from such research would be more consistent with the data obtained from other methods. Demonstrating that SA can be applied to patient individuals is important for the dissemination of a new method that can be used in the clinic.

Goniometric measurements are performed on sick individuals rather than healthy individuals in the clinic.[5,6,8,9] Our research is important in terms of showing results on sick individuals. Determining that it can be used on patients is important in terms of its use in the clinic and its widespread use as a preferred method. In addition, when the literature was examined, UGs were found to have been compared with only SA validity analysis.[11] Determining that it can be used on patients is important for its use and dissemination in the clinic. This study aims to compare the SA method with other traditional methods and to analyze its validity and reliability.

MATERIALS AND METHODS

Ethics Committee Approval: This was a descriptive single-blind study. The research was approved by the Necmettin Erbakan University Health Sciences Scientific Research Ethics (Date:03.01.2024, decision no:2024/632), and all procedures were conducted by the Declaration of Helsinki. All participants provided verbal and written informed consent.

Study Sample: The literature suggests that the acceptable power threshold for research should be 0.80.[14] Roach et al. reported an effect size of 0.92 upon calculating the means and standard deviations of hip joint extension.[15] However, in the present study, the effect size was taken as 0.35 to ensure high power. Using G*Power 3.1.9.2 with an effect size of 0.35, standard error of 0.05, and power of 95%, it was determined that calculations made with ANOVA, including repeated measures and within-group and between-group interactions for three groups and two measurements, should be based on 24 participants. In recognition of the risk of patient dropouts during the research, 27 patients were enrolled in the study.[16] It was observed that similar sized samples were taken in the studies.[8,11] The effect size post power analysis was calculated by taking the means and standard deviations of the second measurements of SA and UG from the knee flexion measurements on the Cohend d, Effect Size Calculator for T-Test website (https://www.statskingdom.com/140Mean T2eq.html) and 0.43 was found. G*Power 3.1.9.2 program, Post power analysis, 0.43 effect size was calculated as 27 participants with 0.05 standard error and 95 percent power (ANOVA: Repeated measures, within-between interaction 3 groups, 2 measurements) and it was determined that the power was 97 percent in post hoc analysis. The effect size of our post hoc results was determined as 0.43 and the effect size was taken as 0.35 at the beginning of our study.

This shows that the sample size of 27 people included in the study is sufficient. These participants included individuals with anterior knee pain who presented to Seydişehir State Hospital. A total of 27 patients with PFP were evaluated in the laboratory of the Seydişehir Vocational School of Health Services between January 2024 and August 2024. Only one extremity was evaluated for each patient. Patients with PFP were included in the study by physiotherapists.[17] Inclusion criteria included anterior knee pain or retro patellar pain caused by at least two of the following activities: prolonged sitting knee flexion, bilateral squatting, ascending and descending stairs, kneeling, running, or jumping. Pain in one extremity.[18] The exclusion criteria were as follows: signs or symptoms of any current or past knee dysfunction, history of surgery on any lower limb joint, and a history of physiotherapy treatment of the knee area within the previous 6 months before the clinical evaluation.[18]

Measurement Protocols: Goniometric measurements were performed for each patient by two evaluators. Active ROM measurement was performed with five volunteers for a pilot study. Subsequently, 27 patients were evaluated. Knee and hip ROM was assessed by two assessors using a UG (Saehan SH5110 steel goniometer set), inclinometer (Baseline digital inclinometer), and SA (Electrogoniometer) (Figure 1). Patients rested for 5 –10 minutes after the first evaluation (Figure 2).[19] The second evaluator then evaluated them. ROM measurements were performed in the same order in all assessments. The measured parameters included the flexion and extension of the knee joint, abduction, and internal/external rotation of the hip joint. After 24–48 hours, the assessment was repeated twice (Figure 2). Both examiners were blinded to the other's measurements.[20] Inter-rater measurements were performed by the same assessor.

Outcome Measures

The sociodemographic characteristics of the participants were recorded. Knee and hip ROM values were determined by UG, DI, and SA.

Knee and hip joint ROM assessment: Participants were asked to maintain their final position at the maximum ROM for at least 3 seconds. Three consecutive measurements were performed, and the mean of those three measurements for each direction was used for analysis. Measurements were performed for the affected lower extremity, and the active ROM was assessed.

Knee joint ROM flexion assessment: With the patient in the prone position, the goniometer was positioned with the pivot point on the femoral lateral condyle, the fixed arm in the direction of the greater

Figure 1. Electrogoniometer application.

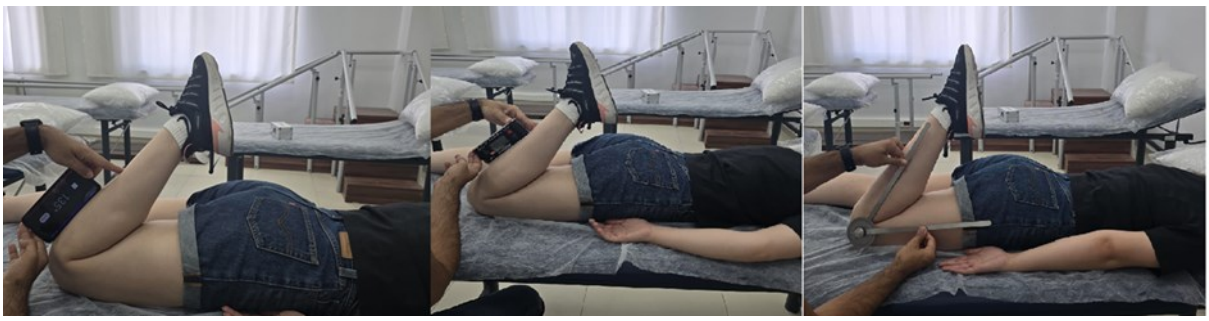

Figure 2. Range of motion measurement tools.

trochanter, and the movable arm in line with the fibular shaft.[19] Starting from the knee joint extension position of 0°, the degree of the angle at the end-point of the knee joint was measured by following the knee joint flexion of the movable arm.[21] DI and SA measurements were made on the midline lateral to the fibula. The knee was bent from full extension (0°) to full flexion.

Hip Joint ROM flexion/extension assessment: The hip extension was evaluated in the prone position and flexion in the supine position. For hip flexion measurement, the goniometer was placed over the trochanter major of the femur, with the fixed arm parallel to the lateral side of the body and the movable arm parallel to the lateral side of the femur.[22] Participants were then asked to perform maximal active hip flexion. The hip joint extension was performed by placing similar points on the goniometer.[22] Measured in a similar way with the DI/SA.

Hip joint ROM abduction assessment: With the patient in the supine position, were made on the spina iliaca anterior superior (SIAS) of the pelvis, with the fixed arm parallel to an imaginary line between the right and left SIAS and the mobile arm following a line parallel to the longitudinal axis of the femur and aligned with the midpoint of the patella. The DI and SA devices were held parallel to the lateral side of the femoral shaft of the patient in the side-lying position and the patient was asked to perform an abduction movement against gravity.[21,22]

Assessment of hip joint ROM internal/external rotation: Participants assumed a sitting position with their hips in 90° flexion, trunk erect, and arms crossed at the chest. The UG axis was placed on the tuberosity of the tibia, the fixed arm was parallel to the ground, and the mobile arm was parallel to the longitudinal axis of the tibia.[21,22] For DI and SA measurements, the phone was held parallel to the anterior longitudinal axis of the tibia in the same starting position, and the same movements were performed.

Statistical Analysis: IBM SPSS 29.00 was used for statistical analyses. Mean and standard deviation for continuous values and number and percentage for categorical values. Data were checked for accuracy and normal distribution using the Kolmogorov–Smirnov test and kurtosis and skewness analysis.[23] ICC, MDC, SD values were calculated to determine the minimum significant difference and the relationship between the measurements. Intraclass correlation coefficients (ICCs) were calculated with 95% confidence intervals (CIs) and standard errors.[19] Standard error of measurement (SEM) values were calculated using the formula SD× ($\sqrt{(1-ICC)}$). Minimum detectable change (MDC) at a 95% CI was calculated as MDC=1.96×SEM×√2.[13] For absolute measures of reliability and validity, the following criteria were used SEM: Poor SEM > 5˚ and Good SEM ≤5˚; MDC: Poor MDC > 9.8˚ and Good MDC ≤9.8.[8] Test-retest Pearson correlation coefficients were used to assess knee and hip ROM ($p<0.05$).[24] Correlations were interpreted as excellent ($r>0.90$), good ($0.90>r>0.71$), fair ($0.70>r>0.51$), moderate ($0.50>r>0.31$) and poor ($r\leq0.30$).[24]

RESULTS

A single extremity was evaluated for each of 27 participants aged 19–45 years. The physical and sociodemographic characteristics are presented (Table 1).

Table 1. Physical and sociodemographic characteristics of the participants (n=27).

Physical characteristics		**Data**
Age (year) Mean±SD, (Min.-Max.)		30.67±14.40 (19-45)
BMI (kg/m^2) Mean±SD, (Min.-Max.)		24.46±4.67 (18.07-34.77)
D**uration of complaint (month)** Mean±SD, (Min.-Max.)		2.48±1.55 (1.00-6.00)
Pain severity Mean±SD, (Min.-Max.)		52.34± 12.9 (27.00-73.30)
Sex n (%)	Female	19 (70.4)
	Male	8 (29.6)
Education level n (%)	Primary school	5 (18.5)
	Middle school	3 (11.1)
	High school	1 (3.7)
	University and above	18 (66.7)
Occupation status n (%)	Student	18 (66.7)
	Worker	3 (11.1)
	Retired	2 (7.4)
	Housewife	4 (14.8)
Marital status n (%)	Married	8 (29.6)
	Single	18 (66.7)
	Divorced	1 (3.7)
Working Status n (%)	Full time	3 (11.1)
	Part-time	0 (0)
	Not working	24 (88.9)

SD: Standard Deviation; BMI: Body Mass Index.

Table 1. Continue.

Income-Expense balance n (%)	Equal	10 (37)
	Income>expense	2 (7.4)
	Income<expense	15 (55.6)
Patient history n (%)	Hypertension	3 (11.1)
	Diabetes	4 (14.8)
	Other	2 (7.4)
	None	18 (66.7)
Party under evaluation n (%)	Right	23 (85.2)
	Left	4 (14.8)

SD: Standard Deviation; BMI: Body Mass Index.

The results of intra- and interrater reliability analyses are shown in Table 2. Good intra- and interrater reliability were found for hip extension, abduction, and external rotation (intrarater reliability) by UG, while excellent intra- and interrater reliability was found for the other measurements. For all measured active hip and knee joint ROM values, intra- and interrater reliability was excellent for DI and SA. When the interrater reliability of the measurement methods was analyzed at a 95% CI, the highest ICCs were determined for knee flexion and hip internal rotation by DI (ICC: 0.97 and ICC: 0.92, respectively) and for hip flexion, extension, abduction, and external rotation by SA (ICC: 0.97, ICC: 0.91, ICC: 0.80, and ICC: 0.88, respectively). When the intrarater reliability of the measurement methods was analyzed at a 95% CI, it was determined that the highest ICCs were obtained for knee flexion and hip internal rotation by DI (ICC: 0.91 and ICC: 0.92, respectively) and for hip flexion, extension, abduction, and external rotation by SA (ICC: 0.97, ICC: 0.91, ICC: 0.80, and ICC: 0.88, respectively) (Table 2). Further data from intra- and interrater reliability analyses, including ICC values with 95% CI, SEM, and MDC, are reported in Table 2. The SEM and MDC values were highest for the goniometer measurements, with intrarater SEM and MDC values of 3.77–7.94° and 10.44–21.99°, respectively, and interrater SEM and MDC values of 2.61–9.45° and 7.23–27.54°, respectively. There were significant differences ($p<0.05$) among the SA, DI, and UG results for all inter- and intrarater measurements.

Validity analysis and criterion validity reflect the extent to which a measurement correlates with the results of other methods that aim to measure the target construct. In the present study of the concurrent validity of knee flexion, hip flexion, extension, abduction, external rotation, and internal rotation ROM measurements made with three different methods, the strongest correlations were found between the SA and DI methods (r=0.952, r=0.993, r=0.842, r=0.807, r=0.970, and r=0.963, respectively). Correlations were also observed between the SA and UG methods for hip flexion, abduction, and external rotation (r=0.986, r=0.680, and r=0.945, respectively) and between the DI and UG methods for knee flexion, hip flexion, and extension, and internal rotation (r=0.914, r=0.986, and r=0.844, respectively). All correlations were significant ($p<0.001$) (Table 3).

DISCUSSION AND CONCLUSION

Clinical measurements should be accurate, reliable, reproducible, sensitive to changes in outcomes, easy to implement, and accessible.[21] In this study, we aimed to evaluate the validity, interrater reliability, and intrarater reliability of measurements of active knee and hip joint ROM in PFP patients by comparing the results obtained from SA, DI, and UG. These methods yielded valid and reliable results for the measurement of lower extremity ROM in patients with PFP. Furthermore, excellent correlations among SA, DI, and UG were demonstrated. These results suggest that SAs are useful tools for measuring knee and hip ROM in clinical settings.

Although reliable intrarater and interrater analysis results were obtained in this study for knee and hip joint measurements using all three methods, it was determined that the reliability of the SA was higher than that of the UG. Similar results were obtained in this study in terms of the reliability of the SA and DI.

Acar et al. found that the interrater and intrarater ICC values for active knee flexion measurements were higher with the SA method compared to the UG method (ICC = 0.749–0.949) ($p=0.013$).[19] Saraç et al. obtained excellent results in their intrarater reliability analysis of UG and SA measurements of the hip joint, but the ICC measurement values obtained with the UG were lower (ICC: 0.96-0.98).[21] Mohammad et al. determined that the ICC values of their DI and SA reliability results were excellent for the evaluation of the ROM of the knee and hip joints (ICC:0.95-0.98).[5] Our results are similar to those of Saraç et al. and Mohammad et al. in terms of reliability.[5,21]

Knee and hip joint movements are critical for performing activities of daily living, such as squatting, walking on an incline, and walking up and down stairs. In several studies of patients with PFP, active

Table 2. Test-retest Reliability measures for the smartphone, inclinometer, and universal goniometer.

ROM Assessment methods (degrees)		R1a (Mean±SD)	R1b (Mean±SD)	R2 (Mean±SD)	Interrater reliability (R1 vs. R2)				Intrarater reliability (R1a vs. R1b)			
					ICC	95% CI	SEM	MDC	ICC	95% CI	SEM	MDC
Knee Flexion	SA	114.33±13.52	116.48±10.54	113.00±13.90	0.96	0.91-0.98	2.70	7.48	0.89	0.75-0.95	4.48	12.41
	DI	116.18±12.26	117.704±9.85	114.04±13.01	0.97	0.93-0.99	2.12	5.87	0.91	0.80-0.96	3.68	10.19
	UG	120.52±10.48	120.70±8.86	117.81±11.84	0.91	0.81-0.96	3.14	8.70	0.87	0.71-0.94	3.77	10.44
Hip Flexion	SA	99.11±21.06	101.26±20.51	99.96±20.21	0.98	0.96-0.99	2.98	8.25	0.97	0.94-0.99	3.65	10.11
	DI	100.56±21.99	102.74±20.88	100.89±20.21	0.97	0.94-0.99	3.80	10.53	0.95	0.89-0.98	4.92	13.63
	UG	102.29±22.93	103.96±16.78	98.85±24.69	0.83	0.64-0.92	9.45	27.54	0.88	0.80-0.96	7.94	21.99
Hip Extension	SA	26.40±5.32	26.56±5.77	26.55±5.23	0.81	0.68-0.94	2.32	6.42	0.91	0.81-0.96	1.60	4.43
	DI	26.67±6.18	27.44±6.22	26.26±5.10	0.88	0.74-0.97	2.14	5.93	0.85	0.67-0.93	2.39	6.62
	UG	27.74±5.69	28.74±5.61	26.26±5.43	0.69	0.33-0.86	2.61	7.23	0.69	0.32-0.86	2.61	7.22
Hip Abduction	SA	42.11±6.89	40.67±7.26	40.93±7.68	0.95	0.89-0.98	1.54	4.27	0.80	0.56-0.91	3.08	8.53
	DI	41.37±6.54	40.37±7.39	40.33±7.30	0.91	0.80-0.96	1.96	5.43	0.79	0.54-0.90	2.99	8.28
	UG	43.37±6.86	44.14±8.41	43.00±8.22	0.57	0.04-0.80	4.49	12.44	0.56	0.03-0.80	4.55	12.60
Hip Internal Rotation	SA	48.00±8.89	49.70±7.45	46.04±8.72	0.94	0.86-0.97	2.18	6.03	0.90	0.79-0.96	2.81	7.78
	DI	48.18±8.90	46.15±7.71	49.37±7.43	0.90	0.79-0.96	2.81	7.78	0.92	0.83-0.96	2.52	6.98
	UG	49.81±9.29	51.44±8.15	47.66±7.70	0.75	0.45-0.89	4.64	12.85	0.82	0.60-0.92	3.94	10,91
Hip External Rotation	SA	48.04±8.64	49.89±6.68	48.00±9.19	0.96	0.92-0.98	1.73	4.79	0.88	0.75-0.95	2.99	8.28
	DI	48.89±8.50	50.26±6.47	50.26±6.47	0.88	0.74-0.95	2.94	8.14	0.86	0.68-0.93	3.18	8.81
	UG	50.11±8.20	49.40±5.97	47.81±6.64	0.70	0.33-0.86	4.49	12.43	0.69	0.32-0.85	4.57	12,66

SA: Smartphone applications; DI: Digital inclinometer; UG: Universal Goniometer; ROM: range of motion; SD: Standard deviation; ICC: Intraclass correlation coefficient; CI:Confidence; Interval: Rater 1a = Rater 1; first measurement: Rater 1b = Rater 1; second measurement: Rater 2 = Rater 2; SEM: Standard Error of Measurement; MDC: Minimum Detectable Change at the %95 confidence level.

Table 3. Concurrent validity analysis of the smartphone, inclinometer, and universal goniometer (n=27).

ROM Measurements	SA vs. DI	DI vs. UG	SA vs. UG
Knee Flexion	r=0.952, p=0.001	r=0.914, p=0.001	r=0.887, p=0.001
Hip Flexion	r=0.993, p=0.001	r=0.984, p=0.001	r=0.986, p=0.001
Hip Extension	r=0.842, p=0.001	r=0.844, p=0.001	r=0.836, p=0.001
Hip Abduction	r=0.807, p=0.001	r=0.562, p=0.001	r=0.680, p=0.001
Hip Internal Rotation	r=0.970, p=0.001	r=0.941, p=0.001	r=0.901, p=0.001
Hip External Rotation	r=0.963, p=0.001	r=0.926, p=0.001	r=0.945, p=0.001

SA: Smartphone applications; DI: Digital inclinometer; UG: Universal Goniometer; ROM: range of motion; r = Pearson correlation coefficient.

hip and knee ROM measurements were performed as the main assessment method.

In this study, the SEM 5˚ and MDC values of SA and DI were lower than 9. 8, while the SEM 5˚ and MDC values of UG were higher than 9.8. This shows that SA and DI are more reliable methods than UG in NEH measurement. Keogh et al. systematic review of SA found that in 13 of 17 studies, joint motion was reduced by SEM < 5˚ or MDC < ± 9.8˚.[8] Saraç et al. determined that the MDC value was between 3.29° and 5.1° in the validity and reliability of a range of motion measurement in the hip joint.[21] The results of Saraç et al. are similar to the results of our study.[21]

In this study, knee and hip joint ROM measurements in PFP patients showed good to excellent correlations between the SA and DI (r: 0.842–0.993), SA and UG (r: 0.680–0.945), and DI and UG (r: 0.562–0.984). Different combinations of DI, UG, and SA were compared in previous studies, but this is the first study to examine these three methods together in patients with PFP. Acar et al. showed very strong correlations between DI and UG (r: 0.855), SA and UG (r: 0.882), and SA and DI (r: 0.891) based on 6-month postoperative knee flexion ROM measurements in a validity and reliability study of UG, DI, and SA for total knee arthroplasties.[19] Our results are similar to those reported by Acar et al. Furthermore, a systematic review of this topic concluded that SAs provide relatively strong intrarater and interrater reliability and interrater validity for assessing joint ROM. This suggests that clinicians can use a relatively wide variety of SAs to measure joint ROM.[8] Individuals can also use their smartphones to monitor their conditions during rehabilitation processes, which can potentially improve the quality of self-rehabilitation or during home physiotherapy practices to increase their motivation.[25]

This study, the time taken for the second evaluation was 24-48 hours. Acar et al. this period for the second evaluation was performed after 1 hour.[19] Sarac et al. performed their second evaluation after 1 day.[21]

Bilateral PFP cases were not included in our study. Patients with pain in a single extremity were included in the study. This increased the strength of our study. SA has advantages such as being free, user-friendly, and easily accessible. Individuals can use their smartphones to monitor their condition during rehabilitation practices, which can potentially improve the quality of self-rehabilitation or home physiotherapy practices by increasing motivation. It can be used more widely in practical applications in the clinic.

Additionally, new studies can be conducted on the validity and reliability of SA for long-term use. This is the first study conducted on patients. New studies could be done on different populations, such as athletes or older adults. In conclusion, SAs are as valid and reliable as DIs for measuring active hip and knee joint ROM in patients with PFP. Although UGs are valid and reliable tools for ROM measurements, it was determined that the results obtained based on SA and DI measurements may be more reliable and valid. This study provides important data for further research on the use of mobile technologies to measure clinical outcomes and demonstrates their usability in a specific patient population. One of the limitations of this study was that patients were in the supine position during hip abduction measurements with the UG, while they were in the side-lying position for measurements performed with the DI and SA. This may have caused the measurement results to differ. Although previous studies in the literature provide similar examples, the measurement interval of 24–48 hours in this study was relatively short. Evaluators could potentially remember the results obtained the previous day due to the learning effect. However, if the interval were prolonged, there could have been a change in the patient's condition, so care was taken not to extend the measurement interval. Additionally, the Bland-Altman test is not used in research analyses. The fact that SA is a new measurement tool in the clinic may cause a prejudice due to the thought that it is not safe enough. In addition, since it is a technological tool, it is thought that there may be limitations in its safe use in the clinic due to water etc.

Ethics Committee Approval: Our study was approved by the Necmettin Erbakan University Health Sciences Scientific Research Ethics Committee (Date: 03.01.2024, decision no: 2024/632).

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