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Agreement in Knee Flexion and Hip Extension Range of Motion Assessment between Digital Goniometer and Video-based Motion Tracking Technology

Nenad Nedović[1], Stevan Jovanović[1], Žiga Kozinc[2], Danilo Vujičić[1]

Affiliations: [1]Academy of Applied Studies Belgrade, College of Health Sciences, Belgrade, Serbia, [2]University of Primorska, Faculty of Health Sciences, Izola, Slovenia

Correspondence: Ž. Kozinc. University of Primorska, Faculty of Health Sciences, Polje 42, SI6310 Izola, Slovenia. E-mail: ziga.kozinc@fvz.upr.si

Abstract

Precise range of motion (ROM) measurements are critical for diagnosing musculoskeletal impairments, planning treatment strategies and monitoring rehabilitation progress. This study compares the reliability and accuracy of ROM measurements using the EasyAngle electronic goniometer device and the Kemtai pose estimation video-based motion tracking software. Participants performed hip extension and knee flexion movements, with measurements taken by two examiners using both tools. The results show that both EasyAngle and Kemtai provide high inter-repetition reliability for knee flexion (ICC 0.93 and. 0.91) and hip extension (ICC 0.96 and 0.93). Kemtai generally overestimated ROM compared to EasyAngle, with relative agreement ranging from poor to good (ICC = 0.71 for knee flexion, ICC = 0.66 for hip extension). Future development and research should focus on refining digital tools like Kemtai to enhance their accuracy and reliability. Given its low cost and ease of use, Kemtai could be a useful tool for clinical practice.

Keywords: *pose estimation, flexibility, goniometry, reliability, application*

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Introduction

The assessment of range of motion (ROM) is essential in both clinical and sports settings, as it provides critical insights into joint function, flexibility, and overall musculoskeletal health. Accurate ROM measurements are crucial for diagnosing impairments, planning interventions, and monitoring rehabilitation progress (Akizuki et al., 2016). Various methods have been developed to measure ROM, including traditional goniometry, digital inclinometers and advanced pose estimation software (Al-Amri et al., 2017; Jovanovic et al., 2024; Hancock et al., 2018; Saiki et al., 2023). Traditional goniometry, which uses a goniometer with arms, is one of the most common methods for measuring ROM. Studies have demonstrated that traditional goniometry can be highly reliable when performed by trained practitioners (Watkins et al., 1991; Brosseau et al., 2001). However, that goniometry can be

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time-consuming and susceptible to variability between different evaluators (Nussbaumer et al., 2010).

In recent years, digital devices such as the EasyAngle have been introduced to enhance the accuracy and reliability of ROM measurements. The EasyAngle is an affordable digital goniometer designed to provide quick and precise measurements of joint angles. Previous studies, including Duffy et al. (2024), have confirmed EasyAngle's reliability across different joints, with Svensson et al. (2019) specifically demonstrating its validity and reliability. With advancements in technology, pose estimation software like Kemtai can be used as a novel method for assessing ROM (Jovanovic et al., 2024). This software utilizes computer vision and artificial intelligence to estimate joint angles and track movements, offering a non-invasive and user-friendly alternative to traditional methods.

The aim of this study is to compare the reliability and accuracy of ROM measurements obtained using the EasyAngle device with those obtained through the pose estimation software Kemtai. By evaluating these two methods, we aim to determine the feasibility and practicality of integrating advanced digital tools in routine clinical assessments.

Methods

Participants

The sample included 23 subjects (12 women, 11 men; age = 22.1 ± 2.9 years). The participants, who were physiotherapy students, were recruited through social media, email, and personal networks as a convenience sample. Exclusion criteria included reporting any knee or hip pain, lack of full range of motion, or previous lower limb injury. Informed consent was obtained from all participants prior to the experiment, which was approved by the ethics board of the Academy of Applied Studies Belgrade, College of Health Sciences (approval number 01-264/4).

Study design

In this cross-sectional study predefined measurement protocol required participants to actively perform hip extension and knee flexion movements. Measurements were alternately taken using the EasyAngle goniometer and the Kemtai software installed on an Apple iPhone 12 mini mobile phone (Apple Inc., Cupertino, California, USA). Kemtai is an AI-powered fitness platform that uses computer vision technology to provide real-time feedback and guidance on exercise form. The Kemtai software analyzes movements by tracking changes in the location of anatomical landmarks based on motion pattern data contained within the system. For the purpose of the research, we used an adjusted version of software (version 4) that measures range of motion.

Measurement procedures

Measurements were performed on a therapy table, with participants in prone position. Each participant underwent two sets of measurements, alternating between each device. The Kemtai measurements were captured using the mobile phone camera mounted on a tripod (1.5 m in height) positioned 0.7 m 70 cm from the participant. Each set included measurements taken with the EasyAngle goniometer (Figure 1) and the Kemtai application (Figure 2), performed by two experienced physiotherapists who were blinded to the results during measurement. The participants were in prone position for all measurements and same leg was measured each time during procedure. Participant was instructed to perform movement in slow manner and to hold little bit at the end of motion so physiotherapist could perform measurements. First, active knee joint flexion was measured using the EasyAngle goniometer by one examiner, followed by

Figure 1. Measurements with EasyAngle digital inclinometer

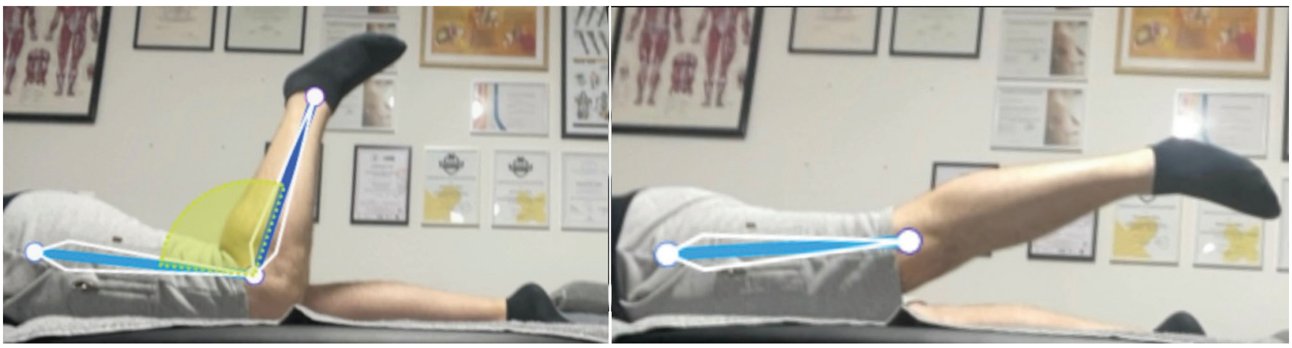

Figure 2. Snapshots of video-based motion tracking analysis done with Kemtai software.

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the same motion being measured using the Kemtai software. This identical procedure was then repeated by a second examiner on the same motion. Then, active hip joint extension was measured in the same manner and order. A third examiner was responsible for recording the values and managing the computer.

Statistical analysis

The data are presented as means ± standard deviations. The reliability between the repetitions for the same device was evaluated with intra-class correlation coefficient (ICC; single measures, absolute agreement). We considered ICC values <0.5 to be indicative of poor reliability, values between 0.5 and 0.75 to indicate moderate reliability, values between 0.75 and 0.9 to indicate good reliability, and values greater than 0.9 to indicate excellent reliability. Additionally, absolute reliability was assessed by calculating the typical error (TE). The agreement between the devices were assessed with ICC, TE and paired-sample t-test with mean difference and 95 % confidence intervals (CI) included. All analyses were carried out using SPSS statistical software (version 25.0, IBM: Armonk, NY, USA).

Results

Reliability

Table 1 contains descriptive statistics and inter-repetition reliability analyses. For knee flexion assessed with EasyAngle, the ICC was 0.93 (95% CI: 0.83–0.97), with a TE of 2.15° (95% CI: 1.66–3.04). For Kemtai, the ICC was 0.91 (95% CI: 0.79–0.96), with a TE of 2.45° (95% CI: 1.89–3.46). Hip extension measured wtih EasyAngle showed and ICC of 0.96 (95% CI: 0.90–0.98), with a TE of 1.83° (95% CI: 1.42–2.60). For Kemtai, the ICC was 0.93 (95% CI: 0.85–0.97), with a TE of 2.41° (95% CI: 1.87–3.42).

Table 1. Descriptive statistics and inter-repetition reliability.

Outcome measure	Repetition 1		Repetition 2		Reliability					
	Mean	SD	Mean	SD	ICC	95% CI		TE	95% CI	
Knee Flexion – EasyAngle (°)	119.74	7.88	119.43	7.10	0.93	0.83	0.97	2.15	1.66	3.04
Knee Flexion – Kemtai (°)	129.83	7.36	130.22	7.98	0.91	0.79	0.96	2.45	1.89	3.46
Hip Extension – EasyAngle (°)	22.57	8.00	23.78	8.98	0.96	0.90	0.98	1.83	1.42	2.60
Hip Extension - Kemtai(°)	31.26	8.44	31.00	9.52	0.93	0.85	0.97	2.41	1.87	3.42

Note. SD: Standard Deviation; ICC: Intraclass Correlation Coefficient; CI: Confidence Interval; TE: Typical Error;

Agreement

The agreement analysis is shown in Table 2. The mean values of knee flexion ROM for EasyAngle and Kemtai were 119.59° (SD = 7.35) and 130.02° (SD = 7.48), respectively. There was a statistically significant difference between the two methods ($p < 0.001$), with mean difference of 10.43° (95% CI: 7.91–12.96; relative difference = 8.6 %). The relative agreement was poor to good, with an ICC of 0.71 (95% CI: 0.42–0.86). For hip extension, the mean values for EasyAngle and Kemtai were 23.17° (SD = 8.41) and 31.13° (SD = 8.83), respectively. There was a statistically significant difference between the two methods ($p < 0.001$) with a mean difference of 7.96° (95% CI: 4.80–11.11; relative difference = 36.6%. The relative agreement was poor to good, with an ICC of 0.66 (95% CI: 0.35–0.84). In summary, both knee flexion and hip extension measurements showed a significant difference between EasyAngle and Kemtai, with the estimation for the relative agreement ranging from poor to good.

Table 2. Agreement between EasyAngle and Kemtai.

Outcome variable	Easy Angle		Kemtai		Difference			Relative agreement		
	Mean	SD	Mean	SD	Mean	95% CI		ICC	95% CI	
Knee flexion (°)	119.59	7.35	130.02	7.48	10.43	7.91	12.96	0.71	0.42	0.86
Hip extension (°)	23.17	8.41	31.13	8.83	7.96	4.80	11.11	0.66	0.35	0.84

Note: SD: Standard Deviation; ICC: Intraclass Correlation Coefficient; CI: Confidence Interval;

Discussion

This study compared ROM measurement reliability between the EasyAngle device and Kemtai software. EasyAngle showed high ICC values (knee flexion: 0.93, hip extension: 0.96) with low typical errors (knee flexion: 2.15°, hip extension: 1.83°), while Kemtai also demonstrated good reliability (knee flexion: ICC 0.91, hip extension: ICC 0.93) with slightly higher typical errors (knee flexion: 2.45°, hip extension: 2.41°), indicating both tools provide consistent and reliable measurements.

These findings are consistent with previous research showing the reliability of digital tools and inertial measurement units for clinical movement analysis (Al-Amri et al., 2017; Keogh et al., 2019). The slightly higher ICC values for EasyAngle suggest it may offer marginally better reliability compared to Kemtai, particularly for hip extension. The typical errors (TE) for both devices are within acceptable ranges, with EasyAngle showing slightly lower TE values than Kemtai, indicating higher precision. These results align with studies by Watkins et al. (2001) and Brosseau et al. (2001), which found high reliability for goniometry assessment and emphasize the importance of precision in ROM measurements. Also, results from some previous studies (Hancock et al., 2018; Kiatkulanusorn et al., 2023; Pantouveris et al., 2024) indicate the effectiveness of digital goniometers in providing reliable data, and to enhance that, it is often advised to use the average of ratings from two or more raters (Perkins, Wyatt, & Bartko, 2000). Overall, the study demonstrates that both EasyAngle and Kemtai are reliable tools for assessing knee flexion and hip extension, however, the agreement between the devices is not sufficient for them to be used interchangeably.

The study also compared knee flexion and hip extension measurements using EasyAngle and Kemtai software. Kemtai consistently measured higher angles than EasyAngle for both knee flexion (mean difference 10.43°) and hip extension (mean difference 7.96°). While there was moderate consistency between the methods (ICC = 0.71 for knee flexion, ICC = 0.66 for hip extension), significant differences were noted, suggesting potential overestimation by Kemtai.

These differences could be attributed to several factors. First, the methodology of Kemtai, which relies on computer vision and pose estimation algorithms, may interpret joint angles differently than the direct measurement approach of EasyAngle, which is a goniometer. The overestimation by Kemtai could be due to the pose estimation software's interpretation of anatomical landmarks and movement patterns like in a similar study (Horsak et al., 2024; Wren et al., 2023), which might not always align perfectly with manual goniometric measurements. The timing and conditions of measurements are crucial in biomechanical studies, as they can significantly impact the accuracy and consistency of the data. Since our goniometric measurements and video analysis are conducted at different times, even slight differences in posture or movement can result in variations in the recorded angles (Nussbaumer et al., 2010). Furthermore, the poor to good relative agreement (ICC values) suggests that while there is some consistency between the two methods, the discrepancies are significant enough to warrant caution. Clinicians and researchers should be aware of these differences and consider them when choosing a measurement tool for specific applications. The significant differences and moderate consistency between the two methods underscore the need for further research to refine and calibrate digital measurement tools like Kemtai. To make the process easier and more accurate during measurements, we could suggest that individuals wear form-fitting clothing like yoga pants or underwear. Such efforts could enhance their accuracy and reliability, making them more comparable to traditional goniometric methods. Additionally, understanding the contexts in which each tool performs best can guide their application in clinical and research settings. It is important to said that both assessors conducted their measurements independently and were kept unaware of each other's results, thereby reducing the potential for bias and ensuring that their assessments did not influence one another.

Some limitations of the study need to be acknowledged. During the measurement of extension ROM, we did not fixate the pelvis because the camera used by the software tends to recognize the person performing the fixation as another object. This can interfere with the accurate identification of joints, leading to measurement errors. As a result, we observed somewhat larger extension ROM values with both devices. This issue highlights a limitation in the accuracy of our measurements due to the lack of pelvic stabilization, which is crucial for obtaining precise and reliable joint angle assessments (Nussbaumer et al., 2010). Also, the lack of simultaneity during measurements may have impacted the reproducibility of the measurements which could also lead to variability in the arithmetic means. Additionally, the study did not extensively address inter-rater variability, focused primarily on static rather than dynamic measurements, and involved a relatively small and homogeneous sample size, limiting generalizability. Further research should address these issues, refine digital tools, and validate their use in diverse clinical settings.

Conclusion

This study demonstrates that both EasyAngle and Kemtai provide high reliability for measuring knee flexion and hip extension. However, significant differences were found between the mean values, with Kemtai generally overestimating compared to EasyAngle. The relative agreement ranged from poor to good, indicating moderate consistency but some discrepancies. Despite these differences, Kemtai could still be used solely for assessment purposes, especially given its non-invasive nature and ease of use. These findings emphasize the importance of selecting the appropriate measurement tool based on specific requirements and suggest the need for further refinement of digital tools like Kemtai to enhance their accuracy and reliability. Future research should focus on standardizing digital measurement methodologies to improve their clinical application.

Author contributions

Nenad Nedović, Stevan Jovanović and Žiga Kozinc conceptualized the idea. All authors worked on obtaining and analyzing the data and worked on finalizing the manuscript.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Ethics approval

The study was approved by the ethics board of the Academy of Applied Studies Belgrade, College of Health Sciences (approval number 01-264/4) and was conducted in accordance with the Declaration of Helsinki.

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