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RELIABILITY AND VALIDITY OF MEASURING SHOULDER JOINT FLEXION USING DIGITAL AND STANDARD GONIOMETRIC METHODS

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Summary

Based on the literature review and clinical experiences, it can be concluded that measuring the amplitude of movement is one of the fundamental kinesiometric methods used in assessing joint functionality. The aim of this study was to examine the reliability and validity of measuring the shoulder joint's range of motion using the digital system KEMTAI compared to a goniometer with arms. This non-experimental observation was conducted on 40 participants whose flexion range in the shoulder joint was measured using both the goniometer with arms and the KEMTAI software system, which utilizes the examiner's mobile phone camera. The results indicated that the lowest mean value was obtained during the first measurement session (M1 = 154.68), while the highest was during the third session (M2 = 156.53). When using the KEMTAI software, the variability of mean values for the total tested population was significantly higher than when using the goniometer with arms. The results suggest that the KEMTAI software/system is reliable when comparing the average results of three measurements. Based on these findings, it is concluded that three experienced measurers demonstrated high reliability in measuring the shoulder joint's flexion range using the goniometer with arms. Despite the identified differences between the measurement results obtained using these two methods, it is considered that the KEMTAI software/system is applicable in practical work.

Keywords: GONIOMETER WITH ARMS/ MOTION TRACKING SOFTWARE/ KINESIOMETRY/ KEMTAI METHOD

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INTRODUCTION

Measuring the amplitude of movement is one of the fundamental kinesiometric methods used to assess joint functionality. The accuracy of measurement and assessment of range of motion is essential in everyday clinical practice for adequately tracking therapeutic effects (Achachagua et al, 2021). Goniometry is a technique essential in research tasks.

The goniometer is one of the oldest instruments used to measure the angle or angular position of a joint. In standard clinical practice, goniometers (with arms or gravity-based) have been used for decades, and are relatively simple to use and do not cost much as instruments. However, there are some drawbacks to using a goniometer with arms. Placing the goniometer can be challenging (Holzgreve et al, 2018; Fraeulin et al, 2020) and highly dependent on the evaluator's experience (Bovens et al, 1990). However, the modernization of clinical practice involves the development of new instruments and associated tools that achieve faster, more efficient, and more adequate measurement of selected parameters of the musculoskeletal system. Measurements based on the KEMTAI software system are typically used to assess body position and movement tracking, which can be utilized to enhance many activities (Stenum, Rossi, and Roemmich, 2021). The subject of this non-experimental observation (observational and causal analysis) is the reliability and validity of the software application called KEMTAI compared to goniometric measurement methods. The aim of the observation is to evaluate the validity, objectivity, reliability of the KEMTAI system, and its usability in clinical practice.

The KEMTAI software system utilizes a camera and its corresponding software for recording, measuring, and analyzing human body movements. By determining specific anatomical points - landmarks, the system tracks and measures the range of motion of body joints, analyzes segment positions, and generates personalized real-time feedback according to required movement patterns. The determination of measurement objectivity in the model of this study was performed around the frontal axis of the shoulder joint through the movement of upper arm flexion. Among all joints of the human body, the shoulder joint has the greatest mobility and is functionally very complex. It provides a "transport function" for the forearm and upper extremity during manipulative hand activities. Assessing the amplitude of shoulder joint movement is important in diagnosing disorders of its function and for evaluating strategies that can restore shoulder function (Hayes, Walton, Szomor, and Murrell, 2001). Additionally, measuring the amplitude/range of motion is also used to detect asymmetry and movement restrictions that may increase the risk of injury (Riemann, Witt, and Davies, 2011; Correll, 2018).

The aim is to determine the degree of reliability and validity of movement amplitude measurements using the KEMTAI system compared to a standard goniometer (with arms). The working and cognitive assumption of this non-experimental observation is that measuring movement amplitude with the KEMTAI system is reliable and provides the same, if not greater, reliability and validity than measurements with a goniometer. Goniometer measurements are based on the measurer's routine, which involves a higher degree of subjectivity, and in that sense, the reliability of measurements depends on the measurer.

B

METHODOLOGY

This was a cross-sectional study involving 40 participants of both genders, without registered musculoskeletal and neuromuscular dysfunctions. The study was conducted at the College of Health Sciences of the Academy of Applied Studies Belgrade, Serbia. All protocols were approved by the institution's ethical committee. Participants provided written consent to participate in the study.

A predefined measurement protocol required participants to actively perform shoulder flexion movements. Measurements were performed alternately using the KEMTAI software installed on an Apple iPhone 12 mini mobile phone (Apple Inc., Cupertino, California, USA) and a goniometer with arms. The KEMTAI software analyzes movements taking into account changes in the location of anatomical points based on motion patterns contained in the system. KEMTAI has been available since 2021 and currently uses version 4.

Measurements were conducted on a therapy table while the participant lay in a supine position. Each participant underwent three series of measurements. Each series included measurements using the KEMTAI application and manual measurements performed by an experienced physiotherapist using the goniometer. Each series began with measurements taken using the mobile phone camera placed on a tripod stand (height 1.5 m) at a distance of 70 cm from the participant. The recording protocol is contained in the instructions for using this tool. Upon the examiner's signal, the participant had 20 seconds to perform the movement. The second measurement was performed with the goniometer by placing the center of the goniometer on the projection of the anterior axis of the shoulder joint, with the stationary arm of the goniometer following the mid-axillary line, and the movable arm following the longitudinal axis of the humerus. A total of three measurements were performed using the KEMTAI system and three measurements using the goniometer. Each individual measurement was performed by a different measurer. Measurements were always performed on the same arm. Measurements were performed successively with a 10-second pause between measurements. Since it was a simple movement in a single joint, and participants did not report dysfunction of the same, no additional testing was conducted.

Kemtai is an exercise platform that provides personalized workouts to users. It utilizes artificial intelligence and computer vision technology to track users' movements during exercises, offering feedback and guidance to improve performance. The platform offers a variety of exercise programs tailored to individual fitness levels and goals, including strength training, yoga, and cardio workouts. The aim of the Kemtai platform is to make home workouts more effective and engaging by providing interactive support and progress tracking over time.

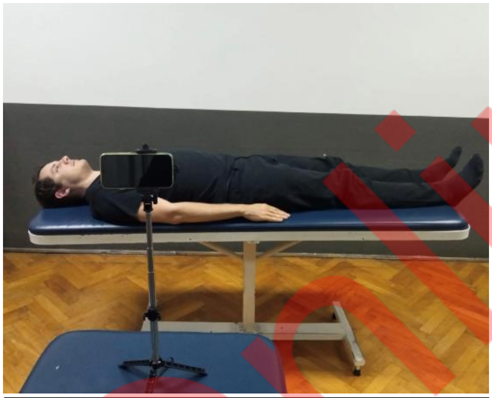

Image 1. Starting position for measurement

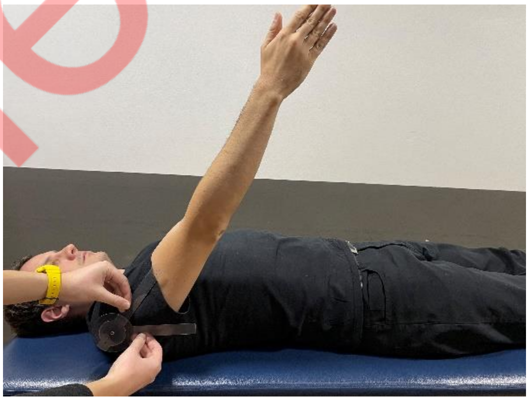

Image 2. Measuring the range of motion with a goniometer with arms

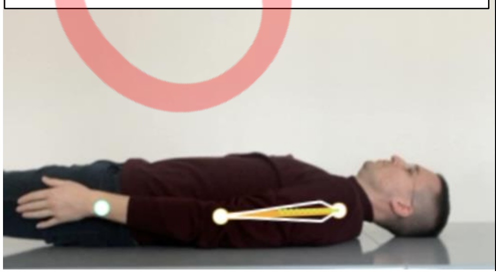

Image 3. Starting position for measuring the range of motion using KEMTAI software

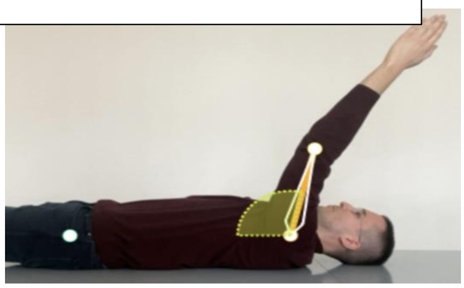

Image 4. Final position for measuring the range of motion using KEMTAI software

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measures was examined by calculating correlation coefficients, Cronbach's alpha coefficients, and intraclass correlation coefficients (ICC). Differences between consecutive measurements within the same measurement

method were tested using one-way repeated measures analysis of variance, while differences between different measurement methods were tested using the t-test for independent samples.

C RESULTS

The results of the angle measurements performed by experienced physiotherapists using a goniometer are presented in Table 1. The ranges of measured values were similar across sessions, as were the mean values.

Table 1. Results of angle measurements of the range of motion with a goniometer with arms (N = 40)

Measuring	Range	M	SD	95% CI	KS Z (p)
First	135 – 165	154.68	7.45	152.29 – 155.08	.09 (.20)
Second	130 – 170	156.53	8.67	153.75 – 159.30	.14 (.04)
Third	130 – 169	154.85	8.76	152.05 – 157.65	.12 (.13)

Note: KS – Kolmogorov-Smirnov test, SD – standard deviation

The lowest average was observed in the first session (M1 = 154.68), while the highest was in the third (M2 = 156.53). Overlapping confidence intervals for the mean values suggest the absence of statistically significant differences between them. This was further confirmed by the results of one-way repeated measures analysis of variance ($F(2, 78) = 2.68$, $p = .07$). The measurements were approximately normally distributed in the first and third sessions (ps > .05), but significant deviations were noticed in the second session (KS Z = .14, $p = .04$) where the distribution was negatively skewed (ZSk = -2.88). As indicated by the results in Table 2, correlations between the three measurements were relatively high, ranging between .77 and .79.

Table 2. Correlation coefficient between angle measurements of the range of motion with a goniometer with arms in three sessions

Measuring	First	Second
Second	.77	
Third	.79	.78

The value of Cronbach's α, or ICC for average measures in a two-way mixed-effects model, was .91 (95% CI [0.85 - .95]). This suggests that the angle measurement results obtained by "averaging" three measures are highly reliable. Furthermore, the reliability of individual measures was lower but still acceptable (ICC = .78, 95% CI [.66 - .87]). The results of angle measurements performed by the software are presented in Table 3.

Table 3. Results of angle measurements of the range of motion using software (N = 40)

Measuring	Range	M	SD	95% CI	KS Z (p)
First	144 – 180	166.73	8.80	163.91 – 169.54	.13 (.10)
Second	150 – 179	169.23	7.19	166.93 – 171.52	.15 (.02)
Third	145 – 180	169.25	7.88	166.73 – 171.77	.11 (.20)

Note: KS – Kolmogorov-Smirnov test, SD - standard deviation

The variability of mean results across different sessions was significantly higher – the mean value observed in the first measurement (M1 = 166.73) was significantly lower ($F(2, 78) = 4.95$, $p = .01$) compared to the mean values observed in the second (M2 = 163.23) and third measurements (M3 = 163.25). The observed measurements were approximately normally distributed in the first and third sessions (ps > .05), but significantly deviated from normality in the second session (KS Z = .15, $p = .02$) where the distribution was negatively skewed (ZSk = -2.37). Correlations between the three software measurements ranged from .64 to .86 (Table 4).

Table 4. Correlation between angle measurements of the range of motion using software

Measuring	First	Second
Second	.86	
Third	.64	.71

Cronbach's alpha coefficients and intraclass correlation coefficients (ICC) for average measures in a two-way mixed-effects model were 0.89 (95% CI [0.81 - 0.94]), indicating that the average software measure was reliable. The reliability of individual measures was lower but still acceptable (ICC = .72, 95% CI [.59-.83]).

Overall, the results presented indicate that both methods of angle measurements can yield reliable results, with measurements by examiners being slightly more reliable. However, overlapping confidence intervals of reliability indices suggest that this difference was not statistically significant. On the other hand, the absolute differences in mean values between the two measurement methods were quite large and highly significant (ts > 10, ps < .001). On average, the software estimated angles to be 13 degrees wider compared to the examiner's assessment (Table 5).

Table 5. Differences between examiner's assessment results using a goniometer with arms and software

	Human experts		KEMTAI		Test of difference		Correlation
Measuring	M	SD	M	SD	t(39)	p	p
First	154.68	7.45	166.73	8.80	12.11	< .001	.71
Second	156.53	8.67	169.23	7.19	10.12	< .001	.51
Third	154.85	8.76	169.25	7.88	12.55	< .001	.62
Total	155.35	7.21	168.40	7.66	14.23	< .001	.70

Additionally, the correlations between human and software measures were lower than acceptable in the second (r = .51) and third sessions (r = .62).

Finally, it should be noted that the mean values observed during goniometer measurements did not differ from the theoretical value of 155 degrees (t(39) = 0.29, p = .77), whereas this was not the case with the mean software measures (t(39) = 11.76, p < .001). This suggests that the software systematically overestimates the given angle.

D

DISCUSSION

By reviewing the literature on similar research problems, it is possible to observe that there are other studies comparing software programs and standard goniometry. For instance, "Kinect measurements" have shown good test-retest reliability and poor to moderate agreement with goniometric measurements (Hawi, 2014).

In this study, we compared measurements of the range of motion of upper arm flexion obtained using a conventional goniometer and the KEMTAI software system. The cognitive process unfolded through comparing the results of three consecutive goniometer measurements performed by three different measurers. It was found that the lowest mean value was obtained during the first session, and the highest during the third session. Similar effects were reported by other authors (Holzgreve, 2020), describing it as an acute effect of increased range of motion after several repetitions of the movement, where there is increased tolerance to stretching and decreased passive torque (Nakamura, Ikezoe, Takeno, and Ichihashi, 2013). According to some interpretations, the muscle-tendon stiffness remained decreased after the third and fourth stretches, but did not decrease further, which speaks in favor of increased range of motion after several repetitions (Ryan, 2009).

The data obtained in our study indicate that the three expert examiners obtained results without statistically significant differences, indicating that the results are approximately equal, which also means high reliability of the examiner's assessment using a goniometer with arms. However, there was a lower, but acceptable correlation between individual measurements.

When using the KEMTAI software, the variability of mean values was significantly higher than when using a standard goniometer with arms. Subjectivity of the expert examiners, who reduced the detected difference with minimal manual repositioning of the goniometer arms, may influence this outcome. The first measurements with the software showed a significantly lower range of motion value compared to the second and third. Here, we would like to remind that the values of the first measurement were lower compared to the second and third, in both methods.

Results also show that the KEMTAI software/system is reliable when comparing the average results of three measurements. Here, we must note that all values obtained by the KEMTAI system are slightly higher (an average of 13 degrees) compared to measurements with a standard goniometer with arms. We believe this is because the software system maps three points (shoulder, elbow, and wrist - see Figures 3 and 4) during the measurement of this movement, rather than the mid-axillary line, which serves as a reference for setting the fixed arm of the goniometer during measurement. In other words, during upper arm flexion in the shoulder joint, there is minimal compensatory movement of the lumbar spine, and consequently, probably the pelvis, which may affect the results obtained by the software system. In contrast, when measuring with a standard goniometer, one of its arms follows the movement of the spine, following the mid-axillary line and thus adjusting (see Figure 2).

CONCLUSION

Measurement of the range of motion of upper arm flexion in the shoulder joint using the KEMTAI software system has proven to be reliable, making it useful not only for its primary purpose but also for practical use as a means of assessment and monitoring the effects and outcomes of therapeutic processes aimed at increasing range of motion. In comparison with the standard method of measuring range of motion, measurement using the KEMTAI system is more practical, as it requires less time and does not require specially expensive equipment, but rather something everyone has with them, and that is a mobile phone. It should be noted that measuring using software also has certain drawbacks, such as systematic overestimation of the angle and lower measurement reliability. In addition to the above, the software system can be used to assess the quantity and quality of movement related to certain musculoskeletal and neuromuscular disorders in clinical settings, as well as for research purposes with a limited degree of reliability.

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Image 1. Starting position for measurement

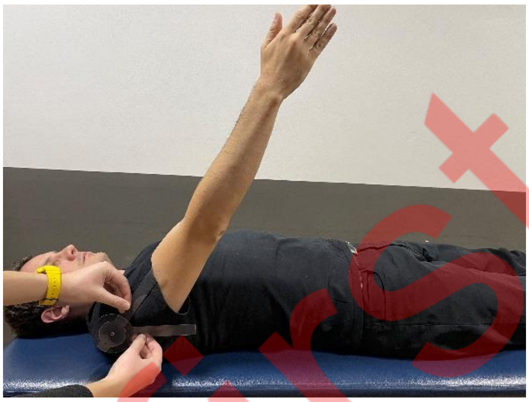

Image 2. Measuring the range of motion with a goniometer with arms

Image 3. Starting position for measuring the range of motion using KEMTAI software

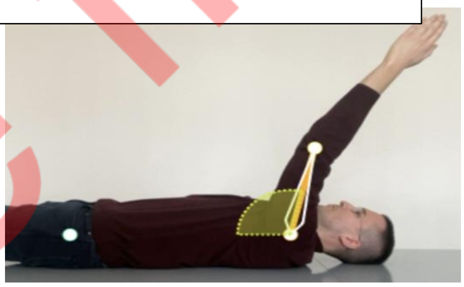

Image 4. Final position for measuring the range of motion using KEMTAI software