International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 24s, 2025
https://theaspd.com/index.php

Kinovea Software Versus Digital Goniometer in Measurement Range of Motion Among School Children

John Fam Habib[1]*, Khaled Ahmed Mamdouh[2], Khaled Ahmed Olama[3], Amira F. Ibrahim[4]
[1,2,3,4]Department of Pediatric Physical Therapy, Faculty of Physical Therapy, Cairo University, Egypt.
Corresponding Author E-mail: Johnfam15@yahoo.com.

ABSTRACT
Background: *As part of their musculoskeletal evaluations, physiotherapists frequently measure the range of motion (ROM) of joints in both passive and active human motions, as well as in static positions. Common tools for traditional range of motion evaluation include goniometers and inclinometers. Kinovea is a versatile and user-friendly software application that has gained popularity in measuring and analyzing ROM.*
Aim: *To measure (ROM) of elbow and knee joints among school children using digital goniometer and Kinovea software then compare the results of both measurements, and to investigate the internal consistency and intra-rater reliability of Kinovea software.*
Methods: *This cross-sectional comparative study included 100 normal healthy children of both sexes recruited from different preparatory and secondary schools at Giza Governorate, Egypt. Digital medical scale was used for measuring body weight, height and calculating BMI on scale screen. Baseline digital goniometer and Kinovea Computer software were used to measure ROM of knees and elbow.*
Results: *The mean value of BMI (kg/m2) was 21.86 ±1.67kg/m2 with minimum value 18.70 and maximum value 24.80. The number (percentage) of gender distribution categories for children were 54 (54.00%) males and 46 (46.00%) females. The statistical analysis showed no significant statistical difference (P>0.05) in elbow flexion, elbow extension, knee flexion in addition to knee extension by the both methods. There was high internal consistency and high Intra-class Correlation Coefficient of Kinovea software in measuring elbow flexion, extension, knee flexion and extension (p=0.001).*
Conclusion: *As there was no difference between both methods in measuring ROM in knee and elbow, it is concluded that Kinovea has the ability to provide accurate knee and elbow ROM measurements without the need for specialized training or expensive equipment makes it an accessible option for clinicians and researchers alike. Kinovea software has high internal consistency and intra-rater reliability, non-invasive, easy to use, and cost-effective tool that is coping with recent technological advancement makes it particularly suitable for pediatric populations, where cooperation and comfort are essential.*
Keywords: *Goniometer, Kinovea, Range of Motion, School Children*

1. INTRODUCTION

Physiotherapists as well as some strength and conditioning trainers conduct musculoskeletal evaluations that include measuring joint range of motion (ROM) in passive as well as active human movements, both in a static and dynamic state. This allows them to examine joint function, identify joint asymmetry, and assess the efficacy of treatment objectively [1]. Measuring ROM assists in discovering restrictions in joint movement and assesses the degree to which a patient is responding to rehabilitation or intervention [2]. Joint ROM measurements are an integral aspect of physical therapists' everyday practice, particularly for those specializing in orthopedics and primary care [3].
Manual goniometers, inclinometers, along with more lately, smartphone apps are among the measurement instruments available to clinicians for measuring joint ROM [4]. A review of the available literature uncovered an extensive number of articles detailing the various methods for determining the ROM of human joints. These methods ranged from the most basic and inexpensive, known as universal goniometry, to the most advanced and expensive, using 3D and 4D motion analysis software. Using goniometers or inclinometers, one can get a traditional ROM evaluation [5].
The main benefits of goniometry are its ease of use in evaluating ROM and its ability to directly measure joint angles without the need for data reduction. The most common, practical, and easily transportable tool for ROM examination is the two-arm goniometer [6]. The digital goniometer stands as a remarkable tool in the field of healthcare, specifically for the assessment of ROM in various joints of the human body. Digital goniometers provide an objective and quantifiable measurement of joint angles [7]. Digital goniometers are seen to be potentially effective way to

measure joint angle when compared to universal goniometers and other observational analytic techniques [8].
On the other hand, when dealing with a complicated joint with several degrees of freedom, the right use of these conventional ROM approaches is operator-dependent, which introduces additional sources of possible error. Additionally, the variety in joint mobility throughout the range is generally ignored in manual goniometry, which focuses solely on the extremes of the ROM [9]. Using digital goniometers requires training before using it on any joint in the body [10].
The use of technology in assessing ROM has revolutionized the way clinicians and trainers evaluate joint flexibility and mobility. Technological advancements, including motion capture systems, smartphone applications, and dedicated software, provide more accurate and reliable data [11].
Kinovea is a versatile and user-friendly software application that has gained popularity in the field of sports science, rehabilitation and biomechanics for its exceptional capabilities in measuring and analyzing ROM. Kinovea is designed to assist professionals as it provides a comprehensive platform for assessing joint mobility and movement patterns with precision and accuracy [12]. One major benefit of Kinovea is that it is easy to use and can conduct analyses without the need for physical sensors or portable devices. Some other advantages of this program are observation, measurement and comparison of ROM. In addition, it is free and can be easily implemented in rehabilitation settings [13]. Moreover, as a technology-based tool, Kinovea takes advantage of digital video analysis, allowing professionals to capture, review, and quantify human movement with precision and accuracy [14].

Aim of Work
To measure (ROM) of elbow and knee joints among school children using digital goniometer and Kinovea software then compare the results of both measurements, and to investigate the internal consistency and intra-rater reliability of Kinovea software responding to the need for a simple, easy to use and cost-effective tool that is coping with recent technological advancement for the measurement of ROM that can be used practically in various clinical settings.

2. PATIENTS AND METHODS
This cross-sectional comparative study was done from February 2024 up to December 2024, the study got approval by the Research Ethical Committee, Faculty of Physical Therapy, Cairo University Egypt (P.T.REC/012/004841). All parents provided a written consent form regarding participation of their children in the study. One hundred normal healthy children of both sexes were recruited from different preparatory and secondary schools at Giza Governorate, Giza. The inclusion criteria encompassed normal healthy school children from both sexes, aged from 12 to 18 years old and with body mass index (BMI) lying within normal range (18.5 to 24.9). Participants were excluded if they had recent upper or lower limb injury, post-surgical procedures in upper limb and lower limb, with presence of bony deformities or congenital anomalies, with any fracture of upper or lower limb, either recent or old, with ligamentous hyper-laxity of elbow or knee joints, and with neurological disorders such as (upper or lower motor neuron lesions).

Sample size calculation
The G*power software 3.1.9 (G power program version 3.1, Heinrich-Heine-University, Düsseldorf, Germany) was used to determine the study's sample size. The sample size estimation was dependent on a pilot study including 15 normal healthy children from both genders were recruited from different schools in Giza city. Sample size calculated based on mean values of elbow flexion variable using digital goniometer (139.65 ±1.05) and Kinovea computer software (140.00 ±0.94). According to t Tests-Means, the sample size was calculated for 88 children: with Type I error (α) = 0.05, power (1-β error probability) = 0.90, effect size d = 0.3501576, as well as difference among two dependent means (matched pairs). At a minimum of 98 children were required for this study to account for a 10% dropout rate.

A. MATERIALS
Digital medical scale (Brand Kaichenyt, Model: Byh01) was used for measuring body weight, height and calculating BMI on scale screen.
For evaluation, digital camera (Nikon Coolpix S3200, Nikon corp., JAPAN, Effective pixels 16MB)

was used. The camera was placed on adjustable tripod stand for standardization. The distance between the tripod and the participant was 1.5 meters by using a tape measurement.

Sticky Markers were used as they are convenient to stick and mark, easy to remove and reposition without ripping. Dell Laptop device with 14.5 diagonal screen size of light emitting diode (LED) display, intel® Pentium™ dual core t4400 processor and genuine windows® 7 ultimate (32bit, English) as operating system was used for operating Kinovea software.

Kinovea software which is a free and open-source software, is created as a tool for motion analysis. It is one of computer programs that measures joint angles from photographs taken using any camera. Kinovea has a catch module for all types of cameras (digital cameras, smartphone camera and all USB video class (UVC) cameras). The program allows the user to place a virtual goniometer over the photograph to measure the joint angle. The line, angle, along with goniometer instruments in Kinovea software are capable of measuring distances and angles. Measurements are performed with subpixel accuracy, and zoom in is available for even more precision. Kinovea software was used to assess ROM of elbow and knee for all participants [15].

The digital goniometer has proved to be a highly reliable instrument for measuring mobility in joint ROM in children. When compared to the universal goniometer, it has comparable inter- and intra-rater reliability and sufficient concurrent criterion-related validity for evaluating joint range of motion [16]. Digital goniometer was used for measurements of active elbow and knee flexion and extension for all children in this study.

The ROM was measured using a baseline digital goniometer, which is an easy-to-use tool with built-in absolute horizontal as well as vertical levels in one arm (Baseline 12-1027 Absolute Axis 360 Degree Digital Goniometer). The device can preserve angle data for reference and shows values on an LCD screen that ranges from 0 to 180 degrees. One 9V battery powers its durable powder-coated steel exterior. Any joint can be used to measure range of motion [17].

Data then was collected before measurements and filled in a sheet containing each child's (name-age-sex-height-weight-BMI).

B. METHODS

1. Measuring ROM of elbow and knee by Digital goniometer

During evaluation of ROM of elbow and knee by digital goniometer, all children were in comfortable and relaxed position, to encourage them to give his or her best performance. Elbow extension, flexion and knee extension and flexion measurements for the right elbow and knee joints were repeated three times and the mean average was recorded with digital goniometer [18].

For active elbow flexion and extension ROM, the starting position for each child was in a standing position with arm beside body, elbow fully flexed and the palm of the hand supinated. For the goniometer, the fulcrum was positioned on the lateral epicondyle and the movable arm was aligned with lateral midline of radius and styloid process and the stationary arm at midline of humerus. Then the child was instructed to fully extend his elbow toward the floor while maintain his hand supinated. The elbow extension ROM was recorded. Then the child was instructed to fully flex his elbow to record elbow flexion ROM [19].

For active knee flexion and extension ROM, the starting position for each child was in prone position with hip extended and knee fully flexed with pillow placed under knee joint to maintain thigh parallel to the floor. For the goniometer, the fulcrum was placed on the lateral epicondyle of femur and the movable arm was placed aligned parallel to the lateral aspect of the leg and pointing toward lateral malleolus and the stationary arm parallel to the lateral aspect of thigh. Then the child was instructed to fully extend his knee to record knee extension ROM then he was instructed to fully flex knee to record knee flexion ROM [20].

2. Measuring ROM of elbow and knee by Kinovea Computer software

During evaluation of ROM of elbow and knee by Kinovea Computer Software, the camera was positioned on the tripod, and the camera was fixed for all children at 1.5-meter distance between the tripod and the child, this distance was measured by tape measurement. The camera was used for capturing photos of elbow and knee joints ROM. The markers were placed at reference points on bony landmarks. The camera was connected with computer for transferring photos and analyzing the ROM by the Kinovea computer program. Elbow extension, flexion and knee extension and flexion measurements for the right elbow and knee joints were captured and measured by the

Kinovea program. The procedures were repeated three times, and then the mean average of the angles was measured by Kinovea program [21].

For active elbow flexion and extension ROM, the starting position for each child was in a standing position with arm beside body, elbow fully flexed and the palm of the hand supinated. Markers were placed on bony landmarks (lateral epicondyle, radial styloid and acromion process). Then the child was instructed to fully extend his elbow toward the floor with maintaining his hand supinated to capture elbow extension ROM then the child was instructed to fully flex his elbow to record the elbow flexion ROM [22].

For active knee flexion and extension ROM, the starting position for each child was in prone position with hip extended and knee fully flexed with pillow placed under knee joint to maintain thigh parallel to the floor. Markers were placed on bony landmarks (lateral epicondyle of femur, greater trochanter, and lateral malleolus). Then child was instructed to fully extend his knee to capture knee extension ROM by digital camera then he was instructed to fully flex his knee to capture knee flexion ROM by digital camera [23].

Statistical Analysis

The data was examined for tests of normality as well as homogeneity of variance. The data was examined for normality utilizing the Shapiro-Wilk test to see if it followed a normal distribution (P>0.05) or a non-normal distribution (P<0.05) following the removal of outliers identified by box and whiskers plots. In addition, if the data is homogeneous (P>0.05) or non-homogenous (P<0.05), the results can be revealed by Levene's test for determining the homogeneity of variance. Parametric analysis is performed after ensuring that the data follow a normal distribution (P>0.05) by the normality and homogeneity tests. Software developed by SPSS, Inc. of Chicago, IL, USA, version 25 for Windows, was used to do the statistical analysis. The means of age, BMI, knee flexion, knee extension, elbow flexion, and elbow extension, along with their standard deviations, are the quantitative factors for children. Qualitative data presented as percentages and frequencies for the gender variable's distribution. A paired t-test was employed to examine the variables of knee flexion, extension, elbow flexion, as well as knee extension in children. Internal consistency reliability was measured by chronbach`s alpha coefficient. Intra-rater reliability was measured by Intra-class correlation coefficient (ICC). The statistical analyses were all considered significant at the 0.05 level of probability.

3. RESULTS

Shapiro-Wilk test (Table 1) was used to test the normal distribution of the study main variable outcomes. This test showed that the data of age, BMI, elbow flexion, elbow extension, knee flexion, along with knee extension were normally distributed (P>0.05) and statistical parametric analysis is performed for these variables in digital goniometer group and Kinovea software group.

Table (1): Test of normality for all measured variable outcomes

Items	Shapiro-Wilk test					
	Digital goniometer group (n=100)			Kinovea Software group (n=100)		
	Statistic value	P-value	Significance	Statistic value	P-value	Significance
Age	0.971	0.894	NS	0.903	0.099	NS
BMI	0.951	0.519	NS	0.909	0.132	NS
Elbow flexion	0.989	0.551	NS	0.937	0.342	NS
Elbow extension	0.974	0.922	NS	0.959	0.692	NS
Knee flexion	0.980	0.269	NS	0.893	0.068	NS
Knee extension	0.948	0.479	NS	0.986	0.372	NS

P-value: probability value
*Significant (P<0.05)
S: significant
NS: non-significant (P>0.05)

Table (2) shows that the mean value of BMI (kg/m2) was 21.86 ±1.67kg/m2 with minimum value 18.70 and maximum value 24.80. The number (percentage) of gender distribution categories for children were 54 (54.00%) males and 46 (46.00%) females.

Table (2): Demographic data of children in population study group

Quantitative variables	Mean ±SD	Minimum	Maximum
Age (year)	13.18 ±1.87	10.00	17.00
BMI (kg/m2)	21.86 ±1.67	18.70	24.80
Qualitative variable (Gender)	Number (percentage)		
Males	54 (54.00%)		
Females	46 (46.00%)		

Quantitative variables data are expressed as mean ±standard deviation; Qualitative variable data are expressed as frequency (percentage)

Table (3) shows that the mean values of elbow flexion in digital goniometer group and Kinovea software group were 141.01 ±3.09 and 141.33 ± 3.26, respectively, with mean difference 0.32 (95% CI -0.14–0.78). The statistical analysis showed that no significant statistical difference (P>0.05) in elbow flexion (P=0.215) between digital goniometer group and Kinovea software group. The internal consistency for elbow flexion was high level with Cronbach's alpha = 0.978, the intra-rater reliability using ICC showed that there was a high reliability of Kinovea software (with ICC=0.958 and P-value=0.0001).

The mean values of elbow extension in digital goniometer group and Kinovea software group were -0.76±0.56 and -0.69±0.50, respectively, with mean difference 0.07 (95% CI -0.04–0.20). The statistical analysis showed that no significant statistical difference (P>0.05) in elbow extension (P=0.223) between digital goniometer group and Kinovea software group. The internal consistency for elbow extension was high level with Cronbach's alpha = 0.856, the ICC showed that there was a high reliability of Kinovea software (with ICC=0.749 and P-value=0.0001).

The mean values of knee flexion in digital goniometer group and Kinovea software group were 139.37±3.41 and 140.14±3.17, respectively, with mean difference 0.77 (95%CI -0.56–2.10). The statistical analysis showed that no significant statistical difference (P>0.05) in knee flexion (P=0.201) between digital goniometer group and Kinovea software group. The internal consistency for knee flexion was high level with Cronbach's alpha = 0.974, the ICC showed that there was a high reliability of Kinovea software (with ICC=0.949 and P-value=0.0001).

The mean values of knee extension in digital goniometer group and Kinovea software group were -0.85 ±0.54 and -0.72 ±0.60, respectively, with mean difference 0.13 (95% CI -0.01–0.27). The statistical analysis revealed that no significant statistical difference (P>0.05) in knee extension (P=0.257) between digital goniometer group and Kinovea software group. the internal consistency for knee extension was high level with Cronbach's alpha = 0.926, the ICC showed that there was a high reliability of Kinovea software (with ICC=0.862 and P-value=0.0001).

Table (3): Comparison mean values of elbow flexion & extension and knee flexion & extension in both groups

Items	Digital goniometer group (n=100)	Kinovea software group (n=100)
Elbow flexion (Mean ±SD)	141.01 ±3.09	141.33 ± 3.26
Mean difference	0.32	
95% confidence interval	-0.14 – 0.78	
t-value	1.283	
P-value	0.215	
Cronbach's Alpha	0.978	
ICC	0.958	
P-value	0.0001	
Elbow extension (Mean ±SD)	-0.76 ±0.56	-0.69 ±0.50

Mean difference	0.07	
95% confidence interval	-0.04 – 0.20	
t-value	1.227	
P-value	0.223	
Cronbach's Alpha	0.856	
ICC	0.749	
P-value	0.0001	
Knee flexion (Mean ±SD)	139.37 ±3.41	140.14 ±3.17
Mean difference	0.77	
95% confidence interval	-0.56 – 2.10	
t-value	1.537	
P-value	0.201	
Cronbach's Alpha	0.974	
ICC	0.949	
P-value	0.0001	
Knee extension (Mean ±SD)	-0.85 ±0.54	-0.72 ±0.60
Mean difference	0.13	
95% confidence interval	-0.01 – 0.27	
t-value	1.134	
P-value	0.257	
Cronbach's Alpha	0.926	
ICC	0.862	
P-value	0.0001	

Data are expressed as mean ±standard deviation
P-value: probability value
ICC: inter class correlation coefficient

4. DISCUSSION

This study aimed to compare among Kinovea software and digital goniometer for measuring ROM of elbow and knee joints among school children. The findings of this study revealed that there were no significant statistical differences in ROM of elbow and knee joints between digital goniometer group and Kinovea software group.

Selecting the digital goniometer for measuring ROM of elbow and knee joints in the present study among school children because it is considered a valid and a reliable tool of evaluation of ROM which come in accordance with Herrero et al. (2011) who mentioned that the goniometer has an excellent intra-examiner reliability and it is a reliable instrument for goniometric measurement of ROM in children confirming its suitability for repeated measurements with minimal variability [17].

The elbow joint, due to its hinge-like structure, requires precise alignment for accurate ROM assessment. Studies such as those by Blonna et al. (2012) have shown that digital goniometers yield highly consistent results when measuring elbow flexion and extension, even in populations with joint contractures or post-surgical limitations. Their findings demonstrated that digital goniometry closely approximated radiographic measurements, reinforcing its validity as a non-invasive and practical alternative [24].

For the knee joint, digital goniometers have been proven especially valuable in orthopedic and sports medicine contexts. In a study by Al-Mahmood et al. (2022), digital goniometric measurements of knee ROM were compared with radiographic assessments in patients with osteoarthritis. The results indicated strong agreement between the two methods, with digital goniometry offering a faster and safer means of evaluation without compromising accuracy. This is particularly important in longitudinal studies where repeated exposure to radiation is undesirable [25].

The current study's findings showed that the Kinovea software has high internal consistency and intra-rater reliability when measuring range of motion angles compared to the standard measures, which makes it a good choice for clinical use. It tested the technology's precision in measuring angles. Kinovea is software for analyzing videos that has an angle selection tool built in. Thus, it is distinct from clinical goniometry, which involves attaching a goniometer to the patient in order to quantify joint ROM, and is alternatively dependent on photography [18,26].

This study showed that using Kinovea software applied on elbow and knee joints is reliable method for ROM measurements. Compared to the existing literature on bi-dimensional analysis, the method being described here is free, open-source, easy to use, and offers interesting practical benefits, such as the fact that it doesn't need any particular lighting, additional foci, or power outlets, and that it can be frozen at the right moment of joint range of motion [27, 28].

Reliable and highly accurate findings can be obtained using Kinovea, even in the absence of prior expertise in video collection or analysis [27, 29]. Contrary to what was found in studies by Elwardany et al. (2015) and Baude et al. (2015), which recommended for training protocol sessions for raters to enhance the accuracy of Kinovea's motion analysis [28-30]. Moreover, Kinovea's ability to provide accurate knee ROM measurements without the need for specialized training or expensive equipment makes it an accessible option for clinicians and researchers alike. As noted by Díaz-Arancibia et al. (2023), the software's intuitive interface and built-in angle tools allow for quick and reliable assessments, even by novice users. This democratization of motion analysis technology is particularly valuable in low-resource settings or remote areas where traditional tools may not be available [31]

The findings of Balsalobre-Fernández et al. (2014) corroborate with the result of the present study as he found that the Kinovea software program had many advantages. The measurements were taken objectively and quantitatively; the program required little effort; subjects didn't have to wear or touch anything; and neither the therapists nor the subjects had to hold or adjust anything [27].

Kinovea software was shown to be a valid and reliable technique for assessing joint angles during functional activity by Cunha et al. (2020). The researchers found strong correlations for repeated assessments and comparisons to gold standard angle measurement devices, which align with the current study's findings [32].

This study results come in agreement with Abd Elrahim and Hassan. (2021) who evaluated the reliability of Kinovea program compared with UG for elbow ROM measurement, with high intra- and inter-rater correlation (ICC=0.998, 95 % confidence interval 0.998-0.999, and ICC=0.998, 95 % confidence interval 0.996- 0.999, respectively). They stated that Kinovea software demonstrated high reliability and low minimal detectable change for evaluating elbow ROM when applied in healthy subjects [23].

In a study by Fernández-González et al. (2020), Kinovea was used to analyze knee flexion and extension during gait, and the results showed strong correlation with three-dimensional motion analysis systems. This suggests that Kinovea can provide valid measurements of dynamic knee ROM, even in functional tasks. The software's frame-by-frame analysis and angle measurement tools allow for precise identification of joint positions, which is critical in evaluating knee mobility [33].

Moreover, Kinovea's validity in assessing knee ROM has been confirmed in rehabilitation settings. For example, Mohamed et al. (2024) used Kinovea to evaluate knee joint angles during squatting exercises and found excellent intra- and inter-rater reliability (ICC > 0.95). [22].

This study's findings are in line with the study of Moral-Muñoz et al. (2015), who demonstrated that Kinovea is a valid and objective tool for assessing hamstring flexibility through knee extension measurements. Their methodology involved marking anatomical landmarks and capturing video footage during passive stretching, which was later analyzed using Kinovea. The high reliability scores reported in their study reinforce the software's utility in measuring knee ROM in both clinical and research contexts [34].

The validity of Kinovea in measuring knee ROM has also been demonstrated in post-operative rehabilitation. For example, Cunha et al. (2020) assessed knee joint angles during functional activities in patients recovering from orthopedic surgery. Their results showed high intra-rater reliability and strong agreement with digital inclinometers, suggesting that Kinovea can serve as a valid tool for tracking recovery progress and guiding therapeutic interventions [32].

Taken together, these findings of the Kinovea software high reliability in measuring ROM and its consistency with gold-standard methods, combined with its affordability and ease of use, positions Kinovea as a practical and reliable alternative for assessing joint mobility in both static and dynamic conditions. Furthermore, the ease of use of Kinovea makes it particularly suitable for pediatric populations, where cooperation and comfort are essential. The ability to freeze video frames at the point of maximum flexion or extension allows for accurate angle measurement without the need for physical contact or complex equipment. This is especially advantageous in school settings or community health programs where access to traditional goniometric tools may be limited. It enables the therapist to save the photograph or motion picture for follow up of the patient`s condition and exhibits the change and prognosis to the patient and/or caregiver.

5. CONCLUSION

From the findings of this study, it can be concluded that Kinovea software is as valid and reliable as the digital goniometer in measuring elbow and knee ROM among school children. Its non-invasive nature, cost-effectiveness, ease of use, and accessibility make it a practical and valuable particularly in pediatric settings. Therefore, Kinovea software may serve as a suitable tool for clinicians, educators, and researchers in both clinical and academic environments.

Conflict of interest

All authors have no conflicts of interest that are directly relevant to the content of this review.
Funding: No sources of funding were used to conduct this review.

REFERENCES

1. Milanese S, Gordon S, Buettner P, et al. (2014): Reliability and concurrent validity of knee angle measurement: smart phone app versus universal goniometer used by experienced and novice clinicians. Manual therapy. 19(6), 569-574.
2. Akizuki K, Yamaguchi K, Morita Y, et al. (2016): The effect of proficiency level on measurement error of range of motion. Journal of physical therapy science. 28(9), 2644-2651.
3. Svensson M, Lind V, Löfgren Harringe M (2019): Measurement of knee joint range of motion with a digital goniometer: A reliability study. Physiotherapy Research International. 24(2), e1765.
4. Charlton PC, Mentiplay BF, Pua Y-H, et al. (2015): Reliability and concurrent validity of a Smartphone, bubble inclinometer and motion analysis system for measurement of hip joint range of motion. Journal of science and medicine in sport. 18(3), 262-267.
5. Kolber MJ, Hanney WJ (2012): The reliability and concurrent validity of shoulder mobility measurements using a digital inclinometer and goniometer: a technical report. International journal of sports physical therapy. 7(3), 306.
6. Nussbaumer S, Leunig M, Glatthorn JF, et al. (2010): Validity and test-retest reliability of manual goniometers for measuring passive hip range of motion in femoroacetabular impingement patients. BMC musculoskeletal disorders. 11(1), 194.
7. Parati M, Gallotta M, De Maria B, et al. (2023): Video-based goniometer applications for measuring knee joint angles during walking in neurological patients: A validity, reliability and usability study. Sensors. 23(4), 2232.
8. Yen TY, Radwin RG (2000): Comparison between using spectral analysis of electrogoniometer data and observational analysis to quantify repetitive motion and ergonomic changes in cyclical industrial work. Ergonomics. 43(1), 106-132.
9. Kurillo G, Han JJ, Abresch RT, et al. (2012): Development and application of stereo camera-based upper extremity workspace evaluation in patients with neuromuscular diseases.
10. Bronner S, Agraharasamakulam S, Ojofeitimi S (2010): Reliability and validity of a new ankle electrogoniometer. Journal of Medical Engineering & Technology. 34(5-6), 350-355.
11. Howe L, Waldron M (2019): Measuring range of motion: an S&C coach's guide to assessing mobility. Professional Strength & Conditioning. 55, 7-17.
12. Roggio F, Ravalli S, Maugeri G, et al. (2021): Technological advancements in the analysis of human motion and posture management through digital devices. World journal of orthopedics. 12(7), 467.
13. Guzmán-Valdivia CH, Blanco-Ortega A, Oliver-Salazar MA, et al. (2013): Therapeutic motion analysis of lower limbs using Kinovea. Int J Soft Comput Eng. 3(2), 2231-2307.
14. Nor Adnan NM, Ab Patar MNA, Lee H, et al. (2018): Biomechanical analysis using Kinovea for sports application. IOP conference series: materials science and engineering. 342, 012097.
15. Pueo B, Penichet-Tomas A, Jimenez-Olmedo JM (2020): Validity, reliability and usefulness of smartphone and kinovea motion analysis software for direct measurement of vertical jump height. Physiology & Behavior. 227, 113144.
16. Carey MA, Laird DE, Murray KA, et al. (2010): Reliability, validity, and clinical usability of a digital goniometer. Work. 36(1), 55-66.
17. Herrero P, Carrera P, García E, et al. (2011): Reliability of goniometric measurements in children with cerebral palsy: a comparative analysis of universal goniometer and electronic inclinometer. A pilot study. BMC musculoskeletal disorders. 12(1), 155.
18. Lind V, Svensson M, Harringe ML (2022): Reliability and validity of a digital goniometer for measuring knee joint range of motion. Measurement in Physical Education and Exercise Science. 26(3), 191-198.
19. Charoenlap, C., & Piromsopa, K. (2020). Digital image processing technique to measure the range of motion of the elbow. Asian Biomedicine, 14(1), 37-44.
20. Hancock, G. E., Hepworth, T., & Wembridge, K. (2018). Accuracy and reliability of knee goniometry methods. Journal of experimental orthopaedics, 5(1), 46.
21. Zsarnoczky-Dulhazi, F., Agod, S., Szarka, S., Tuza, K., & Kopper, B. (2023). Ai based motion analysis software for sport and physical therapy assessment. Revista Brasileira de Medicina do Esporte, 30, e2022_0020.
22. Mohamed Nk, Nabil Ma-A, Ibrahim Pdah (2024): Reliability of Kinovea Program in Measuring Knee Joint Range of Motion. The Medical Journal of Cairo University. 92(03), 215-221.
23. Abd Elrahim, R. M., & Hassan, K. A. (2021). Realiability of computerized software in measuring elbow joint range of motion. Turk. J. Physiother. Rehabil, 32(3).
24. Blonna D, Zarkadas PC, Fitzsimmons JS, et al. (2012): Validation of a photography-based goniometry method for measuring joint range of motion. Journal of shoulder and elbow surgery. 21(1), 29-35.
25. Al-Mahmood MR, Uddin MT, Islam MT, et al. (2022): Correlation between goniometric measurements of range of motion and radiographic scores in osteoarthritis knee: An observational study among females. Medicine. 101(32), e29995.

26. Kleban N, Mann D, Eng P, et al. (2013): Position analysis of tractor ingress and egress. Knee. 5(50th), 95th.
27. 27. Balsalobre-Fernández C, Tejero-González CM, del Campo-Vecino J, et al. (2014): The concurrent validity and reliability of a low-cost, high-speed camera-based method for measuring the flight time of vertical jumps. The Journal of Strength & Conditioning Research. 28(2), 528-533.
28. Baude M, Hutin E, Gracies J-M (2015): A bidimensional system of facial movement analysis conception and reliability in adults. BioMed research international. 2015(1), 812961.
29. Puig-Diví A, Escalona-Marfil C, Padullés-Riu JM, et al. (2019): Validity and reliability of the Kinovea program in obtaining angles and distances using coordinates in 4 perspectives. PloS one. 14(6), e0216448.
30. Elwardany SH, Eleiny KEA, Arabia S (2015): Reliability of Kinovea computer program in measuring cervical range of motion in sagittal plane. Open Access Library Journal. 2(09), 1.
31. Diaz-Arancibia J, Cordova M, Arango-Lopez J, et al. (2025): Automatic gait analysis through computer vision: a pilot study. Neural Computing and Applications. 37(11), 7619-7639.
32. Cunha AB, Babik I, Harbourne R, et al. (2020): Assessing the validity and reliability of a new video goniometer app for measuring joint angles in adults and children. Archives of Physical Medicine and Rehabilitation. 101(2), 275-282.
33. Fernández-González P, Koutsou A, Cuesta-Gómez A, et al. (2020): Reliability of kinovea® software and agreement with a three-dimensional motion system for gait analysis in healthy subjects. Sensors. 20(11), 3154.
34. Moral-Muñoz JA, Esteban-Moreno B, Arroyo-Morales M, et al. (2015): Agreement between face-to-face and free software video analysis for assessing hamstring flexibility in adolescents. The Journal of Strength & Conditioning Research. 29(9), 2661-2665.