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VALIDITY AND RELIABILITY OF KINOVEA SOFTWARE MEASUREMENT OF HAMSTRING EXTENSIBILITY USING SIT & REACH TEST

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ABSTRACT

Background: Numerous reliable methods are available for evaluating hamstring flexibility, with the sit-and-reach test emerging as the most widely employed approach. **Objective:** To analyze the intra-rater and inter-rater reliability and the criterion validity of Kinovea software for measuring hamstring extensibility using the sit-and-reach test. **Methods:** 65 participants, aged between 18 and 25 years, participated in this study. Hamstring extensibility was measured through the sit-and-reach test, concurrently captured by a video camera. Each video underwent downloading onto a computer, followed by analysis using Kinovea software to evaluate criterion validity. Participants received two shots; the 1st shot had been done in the 1st of assessment and the 2nd shot had been done 1 week later to asses intra rater reliability and first assessment had been done by two different examiners to assess inter rater reliability. **Results:** The correlation coefficients indicated an extremely high correlation between the sit-and-reach test and Kinovea measurements ($p < 0.001$). Intra-rater reliability was excellent, showing an intraclass correlation coefficient (ICC) of 0.996 for Kinovea measurements. Inter-rater reliability was excellent, showing an ICC of 0.999 for Kinovea measurements. Cohen's Kappa statistic showed almost perfect agreement between raters, with a value of 0.969 for all measurements. **Conclusions:** The Kinovea software showed excellent intra-rater, inter-rater reliability and strong criterion validity for measuring hamstring extensibility compared to the sit-and-reach test.

Key words: Sit and reach test, Kinovea Software, Hamstring Extensibility

1. Introduction

Flexibility is a vital aspect linked to physical fitness related to health. Specifically, the substantial contribution of hamstring flexibility is noteworthy in upholding proper spinal posture and averting potential injuries. There exists a correlation between diminished hamstring flexibility and an elevated risk of encountering hamstring injuries (**Shepherd et al., 2017)**.

The length of the hamstrings holds critical importance for the efficiency and effectiveness of fundamental human locomotion, including walking and running **(Bohm et al., 2018).**

Hamstring extensibility exhibits a 9.9° elevation in females in comparison to males **(Marshall & Siegler, 2014)**. Hamstring tightness affects approximately 45% of college students **(Koli & Anap, 2018)**. Research findings suggest that elevated levels of obesity negatively impact various physical fitness parameters (**Posadzki et al., 2020)**.

The sit and reach (SR) test serves as a practical tool for the evaluation of hamstring and low back flexibility **(Samant et al., 2016)**. The application of sit and reach tests to assess hamstring muscle flexibility, along with their reliability, should be tailored to each sport. This is necessary because sports vary in technical skills, specific movements, training intensity, and physical abilities. The unique adaptations that occur through sport-specific training may lead to individual musculoskeletal changes. Consequently, these adaptations could potentially alter hamstring muscle flexibility and impact the reliability of sit and reach tests **(Ayala et al., 2012)**.

Today, there are new affordable 2D technologies like Kinovea emerging. Some of these technologies might offer precision similar to expensive high-end systems but at a significantly lower cost. However, before these tools can be used to assess human gait, it's crucial to demonstrate their accuracy and consistency for approval **(Ugbolue et al., 2013; Thewlis et al., 2013)**.

Kinovea is an unrestricted 2D movement analysis software underneath the General Puplic License version 2 (GPLv2) that was built in 2009 by a non-profit partnership of scientists, athletes, trainers, and developers from around the world. It allows the frame-by-frame evaluation of spaces, angles, coordinates, and spatiotemporal parameters from a video clip **(Balsalobre et al., 2014)**.

The aim of this study was to asses the validity and reliability of kinovea software in measuring hamstring extensibility using the sit and reach test.

2. Material and methods

2.1. Design and setting

Observational study with repeated measures crossover design.

2.2. Subjects

Sixty-five normal subjects between 18 and 25 years old participated. Enrollment included males and females with normal BMIs (18-24.9) and waist-hip ratios within typical limits (males: 0.9-1.0, females: 0.85). Subjects were excluded from this study if : they had Hamstring injury, Hip, knee and ankle orthopedic problems, Shoulders, Elbow and Wrist orthopedic problems, Athletes, Lumber Disc prolapse, Spinal fixation, Spinal deformities like scoliosis and kyphosis, Pregnant woman, Spastic Colon, or Subject taking any muscle relaxant.

2.2.1. Ethical considerations

The research Ethics Committee of the faculty of physical therapy at Cairo University granted approval for the study (No.: P.T.REC/012/004274). Prior to participation, all participants provided their informed consent. They were informed about the study's objectives, procedures, potential benefits and risks, data privacy, and data usage.

2.2.2. Sample size calculation

The sample size was calculated using the web-based sample size calculator for reliability studies developed by Arifin et al. A sample size of 65 participants was estimated with an α value of 0.05, a statistical power (1- β) of 85%, a number of measurements/examiners equal to 2, a minimum acceptable reliability of 0.75, and a 20% rate of dropouts **(Arifin et al., 2018)**.

2.3. *Instruments:*

2.3.1. Weight and height scale:

It was utilized to determine each subject's weight in kilograms (kg), height of in centimeters (cm) and BMI (weight in kilograms / height in meters squared).

2.3.2 Kinovea Motion Analysis Software:

It is a free and open-source solution for video analysis. This software may be valuable to those in the medical profession. Players and coaches can still utilize it primarily in the playing area. With the use of Kinovea Computer Program (KCP), the investigator can evaluate distance, speed, and line extension on a specific film. Data from the analysis can be converted to Excel and plain text. Assessment of the captured videos was done through Kinovea v0.8.15, the software's stable version (Kinovea, Bordeaux, France) **(Pueo et al., 2020)**.

2.3.3 Smart-phone camera:

A smartphone equipped with high-speed video recording capabilities (1080 pixels at 60 fps) was positioned on an adjustable tripod stand for standardization. The tripod's height was set at 1 meter, and the distance between the tripod and the participant's feet was maintained at 3 meters **(Pueo et al., 2020)**.

2.3.4 Sheer spot:

Circle marker had been placed on the fingertip of the middle digit. The fingertip of middle digit at the starting point and the end point of the reach on the Sit and reach box (SR box), were identified anatomically with sheer spot.

2.3.5 Computer system:

A Laptop with processor speed 2.5, caches memory 3 MB, Memory data FSB1333 MHZ, 8 gab ram, hard drive storage 750, angular velocity 5400 RPM, graphics processing unit, HD Bright image LED (Light Emitting Diode)-backlit with 1366 768 display resolution, dimension 15.6 inches was used for measuring and analyzing the collected data.

2.3.6. A standard sit-and-reach box (SR box):

Subjects were placed using a standard sit-and-reach box, measuring 31 cm in height, while their SRT scores were obtained using the sliding ruler positioned at the box's top center.

2.4. Procedures

A) Sit and reach test:

The SR box was positioned on the plinth, and participants were directed to ensure the soles of both feet were flat against the SR box while maintaining straight legs.

Participants were instructed to extend both arms straight out in front at shoulder level, with one hand atop the other. Placing their palms downward, participants were further guided to bend forward until they experienced a strong yet tolerable stretch in the posterior thigh. During this movement, they slid their hands along the box, maintained knee extension, and held the position of maximal flexion for about 5 seconds. To assist with the best assessment, the subject should drop the head between the arms when reaching.

The starting point of the subject's tip of middle finger recorded and the distance that the subject abled to reach forward (end point) recorded in centimeters from a ruler located on the SR box. (fig 1)

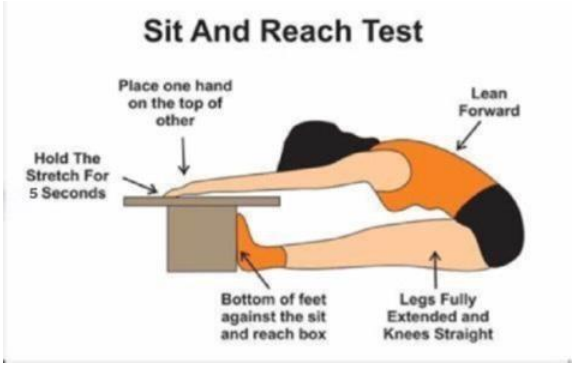

Fig. (1): Sit and Reach Test – https://physio-study.com/sit-and-reach-test/

After that, the examiner calculated the difference between the end point and the starting point in order to measure the distance that represents the extensibility of hamstring. Three trials were conducted, and the average score from these trials was utilized for analysis purposes.

The ruler markings were aligned in a manner such that the 23-cm point corresponded to the position where the subjects' fingertips were in line with their toes. This arrangement ensures that the SRT score remains consistently positive, regardless of participants' ability to reach their toes.

B) Assessment of hamstring extensibility by kinovea software:

The trials of sit and reach test recorded at the first assessment by the 1st examiner and then recorded at the 2nd assessment of the 1st examiner after 7 days. Each video was downloaded to a computer and analyzed using kinovea software programme. The calibration of the distance was established using the centrally positioned sliding ruler on the sit-and-reach box. The marker placed on the tip of middle finger was the starting position by (Marker) tool of the kinovea software. Using the (Marker) tool, the coordinates of end position of the marker had been located after reaching forward to the maximum distance and holding this position for 5 seconds. The horizontal distance between the 2 coordinates (starting-end) will be measured by (Line) tool in centimeters. The score average of the 3 trials had been used for statistical analysis.

For assessment of Inter-rater reliability, 1st and 2nd examiner analyzed the video recorded in the 1st assessment. For assessment of Intra-rater reliability, the 1st examiner analyzed the videos recorded at the 1st assessment and 1 week later. Validity was assessed through correlating the results of sit and reach test with those of the kinovea software.

2.5. *Statistical analysis*

Descriptive statistics including mean, standard deviation, minimum, maximum, and quartiles were calculated for the demographic variables using SPSS 27 (IBM Corp, Armonk NY).

To assess the reliability of Kinovea software for measuring hamstring extensibility, the study calculated the test-retest and inter-rater reliability using the intraclass correlation coefficients (ICCs) and the 95% confidence interval (CI). The criteria to interpret the reliability of the results were as follows: ICCs below 0.50 indicated poor reliability, ICCs ranging from 0.50 to 0.75 indicated moderate reliability, ICCs ranging from 0.75 indicated good reliability, and ICCs above 0.9 indicated excellent reliability (Koo & Li 2016). Furthermore, in order to assess its criterion validity, the study calculated the Pearson correlation coefficient. The strength of the correlation was interpreted as strong if it was greater than 0.70, moderate if it fell between 0.50–0.70, and low if it was less than 0.30. To further evaluate the agreement between the two methods, Bland–Altman plots were created.

3.Results

3.1. Demographic data

The demographic data and physical characteristics of the 65 participants included in the study as presented in (table 1).

Table (1): Demographic characteristics of the participants (n=65)

Variable	Mean	Standard Deviation	Min	Max
Age (years)	22.09	2.20	18.0	25.0
Weight (kg)	68.80	9.72	46.0	87.0
Height (cm)	173.66	9.95	149.0	192.0
BMI (kg/m2)	22.55	1.77	18.81	24.91
Waist/Hip Ratio (points)	0.891	0.045	0.85	0.979

*Min= minimum, Max= maximum, BMI - body mass index

3.2. Intra-rater reliability

The intra-rater reliability was calculated by 2 assessments of the 1st examiner using both the interclass correlation coefficient (ICC) and the Pearson correlation coefficient. The ICC values showed intra-reliability for 1st measurement, achieving an ICC of 0.9961 and 0.9958 intra-reliability for 2nd measurement .These high ICC values indicate a high degree of agreement between the two measurements. (Table 2)

Table (2): Interclass Correlation Coefficients (ICC) for Intra-rater Reliability

	Assessment I	Assessment II	ICC Value
	M ± SD	M ± SD	-0.9961
Examiner I	23.6 ± 6.97	23.8 ± 6.95	

**Interclass Correlation Coefficients (ICC) values close to 1 indicate excellent reliability, while values close to 0 indicate poor reliability. In some cases, negative ICC values can be observed due to negative variance components, which might arise due to the small sample size or other factors.*

3.3. Inter-rater reliability

In order to assess the consistency of the results obtained by two different examiners, the inter-rater reliability was calculated by comparing the data collected by Examiner 1 and Examiner 2. The ICC values for the sit & reach test and the Kinovea measurements were 0.9989 and 0.9985 respectively, suggesting excellent inter-rater reliability (Table 3).

Table (3): Interclass Correlation Coefficients (ICC) for Inter-rater Reliability

Examiner I	Examiner II	ICC Value
M ± SD	M ± SD	-0.9989
23.6 ± 6.97	23.67 ± 6.9	

**Interclass Correlation Coefficients (ICC) values close to 1 indicate excellent reliability, while values close to 0 indicate poor reliability. In some cases, negative ICC values can be observed due to negative variance components, which might arise due to the small sample size or other factors.*

4. Criterion validity

To assess the criterion validity of this measurement method, the study calculated the correlation between the sit and reach rest and Kinovea. The results showed a strong correlation between the sit and reach test and the Kinovea software ($p < 0.001$) using the Pearson correlation coefficient (Table 4).

To further illustrate the agreement between the 2 measurements, the study presented a Bland – Altman plot in (Figure 2 & 3).

The agreement between raters using the Cohen's Kappa statistic was illustrated in (Table 5).

Table (4): Criterion Validity - Correlation between Sit & Reach Test and Kinovea Measurements

	1st Kinovea*	2nd Kinovea*
Sit&Reach Test	0.9997	0.9963

*Pearson correlation coefficients showcase the relationship between the Sit & Reach test and the Kinovea software measurements.

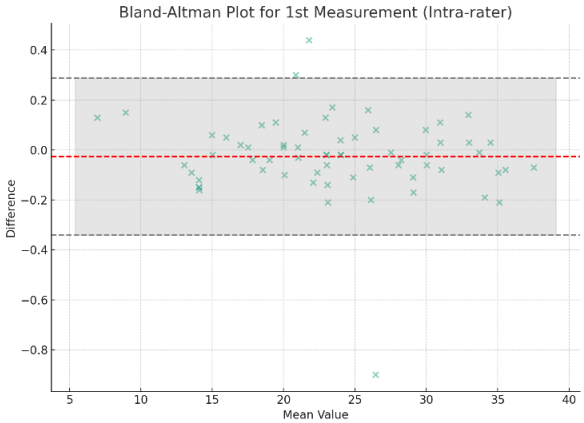

Figure 2: Bland-Altman Plot for 1st Measurement (Intra-rater)

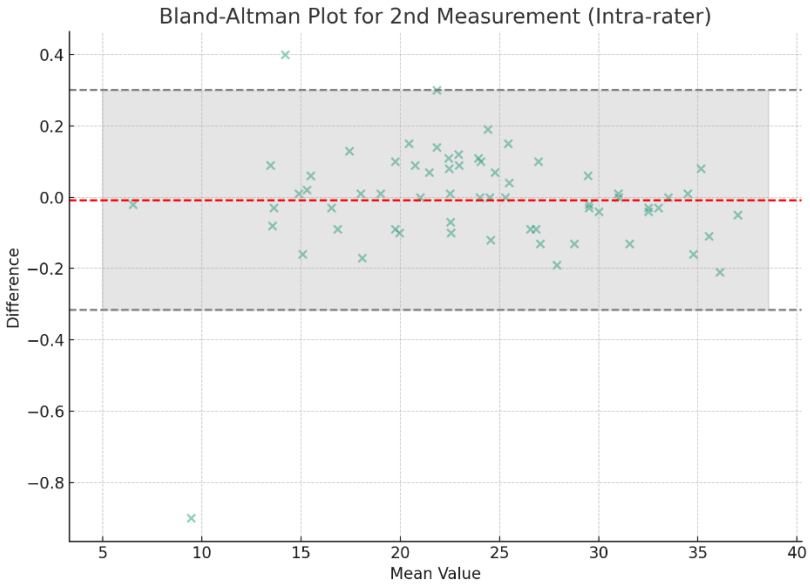

Figure 3: Bland-Altman Plot for 2nd Measurement (Intra-rater)

Table (5): Agreement Analysis between Sit & Reach Test and Kinovea Measurements

Measurement	Cohen's Kappa*	p-value
1st Measurement (1st examiner)	0.9795	<0.0001
2nd Measurement (1st examiner)	0.9795	<0.0001
1st Measurement (2nd examiner)	0.9795	<0.0001

**Cohen's Kappa values close to 1 indicate strong agreement between the measurements. The p-values, being significantly less than 0.05, indicate that the observed agreement is statistically significant.*

4.Discussion

The present study investigated the intra-rater and inter-rater reliability and the criterion validity of Kinovea software for measuring hamstring extensibility using the sit-and-reach. It was found that both intra-rater and inter-rater reliability were excellent. A very strong relationship and agreement between the sit-and-reach and the Kinovea software for measuring hamstring extensibility was found. This study yielded promising results, indicating that Kinovea software is a valid and reliable tool for evaluating hamstring extensibility.

This tool could be useful for measuring and following up reduced hamstring flexibility. The efficiency of basic human movements, such as walking and running, could be affected if subjects maintain shorter hamstrings. Limited hamstring flexibility is associated with various musculoskeletal alterations, including specific disorders of the lumbar spine, such as low-back pain **(Sjolie, 2004)** and changes in the lumbopelvic rhythm **(Esola, 1996)**.

Though the floor sit-and-reach evaluation has prevailed as the predominant hamstring flexibility field technique, it is less accurate and more time-consuming **(Mathias & Raj, 2015)**. Kinovea, a low-cost motion analysis technology, provides more accurate data and allows for the analysis of angles and spatiotemporal parameters **(Balsalobre- Fernandez et al., 2014).**

Sañudo et al., 2016 found that Kinovea enables users to control temporal factors and calculate angles and distances frame-by-frame. Furthermore, its non-perpendicular camera-object calibration capacities allow multi-perspective quantification. Moreover, **Senden et al., 2012** found that video cameras or smartphones with built-in accelerometers and cameras can be utilized to record subject movement. There is an increasing need in modern biomechanics for two-dimensional software to analyze subject movement and indirectly calculate center of mass displacement and gait. **Krishnan et al., 2015** revealed that users can pick the 2D analysis plane in Kinovea, which is not 3D software. While 3D motion labs offer rigorous, valid, highly accurate kinematic data, they pose challenges in interpretation and set-up. Kinovea has applications across three areas: athletics, clinical analysis, and establishing reliability of novel systems.

Guzmán-Valdivia et al., 2013 documented Kinovea's use in physical therapy and rehabilitation for evaluating lower extremity movement. Through angle and tracking tools, it analyzes position, velocity, and acceleration. The researchers determined that Kinovea effectively quantified these metrics as well as multi-joint angular movements.

The findings of this study have significant implications for clinical practice, highlighting the potential benefits of employing Kinovea software in evaluating hamstring extensibility. However, it is important to acknowledge several limitations in our study. Firstly, The study is limited to a specific population of 18 to 25-year-old students from the Faculty of Physical Therapy at Delta University. This limited sample may not be representative of the broader population, and the results may not generalize well to other age groups or demographics. Secondly, the study excludes individuals with certain medical conditions, orthopedic problems, athletes, and those taking muscle relaxants. These exclusion criteria may limit the external validity of the findings, as the software's performance might differ when applied to a more diverse or clinical population. Despite these limitations, our study contributes to the growing body of literature supporting the use of Kinovea software in evaluating hamstring extensibility. Further research in this area is warranted to fully understand the potential benefits of this innovative technology in clinical practice.

Conclusion

The Kinovea software's measurements were found to be consistent with the gold standard sit & reach test, and both intra-rater and inter-rater reliabilities were deemed excellent. The study further indicated that the Kinovea software can potentially serve as a reliable tool for assessing hamstring extensibility in clinical and research settings.

Disclosure

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Conflict of interest

No competing interests have been reported by the authors carrying out this work.

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