ORIGINAL ARTICLE

IJPHY

The Intra and Inter-Rater Reliability of Kinovea Software In Measuring Pelvic Tilt On Healthy Individuals In Sagittal Plane: An Analytical Study

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ABSTRACT

Background: Recently, there has been an increased interest in software-aided goniometric measurements in clinical establishments because of their uncomplicated availability and accuracy. This study evaluates the reliability of Kinovea software as a measurement tool for pelvic tilt in a sagittal plane.

Methods: Ninety-five healthy people with a mean age of 20.67 ± 1.91, ninety-three females and two males, had reflective markers placed on the anatomical landmarks of ASIS and PSIS and were photographed with a tripod-mounted camera from 180 cm. The photos were taken thrice on both the right and left sides of the pelvis in the sagittal plane. They were then analyzed using Kinovea software to measure the pelvic tilt. The measured data were subjected to intra-rater reliability in two sessions at an interval of 24 hours. For inter-rater reliability, the second rater analyzed the coded photos of each subject on the fourth day. Both the raters were blinded to each other, and the subjects were blinded to the readings until the study was completed.

Results: For intra-rater reliability, the results showed excellent reliability for the measurement of pelvic tilt on both sides of the pelvis between the first and second session (Cronbach's alpha = 0.98 and ICC=0.98), and for inter-rater reliability showed significant agreements between the raters (Cronbach's alpha value = 0.98 and ICC =0.98).

Conclusion: Kinovea software is a highly reliable and promising tool for measuring pelvic tilt in the sagittal plane for posture analysis.

Keywords: Kinovea, Pelvic tilt measurement, Pelvic inclinometer, Sagittal plane, Pelvic posture, Pelvic deviations.

Received 07th December 2023, accepted 15th February 2024, published 09th March 2024

www.ijphy.com

10.15621/ijphy/2024/v11i1/1421

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INTRODUCTION

The pelvis is positioned in the body's center, which supports the weight, transmits forces, and creates a functional chain effect on the axial skeleton [1,2]. Therefore, deviations in pelvic alignment imply an alteration in posture and subsequent biomechanical malalignment and secondary clinical problems [3]. Therefore, pelvis posture analysis is routinely surveyed to identify multiple musculoskeletal pathologies and potential issues with neighboring structures.

Various examinations have assessed the association between pelvis alignment and musculoskeletal pathology. The relationship between the pronation of the foot, deviation in the shoulder posture, pelvic distortion, and exaggerated lumbar lordosis has indirectly affected the pelvis, ultimately leading to the importance of pelvis assessment [4].

Various methods of measuring pelvic tilts range from visual observation, which is subjective, to objective radiograph measures. Recently, some measuring instruments investigated include sensor-based systems such as Viacon, navigated ultrasound systems, EOS imaging systems, handheld inclinometers like PALM (Palpation Meter), smartphone build applications like i@ handy, and computer-based applications like MB-ruler [5-10]. However, though accurate and reliable, these methods are expensive hardware and software, require spacious evaluation areas, or have small screens, such as in smartphone applications, and might be harmful to regular use, such as in radiographic methods. Adding to this, the affordability of many of the mentioned methods is a key factor to consider in underprivileged geographies, where a cheaper alternative may become more helpful in assessing and managing musculoskeletal conditions.

The above disadvantages and lack of literature evidence on the reliability and validity of these methods led to exploring Kinovea, a free software allowing two-dimensional analysis widely used for observation and tracking of different angular kinematics, motion analysis, and imaging analysis. Several previous studies tested Kinovea under various conditions and found it helpful. Fernández-González P et al. (2020) assessed the inter-rater and intra-rater reliability of Kinovea and a 3D motion system for detecting the joint angles of the hip, knee, and ankle during the initial contact phase of walking and intra-class correlation coefficient was good for intra-rater reliability and higher agreement between observers in favor of Kinovea. Bland-Altman plots revealed conflicts between observers, measurements, and systems [11]. Adnan et al. (2018) compared HD VideoCam–Kinovea against HAWK Cameras and CORTEX Software parameters, 3-dimensional infrared motion capture cameras and concluded that HD VideoCam-Kinovea integration is a reliable and repeatable alternative for motion capture-analysis of drop jump movement [12]. Hisham et al. (2017) aimed to find the reliability of Kinovea combining HD DSLR Camera by measuring the ankle angle during walking and proved that the protocol is repeatable and reliable [13]. Baude M et al. (2015) designed a bi-dimensional facial movement measuring tool using Kinovea software to track pre-selected points during movements. The authors concluded the proposed method was reliable and could be executed without formal training. [14]

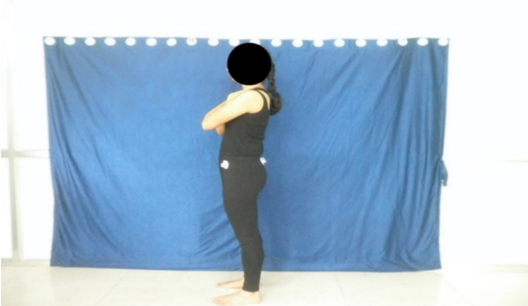
The primary advantages of Kinovea are it is an entirely open source software, available from https://www.kinovea.org/, its non-use of physical sensors, its ability to measure slight deviations by zooming the image, uncomplicated accessibility anytime, and the ability to compare pre-and post-treatment angles in one frame [14-17]. Recently, there has been an increased interest in using Kinovea as a goniometric measurement tool in clinical establishment because of its advantages and accuracy [18,19]. No data on Kinovea software's reliability as a pelvic tilt measurement tool has been available. So, this study tries to check the reliability of Kinovea software for measuring pelvic tilt in a sagittal plane.

This study aimed to investigate the intra-rater and inter-rater reliability of Kinovea software for measuring pelvic tilt in healthy asymptomatic individuals in the sagittal plane.

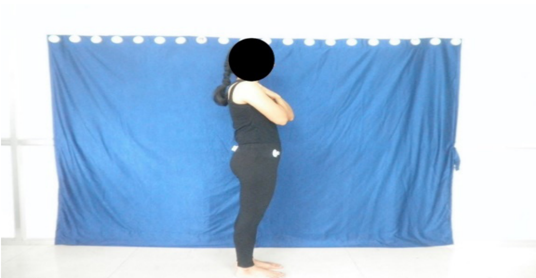
METHODS

Ninety-five healthy asymptomatic subjects were included in this study; ages ranged from 18 to 25 years from both genders. The sample size calculation is conducted by using a web-based calculation tool developed by Arifin NW [20] (Available from https://wnarifin.github.io/) and reference to the work by Walter SD et al. (1998). [21] For sample size calculation, we set a minimum number of repeated observations by different judges (n) as 3, significance (α) at 0.50, Power ($1-\beta$) at 0.95, Minimum acceptable reliability ($\rho 0$) at 0.60, level of expected reliability ($\rho 1$) at 0.80 and expected dropout at 14%. The Exclusion criteria for subjects were neurological, musculoskeletal, cardio-pulmonary conditions, unpalpable PSIS bony landmark, uncooperative subject, inability to understand the explained study procedure, and non-readiness to consent. An institutional ethical committee approved this study, and all subjects signed an informed consent document before participating. The study setting was MGM College of Physiotherapy, Navi Mumbai. The protocol was registered with the Clinical Trials Registry of India with the CTRI/2019/08/020844 trial number.

A 16-megapixel COOLPIX B500 camera that delivers excellent image quality was mounted on a tripod stand with a height of 100 cm and the distance between the tripod and the feet of the participant at 180 cm. Round reflective markers were stuck on ASIS and PSIS bony landmarks over a firm but comfortable dark-colored fitting yoga outfit. The ASIS is the most prominent aspect of the iliac crest anteriorly. The assessor moves her fingers to follow the iliac crest anteriorly and inferiorly to palpate the bony prominence in front. The PSIS is the most prominent posterior aspect of the iliac crest. She moves her thump in and down posteriorly along the iliac crest until a prominent bony bump is found near the sacral dimples. The markers are placed so the center lies over the most prominent area of ASIS and PSIS.[22] The subjects were made to stand in a normal, relaxed position without shoes or footwear on a level floor, and both hands were placed on the opposite shoulder (Figures 1 and 2). The participants' photos were taken on a sagittal plane where markers are clearly visible (Figure 1). Both the right and left sides of the pelvis were photographed. The photos were then uploaded to the laptop with Kinovea software installed.



A

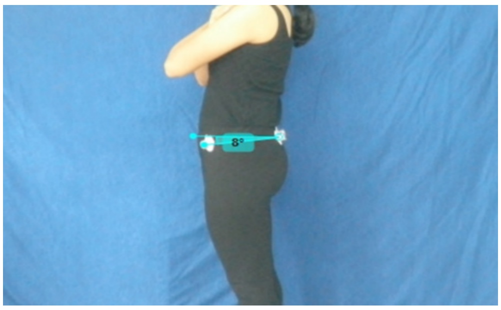


B

Figure 1: Subject standing erect with hands on the opposite shoulder and placing the marker on **A.** the left side of the pelvis and **B.** Right side of the pelvis.

The images were then subjected to processing by Kinovea software, where the pelvic tilt angle was measured in a sagittal plane in the following steps (Figure 2):

1) Zoom the image up to 200% for better tracking of the midpoint of the markers.
2) The 1st line connecting the PSIS and the ASIS marker was drawn, and the 2nd line from the PSIS to the horizontal matched the horizontal grid on the software interface, which can be activated/deactivated on will.
3) The software measured and displayed the angle, which was viewed on the screen immediately.
4) The image was saved in the folder.



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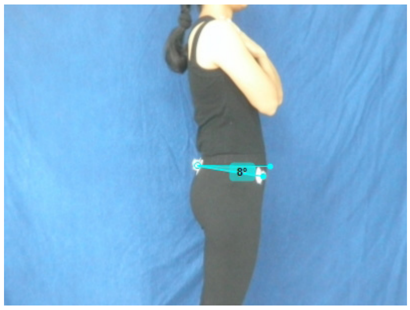

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Figure 2: Analysed image of the subject using the Kinovea software of **A.** the left side and **B.** the right side of the pelvis.

The clicked image was analyzed for intra-rater reliability in two sessions, i.e., 1st day and 24 hours later. For inter-rater reliability, the second rater is a postgraduate physiotherapy student at the same university. Training was given on the operation of Kinovea software for measuring pelvic tilt before conducting the session. The second rater analyzed the coded photos provided by the principal investigator in the third session after a gap of four days. It was documented on a separate case record form. Both the raters were blinded to each other, and none of the readings were disclosed to the subjects until the study was completed. All the tests were repeated thrice in each session, and the mean was calculated for each subject. Refer to Figure 3 for the plan of action in a flowchart.

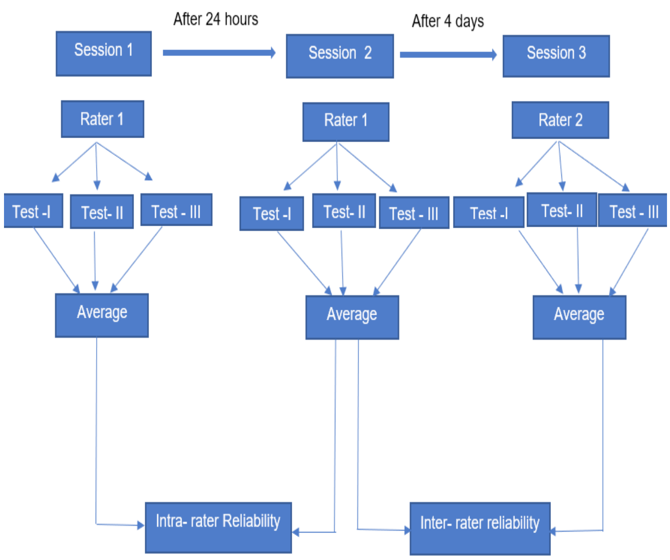

Figure 3: Flow chart showing the plan of action. There were three sessions, 1st and 2nd, by the first tester and four days after by the second tester. The test was repeated thrice in each session, and the mean was calculated for each subject.

STATISTICAL ANALYSIS

MS-Excel 2016 was used for data entry and basic Descriptive Statistics. The test of significance was analyzed using SPSS software (Version 24). All results were reported by mean and SD; the statistical significance was $p = < 0.05$. In reliability assessment, a 2-way mixed-effects model ICC was computed to show the agreement between the rater and raters. An ICC was calculated for each right and left side of the pelvis in the sagittal plane and expressed as ICC with a 95% confidence interval (CI). Cronbach's alpha was used to determine the accuracy. The evaluation criteria and accepted standards for ICC values were outlined: < 0.5 - Poor; 0.5 to 0.75 - Fair; 0.75 to 0.9 - Good; and > 0.9- Excellent. [23] Cronbach's alpha ranges from 0 to 1, with higher values showing greater internal consistency and ultimate reliability. α values of 0.7 to 0.8 are satisfactory, and higher values interpret a more desirable outcome. [24]

RESULTS

The mean age of the subjects in the study was 20.67 ± 1.91. The number of female subjects was 93 against two males, 97.9% and 2.1%, respectively **(Table 1)**. The Descriptive statistics for different raters and sessions for right and left pelvic tilt are in **Table 2**.

Table 1: Descriptive characteristics of participants

Gender	Female: 93 (97.9 %)	Male: 2 (2.1 %)
Age (Mean ± Standard Deviation)	20.67 ± 1.91	
Period of study	2018-2020	

Table 2: Descriptive statistics for different raters and sessions.

Pelvic Tilt	Rater 1 in Session 1.	Rater 1 in Session 2.	Rater 2 of Session 3.
Right Side	9.18 ± 3.92	9.32 ± 3.99	9.71 ± 3.74
Left Side	9.8 ± 4.14	9.99 ± 4.15	9.84 ± 4.05

Mean ± Standard Deviation.

Intra-rater reliability:

To calculate the intra-rater reliability, the mean average of the right and left pelvic tilt values was compared separately between each two trials. The results of the ICC and Cronbach's alpha between the two trials of the same rater are shown in Table 3 and Figure 4. Intra-rater reliability analysis for right and left-sided pelvic tilt shows an ICC of 0.983 and 0.986, respectively. Their corresponding upper and lower bound values at 95% CI are 0.989 and 0.975 for the right and 0.991 and 0.979 for the left side pelvic tilt, and p-values are significant as they are < 0.05 in both cases. With the ICC and alpha values greater than 0.9, excellent and consistent reliability is shown for the results given by Kinovea software for measuring pelvic tilt.

Table 3: intra-rater reliability analysis for pelvic tilt

Intra-class Correlation Coefficient								Cronbach's Alpha
Average Measures for	ICC	95% Confidence Interval		F Test with True Value 0				
		Lower Bound	Upper Bound	Value	df1	df2	p-value	
Right Side	0.983	0.975	0.989	59.385	94	95	0.001*	0.983
Left Side	0.986	0.979	0.991	73.046	94	95	0.001*	0.987

ICC is strong as a correlation > 0.9, and the p-value is significant as it is < 0.05. Also, the Cronbach's Alpha value for both right and left pelvic tilt is> 0.9, which showed excellent reliability.

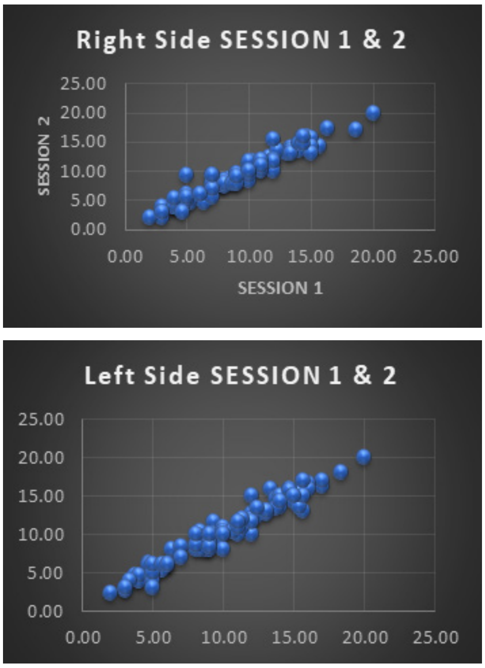

Figure 4. The scatter plot of the data set for right and left pelvic tilt shows a strong correlation in both cases.

Inter-rater reliability

To calculate the inter-rater reliability, the mean average of the right and left pelvic tilt values was compared separately between each two trials. The results of the ICC and Cronbach's alpha between the two trials of the two raters are shown in Table 4 and Figure 5. Interrater reliability analysis for right and left-sided pelvic tilt shows an ICC of 0.983 and 0.989, respectively. Their corresponding upper and lower bound values at 95% CI are 0.989 and 0.975 for the right, and 0.993 and 0.984 for the left side pelvic tilt, and p-values are significant as they are < 0.05 in both cases. With the ICC and alpha values greater than 0.9, excellent and consistent reliability is shown for the results given by Kinovea software for measuring pelvic tilt in between rater analyses.

Table 4: inter-rater reliability analysis for pelvic tilt

Intra-class Correlation Coefficient								Cronbach's Alpha
Average Measures for	ICC	95% Confidence Interval		F Test with True Value 0				
		Lower Bound	Upper Bound	Value	df1	df2	p-value	
Right Side	0.983	0.975	0.989	59.610	94	95	0.001*	0.988
Left Side	0.989	0.984	0.993	94.799	94	95	0.001*	0.989

ICC is strong as a correlation > 0.9, and the p-value is significant as it is < 0.05. Also, Cronbach's Alpha value for both right and left pelvic tilt is> 0.9, which shows excellent reliability.

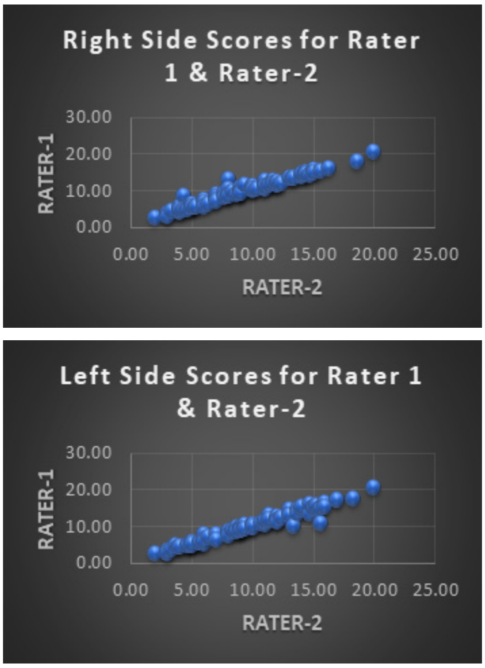

Figure 5. The scatter plot of the right and left pelvic tilt data shows a strong correlation between rater analysis in both cases.

DISCUSSION

This study aimed to determine the intra-rater and inter-rater reliability of Kinovea software for measuring pelvic tilt in healthy asymptomatic individuals in the sagittal plane. Ninety-five subjects were recruited, with no dropouts during the study. The results show excellent intra and inter-rater reliability in this study.

Clinical studies have shown that pelvic alignment affects the lumbar lordosis, and distortion in pelvic tilt disturbs the upper and lower limb kinetic chain muscle balance and is one cause of low back pain. [25-32]

As it is important to measure pelvic tilt regularly in a clinical assessment and research, it is essential to have a robust, reliable method of evaluation and re-evaluation tool. They should be cost-effective, easy to use, and require a lean learning curve apart from reliability and consistency. [19,33]

In developing countries where affordability is the first priority when choosing an assessment or treatment tool, many currently available objective and reliable methods are expensive and may require intricate hardware and setup. In pursuit of affordable measurement methods, researchers innovate using low-cost, easy-to-implement diagnostic and clinical measurement alternatives instead of intricate or expensive techniques. Thus comes the importance of open source and freely distributed tools like Kinovea, but before implementing such tools, it is commonly agreed that the reliability and validity of these tools be checked. For a measurement instrument to be helpful, the variables they provide should be reliable and can influence the objective estimations. The inspiration for this study is the same, and as a freely available source, Kinovea is also gaining popularity in India. This study on the reliability of Kinovea software aims to determine that it assesses what is proposed to quantify and can aid clinicians in deciphering the information correctly.

The study results displayed excellent and consistent intra-rater and inter-rater reliability for Kinovea software for measuring pelvic tilt, where the right and left pelvic tilt values were compared separately, with the ICC and alpha values greater than 0.9. These results, when compared with similar studies, show consistency. In a study aimed to measure the reliability of Kinovea by measuring ankle angle during walking, Hisham and colleagues 2017 proved that the protocol they were testing with HD DSLR Camera-Kinovea combination is reliable and repeatable. [13] Kinovea software was used by Abd Elrahim RM et al. (2016) in their video-based virtual goniometer to measure shoulder joint ROM, and it showed high intra- and inter-rater reliability. [19]

To ensure the precision of the results, we attributed the use of standardized experimental procedures throughout this study. The subjects' standing posture was maintained constantly from the beginning of the recording procedure. An emphasis on the instructions given to the subjects was considered important, reminding the subjects to stand erect with no movement. We considered the placement of the markers to be important for the measures taken with the Kinovea software to capture and overcome minute changes in the angle. Finally, measurements with the Kinovea software on day one and day two were taken at 24-hour intervals, always simultaneously, to eliminate any extraneous variables influencing the readings. One limitation of this study is a lack of comparison of Kinovea with another proven and reliable objective evaluation method of pelvic tilt measurement. However, this result would pave the way for more intense research on using Kinovea in pelvic tilt measurement.

Though Kinovea has the advantage of being open source, it is a tool that requires a brief training session. Besides this, the overall system includes a camera and laptop with installed Kinovea software, so know-how on the operation of these gadgets is essential, or help is needed from an operator. Another disadvantage we felt during this study is the need to disrobe sufficiently to expose the ASIS and PSIS and mark landmarks with adhesive markers, which can be improbable in a busy clinic and might cause inconvenience because of cultural challenges.

CONCLUSION

This study determined the intra-rater and inter-rater reliability of the Kinovea software in measuring pelvic tilt, and it can be concluded that the Kinovea software is a highly reliable tool for measuring pelvic tilt in a sagittal plane.

Ethical Approval: IERC, MGM College of Physiotherapy, Navi Mumbai with Ref. No. MGM/COP/IERC/2018-19-5/95/2019

Source of funding: Self-financed study.

Conflicts of Interest: NIL

Acknowledgment: The authors sincerely thank all the participants who consented to the study.

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