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Original Research

Kinovea Program for Assessment of Female Student's Knee Joint Proprioception in Closed Kinetic Chain: Emphasis on Validity and Reliability

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ABSTRACT

This study aimed to investigate the validity and reliability of Kinovea software in assessing the position sense of knee joint. Methods: 15 female students of physical education and sport science (20-25aged) participated at this study voluntarily. In this study, knee joint position sense was measured using photography (Kinovea software) and goniometer methods and calculation of the reconstruction angle and reconstruction angle error methods at three different closed kinetic chain knee flexion angles of 120, 135, 150 degrees while open and closed-eye conditions. SPSS26 software and Pearson correlation method was used for data analysis. The significance level was set at $\alpha = 0.05$. The reliability of Kinovea and goniometer measurements were assessed using test-retest method. Also, the correlation between the Kinovea and goniometer measurements were used for the assessment of validity of Kinova software in evaluating knee joint position sense. Results showed that Kinovea software has high validity in assessing the knee joint proprioception in all three different knee flexion angles of 120, 135, 150 degrees and eyes open and closed conditions($p<0.05$) and there were significant positive correlations between two methods under different conditions. Also, both Kinovea and goniometer methods had high repeatability ($p<0.05$). Kinovea software has high validity and reliability in assessment of knee joint position sense. So, this software can be recommended as a valid, reliable, easy, efficient, and cost-effective method for assessing knee joint proprioception in sports and clinical settings.

Keywords: Kinovea software, Joint position sense, Knee joint, Flexion.

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INTRODUCTION

The concept of proprioception was first introduced by Sherrington in 1906, and it was defined as a type of internal feedback from the body's organs to the central nervous system (CNS) [1]. Proprioception refers to the sense of movement and position of different body parts in space, and it is one of the essential components of the neuromuscular function and the primary element in controlling self-movement, balance, and joint stability [2]. This sense informs individuals about the joint movement and ultimately regulates the muscle contractions to move and stabilize the joint [3]. Muscle and joint receptors are the major sources of joint proprioception [4]. Position sense receptors include the muscle spindles, Golgi tendon organs, and joint receptors that transmit information regarding this sense to the CNS [5]. After receiving sensory information through these receptors, the CNS determines the joint position and movement and accurately identifies the direction, intensity, and velocity of the joints [6].

The knee joint is one of the most critical joints in the body for performing daily living activities and sports, and due to its mechanical demands and reliance on soft tissue support, it is at risk of injury and affects joint proprioception [2]. Knee joint proprioception is composed of the sum of incoming messages from muscle receptors, tendons, joint capsules, ligaments, meniscus, and skin. In dynamic conditions, proprioception plays an important role in maintaining knee joint stability. Due to the importance of proprioception in preventing joint injuries, various studies have evaluated joint proprioception using different tools such as goniometers, isokinetic dynamometers, and video analysis systems. These tools mainly focus on the joint range of motion and angle reproduction [7]. The standard goniometer is widely used in clinical settings due to its transparent plastic material, ease of landmark and joint range of motion visualization, low cost, availability, ease of use, and portability [8]. However, the use of this device is associated with some problems for researchers, such as its boring and time-consuming nature when used repeatedly or for a large population [9]. More accurate and extensive joint range of motion measurements can be obtained using advanced motion analysis systems. These devices are expensive, complicated, not portable, and requires expertise. An ideal measurement system is a device that is inexpensive, can be easily used without sensors attached to the body, and easy to learn [10]. Kinovea software has the above mentioned properties, it is a free, portable, and inexpensive software with 2D imaging that does not require sensors during analysis [10]. It is used for measurement of active and passive range of motion [11]. It is also suitable for physical education coaches and teachers.

Gupta et al, (2022), in their study demonstrated that motion analysis softwares such as Kinovea and Templo are reliable for measuring the knee flexion and extension and other kinematic parameters[12]. Also, Ralph et al, (2015), measured the accuracy and reliability of knee joint proprioception in active and passive sitting and standing positions, using image capture and Image software (Image J, U.S. National Institutes of Health) and showed high accuracy and reliability [13]. Abdullahi et al, (2021), also reported good repeatability in measuring shoulder joint proprioception using imaging techniques [14]. However, only a limited number of studies have used Kinovea software to evaluate joint proprioception. In the study by Yazdani et al, (2022), high validity and reliability of Kinovea software has been reported in assessing shoulder joint position sense in female volleyball players.[15]. However, the reliability and validity of Kinovea software for the assessment of position sense of lower limb joints has not been well addressed yet. Therefore, the present study aimed to investigate the validity and reliability of Kinovea software for evaluating the knee joint position sense.

MATERIAL AND METHODS

In this cross sectional semi experimental study, the subjects were selected using purposive sampling method. The study population consisting of female physical education students at university of Tabriz in Tabriz city. From this population, 15 female students aged 20-25 years (mean age 20.9 ± 2.4 years, height 167.6 ± 5.7 cm, weight 68.3 ± 7.5 kg) volunteered to participants at this study. The results of G*power software revealed that with the effect size of 0.66, power of 0.9 and α error probability of 0.05, 15 subjects were sufficient for this study. The inclusion criteria for the participants in this study were: having normal posture, no lower limb abnormalities, fractures or previous musculoskeletal disorders, no neurological disorders and no history of surgery [16]. Subjects who had balance disorders, trauma, leg length discrepancy, history of pain at trunk or lower extremity, and physical activity in the 48 hours prior to the measurement were excluded from study [16]. Prior to the measurements, the purpose of the test and all stages of the work were fully explained to the participants, and they were asked to read and sign a written consent form for voluntary participation in the study. Participants were asked to wear light clothes above the knee to prevent movement restrictions and better identification of landmarks.

Process of Study

To measure knee joint proprioception, the active reproduction angle (reconstruction angle and reconstruction error) of knee flexion was measured in three angles of 120, 135, and 150 degrees with a Canon EOS 850 camera, 24 Mp, shooting speed of 7.5 f /s and BSB Goniometer (a Swiss-made metal standard with a 1-degree error coefficient) while open and closed eye conditions. In the camera motion recording method, Kinovea program (0.9.5 version) was used to calculate the angles. For this aim, first, the relevant landmarks for measuring each joint were identified with purple markers [14]. Then, the camera was placed on a tripod at a distance of 3 meters from the wall at a height of 70 centimeters, and the tripod was placed on tape markers on the floor to maintain a constant distance between the camera and the wall. A blindfold was used to eliminate visual feedback in closed-eye proprioception measurements [17]. To facilitate goniometry, four markers were attached to the skin using double-sided tape. Each marker consisted of a purple circle with a diameter of 3 centimeters. The markers were located at the greater trochanter of the femur, the distal end of the iliotibial band at the knee, and the outer malleolus prominence of the ankle [18]. To perform knee flexion angle measurements in the squat position, the participant was asked to stand facing the camera next to the wall, with their left side facing the camera and their right side facing the wall. The participant then placed their foot in a flexion angle of 120 degrees and held it at the target angle for 10 seconds to memorize the angle. After returning to the starting position, they were asked to flex their knee to the specified angle with open eyes and hold it for 10 seconds. Then, after one minute of rest, the participant was asked to bring their knee to the predetermined angle, and the movement was recorded by the camera. This was repeated three times for each angles of 135 and 150 degrees with both open and closed eyes. At the same time as each test and camera motion recording, the range of motion of the joints was also measured using a goniometer.

After motion capture, the degree of angle reconstruction and the reconstruction error were calculated using Kinovea program [15]. To determine the validity of the Kinovea software, the correlation between the degree of angle reconstruction and the angle reconstruction error calculated by the software and the goniometer was calculated. To assess the reliability of knee joint proprioception tests using Kinovea measurements and goniometer methods, a test-retest method was employed. Two days after the initial test, the tests were repeated using the camera and goniometer.

Statistical Analysis

All statistical analyses were performed using SPSS 26 software. The Shapiro-Wilk test was used to assess the normality of the data, and descriptive statistics were used to determine the mean characteristics of the participants. Pearson correlation coefficients were used to assess the validity and reliability of the Kinovea software and goniometer. The significance level was set at ($P < 0.05$).

RESULTS

The results of the mean knee joint proprioception during the reconstruction of knee joint flexion angle at three different angles of 120, 135, and 150 degrees under open and closed-eye conditions using Kinovea software and goniometer are summarized in Table 1. Based on the results of the Shapiro-Wilk test, the data were normally distributed, and therefore Pearson correlation coefficient was used to examine the validity and reliability of the Kinovea program.

Table 1: Mean knee joint range of motion during knee flexion reconstruction at three angles of 120, 135, and 150 degrees under open and closed-eye conditions using Kinovea software and goniometer.

Tools		Knee Flexion	120 Degree	135 Degree	150 Degree
Goniometer	open-eyes	Reconstruction angle	115.40 ± 2.04	130.70 ± 1.01	150.50 ± 1.20
		Reconstruction error	-4.60	-4.30	0.50
	closed eyes	Reconstruction angle	114.60 ± 2	131.90 ± 1.38	149 ± 1.38
		Reconstruction error	-5.40	-3.10	-1.00
Kinovea	open-eyes	Reconstruction angle	115.70 ±2	130.90 ±0.91	151.10 ± 1.19
		Reconstruction error	-4.30	-4.10	1.10
	closed eyes	Reconstruction angle	114.50 ± 1/83	132.20 ± 1.53	149.30 ± 1.49
		Reconstruction error	-5.50	-2.80	-0.70

To assess the reliability of Kinovea and goniometer measurements, a test-retest method was used. The results of the correlation between Kinovea and goniometer measurements for knee joint proprioception in the two measurement sessions are shown in Tables 2 and 3 respectively. Based on the results, a significant positive correlation was observed between the knee flexion reconstruction error in both measurement sessions under open-eye conditions and at all flexion angles, and Kinovea measurements showed high reliability in assessing knee joint proprioception in open-eye condition ($p < 0.05$). Similar results were observed in closed-eye condition, indicating that reproducibility of Kinovea measurements in closed eye condition was high ($p < 0.05$).

Table 2: Correlation between reconstruction error measurements using Kinovea in two measurement sessions at different flexion angles of 120, 135, and 150 degrees under open and closed-eye conditions.

movement			120 Degree	135 Degree	150 Degree
Knee Flexion	open eyes	**r**	0.986	0.954	0.943
		P	*0.0001	*0.0001	*0.0001
	closed eyes	**r**	0.980	0.991	0.979
		P	*0.0001	*0.0001	*0.0001

Also, there were positive significant correlations between the knee flexion reconstruction error in both measurement sessions using goniometer while open-eye and closed eye conditions at all knee flexion angles ($p < 0.05$). these results have been shown at table 3.

Table 3: Correlation between reconstruction error measurements using goniometer in two measurement sessions at different flexion angles of 120, 135, and 150 degrees under open and closed-eye conditions.

movement			120 Degree	135 Degree	150 Degree
Knee Flexion	open eyes	**r**	0.997	0.986	0.982
		P	*0.0001	*0.0001	*0.0001

	closed eyes	r	0.992	0.980	0.989
		P	*0.0001	*0.0001	*0.0001

p = p-value

r = correlation coefficient

*= represents significant correlation

To examine the validity of Kinovea measurements, the correlation between Kinovea reconstruction error and goniometer reconstruction error measurements for knee joint flexion was calculated. Table 4 presents the results of this correlation. As shown in this table, a significant positive correlation was observed between the two measurement methods in all three flexion angles of 120, 135, and 150 degrees under open-eye condition, indicating the high validity of Kinovea measurements in assessing knee joint proprioception ($p < 0.05$). Similarly, under closed-eye conditions, the measurements related to knee joint proprioception showed high validity in all three flexion angles ($p < 0.05$), and a significant positive correlation was observed between Kinovea and goniometer measurements.

Table 4: Correlation coefficients between goniometer and Kinovea reconstruction error measurements at different flexion angles of 120, 135, and 150 degrees under open and closed-eyes conditions

movement			120 Degree	135 Degree	150 Degree
Knee Flexion	open eyes	r	0.973	0.887	0.756
		P	*0.0001	*0.001	*0.011
	closed eyes	r	0.975	0.968	0.579
		P	*0.0001	*0.0001	*0.0001

p = p-value
r = correlation coefficient
*= represents significant correlation

DISCUSSION

The aim of the present study was to investigate the validity and reliability of Kinovea software in assessing knee joint proprioception. The results showed that Kinovea software has high validity in assessing knee joint proprioception. This finding is consistent with the results of Pueo et al. (2020), who demonstrated that Kinovea and Smartphone are valid, reliable, and cost-effective tools for assessing vertical jump in the lower limb ($r = 0.985$; $r = 0.986$; $r = 0.997$) [19]. In addition, Abd Elrazik et al. (2020), reported high validity of Kinovea software in measuring the range of motion (ROM) of the shoulder joint in patients with adhesive capsulitis [20]. Studies using Kinovea for measurement of the joints' range of motion revealed that this system has high inter-rater and intra-rater reliability, with no effect of the testers' background and expertise [21-23]. Consistent with our findings, Sharifnezhad et al. (2021) demonstrated that Kinovea has high intra-group and inter-group repeatability in measuring kyphosis and lordosis [24]. Similarly, Fernández-González et al. (2020), showed that Kinovea is a reliable and accurate tool for gait analysis in healthy subjects, but further research is needed to validate its use in clinical populations [25]. Additionally, Yazdani et al. (2023) demonstrated high validity of Kinovea software in assessing shoulder joint proprioception in female volleyball players [15].

Moreover, in the present study, the reliability and repeatability of Kinovea measurements for assessing knee joint proprioception were also high. Our findings are consistent with those of Sharifnezhad et al.

(2021), Yazdani et al. (2023), Abd Elrazik et al. (2021) and Ralph et al. (2018), regarding the reliability of Kinovea software in assessing joint proprioception and range of motion in various joints and planes.

However, in contrast to our findings, Irving et al. (2016) reported poor to moderate repeatability for knee joint proprioception measurements using a goniometer and imaging technique in standing positions at angles of 20, 40, 75, and 100 degrees. They attributed the poor to moderate repeatability to the long time interval between two measurements and only one imaging from an angle [26]. Similarly, Pillbeam and Hood (2018) reported poor to moderate repeatability for wrist joint proprioception assessed using a goniometer at angles of 20 and 45 degrees of extension and flexion [27]. These results do not match the findings of the present study. The reasons for such discrepancies could be attributed to the joint being measured, the technique used, the angles of measurement, and the distance between measurements.

Based on the high validity and reliability of Kinovea measurements, this software can be considered as an easy, cost-effective, reliable, accessible, and usable tool for assessing knee joint proprioception in various settings.

One of the limitations of this study was the small sample size. Also, in this study, the healthy subjects at the range of 20-25 years of age included and just knee joint was evaluated. So, these results should not be generalized to pathologic populations as knee problems, other age groups and other joints. It is recommended to evaluate the validity and repeatability of Kinova measures in larger sample size, pathologic populations, other age groups and joints in future researches.

CONCLUSION

This study aimed to investigate the validity and reliability of Kinovea software in measuring the knee joint proprioception. These findings suggest that Kinovea software is a valid and reliable tool for assessing knee joint proprioception. It provides a cost-effective and accessible alternative to expensive equipment such as the isokinetic dynamometer.

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برنامه کینووا در ارزیابی حسی وضعیت مفصل زانو دانشجویان دختر در زنجیره بسته: تاکید بر روایی و پایایی

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چکیده: هدف پژوهش حاضر بررسی اعتبار و پایایی نرم‌افزار کینوا در اندازه‌گیری حس وضعیت مفصل زانو بود. ۱۵نفر دانشجوی تربیت بدنی دختر (سن ۲۰-۲۵) به روش نمونه‌گیری هدفمند و در دسترس انتخاب شدند. با استفاده از نرم افزار کینوا و گونیامتر حس‌عمقی مفصل زانو با روش محاسبه زاویه بازسازی و خطای زاویه بازسازی در شرایط چشم باز و بسته در سه زاویه ۱۲۰، ۱۳۵ و ۱۵۰ درجه مورد اندازه‌گیری قرار گرفت. داده‌های به دست آمده با استفاده از نرم افزار SPSS26 و روش همبستگی پیرسون مورد تحلیل قرارگرفت. سطح معنی داری آزمون ۰/۰۵ درنظر گرفته شد. در بررسی پایایی اندازه‌های کینوا و نیز گونیامتر از روش آزمون-آزمون مجدد استفاده شد. برای بررسی روایی نیز همبستگی بین نتایج دو روش کینوا و گونیامتر محاسبه گردید. نتایج نشان دادند که در شرایط چشم باز و چشم بسته در هر سه زاویه فلکشن ۱۲۰، ۱۳۵، ۱۵۰ درجه مفصل زانو، اندازه های کینوا از پایایی بالایی برای بررسی حس عمقی برخوردار بودند ($P<۰/۰۵$) و در شرایط مختلف همبستگی مثبت معنی داری بین دو روش اندازه گیری وجود داشت. همچنین تکرارپذیری اندازه های کینوا و نیز گونیامتر نیز در بررسی حس وضعیت مفصل زانو در همه زوایا بالا بود ($P<۰/۰۵$). نتیجه گیری: نرم‌افزار کینوا دارای اعتبار و پایایی بالا در ارزیابی حسی‌عمقی مفصل زانو است. بنابراین این روش به عنوان یک روش ارزیابی قابل اعتماد، ساده، کارآمد و با هزینه کم می تواند در محیطهای ورزشی و کلینیکی مورد استفاده قرار گیرد.

واژه‌های کلیدی: نرم افزار کینوا، حسی عمقی، مفصل زانو، فلکشن.