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Reliability of Kinovea Program in Measuring Knee Joint Range of Motion

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Abstract

Background: Evaluating knee range of motion (ROM) is essential to consider as having broad use in the orthopedic and rehabilitative specialties. Kinovea is a free software that uses a virtual goniometer to measure joints ROM. However, Kinovea reliability in measuring knee full ROM has not been investigated.

Aim of Study: This study was conductedto investigate the intrarater and interrater reliability of the Kinovea program in measuring knee joint ROM.

Subjects and Methods: One hundred healthy male subjects from Alexandria University students and employees, with age mean 22.62±3.72 years old and body mass index mean 22.56±1.78kg/m^2. Digital camera and laptop with installed Kinovea software were used. The video recordings of knee ROM for each participant were measured by three raters (1, 2, and 3) using Kinovea computer program in two sessions separated by one week; in order to detect intrarater and interrater reliability.

Results: Kinovea program showed excellent intrarater reliability in measurement of knee ROM; ICC for rater 1 was 0.990, with 95% CI (0.985-0.993), for rater 2, ICC was 0.989 with 95% CI (0.984-0.993), and for rater 3, ICC was 0.972 with 95% CI (0.959-0.981). Kinovea program showed excellent interrater reliability in measurement of knee ROM; ICC for trial 1 was 0.987, with 95% CI (0.982-0.991), for trial 2, ICC was 0.989 with 95% CI (0.985-0.993).

Conclusion: Kinovea program is a reliable cheap easy applicable tool that can be used in knee joint ROM measurement in everyday clinical practice.

Key Words: *Kinovea – Knee ROM – Goniometry – Reliability – Movement.*

Introduction

Knee problems such as pain, giving-way, locking or being unstable are a common source of functional limitations **[1].** Measuring joint range of motion (ROM) is crucial to detect limitations in joint motion and to assess the outcome of a rehabilitation program or an intervention **[2].** The ROM measurement tool should deal with the new technology as the kinematic data describes the movement of limbs and is used in biology, sports, orthopedics, and rehabilitation medicine. The data is acquired using motion imaging systems, tracking systems or computer simulation. Recently new software programs were developed to measure joints ROM **[3].**

New two-dimensions (2D) low-cost technologies are available nowadays, some of which may have a precision comparable to the leading high-end reference systems **[4].** One such low-cost technology is Kinovea. Kinovea is a free 2D motion analysis software **[5].** The two-dimensional (2D) video-based assessment techniques like Kinovea program are inexpensive, require no sensors for motion analysis, and easy-to-handle; thus have been emphasized in clinical practice for motion analysis **[6].**

Reliability is one of the basic quality criteria of an instrument, as it estimates very important psychometric properties since before a test can be considered valid, it must be reliable **[7,8].** Kinovea reliability was concluded in measuring cervical ROM in sagittal plane **[9]**, cervical ROM in frontal plane **[10]**, dominant wrist joint ROM **[11]**, shoulder ROM **[6]**, ankle joint ROM during walking **[12]**, and in obtaining distance and angles from coordinates in different perspectives **[5].**

The Kinovea program reliability was investigated in measuring knee angle at running foot strike phase **[13]**, walking initial contact phase **[14]**, and while investigating the mechanisms of non-contact secondary ACL injuries **[15].** However, those studies did not discuss a full knee excursion; so the aim of this study was to investigate the intrarater and interrater reliability of Kinovea program in measuring full knee ROM.

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Subjects and Methods

This study was an observational study design. Subjects were recruited from Alexandria University students and employees. The study was conducted in Alexandria University from July 2021 to July 2022. The study was approved by the Faculty of Physical Therapy Ethics Committee, Cairo University, Egypt with number NO:P.T.REC/012/002403.

The study was conducted on a convenient sample of 100 subjects. The inclusion criteria were healthy male subjects, their age was between 18 to 30 years old, and their body mass index was from 18.5 to 25kg/m^2. The exclusion criteria were any subject with a musculoskeletal problem, neurological problem, or previous surgery of the examined lower limb. Subjects were verbally asked to join the study. All participants signed an informed consent form. All participants did not receive monetary rewards or compensation for their time and participation to this study.

Sample size was calculated based on assuming a significance level α of 0.05 and 90% power. It was considered that a minimally acceptable ICC p_0 (p null) of 0.60, and an expected ICC (p) of 0.75. The sample size using three raters was 90 subjects. Expecting 10% of dropout, 99 subjects were needed. Finally, the sample size consisted of 100 subjects *[16]*.

Three raters (1, 2, and 3) who completed a training of two hours to adequately manipulate the Kinovea computer program participated in the study. All raters were physiotherapists with at least fifteen years of clinical experience in orthopedic physical examination and goniometry. All raters had no previous experience with the Kinovea computer program before applying this experiment. The researcher was the rater (1) with fifteen years of experience with orthopedic and neurological physical examination and goniometry.

A digital camera (Canon IXUS 185) was mounted on a tripod stand 100 cm above floor leveland 115 cm away from the subject's limb; they were determined on the basis of the position of the subjects *[9]*. The camera and tripod stand were positioned and maintained at 90 degrees to the long axis of the bed *[17]*. Both the bed and tripod were maintained in position using landmarks to ensure standardization *[6]*.

The researcher gave an informative talk to participants to explain the purpose and methodology of the study. The consent forms were then given to them. The participants were asked to wear a suitable shorts. Shorts should not cover the greater trochanter of the femur. After collecting the consent forms, the researcher asked the participant about any previous history of surgery of the examined limb. The researcher physically examined the participant to exclude any musculoskeletal or neurological problem.

A digital weight scale and a wall mounted measuring tape were used to get participant's weight and height. The weight and height were recorded to calculate the Body Mass Index (BMI) by the next formula BMI = (Weight in kg)/((Height in meter)^2) kg/m^2. The participant has to have a normal BMI between 18.5 and 25kg/m2 to be included to the study.

For the purpose of measuring the knee angle; an adhesive reflective markers were put on greater trochanter, lateral epicondyle of the femur and the center of the lateral malleolus *[18]*. The subject was placed in supine positionon a bed 70 cm above floor level with the examined lower limb positioned parallel to the edge of the bed *[19]*. Before recording any measurement, active knee full flexion from full extension position was practiced three times to familiarize the participants with the procedure and the motion being measured *[11]*.

The participant was asked to fully flex the knee from the full extension position and to maintain for 5 seconds, while recording the motion by the camera. Three videos for every participant were captured by each rater *[9]*. Every video was numbered using a number board during recording. The three videos for every participant were numbered using A, B and C. The raters used the numbered board to record the relevant analysis data. The video scope did not show the participant face to minimize recall bias while measuring by raters. The captured videos were transferred from the camera to the computer using USB to Mini B cable. The set-up protocol was standardized for all raters and participants *[10]*.

Kinovea 0.8.15 free computer software was downloaded from www.kinovea.org. It was installed on the laptop (Dell Inspiron 3567) before applying the measurement procedure. Femur-line method was used to measure the knee ROM. This method includes a drawing of two lines.The first line, extending from the marker on the center of greater trochanter passing by the marker on the lateral femoral epicondyle (axis of the femur). The second line, extending from the marker on lateral femoral epicondyle to the marker on the center of lateral malleolus (axis of the tibia). Then, the Kinovea angle tool was used to measure the angle between the previously drawn lines, as the marker on the lateral femoral epicondyle is the center of the measured angle (Fig. 1) *[20]*.

Fig. (1): Analysis of knee joint ROM using Kinovea program.

The three raters analyzed the knee joint range of motion for all subjects on Kinovea tracking system software. The same captured videos and laptop were used at the holding five seconds full knee flexion video-frame done by the participant. Raters were told to view each image only once so that they would not change their assessment. Each rater took two measurements of every video with an interval of one week to minimize any learning effect.

Before the next session of analysis, the order of appearance of the images on the laptop screen was randomized by an assistant to minimize any learning or order effects. All raters were blinded to the results of each others' assessment and to their own consecutive repeated results **[6]**. The three videos for every participant were used to get the mean average **[10].**

Statistical analysis:

Intrarater and interrater reliability were expressed as Intra-class Correlation Coefficients (ICCs) with 95% CIs. Measurement error was expressed in the standard of measurement (SEM) and the smallest detectable change (SDC). SEM = pooled SD -V(1-ICC). The SDC was calculated as 1.96 x-V2 x SEM. The level of significance for all statistical tests was set at $p<0.05$. Statistical analysis was conducted through the statistical package for social studies (SPSS) version 25 for windows (IBM SPSS, Chicago, IL, USA).

Results

Subject characteristics:

Table (1) showed the mean ± SD of subject's characteristics of the study group.

Table (1): Basic characteristics of all participants.

	Mean ± SD	Minimum	Maximum	Range
Age (years)	22.62±3.72	30	18	12
Weight (kg)	68.16±9.14	90	50	40
Height (cm)	173.48±7.03	190	160	30
BMI (kg/m^2)	22.56±1.78	25.01	18.83	6.2

SD: Standard Deviation.

Descriptive statistics of knee ROM measured by Kinovea program:

The mean ± SD knee ROM measured by Kinovea program during first trial of rater 1, 2 and 3 were 143.71±5.15, 144.28±5.25 and 143.55±4.97 degrees respectively. The mean ± SD knee ROM measured by Kinovea program during second trial of rater 1, 2 and 3 were 143.89±5.17, 144.35±5.25 and 143.93±5.14 degrees respectively. (Table 2).

Table (2): Descriptive statistics of knee ROM measured by Kinovea program.

Knee ROM (degrees)	Rater 1 Mean ± SD	Rater 2 Mean ± SD	Rater 3 Mean ± SD
1st trial	143.71±5.15	144.28±5.25	143.55±4.97
2nd trial	143.89±5.17	144.35±5.25	143.93±5.14

SD: Standard Deviation.

Reliability of knee ROM measured by Kinovea program:

Intrarater reliability of knee ROM measured by Kinovea program:

Kinovea program showed excellent intra-rater reliability in measurement of knee ROM; ICC for rater 1 was 0.990, with 95% CI 0.985-0.993, for rater 2, ICC was 0.989 with 95% CI 0.984:0.993 and for rater 3 ICC was 0.971 with 95% CI 0.959:0.981. (Table 3).

Interrater reliability of knee ROM measured by Kinovea program:

Kinovea program showed excellent inter-rater reliability in measurement of knee ROM; ICC for trial 1 was 0.987, with 95% CI 0.982-0.991, for trial 2, ICC was 0.989 with 95% CI 0.985:0.993. (Table 4).

Table (3): Intra-rater reliability of Kinovea program in measurement knee ROM.

Knee flexion	ICC	(95% CI) Lower bound	(95% CI) Upper bound	*p*-value	SEM	SDC
Rater 1	0.990	0.985	0.993	0.001	0.52	1.43
Rater 2	0.989	0.984	0.993	0.001	0.55	1.53
Rater 3	0.971	0.959	0.981	0.001	0.85	2.35

ICC: Intraclass correlation coefficient value.
CI : Confidence Interval.
p-value: Probability value.
SEM : Standard error of measurement.
SDC : The smallest detectable change.

Table (4): Inter-rater reliability of Kinovea program in measurement knee ROM.

Knee flexion	ICC	(95% CI) Lower bound	(95% CI) Upper bound	*p*-value	SEM	SDC
Trial 1	0.987	0.982	0.991	0.001	0.58	1.62
Trial 2	0.989	0.985	0.993	0.001	0.54	1.51

ICC: Intraclass correlation coefficient value.
CI : Confidence Interval.
p-value: Probability value.
SEM : Standard error of measurement.
SDC : The smallest detectable change.

Discussion

This study was designed to investigate the intrarater and interrater reliability of the Kinovea program in measuring knee joint ROM in healthy subjects. The results of the current study showed excellent both intrarater and interrater reliability of Kinovea program in measuring knee ROM in healthy subjects. The intrarater reliability ICC for raters 1, 2, and 3were 0.990, 0.989, and 0.972 respectively with 95% CI (0.956-0.993) and $p<0.001$. The interrater reliability ICC for the first and second trials were 0.987, 0.989 respectively with 95% CI (0.982-0.993) and $p<0.001$. These results reject the null hypotheses that Kinovea program has neither intrarater nor interrater reliability in measuring knee joint ROM.

The results of the current study showed excellent intrarater reliability of Kinovea program in measuring knee ROM in healthy subjects. The results of the current study are in agreement with other studies in measuring full ROM of other joints *[6,9,11]*.

Abd El-Raheem et al. *[11]* measured the dominant wrist ROM of 100 subjects (male and female). They concluded excellent intrarater reliability of Kinovea in measuring dominant wrist joint ROM (ICC from 0.926-0.987 with 95% CI). Although intrarater reliability of their study was analyzed using measurements of three sessions, only one rater measurements was used to conclude the intrarater reliability. However, the intrarater reliability in our study has more powerful statistical significance being analyzed for the three raters involved in the study. Also, they captured one video for every participant, then used it by all raters in the analysis phase; thus their study investigated the reliability of raters just in the analysis phase and ignoring the reliability of the video recording phase which may be affected by the recording angle and perspective *[5]*.

Also, Elwardany et al. *[9]* approved excellent intrarater reliability of Kinovea in measuring cervical ROM in sagittal plane using a sample of 65 normal subjects (ICC 0.920-0.995 with 95% CI and $p<0.05$). The video recording was done by all raters for every participant. Measurements of only one rater in three trials showed the results of the study. In the current study, the intrarater reliability of different three raters was investigated in two sessions, which inforce the conclusion of our results depending on the variety of raters.

Moreover,Elrahim et al. *[6]* discussed the intrarater reliability of Kinovea in measuring shoulder ROM on 55 participants. They found Kinovea to have excellent intrarater reliability in the measurements of shoulder ROM (ICC 0.95 to 0.98 with 95% CI). Though these results, the study has a designing drawback of time interval accepted to calculate an intrarater reliability. This time interval was just three hours between the two sessions of measurement. That few hours between the two sessions does not support ensuring the stability of results over extended time. The stability is a main feature of reliability as it assesses the consistency of measurement repetition *[21]*. Again, by using the same participant's video to be analyzed by all raters, their study investigated the reliability of the analysis phase and dropped-out the effect of video recording angle on the end result reliability in clinical use *[5]*.

Furthermore, the results of the current study are supported by the results of Damsted et al. *[13]*; Hisham et al. *[12]*; and Fernández-González et al. *[14]* which discussed the intrarater reliability of Kinovea in measuring different joints ROM during functional activities.

Enforcing the results of the current study, Damsted et al. *[13]* assessed intrarater, both within and between days reliability of Kinovea for the analysis of knee angulations of 18 recreational runners at foot strike during running. Within day, the 95% prediction interval for the intrarater reliability varied 3° to 6° for the knee. Between day, the 95% prediction interval for the intrarater reliability varied 9° to 14°for the knee. They concluded that the angular difference ratio obtained was sufficiently accurate to encourage the in-clinic use of Kinovea. However, it remains controversial if these intervals, indicating the size of the differences between the ratings, are clinically relevant and thus affect the possibility of measuring joint angles in clinical practice. Also, small sample size of the study limits its results generalization.

In support to the current study, Hisham et al. *[12]* haveinvestigated the reliability of Kinovea in measuring ankle ROM of 3 subjects while walking by only one rater. They concluded its reliability with no statistically significant difference (variance <5%) in the data for the same subject under different trials. However, their study was a small sample size which makes it limited to be generalized to population. In addition to depending on one observer in obtaining measurements that weakens the study power.

Moreover, Fernández-González et al. *[14]* proved good intrarater reliability of Kinovea program in measuring hip, knee, and ankle joints ROM of 50 healthy subjects during initial contact of the gait cycle in two separate sessions (ICC 0.859-0.886 with 95% CI and $p<0.05$). These results of just good intrarater reliability may be due to variability sources of procedures as marker position error, and processing errors (rater error as in identification of gait cycle event) *[22]*.

All of the previous three studies of Damsted et al. *[13]*; Hisham et al. *[12]*; and Fernández-González et al. *[14]* have a methodological drawback; as the same video recordings were used by all raters to investigate the intrarater reliability of Kinovea, which ignore the effect of the recording angle-differing

from a rater to another on the investigated reliability [5]; thus making their results questionable.

Puig-Diví et al. [5] discussed the intrarater reliability of Kinovea in obtaining distance and angles from coordinates in different perspectives (90º, 75°, 60º and 45º). A printed geometric figure with 25 numbered marks resembling lower limb moments during gait cycle was used for that purpose. They concluded excellent intrarater reliability of Kinovea program in obtaining distances and angles from coordinates in different perspectives (ICC = 0.99-1 with 95% CI). However, the differences found between the four tested perspectives suggest that Kinovea is best employed at 90˚ rather than 45˚. This study main drawback is the usage of a printed geometric cardboard; which do not support its application on real subjects.

The results of the current study showed excellent interrater reliability of Kinovea program in measuring knee ROM in healthy subjects. The results of the current study are in line with other studies in measuring full ROM of other joints [6,9,11].

Abd El-Raheem et al. [11] measured the dominant wrist ROM of 100 subjects (male and female). The results showed good to excellent interrater reliability of Kinovea in measuring ROM of dominant wrist joint (ICC 0.877-0.979 with 95% CI). The current study approved excellent interrater reliability of Kinovea depending on the measurements of two sessions, which superimpose good to excellent interrater reliability by analysis of one session measurements as in the aforementioned study. Also, they depend on the same captured video to be analyzed by all raters which did not consider the effect of the angular differences while recording on the investigated reliability [5].

Also, Elwardany et al. [9] studied the Kinovea reliability in measuring cervical ROM from sagittal plane on 65 participants. They concluded excellent interrater reliability (ICC 0.988-0.997 with 95% CI and $p<0.05$). Prior training of raters and following of a standard protocol procedures gave hand in decreasing data sources of error; that should be applied in other research protocols in addition to clinical practice.

Moreover, the study of Elrahim et al. [6] showed excellent interrater reliability of Kinovea in the measurements of shoulder ROM of 55 healthy subjects (ICC 0.98 to 0.99 with 95% CI). This study depended on putting of some landmarks over clothes. Even the clothes were light, it is still more movable landmark than usual skin landmark; that bring more measurement error to the study results. Another methodological deficit is the dependence on one video recording for the analysis by all raters, which ignored the clinical fact that video capturing for the same participant may be done by different raters resulting in different capturing angle. That fact had to be considered while study planning as affecting the reliability end result [5].

Furthermore, Wardany et al. [10] found good interrater reliability of Kinovea in measuring of cervical ROM in frontal plane (ICC 0.779-0.789 at $p<0.0001$). The study sample size consisted of sixty four normal subjects. Though that the study sample size was small, their study still have other positive points mainly its procedures standardization.

Damsted et al. [13]; Fernández-González et al. [14]; and Vargas et al. [15] discussed the interrater reliability of Kinovea in measuring different joints ROM during functional activities, concluding results that agree with the results of the current study.

In line with the current study, Damsted et al. [13] assessed interrater within day reliability of Kinovea for the analysis of knee and hip angulations of 18 persons at foot strike during running. With 95% prediction interval for the inter-rater reliability, the range varied from 6° to 8° for the knee angle. The variability of measurement that excess 5° should arouse concern and may be sufficient to mislead clinical interpretation [23]. The two raters participated in the study used the same video recordings; thus their study of the reliability was limited to the analysis phase only and did not investigate the whole process starting from recording. The recording angle may alter between different capturers and thus affecting the reliability [5].

In agreement with the current study, Fernández-González et al. [14] concluded excellent interrater reliability of Kinovea program in measuring hip, knee, and ankle joints ROM of 50 normal participants during initial contact of the gait cycle (ICC 0.933-0.994 with 95% CI and $p<0.05$). However, they studied measurement of knee angle only at initial contact not full ROM; that does not support the clinical use of Kinovea and limits it to that gait phase analysis only. Their study did not take in consideration to investigate the video recording phase reliability in order to the joint angle measuring reliability; as different video capturing perspective results in different reliability levels [5].

Also, supporting the results of current study, Vargas et al. [15] used a subcohort from the total investigation sample (20 videos from a total of 26 videos). The studyapproved excellent interrater reliability of Kinovea program in measuring knee angle measurements (ICC = 0.975). Measurements was at initial contact phase as well as 33ms and 66ms following initial contact. The study aimed to investigate the mechanisms of non-contact secondary ACL injuries. This results is limited by insufficient sample size hindering its generalization. Also, measuring knee angle only at initial contact, 33ms, and 66ms after initial contact is not full knee ROM, while the current study results support Kinovea usual clinical application by approving its reliability in

measuring full knee ROM. Vargas et al. **[15]** used the same videos to discuss the interrater reliability of Kinovea in measuring knee angle at initial contact. Using the same videos to investigate reliability excludes the effect of video recording from different angles on end results reliability. That can be explained by their study goal of investigating ACL injuries and thus collecting the injury videos from different sources.

Puig-Diví et al. **[5]** investigated the interrater reliability of Kinovea in obtaining distance and angles from coordinates in different perspectives (90°, 75°, 60° and 45°). A geometric printed cardboard with a drawn lower limb simulating 5 moments of the human gait cycle was used. Although their results proved excellent interrater reliability (ICC = 0.99-1 with 95% CI), which come in agree with the results of the current study, that does not support its clinical use. This is due to using of a 2D printed geometric cardboard and not a real subject. Nevertheless, their findings that Kinovea is best employed at 90º rather than 45°, may help in standardization of obtaining angles and distance by Kinovea software in future studies.

Further studies is recommended on female subjects, patients' population, obese subjects, and to investigate passive knee flexion, passive and active knee extension.

Conclusion:

The Kinovea program has excellent intrarater and interrater reliability in measuring knee ROM in healthy subjects. Kinovea program is a cheap applicable tool that can be used in clinical settings as well as research studies.

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مصداقية برنامج كينوفيا فى قياس المدى الحركى لمفصل الركبة

الخلفية العلمية: إنتقييم المدى الحركى للركبة له أهمية كبيرة نظراً لاستخدامه الواسع فى تخصصىّ العظام و التأهيل. إن كينوفيا هو برنامج مجانى يستخدم القياس الافتراضى لقياس زوايا المفاصل. وعلى الرغم من ذلك، فإن مصداقية برنامج كينوفيا لقياس المدى الحركى الكامل للركبة لم يتم بحثه.

الغرض: صُممت هذه الدراسة لبحث مصداقية برنامج كينوفيا داخل المقيّم، وبين المقيّمين فى قياس المدى الحركى لمفصل الركبة.

المشاركون: مائة شخص من الذكور الأصحاء من طلبة وموظفيّ جامعة الاسكندرية بمتوسط عمر ٢٢,٦٢±٣,٧٢ عاماً، و بمتوسط مؤشر كتلة الجسم ٢٢,٥٦±١,٧٨ كجم/م2.

الطريقة: تم استخدام كاميرا رقمية و جهاز حاسب آلي محمول محمّل ببرنامج كينوفيا. تسجيلات فيديو المدى الحركى لمفصل الركبة لكل مشارك تمّ قياسها من قبل ثلاثة مقيّمين (أ، ب، ج) باستخدام برنامج كينوفيا فى جلستين منفصلتين بينهما أسبوع، من أجل تقييم مصداقية داخل المقيّم، وبين المقيّمين.

النتائج: كان هناك مصداقية ممتازة لبرنامج كينوفيا فى مصداقية الأشخاص المقيّمين بمعامل ارتباط للمقيّم أ ٠,٩٩٠ مع ٩٥٪ فترة ثقة (٠,٩٨٥–٠,٩٩٣)، للمقيّم ب ٠,٩٨٩ مع ٩٥٪ فترة ثقة (٠,٩٨٤–٠,٩٩٣) وللمقيّم ج ٠,٩٧٢ مع ٩٥٪ فترة ثقة (٠,٩٥٩–٠,٩٨١). وكذلك كان هناك مصداقية ممتازة لبرنامج كينوفيا فى مصداقية ما بين المقيّمين فى قياس المدى الحركى لمفصل الركبة؛ معامل الارتباط للمحاولة ١ كان ٠,٩٨٧ مع ٩٥٪ فترة ثقة (٠,٩٨٢–٠,٩٩١)، وللمحاولة ٢ كان معامل الارتباط ٠,٩٨٩ مع ٩٥٪ فترة ثقة (٠,٩٨٥–٠,٩٩٣).

الاستنتاج: برنامج كينوفيا هو أداة ذات مصداقية، رخيصة، سهلة، وقابلة للتطبيق وبالتالى ممكن استخدامها فى قياس المدى الحركى لمفصل الركبة فى الممارسات الاكلينيكية اليومية.