Review Article: Methods Used for the Assessment of Knee Joint Arthrokinematics: A Review of Literature

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ABSTRACT

Background: Studying joint arthrokinematic motion parameters can be valuable to health professionals in terms of diagnosis of illnesses and injuries of the joint, assessment of treatment results, and identifying the type and degree of injury.

Objectives: An exhaustive review of the methods for the assessment of knee joint arthrokinematics is provided.

Methods: Some known databases, including ScienceDirect, PubMed, EMBASE, CINAHL, and Google Scholar were explored for articles published from 1985 to February 2020.

Results: After the assessment steps, 14 articles were chosen based on the criteria and objectives of the research; 13 articles in entirety and one as a summary. Through a review of the studies, it was observed that various methods were used for the assessment and measurement of knee joint arthrokinematic movements. In the beginning, the focus was on transitional motion, in which knee arthrokinematic movements were studied in the static state; but over time, knee transitional movement was studied in a dynamic state as well. More recent studies scrutinized three main types of arthrokinematics: motion rolling, gliding, and spinning. There were also studies that tried to implement tools, which required minimum cost and scrutinized the knee arthrokinematic movements without complicated state-of-the-art equipment. All the used equipment was designed aiming to diagnose how the arthrokinematic movements of an injured knee compared to a healthy one.

Conclusion: Results of our analysis showed that the literature is rich with a variety of instruments for measuring knee arthrokinematic movements. By classifying the instruments, it was found that studies of four different measurement methods, including static, dynamic, functional, and qualitative examined the arthrokinematic movements of the knee.

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1. Background

The knee is a large synovial joint with three internal capsular joint surfaces (two tibiofemoral medial and lateral joints, which bear the weight and a patellofemoral joint surface); it is protected by various tendons, ligaments, muscles, bones, and cartilages [1]. Being exposed to external forces, these elements are more prone to injury [2, 3]. In athletes, these injuries are caused by either severe and sudden impacts or weak and repetitive ones and lead to acute, gradual, or chronic clinical symptoms; they may bring about abnormal arthrokinematic of the knee joint [4].

Abnormal arthrokinematic of the knee joint changes the force distribution and loading mechanisms of different joint structures; thus, it not only augments the primary injury but also it may be a predisposing factor, which increases vulnerability in ligament and other joint structures [5]. Abnormal motion leading to stress occurs at the first few degrees of movement or at the beginning of an activity. It is believed that the major disturbance occurring at the first degrees of motion is an arthrokinematic movement, not an osteokinematic one [6].

Kinematic knowledge is also essential for proper diagnosis and surgical treatment of joint disease and the design of prosthetic devices to restore function. In general, kinematic analysis of human movement can be categorized into two main areas:

1. Gross movement of the limb segments interconnected by joints, where the relative three-dimensional joint rotation is described by adopting the Eulerian angle system. With proper selection of axes of rotation between two bone segments, the associated finite rotation becomes sequence-independent. This concept is particularly useful since it matches precisely the clinical definition of joint motion.

2. Detailed analysis of joint articulating surface motion, where generalized three-dimensional, unconstrained rotation and translation are described utilizing the concept of the screw displacement axis [7]. Osteokinematic is the movement of bones relative to one another and can be done actively or passively [8]. Arthrokinematics deals with the real movement of joint surfaces on each other and focuses particularly on momentary movements, which take place in the joint between the joint surfaces [9].

Osteokinematics is the branch of biomechanics concerned with the description of bone movement when a bone swings through a range of motions around the axis in a joint, such as with flexion, extension, abduction, adduction, or rotation [10]. Osteokinematics describes clear movements of bones, which are visible from the outside. They are gross movements that happen between two bones. They arise from rotation around the joint axis. Osteokinematics differs from arthrokinematics. In general, osteokinematics means bone movement and arthrokinematics is joint movement (represents the small movements happening at the joint surface itself) [11]. Arthrokinematics refers to the movement of joint surfaces.

Three main types of arthrokinematic motion occur between two joint surfaces: rolling (rotary or angular), gliding (sliding), spinning (rotational). The angular movement of bones in the human body occurs as a result of a combination of rolls, spins, and slides. A roll is a rotary movement when one bone rolls on another. A slide is a translatory movement, sliding of one joint surface over another [10]. Most the joint movements are a combination of the three [12]. Normal osteokinematic motion is not possible without arthrokinematic motion [13]. One of the factors that predict the complexity of human joints is their arthrokinematic movements. Even though these movements are not voluntary, they are essential for the movability and the natural functioning of the joint [14]. Studies have identified perturbation in arthrokinematic motion as the cause of movement disorders that result in the degradation of knee joint surfaces [15].

Hence, studying joint arthrokinematic motion parameters can be valuable to health professionals in terms of diagnosis of illnesses and injuries of the joint, assessment of treatment results, and identifying the type and degree of injury. This is the case when there is no exhaustive study to set how kinematic parameters of the knee could be measured and assessed, or whether assigning a numerical value to arthrokinematic movements is feasible or not. As a result, the present study was a review of arthrokinematic movements of the knee joints in order to provide exhaustive data about the assessment of accessory (arthrokinematic) movements of the knee and the required tools.

Objectives

An exhaustive review of the methods for the assessment of knee joint arthrokinematics is provided.

2. Methods

This is a systematic review based on guidelines of preferred reporting items for systematic reviews and meta-analyses (PRISMA).

Search strategy

Primary sources were obtained from nine databases, including ScienceDirect, MEDLINE/PubMed, LILACS, SCOPUS, CENTRAL (Cochrane Central Register of Controlled Trials), CINAHL, PEDro, Web of Science, and Google Scholar. The search period covered years from inception to February 2020. These electronic databases were searched using a combination of the following keyword groups: knee* and arthrokinematics* or knee arthrokinematics or accessory movement* and motion quality of the knee* or in vivo knee kinematics or three-dimensional movement* and range of motion.

Eligibility criteria

Search for articles was narrowed down by title and articles in the English and Persian languages, human studies, original articles, and review articles were included. Once the search results were gathered, the title and then the summary of the articles were studied. If the articles matched the inclusion criteria, they were used in the review; otherwise, they were discarded.

Study selection

At the first step, titles and abstracts of descriptive articles were examined with a focus on assessment methods of knee joint arthrokinematics published in English and Persian. A research assistant independently studied the abstracts of articles. In the second phase, the whole text was studied according to the following factors: indicator release (methods for knee joint arthrokinematic assessment) and definition of the target group. The whole text was checked by a single researcher. Also, a senior researcher checked the final list of the articles in order to make sure they all matched the purpose of the research. Target group definition implies whether it is specified which joint (e.g. knee, ankle, waist, etc.) the arthrokinematic assessment was done onto. In cases where the tool was used other than knee joint, the article was discarded. A summary of descriptive information was gathered by the research assistant and checked by the senior researcher. A sample chart (Figure 1) was used for the extraction of information on the target group, arthrokinematic assessment of knee joint, and their results (Table 1).

Quality evaluation

Physiotherapy Evidence Database "Remote Optics" (PEDro) was used to calculate the scores of quality assessment for the eligible studies. The total PEDro score was 11 and incorporated statistical analysis and evaluation criteria of internal validity. Studies that scored 7-11 were considered methodologically "high", 5 to 6 were "fair", and ≤4 were considered "poor" [16].

3. Results

The process of selection of the articles is shown in Figure 1. A total number of 155 articles were found from ScienceDirect, MEDLINE/PubMed, LILACS, SCOPUS, CENTRAL (Cochrane Central Register of Controlled Trials), CINAHL, PEDro, Web of Science, and Google Scholar. By checking the sources of the articles, six more articles were added. After the omission of duplicates, 121 abstracts were chosen for the review. After further study of the titles and abstracts, 86 articles were discarded and the number of the articles to be read fully was cut down to 35. After studying the full texts, 14 articles, which had studied the methods for arthrokinematic assessment of knee joint were chosen, and their results are reported in Table 1. By classifying the instruments, it was found that studies of four different measurement methods, including static, dynamic, functional, and qualitative had examined the arthrokinematic movements of the knee (Table 2). According to the PEDro Scale, all studies scored above 7; therefore, studies examining the assessment methods of knee joint arthrokinematics were of the high-quality category (Figure 1).

4. Discussion

The present review was done to study the methods for the assessment and measurement of arthrokinematic motion of knee joint. It was observed that different methods were used to study arthrokinematic motion of the knee joint. Here, 14 articles (classified in four different measurement methods, including static, dynamic, functional, and qualitative) were specified and their methods were further examined.

Tools measuring static knee arthrokinematic movements

Daniel et al. designed the first instrument for measuring the glide of the tibia on the femur (MEDmetnc Arthrometer, model KT1000). This tool was primarily designed to diagnose the degree of tear in anterior and posterior ligaments in the knee. Previously, through functional tests (such as Lachman test, Anterior Drawer Test, Jerk, etc.) tears in knee ligaments were diagnosed, and these tests qualitatively scrutinized the degree of glide of the tibia on femur and spotted tears in anterior and posterior knee ligaments. However, it was designed to measure glide of the tibia on femur numerically and measured the

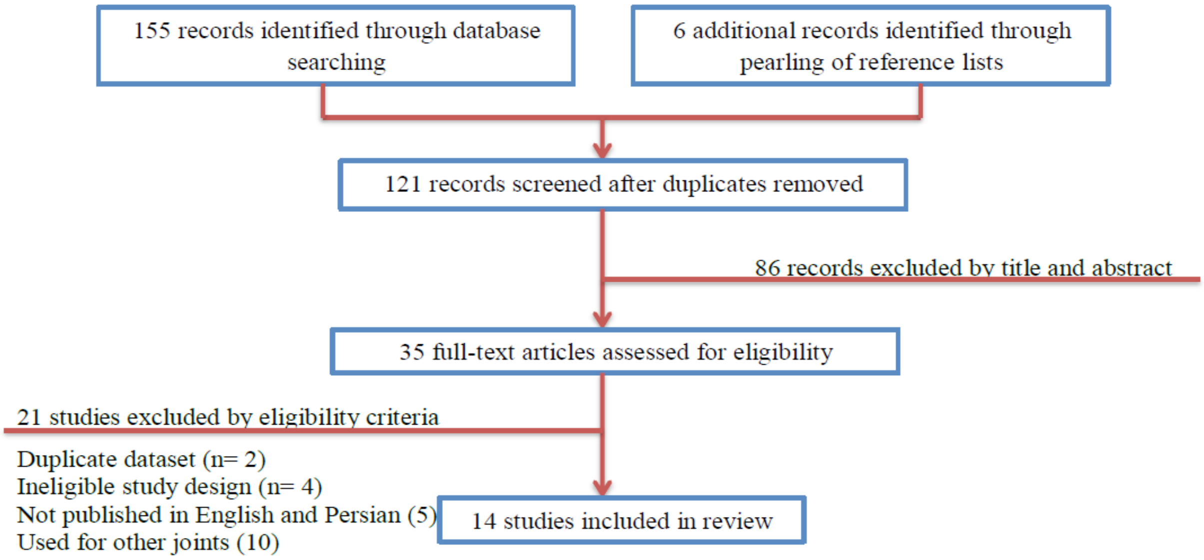

Figure 1. Flowchart for screening of articles

glide with an accuracy of up to 0.5 mm [17]. In keeping with the present study and similar to this tool, Robert et al. designed and built a machine called GNRB laxity measurement. It performs the same task as Arthrometer but its accuracy is reported as 0.1 mm [14]. Fujie et al. introduced an instrument called Robotic Testing System, an earlier version of which was designed years earlier. This instrument, however, had advantages, including enhancing repeatability of the situation from 0.5 to 0.05, as well as controllability of the applied force and, as a result, motion control. The machine was designed for synovial joints and was capable of measuring the degree of motion, or gliding of the joint in arthrokinematic terms. This tool fixed the proximal bone, the force was exerted on the distal bone, and consecutively the movement of the distal bone was measured relevant to the proximal bone. Force and motion were measured by a sensor connected to a computer [18]. Vergis et al. offered Electrogoniometer and Fluoroscopy for knee arthrokinematics measurement, which assessed rotation and linear movement of the tibia on the femur [19, 20]. Moreover, Amerinatanzi et al. used MRI and an automated Matlab-based measurement to examine tibia slope on the femur [21]. Interestingly, all the existing tools measure static knee arthrokinematic movement, and a few studies have measured dynamic movement.

Tools measuring dynamic knee arthrokinematic movements

Hollman et al. used two cameras and a software program to analyze weighed and weight-free knee arthrokinematic movement. They reported that rolling movement was more frequent in the weighted state than the weight-free state in the final phase of knee extension [22]. Similarly, Tashman et al. studied static and dynamic knee arthrokinematics movement. They performed biplanar knee stereo radiography and measured tibial rotation on the femur (flexion, extension, abduction, adduction, internal rotation, and external rotation) [23]. Bey et al. also applied stereo radiography but used their own model for the analysis of patellofemoral arthrokinematic motion. They reported highly accurate results but only measured static movement [24]. Wu et al. utilized the VICON 3D motion system to examine tibial angle, velocity, speed, and linear movement on the femur [25]. They measured dynamic arthrokinematic motion in walking mode but failed to report the accuracy of their measurements. There are also studies that measured functional and real-speed knee arthrokinematic movement.

Tools measuring functional and real-speed knee arthrokinematic movements

Guan et al. examined fluoroscopy data in functional mode [26], which were studied by Vergis et al. in static mode. Guan et al. measured real and functional performance to help with rehabilitation, diagnosis, and treatment decisions. Yang et al. used computed tomography to study kinematic and arthrokinematics movements, and the path of the center of closest contact in normal people compared to those with an ACL injury during walking and running practices. They showed that anterior-posterior translations were significantly larger in ACL-deficient than unaffected knees, and found that closest contact points on the femur in ACL-deficient

Table 1. Results of the research assessing arthrokinematic assessment of knee joint

Researchers	Measuring Tools	Measurement Accuracy	Objectives	PEDro Scale	Descriptions
Daniel et al. [17]	KT-1000 arthrometer	Nearest 0.5 mm	Measurement of The anteroposterior tibial translation	9/11	The arthrometer was applied to the leg oriented in a position so that pressure on the patellar sensor pad will stabilize the patella within the femoral trochlea. This usually orients the force handle parallel to the foot axis. Constant firm pressure was then applied to the patellar sensor pad and maintained throughout the test. The patellar pad pressure must remain constant during the test because variation in this pressure will alter the position of the patellar sensor pad secondary to soft tissue and cartilage compression and will result in spurious measurements.
Fujie et al. [18]	Robotic testing system	Position repeatability 0.05 mm	An Anterior-Posterior (A-P) translation	7/11	Robotic technologies were modified to control and measure both the force and position of synovial joints for the study of joint kinematics. Such a system was developed to perform kinematic testing of a human joint. A 6-axis articulated robotic manipulator with 6 Degrees of Freedom (DOF) of motion was designed and constructed; a mathematical description for joint force and position was devised; and hardware and software to control forces applied to the joint, as well as position of the joint, were developed.
Vergis et al [19]	CA-4000 electrogoniometer	The mechanical error in the system varies from 0.1 to 2.4% (median 1%) for sagittal displacement and from 0.1% to 0.6% (median 0.5%) for angular displacement	Measurement of the three tibial rotations and the sagittal anteroposterior translation	7/11	The electrogoniometer system was used to measure the three tibial rotations and the sagittal antero-posterior translation. The potentiometer for sagittal motion registered the difference in position between a patellar pad and the tibial tuberosity. The knee flexion/extension potentiometer was aligned with the center of the lateral femoral epicondyle. The femoral and tibial frames and the rotation module of the computerized goniometer linkage system were mounted on the knee. The potentiometer in the rotation module registered knee flexion-extension; the potentiometer was connected to the patellar pad, which registered the sagittal tibial displacement; the potentiometer registered varus-valgus; the potentiometer registered internal-external rotation.
Vergis et al. [20]	Fluoroscopy	Validation: the absolute mean difference 0.4 mm and the 95% Confidence Interval (CI) ±0.5 mm. the absolute mean difference of the femorotibial per degree of knee extension using the femoral point 0.07 mm degree-1(95% CI ±0.02 mm) and using the patellar point 0.03 mm degree-1(95% CI±0.02)	Measurement of the three tibial rotations and the sagittal anteroposterior translation	8/11	The fluoroscopy table (Philips Multidiagnost DSI) was tilted to 90 degrees, and the footrest was used as a 21-cm high step. Lateral radiographs of the knee were obtained at 8 frames/ s, using 75 ms X-ray pulses. A 100-mm graduated radiological marker was taped to the center of the patella. The foot of the test limb was taped on the step; the body was elevated and the contralateral limb followed.
Hollman et al. [22]	Panasonic AG-455P SVHS video cameras and Ariel Performance Analysis System	Accurate measurements of linear (mean error less than 2 mm) and angular (mean error less than 0.3°) standards	Measurements of the linear and angular motion	7/11	Movements were recorded with two Panasonic AG-455P SVHS video cameras. Kinematic data were processed with Ariel Performance Analysis System (APAS). APAS software provided accurate measurements of linear and angular standards.
Tashman et al. [23]	Stereoradiographic system (biplane X-ray)	The static bone position has been well established, with precision reported in the ±10 to 250 μm range. Dynamic knee motion measurement, with 3D accuracy of ±0.1 mm and rates up to 1000 frames/s	Three dimensional (3D) studies. Dynamic and static knee motion	9/11	During the ACL reconstruction procedure, tantalum spheres (1.6-mm diameter) were inserted into the distal femur and proximal tibia of both limbs using a cannulated drill. These markers provided high-accuracy radiographic targets for radiostereophotogrammetric analysis.

Researchers	Measuring Tools	Measurement Accuracy	Objectives	PEDro Scale	Descriptions
Bey et al. [24]	Biplane x-ray imaging combined with model-based tracking	Overall dynamic accuracy indicated errors of less than 0.395 mm for the patellar shift, 0.875° for flexion, 0.863° for tilt, and 0.877° for rotation	Measuring in-vivo motion of the knee's patellofemoral	10/11	To assess the accuracy of this technique, tantalum beads were implanted into the femur and patella of three cadaveric knee specimens, and then dynamic biplane radiographic images were recorded while manually flexing and extending the specimen. The position of the femur and patella was measured from the biplane images using both the model-based tracking system.
Robert et al. [14]	GNRB laxity measurements	0.1 mm precision	Measurement of the antero-posterior tibial translation	7/11	The GNRB® is a knee laxity testing device for the measurement of anteroposterior tibial translation at 20◦ of knee flexion leading to reproducing the Lachman test position.
Wu et al. [25]	VICON 3D motion system	Indistinctive	Arthro-kinematics through 3D motion tracking	7/11	Reflective markers were attached to bony landmarks according to the Plug-in Gait module within the VICON 3D motion system. The knee arthro-kinematic parameters included translation, knee flexion-extension angle, angular velocity, and angular acceleration of the tibiofemoral joint.
Guan et al. [26]	mobile bi-plane X-ray (MoBiX) (CINARTRO)	Maximum root-mean-squared errors were 0.33 mm and 0.65 for translations and rotations of the TKA knee and 0.78 mm and 0.77 for translations and rotations of the intact knee	Functional knee joint arthokinematics	9/11	The overall dimensions of the system were 7.2 m 4.0 m 1.9 m (length width height) with the walkway measuring 7.2 m 2.0 m (length width). Each X-ray unit comprised of an X-ray tube and an image intensifier, which were mounted on a robotic arm that was translated along with the vertical guide of a mobile column. The mobile column was translated along with a horizontal guide that was positioned along the length of the walkway. The X-ray image captured volume translated both horizontally and vertically as a consequence of this configuration. Each imaging unit (X-ray tubes and intensifiers) had three lockable degrees of freedom (two horizontal translations and one rotation about a vertical axis) with respect to its linearly actuated mount, which allowed the configurations of the imaging units to be altered, thereby changing the inter-beam angle. An inter-beam angle of~60ºwas used in this study.
Yang et al. [27]	Computed Tomography (CT)	Accuracy of 0.7 mm or better in translation and 0.9 degrees or better in rotation	Measurements of the linear and angular motion	8/11	The knees of each subject were scanned by computed Tomography (CT) (Light Speed Pro 16, GE Medical Systems) from 15 cm proximal to 15 cm distal to the joint line with a slice interval of 0.625 mm. Subject-specific CT-based bone models of the femur and tibia were matched to the biplane radiographs using an automated matching process. Coordinate systems constructed in the femur and tibia were used to calculate relative translations (anterior–posterior, medial-lateral, and proximal-distal) and rotations (flexion–extension, internal-external, and abduction–adduction).
Amerinatanzi et al. [21]	MRI and measured using an automated Matlab-based	Indistinctive	Slope measurement in three motion planes	8/11	The subjects were positioned supine, unloaded, and neutrally aligned during the collection of frontal, sagittal, and axial images. A custom code was developed in Matlab (Mathworks, Natick, MA, USA) to locate MRI slices in Mimics, perform curvature analysis, and calculate slope measurements from each slice.
Bączkowicz et al. [28]	Vibroarthrography (acceleration sensor)	Indistinctive	Quality of arthrokinematic motion	7/11	Each knee was assessed for the quality of arthrokinematic motion during an open-chain flexion/extension task using an acceleration sensor placed 1 cm above the apex of the patella.
Jonak et al. [29]	EEMD-RQA algorithms	Indistinctive	Quality of arthrokinematic motion	9/11	The acoustic signal was measured using an analogue contact microphone CM01b connected to a National Instruments data acquisition card. The signal was sampled at 1kS/second for 30 seconds. The analogue to digital converter resolution was set at 16 bits. At 5V reference voltage, this resulted in about 76 microvolts resolution. The recorded data were subjected to signal analysis. The studies were connected with RQA (Recurrence Quantification Analysis) preceded by EEMD (Ensemble Empirical Mode Decomposition) filtration methods used for acquired bioacoustic signals.

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Table 2. Classification of the available tools for assessing knee joint arthrokinematics

Classifications	Measuring Tools	Measurement Accuracy	Objectives	Researcers
Tools measuring static knee arthrokinematic movements	KT-1000 arthrometer	Nearest 0.5 mm.	Measurement of the anteroposterior tibial translation	Daniel et al. [17]
	GNRB laxity measurements	0.1mm precision	Measurement of the anteroposterior tibial translation	Robert et al. [14]
	Robotic testing system	Position repeatability 0.05 mm	An anterior-posterior (A-P) translation	Fujie et al. [18]
	CA-4000 electrogoniometer	The mechanical error in the system varies from 0.1 to 2.4% (median 1%) for sagittal displacement and from 0.1% to 0.6% (median 0.5%) for angular displacement	Measurement of the three tibial rotations and the sagittal anterior-posterior translation.	Vergis et al. [19]
	MRI and measured using an automated Matlab-based	Indistinctive	Slope measurement in three motion planes	Amerinatanzi et al. [21]
	Fluoroscopy	Validation: the absolute mean difference 0.4 mm and the 95% Confidence interval ±0.5 mm. the absolute mean difference of the femorotibial per degree of knee extension using the femoral point 0.07 mm degree-1(95% CI ±0.02 mm) and using the patellar point 0.03 mm degree-1(95% CI±0.02)	Measurement of the three tibial rotations and the sagittal anteroposterior translation	Vergis et al. [20]
Tools measuring dynamic knee arthrokinematic movements	Panasonic AG-455P SVHS video cameras and Ariel Performance Analysis System	Accurate measurements of linear (mean error less than 2 mm) and angular (mean error less than 0.3°) standards.	Measurements of the linear and angular motion	Hollman et al. [22]
	Stereoradiographic system (biplane X-ray)	The static bone position has been well established, with precision reported in the ±10 to 250 µm range. dynamic knee	Three dimensional (3D) studies Dynamic and static knee motion	Tashman et al. [23]
	Biplane x-ray imaging combined with model-based tracking	Overall dynamic accuracy indicated errors of less than 0.395 mm for the patellar shift, 0.875° for flexion, 0.863° for tilt, and 0.877° for rotation	Measuring in-vivo motion of the knee's patellofemoral	Bey et al. [24]
	VICON 3D motion system	Indistinctive	Arthro-kinematics through 3D motion tracking	Wu et al. [25]
Tools measuring functional and real-speed knee arthrokinematic movements	mobile biplane X-ray (MoBiX) (CINARTRO)	Maximum root-mean-squared errors were 0.33 mm and 0.65 for translations and rotations of the TKA knee and 0.78 mm and 0.77 for translations and rotations of the intact knee.	Functional knee joint arthokinematics	Guan et al. [26]
	Computed Tomography (CT)	Accuracy of 0.7 mm or better in translation and 0.9 degrees or better in rotation	Measurements of the linear and angular motion	Yang et al. [27]
Tools measuring qualitative knee arthrokinematic	Vibroarthrography (acceleration sensor)	Indistinctive	Quality of the arthrokinematic motion	Bączkowicz et al. [28]
	EEMD-RQA algorithms	Indistinctive	Quality of the arthrokinematic motion	Jonak et al. [29]

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knees were consistently more anterior in the lateral compartment [27]. However, there are studies that used easy-to-use, simpleand inexpensive tools for the analysis of knee arthrokinematic movements.

Tools measuring qualitative knee arthrokinematic

Bączkowicz et al. used vibroarthrography to evaluate the quality of knee arthrokinematic movements in individuals with osteoarthritis. They measured the mean, speed, and fluctuation of knee motion using an accelerator sensor connected to the patella [28]. Motion quality was measured before and after rehabilitation, prediction, and diagnosis. The advantage of this model to other tools is that it is easy-to-use, inexpensive, and needs no advanced high-tech instrument. Jonak et al. used EEMD-RQA algorithms to study arthrokinematic movements and also used vibration signals to measure the quality of motion [29]. In this model, the internal level of joints can be examined without invasive intervention.

The results of the study of static knee arthrokinematic assessment methods showed that the measurement accuracy of these tools at 0.5 mm [17] reaches 0.05 mm and the error rate decreases by one percent [18]. This indicates that, over time, the accuracy of the tools used to measure knee arthrokinetic movements increases statically. In addition to tibial transitional motions relative to the femur, arthrokinematic rotational movements were also measured [19, 20], but the disadvantages of these methods are that they evaluate arthrokinematics in a static state, while all arthrokinematic movements are performed in a functional and dynamic state. Over time, VICON 3D motion system and fluoroscopy instruments were developed to measure knee arthrokinematics, which is an advantage over the static method [20, 25]. These tools are evaluated by a dynamic and functional arthrokinematic method, and the data obtained from these tools are more reliable.

Fluoroscopy measurement accuracy has been reported to be 0.4 mm, which is lower than static methods; however, the accuracy of the VICON 3D motion system tool has not been reported, and future studies need to focus more on the measurement accuracy of these tools. Arthrokinematics were also studied using accelerator sensors [28, 29]. The advantage of these methods over previous studies is that they are simple and exploit inexpensive tools and evaluate the speed, acceleration, and quality of arthrokinematic movements. However, the accuracy of these tools has not been reported, which requires further studies to check for validity and accuracy. Summarizing the studies, it can be concluded that the instruments used to evaluate static arthrokinematics of the knee have a higher measurement accuracy than other instruments, but evaluate limited factors, while dynamic assessment methods and accelerator sensors evaluate several factors of knee arthrokinematics. Nevertheless, the accuracy of these tools needs to be further evaluated. The present study was systematic but offered no qualitative assessment of the literature. Though all the articles reviewed in this attempt were obtained from authentic journals, the results should be generalized with caution. Moreover, only articles in Persian and English were selected for analysis and there may be similar studies in other languages that were not included in our assessments. Considering the above limitations, it is suggested that further studies perform more qualitative analyses. It is also suggested that researchers examine arthrokinematic movements in other synovial joints to see what tools are good for this purpose.

5. Conclusion

Results of our analysis showed that the literature is rich with a variety of instruments for measuring knee arthrokinematic movements. Earlier studies had focused on the translational motion to examine the static movement of knee. However, dynamic knee arthrokinematic movement was later given more attention. There were some studies that used inexpensive and easy-to-use instruments for the analysis of the quality of knee arthrokinematic movements in individuals with knee injuries compared to normal knee functions.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

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Authors' contributions

Both authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interests.

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