Reliability of Digital Compass Goniometer in Knee Joint Range of Motion Measurement

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Objective: *To compare the reliability of range of motion measurement in the knee joint using a digital compass goniometer combined with inclinometer with standard range of motion measurement from roentgenographic picture.*
Material and Method: *Range of flexion and extension of the knee joint in volunteer participants was measured by the newly developed digital compass goniometer combined with inclinometer (DCG). The results were compared with range of knee joint motion obtained from standard roentgenographic picture by intraclass correlation coefficient.*
Results: *Range of motion of knee joint measured by DCG correlated very well with the data obtained from standard knee roentgenographic picture. The intraclass correlation coefficient equals 0.973.*
Conclusion: *The digital compass goniometer was a reliable tool to measure knee joint range of motion in flexion and extension plane.*

Keywords: *Arthrometry articular, Instrumentation, Equipment and supplies, Knee joint, Range of motion articular*

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Range of motion (ROM) of the joint is one of the factors that determine function of the musculoskeletal system. This parameter should be able to measure and record by an accurate and reproducible method.

Goniometry has been described as a tool to measure angle. It gives the physician a useful method to diagnose musculoskeletal function in terms of ROM, monitor the progress of an intervention, record the data for future follow-up, and meet statutory and legal requirements for impairment rating and disability determinations where applicable. Two-arm goniometer is still widely used in measuring uniaxial ROM of joint of extremity. It is an inexpensive tool and it can be applied in any plane. Its disadvantages include a limitation in an accuracy and reproducibility of the data. It is also difficult to position the device on patients with a poor bony landmark. Inclinometer, also called angle finder or level indicator, is a small angle measuring device used for measure angle and ROM of joint, work on the principle of gravity or gravity-related water level[1,2].

Knee joint, the major joint of the lower extremity, is frequently involved in degenerative process. In patients with advanced stage of osteoarthritis of the knee who required a total knee arthroplasty (TKA) operation, the goal of surgery is to provide the best possible outcome. ROM of the knee joint is one of the major factors determining the outcome after TKA. It is also an important measurement required by many knee scoring systems to determine the pre operative status and post operative outcome[3]. The ideal measuring device should give accurate and reproducible data. It must be easy to handle and apply on to the patient. To overcome those two drawback features of a simple goniometer, the authors designed a digital compass goniometer (DCG) specifically for the knee joint consisting of a digital compass angle finder combined with an inclinometer. The authors compared its reliability with a ROM data obtained from standard roentgenographic picture.

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Material and Method

The present study was conducted at the outpatient department of Chulalongkorn Hospital. Participants were recruited from patients with osteoarthritis of the knee who required TKA operation and were able to follow standard radiographic protocol. Exclusion criteria were patients who were unwilling to participate, unable to cooperate with standard radiographic protocol, or having an incomplete medical record.

A standard long cassette (14 x 17 inches) lateral roentgenographic picture of the knee was ordered. Two lateral pictures were taken separately while the knee was maintained in full extension and flexion, respectively. This will be done on either side or both depending on the patients' symptoms.

An invented goniometer was made using digital compass angle finder (Casio Model 2894, Casio Corp, Japan) and fluid base inclinometer (Fig. 1-3).

Measurement procedure and instrument application

The patient was positioned on the roentgenographic table in the lateral decubitus position with the involved knee up and the patient's trunk parallel to the longitudinal axis of the roentgenographic table. The pelvis was stabilized anteriorly at the pubic symphysis and posteriorly at the lumbar spine by a block supplemented with sand bags. Head, arm, chest, and contralateral leg were secured to the roentgenographic table. The involved knee was now freely mobile. The DCG instrument was applied on the lateral aspect of the leg. The landmark of the DCG located at 5 centimeters above the lateral malleolus. The inclinometer was checked for the parallelism between the leg and goniometer to control the plane of measurement. The lateral radiographic picture was taken while an involved knee was in the extension position and the angle read on the DCG was recorded simultaneously. These two comparative values were thus measured at the same time to reduce the erroneous from separated measurement. This step was repeated when an involved knee was in flexion position (Fig. 4-5).

The fluid level in the inclinometer was checked to control the horizontal plane between the leg and the digital compass in both flexion and extension position. This is done to ensure that the goniometer measured only a single plane of motion. Fig. 6 shows a fundamental function of the compass. The 360 degrees radius was divided by 16 directions. Each segment equaled 22.5 degrees.

Fig. 1 A front view of the digital compass angle finder

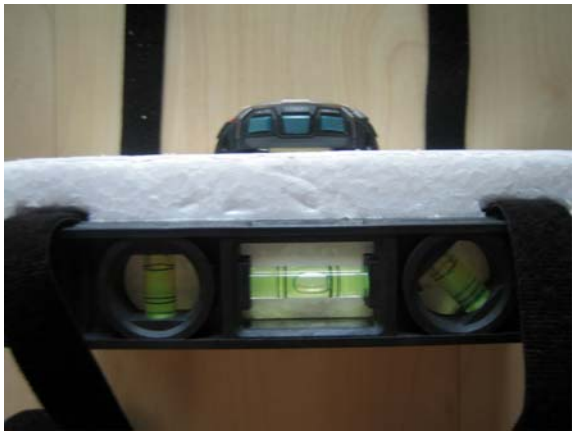

Fig. 2 A fluid base inclinometer with a digital compass angle finder mounted on the stable platform

Fig. 3 A top view of the designed instrument, note an inclinometer along the side and a digital compass angle finder on the top of the platform with a Velcro strap

Fig. 4 Positioning of the patient on the table with the DCG instrument mounted on the leg

Fig. 5 The inclinometer was checked to control plane of measurement. The angle read on the digital compass was recorded at the same time as the roentgenographic picture of the knee was taken.

The DCG displayed the direction in the numeric degree by reference from the North Pole. The number read from flexion and extension position was calculated with reference to zero degree to obtain an actual range of knee joint movement in horizontal plane. On the lateral knee film, the long axis of the femur and tibia was drawn. The angle formed by an intersection of these two lines was measured by standard handheld goniometer. This measurement was done on both flexion and extension film then the two

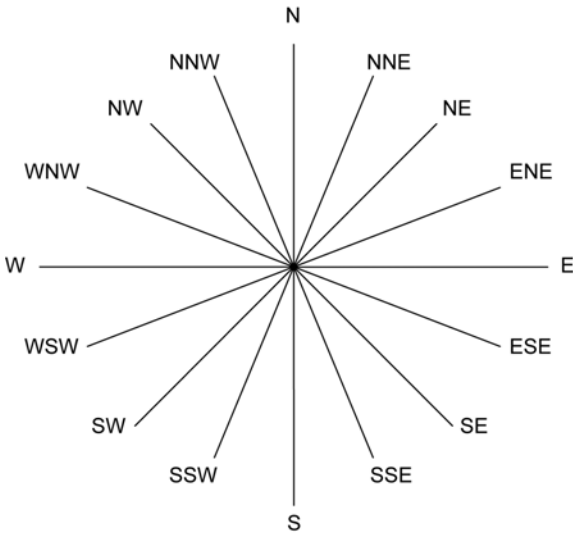

Fig. 6 Fundamental direction reading from the digital compass with 16 directions. N = North, S = South, NNE = North North East, SSW = South South West, NE = North East, SW = South West, ENE = East North East, WSW = West South West, E = East, W = West, ESE = East South East, WNW = West North West, SE = South East, NW = North West, SSE = South South East, NNW = North North West

was subtracted to find a range of knee joint motion from the standard lateral roentgenographic picture. Range of knee joint motion measured by the DCG in lateral decubitus position was then compared to the angle measured from lateral radiographic picture.

Data analysis

Data from the DCG and the radiograph was compared. Two independent testers were involved in the process of data interpretation. One tester analyzed the data from the DCG while the other took care of the data from standard roentgenographic picture. Agreement between these two sets of data was calculated by Intraclass correlation coefficient (ICC) to demonstrate a reliability of the developed device. The ICC varies from 0 to 1, the value above 0.75 indicates good reliability and those below 0.75 indicate moderate to poor reliability.

The authors conducted a pilot study of five cases for this instrument and resulted in ICC of 0.979 when compared to standard measurement. This gave a sample size of four knees calculated by Power Analysis Sample Size program (PASS). SPSS version

13.0 (SPSS Inc. Chicago, IL, USA) and PASS (NCSS, Kaysville, UT, USA) was used.

Results

There were 10 volunteer participants (15 knees) enrolled into the present study. All were patients with unilateral or bilateral osteoarthritis of the knee who required TKA operation. The examination was done on the involved side only. Table 1 shows the data from DCG and lateral knee roentgenographic picture.

The authors compared the ROM from the DCG with the one from standard measurement in the lateral radiographic picture in the same participant. The result of ROM was calculated for intraclass correlation coefficients (ICC). It was 0.973, which demonstrated that the DCG had a good reliability when it was compared to outcome from standard measurement (ICC > 0.75).

Discussion

Finding an accurate and reliable instrument to measure range of motion of the joint is always of interest to the physician. Knee joint pathology often required this measurement as part of treatment. In this study, we designed a digital goniometer using a digital compass direction finder that reported an angle. This should increase an accuracy when compare to reading the result from handheld goniometer either conventional or electronic-type. Then we combined the device with a fluid base inclinometer to control the measurement to unilateral plane of movement. The instrument's reliability was tested against the data obtained from the two-arm goniometer, as measured on the lateral radiographic picture, which is considered as a gold standard[2,4,5].

From the literature reviewed, result of reliability and validity testing of goniometric measurement at the knee indicated that it is an acceptable method[2,4,5]. Concurrent validity and intertester reliability of universal and fluid-based goniometer for active elbow ROM demonstrated that a fluid-based system might improve the validity and reliability of the instrument[6]. Comparison of the reliability of the electronic goniometer (Orthoranger) with the standard goniometer in assessing active lower extremity ROM found that the standard goniometer was more reliable than the electronic-type goniometer when used by a trained evaluator[7]. Intra- and intertester reliability and criterion validity of the parallelogram and universal goniometer for measuring maximum active knee flexion and extension in patient with knee restriction also found that the result taken on subjects with impaired knee ROM was reliable when using either the Parallelogram or Universal goniometer[8].

The main purpose of the present study was to test the reliability of this newly developed instrument.

Table 1. Raw data obtained from the measurement in each knee by digital compass goniometer and lateral radiographic picture

Patient	DCG			Roentgenographic picture		
	Extension	Flexion	ROM	Extension	Flexion	ROM
1) Left	NNE 15°	W 280°	95°	150°	60°	90°
2) Right	NNE 11°	E 90°	79°	154°	78°	76°
Left	NNE 19°	WNW 283°	96°	166°	76°	90°
3) Right	NNE 20°	SE 124°	102°	168°	62°	106°
4) Right	NW 315°	NNE 31°	76°	132°	62°	70°
Left	NW 310°	WSW 258°	52°	152°	94°	58°
5) Right	NNE 15°	SE 125°	110°	172°	56°	116°
Left	NNE 13°	W 275°	98°	170°	70°	100°
6) Left	NNE 20°	NW 317°	63°	168°	102°	66°
7) Right	NNE 20°	ESE 105°	85°	160°	80°	80°
Left	NNE 14°	NW 314°	60°	156°	92°	64°
8) Right	NNE 16°	E 90°	74°	170°	90°	80°
9) Left	NNE 15°	WNW 295°	80°	160°	75°	85°
10) Right	NNE 20°	ENE 63°	43°	175°	135°	40°
Left	NNE 15°	NNW 333°	52°	170°	120°	50°

This instrument has a good reliability when compared with gold standard measurement resulting in very high correlation coefficient from the statistical calculation. The result of the present study has confirmed the authors' theory that ROM measured by digital compass in unilateral plane and goniometer measurement of standard radiographic picture was similar.

By the way, the authors encountered some minor problems during using this device. The stable platform made from a box of foam needs to be adjusted to the size of the leg in each individual patient. Secondly, the user needed some basic knowledge in reading a compass. The data was represented by the numerical digit in degree and the symbol of the direction, for example; NNE 15°, W 280° etc. Physicians should be familiar with the direction interpretation before mastering the device.

Once the minor modification had been made to accommodate the platform size to each individual patient size and the tester was familiar with the digital compass reading, the DCG was a very simple tool and easy to use. It gave a reliable result without requiring patient to be exposed to multiple roentgenograms. The concept of using DCG with inclinometer can be applied to any other major joint in the body such as hip or elbow joint. It should give the same accurate and reliable result of measuring range of flexion and extension as it has shown here at the knee.

In conclusion, the result of the current study showed that the ROM of the knee joint reading from DCG obtained a high level of correlation with the result from standard goniometer measurement on the lateral roentgenographic picture. This suggested that this device was a very reliable instrument in measuring knee joint ROM. It may be used as an alternative to the gold standard. Its indication also can be expanded to any clinical setting that required range of motion measurement. Further development is warrant for this instrument to be applied to other joints.

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ความน่าเชื่อถือของเครื่องมือวัดพิสัยชนิดเข็มทิศดิจิตัล ในการวัดพิสัยการเคลื่อนไหวของข้อเข่า

น้ำมนต์ ใหญ่กว่าวงศ์, ณพชาติ ลิมปพยอม, วัชระ วิไลรัตน์

วัตถุประสงค์: *เพื่อทดสอบความน่าเชื่อถือในการวัดพิสัยการเคลื่อนไหว ของข้อเข่าของเครื่องมือวัดการเคลื่อนไหวชนิดเข็มทิศดิจิตัลเมื่อเทียบกับค่าที่ได้จากการวัดพิสัยการเคลื่อนไหวจากภาพรังสีมาตรฐาน*

วัสดุและวิธีการ: *พิสัยการเคลื่อนไหวของข้อเข่าในผู้ป่วยอาสาสมัครถูกบันทึกโดยเครื่องมือวัดการเคลื่อนไหวที่ประดิษฐ์จากเข็มทิศดิจิตัล และพิสัยการเคลื่อนไหวของเข่าข้างนั้นถูกวัดในเวลาเดียวกันจากภาพรังสีมาตรฐาน ค่าพิสัยการเคลื่อนที่ ของข้อเข่าจากการวัดทั้งสองวิธีถูกนำมาเปรียบเทียบ เพื่อทดสอบความน่าเชื่อถือของเครื่องมือวัดโดยวิธี Intraclass correlation coefficient*

ผลการศึกษา: *จากการวัดพิสัยการเคลื่อนไหวของข้อเข่าในแนวงอ และเหยียดโดยเข็มทิศดิจิตัลในผู้ป่วยอาสาสมัครจำนวน 10 ราย หรือ 15 เข่า พบว่าค่าที่ได้มีความน่าเชื่อถือสูงเมื่อเทียบกับค่าพิสัยการเคลื่อนไหว ที่วัดได้จากภาพรังสีมาตรฐาน จากการคำนวณมีค่าเท่ากับ 0.973*

สรุป: *เครื่องมือวัดพิสัยการเคลื่อนไหวชนิดเข็มทิศดิจิตัลที่ประดิษฐ์นี้ ให้ความน่าเชื่อถือสูงในการที่จะใช้วัดพิสัยการงอและเหยียดของข้อเข่าในผู้ป่วยอาสาสมัครเนื่องจากค่าที่ได้มีค่าใกล้เคียงกับค่าที่ได้จากการวัดภาพรังสีมาตรฐาน*