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Assessing the knee flexion range of motion after total knee arthroplasty: Technology versus senses

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Introduction: Following total knee arthroplasty surgery, attention should be paid to post-operative knee range of motion to achieve daily activities. Goniometer assessment is widely used to assess the range of motion in the post-operative period. This study aimed to determine the inter-rater ability of a smartphone application and visual estimation of the knee joint after total knee arthroplasty among different professions that commonly work together and compare whether any method is superior to another.
Method: Range of motion measurements was performed by four clinicians as two physiotherapists and two orthopedic fellows. They utilized the Goniometer Reports application for smartphones, universal goniometer, and visual estimation to measure angles of knees which was operated. A two-way mixed model of intra-class correlation coefficient (ICC) with a 95% confidence level was used to assess inter-rater reliability.
Results: Thirteen patients (11 female) and 20 knees (10 right) were assessed. The ICCs were found excellent both for between methods and between raters.
Conclusion: Our results show that technology seems a more accurate way to determine the knee range of motion after knee arthroplasty compared to senses. However, in lack of technological resources or time, or to avoid possible infection, visual estimation also could provide useful information.

1. Introduction

The rate of knee osteoarthritis, which causes pain, weakness, and functional limitations in daily activities, is steadily increased (Rex, 2018). Total knee arthroplasty is one of the pervasive, feasible, and effective treatment strategies for knee osteoarthritis (Hauer et al., 2020). After the total knee arthroplasty surgery, attention should be paid to postoperative knee range of motion (ROM) to achieve daily activities (Yang et al., 2019). Rex et al. stated that after the total knee arthroplasty the rehabilitation goal should be a 110-degree of flexion angle. They also denoted most of the daily activities required >120 degrees of flexion angle (Rex, 2018).

Joint ROM assessment is one of the most common measurements used in daily clinical practice (dos Santos et al., 2017; Gajdosik and Bohannon, 1987). Goniometry is used to assess the joint extent of movement for many purposes as detecting the lack of the free range of motion or determining the outcomes after an operation. (Gajdosik and Bohannon, 1987). Especially in the post-operative rehabilitation period, goniometer assessment is widely used to determine the prognosis of the condition, the efficacy of an intervention, and as an indicator for hospital discharge (Devers et al., 2011).

Universal goniometers are reported as the most used tools in daily practice and research (Gajdosik and Bohannon, 1987). However, as technology improves every minute, smartphone applications have brought user-friendly and easily available services into

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our practice. Most smartphone goniometer applications are free to download, which creates a positive point as well (dos Santos et al., 2017; Keogh et al., 2019; Lee et al., 2018; Lin et al., 2020; Otter et al., 2015). The validity and reliability of smartphone goniometers have become an interest to researchers recently, and lots of studies can be found about smartphone goniometer applications for different regions of the body (Alawna et al., 2019; Bruyneel, 2020; Keogh et al., 2019; Meislin et al., 2016; Otter et al., 2015; Werner et al., 2014). The first validated application for goniometric measurement in rehabilitation was analyzed in 2011 (Milani et al., 2014).

In some clinical settings, there would be limited time or resources to perform complete procedures. Therefore, the clinician might prefer to trust own senses, and she/he employs the visual estimation for the range of motion. The reliability study of visual estimation for knee joints was conducted by Watkins et al.. The authors determined the inter-tester reliability for the visual approximation strategy in the passive range of motion knee joint flexion and extension as 0.83 and 0.82, respectively (Watkins et al., 1991). Despite this, the effect of experience on the reliability of knee joint range of motion assessments that were performed by the smartphone applications (Hambly et al., 2012; Milanese et al., 2014), as to our knowledge, no inter-disciplinary comparisons are available. Best of our knowledge, no study compares visual estimation with a smartphone goniometer application. Orthopedic surgeons and physiotherapists commonly work together in the process of the rehabilitation and management of the patient, especially in the acute phase after any orthopedic operation. Accurate and similar assessments allow these professionals to speak the same language. Therefore, this study aimed to determine the inter-rater ability of a smartphone application and visual estimation of the knee joint after total knee arthroplasty among different professions that commonly work together and compare whether any method is superior to another.

2. Material and methods

The ethics approval was obtained from the Dokuz Eylül University Ethics committee (2300-GOA, 2015/23–32). In the beginning, informed consent was obtained from the patients as well. The demographic data as gender, age, height, weight, body mass index, and medical history were recorded.

2.1. Examiners

Range of motion measurements were performed by four clinicians as two physiotherapists who work in an acute-setting of orthopedic rehabilitation field with 2-year and 4-year experiences and two orthopedic fellows who work in the same place and have the same experience levels as the physiotherapists.

2.2. Patients

Patients who were gone knee arthroplasty surgery were included in the study. The number of necessary knees was calculated as 20 knees with a 95% power, 0.05 significance, and 0.6 effect size (Pereira et al., 2015; Russo et al., 2017). Inclusion criteria were as follows; having a knee arthroplasty due to osteoarthritis and being able to understand the examiners' comments. The patients were excluded if their medical status were unstable. All patients were operated on by the same surgery team and the same procedure. All the measurements were performed postoperative day three.

2.3. Instrumentation

A plastic universal goniometer (Baseline™ goniometer), with a 360° goniometer face and 20 cm arms were used. For smartphone measurements, Goniometer Records (Indian Orthopaedic Research Group) application was downloaded into a Samsung Note 4 smartphone. All the smartphone measurements were performed with the same smartphone. Goniometer Records is based on accelerometer technology, and it returns a value in direct proportion to the acceleration it experiences (Ockendon and Gilbert, 2012).

2.4. Procedures

Three sets of passive range of motion assessments as visual estimation, universal goniometer, and smartphone goniometer were performed. The patients wore shorts to expose their operated legs. The patients were laid down in a supine position, and their operated leg was fixed in the maximum flexed position that the patient was passively able to do (Batista et al., 2006; Hancock et al., 2018). The fixation was provided with external support which is secured by a senior-class physiotherapy student. Each examiner was numbered by a randomization (PT 1 = 1, PT 2 = 2, MD 2 = 3, MD 1 = 4) and the measurements were done in an order of (1,2,3,4); (2,3,4,1); (3,4,1,2) and (4,1,2,3) for four consecutive patients. Then the order started with the same sequence for the next four consecutive patients. Examiners always performed the visual estimation first to not be influenced by directly measured angles.

2.5. Visual estimation

For the visual estimation, the examiner stood in side the patient and looked at the pivot point of the knee joint. The estimation of the examiner is recorded after 5 s of thinking. No comparison was allowed with any upright object (Dietz et al., 2017).

2.6. Universal goniometer protocol

The goniometer axis was placed over the lateral condyle of the femur. One of the goniometer arms rested parallel to the longitudinal axis of the femur, aligned with the greater trochanter, and the other one was placed parallel to the longitudinal axis of the fibula, aligned with the lateral malleolus (Kornuijt et al., 2019).

2.7. Goniometer reports android app protocol

Smartphone goniometer protocol was started by putting the device on the anterior surface of the femur. At this stage, the angle of the femur was measured as touching the start button. Then, the smartphone was placed on the anterior surface of the distal tibia, and the finish button was touched. The device displayed the total knee flexion angle of the two measurements (Dietz et al., 2017).

2.8. Statistical analysis

Data analysis was performed using Statistical Package for the Social Sciences (SPSS Inc. version 15.0, Chicago, Illinois, USA) for the Windows program. As the data were not distributed normally, medians and min-max ranges were used for descriptive statistics. The absolute median difference between universal goniometer and smartphone application was calculated for each examiner and the differences between examiners were detected by the Wilcoxon test. The p values were deemed significant at <0.05. A two-way mixed model of intra-class correlation coefficient (ICC) with a 95% confidence level was used to assess inter-rater reliability. ICCs were interpreted as follows: good to excellent (>0.75), moderate to good (0.50–0.75), or fair correlations (<0.50).

3. Results

Thirteen participants who experienced total knee arthroplasty were included in the study. Eleven of the patients were female. Among the whole sample, seven patients were operated on bilaterally, thus in total 20 knees (10 right) were assessed. The median degrees of flexion assessed by each examiner for all methods were given in Table 1.

The ICCs were found excellent both for between methods and between raters (Table 2). However, the universal and smartphone goniometer ICCs were found higher between raters.

It was found that while the absolute median differences were not significantly different in novice PT, and both MDs, there was a difference between smartphone goniometer and visual estimation results in experienced PT. Total and the absolute median difference according to goniometer testing were lesser in smartphone assessments ($p < 0.001$, Table 3).

4. Discussion

The current study aimed to determine the inter-rater ability of a smartphone application and visual estimation of the knee joint after total knee arthroplasty among different professions that commonly work together and compare whether any method is superior to another. Due to the reported reliability and widespread use, several studies have used the universal goniometer as the reference standard for validating a different range of motion assessments (Brosseau et al, 1997, 2001; Chae et al., 2020), so do the current research. The ICCs were found excellent both for between methods and between raters in this study.

The use of smartphones by health professionals is increasing because of the growing number of downloadable applications which transform the mobile phone into a medical device (Lin et al., 2020; Terry, 2010). However, choosing reliable applications is also an important point. There are plenty of available applications, and their reliability was shown differently when compared to the other goniometers (Mourcou et al., 2015). However, it can be said that in general smartphone-based goniometers for knee range of motion assessment show good-to-excellent reliability (dos Santos et al., 2017; Mourcou et al., 2015), and our study also determined that the method we employed showed excellent reliability. Watkins et al. was determined the inter-tester reliability of the visual estimation in the knee joint for passive range of motion as 0.83 for flexion when the assessment was performed by physiotherapists (Watkins et al., 1991). We also determined the inter-tester reliability for PT1 and PT2 exactly the same as 0.83. It also may be interpreted that the reproducibility of the three methods was excellent both for between measurements and between examiners.

Previous studies performed on the wrist, hand, and finger joints, concluded that there is no difference between visual estimation and universal goniometer measurement results (Lee et al., 2018; McVeigh et al., 2016). In the current study, the inter-rater reliability found excellent between methods in accordance with existing evidence. According to present results, even though it seems most of the examiners measured the range of motion similarly with the smartphone and visual estimation like the previous studies and the results in accordance with the universal goniometer, but, when all the assessments were taken into account it was seen that smartphone assessment was closer to the universal goniometer and the chance of making mistake is higher in the visual assessment. However, as the absolute median difference was smaller than 5°, it can be considered that in the absence of the goniometers, visual assessment for the range of motion can be recruited especially in a clinical setting. However, in scientific studies, smartphone assessment seems a more accurate technique. A possible preference for visual estimation could be related to infection risk. Smartphone range of motion measurement may require contact of the smartphone with the patient's skin or clothes or with clinical instrumentations, increasing the risk of transmission of pathogenic bacteria to users and patients (Visvanathan et al., 2012). It was reported that protective cases or other additional accessories seem inadequate to reduce this risk (Albrecht et al., 2013).

McVeigh et al. did not find any differences in accuracy of visual estimation and goniometer measurements between surgeons and therapists (McVeigh et al., 2016). Our results showed like previous studies, all three methods could be used to report the patient's situation between professions. However, it should be denoted that since the visual estimation showed lower ICC scores, universal goniometers and smartphone goniometers would provide more reproducible results.

Milanese et al. investigated the role of the experience on the reliability of the knee goniometer and smartphone measurements and found that both methods had excellent reliability and the reliability was independent of experience (Milanese et al., 2014). In our study, we also obtained a similar result. Although, Milanes et al., compared graduated physiotherapists with final year physiotherapy students (Milanese et al., 2014), we compared physiotherapists with two different experience levels as 2-years against to 4-years. Recently, Whyte et al. demonstrated the reliability of smartphone goniometric measurements on the hip joint for experienced and novice clinicians, and they found smartphone goniometric measurements of hip range of motion have high reliability for both novice and expert clinicians (Whyte et al., 2021). These results are compatible with the current study.

Radiographic evaluation is accepted as the reference technique for the range of motion evaluation, but the additional exposure prevents its widespread use. On the other hand, digital goniometers, gait analysis, or digital imaging with computer image analysis could provide accurate results, but they are too expensive or time-consuming to be used on a routine basis. However, visual estimation and goniometers are fast, easy to perform, inexpensive, and reliable methods following existing evidence and current results.

There are some limitations to this study. The most important one is the results were only limited to passive range of motion measurements and for the knee joint. The same methods might

Table 1
Median degrees of flexion measured by each examiner.

	Visual Estimation Median (Min-Max)	Universal Goniometer Median (Min-Max)	Smartphone Goniometer Median (Min-Max)
PT 1	60 (30–105)	62 (36–108)	61.5 (32–100)
PT 2	65 (40–100)	65 (50–98)	64 (44–97)
MD 1	62.5 (35–95)	65 (45–100)	63 (36–102)
MD 2	60 (30–95)	62 (34–97)	64 (36–99)

PT: Physiotherapist, MD: Medical Doctor (Orthopedic Fellow).

Table 2
ICCs of the three methods between methods and between raters.

	Between Gonio-Visual	Between Gonio-Smart	Between Raters in Gonio	Between Raters in Visual	Between Raters in Smart
PT1	0.99 (0.96–0.99)	0.98 (0.97–0.99)	NA	NA	NA
PT2	0.92 (0.80–0.96)	0.98 (0.96–0.99)	NA	NA	NA
MD1	0.95 (0.88–0.98)	0.97 (0.92–0.98)	NA	NA	NA
MD2	0.98 (0.95–0.99)	0.99 (0.95–0.99)	NA	NA	NA
PT1-PT2	NA	NA	0.93 (0.82–0.97)	0.83 (0.49–0.94)	0.96 (0.89–0.98)
PT1-MD1	NA	NA	0.92 (0.82–0.97)	0.89 (0.73–0.95)	0.93 (0.84–0.97)
PT1-MD2	NA	NA	0.88 (0.68–0.95)	0.84 (0.60–0.93)	0.88 (0.72–0.95)
PT2-MD1	NA	NA	0.94 (0.84–0.97)	0.80 (0.51–0.92)	0.93 (0.84–0.97)
PT2-MD2	NA	NA	0.89 (0.73–0.95)	0.79 (0.48–0.91)	0.90 (0.75–0.96)
MD1-MD2	NA	NA	0.95 (0.88–0.98)	0.90 (0.75–0.96)	0.96 (0.90–0.98)

PT: Physiotherapist, MD: Medical Doctor (Orthopedic Fellow), NA: Not applicable.

Table 3
Absolute median differences between goniometer and other assessments for each examiner and in total.

	Absolute median differences between goniometer and smartphone Median (Min-Max)	Absolute median differences between goniometer and visual estimation Median (Min-Max)	p[ǂ]
PT1 Difference (Range)	2 (0–8)	2 (0–10)	0.811
PT2 Difference (Range)	1.5 (0–6)	5 (0–15)	**0.003**
MD1 Difference (Range)	3 (0–12)	5 (0–10)	0.070
MD2 Difference (Range)	2 (0–6)	2 (0–10)	0.184
Total Difference (Range)	2 (0–12)	4 (0–15)	**0.001**

PT: Physiotherapist, MD: Medical Doctor (Orthopedic Fellow), ǂ: Mann Whitney *U* test, $p < 0.05$.

show different results when measured actively or in a different region of the body. Although the radiographic measurements are considered the gold standard for the range of motion assessments, radiation exposure is the major limitation of that method (Dietz et al., 2017). In the current study, to avoid inessential radiation exposure universal goniometer was considered as the reference method. This situation is also one of the limitations of this research. Another limitation of the current study is the small sample size, and the authors' advice to acquire more robust evidence the research should be performed with a larger sample size.

5. Conclusion

In conclusion, technology seems a more accurate way to determine the knee range of motion after knee arthroplasty compared to senses. However, in lack of technological resources or time, or to avoid possible infection, visual estimation also could provide useful information both for physiotherapists and orthopedic surgeons.

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CRediT authorship contribution statement

Umut Ziya Kocak: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing. **Ortac Guran:** Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing – original draft. **Serpil Kalkan:** Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing – original draft. **Erol Kaya:** Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing – original draft. **Merve Kurt:** Conceptualization, Methodology, Investigation, Resources, Writing – original draft. **Vasfi Karatosun:** Conceptualization, Methodology, Formal analysis, Investigation, Resources, Writing – review & editing. **Bayram Unver:** Conceptualization, Methodology, Formal analysis, Investigation, Resources, Writing – review & editing.

Declaration of competing interest

Authors have nothing to disclose, neither financial interests nor non-financial interests.

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