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Reliability of Goniometric Measurements of Flexion in Total Knee Arthroplasty Patients: with Special Reference to the Body Position

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Abstract. [Purpose] To compare the reliability of goniometric measurements of knee flexion obtained in three different body positions of patients with total knee arthroplasty (TKA). [Subjects] The knees (151) of 92 TKA patients were the subjects of this study. [Methods] The range of flexion was measured at three instances: preoperatively, postoperative fifth day and at the time of discharge by universal goniometer measurement with the patient positioned in the supine, prone and sitting positions. [Results] There were no significant differences between the range of motion measurements in the three testing positions at the three instances. Also, the results from the three different testing positions were highly correlated ($r>0.80$). [Conclusion] The results of this study indicate that the position of the patient during the evaluation of range of knee flexion does not affect the results and that the three different body positions can be used interchangeably.
Key words: Total knee arthroplasty, Goniometry, Reliability

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INTRODUCTION

Total knee arthroplasty (TKA) is established as a valuable procedure for the management of patients with disabling knee osteoarthritis[1–4)]. Range of motion (ROM), along with relief from pain, is an important measure of the success of TKA[2,5,6)] and is an important part of most knee scoring systems[2,5)]. Postoperative rehabilitation following TKA frequently involves the utilization of continuous passive motion. The goniometric measurement of knee joint ROM is used in everyday clinical practice to determine the degree of increase of continuous passive motion[7)]. Also, measurements of the range of joints are commonly recorded in patients' medical records, as they are considered to be acceptable clinical data for the evaluation of impairment[8–10)].

Any measurements that are used as a basis for treatment planning or for research purposes need to be reliable[11)]. Reliability is defined as the reproducibility or consistency of a measure. Test-retest reliability is the degree to which the measurements remain stable when repeated two or more times. Intra-tester reliability describes the consistency of repeated measurements taken by the same clinician. If intra-tester reliability is demonstrated, then one can have confidence in the accuracy of the measurement compared with other measurements by the same clinician under similar conditions. Inter-tester reliability describes the consistency of repeated measurements taken separately by two or more clinicians. If inter-tester reliability is demonstrated, then one can have

confidence in the accuracy of the measures compared with measurements taken by other clinicians under similar conditions[12].

The usefulness of goniometric measurements for providing objective assessments of a patient's initial status and progress depends on the reliability and validity of the measurements[11]. The universal goniometer is a frequently used instrument, and it permits physical therapists to quantify restrictions in ROM, to guide treatment interventions, and to document the efficacy of their approach[13]. Unfortunately, goniometric measurements are often inconsistent. The inconsistencies are partially due to inter-tester differences in measurements technique, including differences in patient and goniometric positioning[11,14–18]. Also a particular patient may be difficult to assess for specific technical reasons[11] or therapists may use different patient positions for measuring the same joints[11,17] and several studies have revealed that the position of the patient results in significant differences in the outcome measures[8,10,13–15,17,18].

Knee flexion ROM is usually the primary outcome measure in TKA an is used to evaluate both short-term effectiveness (measured at the end of the hospital stay after TKA) and long-term effectiveness (measured 2–12 months after TKA) of TKA[4,19]. Knee flexion ROM is also used for continuous passive motion treatment planning[7]. A review of the literature revealed that ROM of the knee joint is generally measured in the prone position[14,16,20,21]. However, this position can not always be utilized due to the motivation of the patient[11] and the ability of the patient to tolerate pain and discomfort during measurement of knee flexion in this position in the early postoperative stage[5]. According to Chiu KY et al., differences in the testing position may preclude direct comparison of studies[5]. So, we decided to evaluate the influence of different positions of the patients on the reliability of goniometric measurements of knee flexion of TKA patients.

SUBJECTS AND METHODS

Subjects

The series consisted of 151 knees of 92 patients who underwent TKA. All operations were performed by the same surgeon (VK) using the paramedian approach. All knees were implanted with cemented TKA with cruciate retaining (Nexgen®, Zimmer, Warsaw, IN, USA). The preoperative diagnosis was osteoarthritis in all patients. Only patients with primary TKA were included in this study. Patients with rheumatoid arthritis, septic arthritis, gout, paresis, metastatic bone disease or previous fracture of the lower limbs were excluded from the study. The mean age of the patients was 66.8 ± 8.7 (range 47–88) years. The patients were discharged from hospital at a mean 9.8 ± 3.5 postoperative days (range 5–16).

Methods

After surgery, all patients were allowed to bear weight as tolerated and physical therapy was started on the first postoperative day. All patients received standard postoperative treatment from a physiotherapist, including continuous passive motion, active-assistive and active range of motion exercises, isometric and isotonic strengthening exercises, gait training and transfer training[4,22].

Range-of-motion of the knee was measured at three instances: preoperatively, postoperative fifth day and at the time of discharge. Two examiners with eight years of experience independently evaluated the ROM of the knee. Intra-tester reliability was assessed on 20 knees of 10 patients with bilateral osteoarthritis of the knee. The osteoarthritis was verified both clinically and radiologically. The mean age of these patients was 63.9 ± 8.6 (range 52–80) years and there were 7 females and 3 males. Measurements were repeated 1 hour apart and the intra-tester reliability calculated. Inter-tester reliability was assessed at the end of the study using the data from all of the subjects.

Measurements were performed using written guidelines. The active range of knee motion was measured using a full-circle manual goniometer made of flexible clear plastic with arms 30 cm in length. This device fulfilled the requirements of a universal goniometer as described by Moore. The protractor portion was divided in to 1° increments, and a scale on one of the arms made it possible to obtain measurements to the nearest degree[9].

Range-of-motion was documented by universal goniometer measurement with the patient positioned in the supine, prone and sitting positions. The fulcrum of the goniometer was placed over the lateral epicondyle of the femur. The stationary arm of the goniometer was placed parallel to the longitudinal axis of the femur, pointing toward the greater trochanter, and moveable arm parallel to the

longitudinal axis of the fibula, pointing toward the lateral malleolus. The patient was then instructed to move the knee to maximum flexion and the degree of flexion was measured[16].

Statistical analysis was performed using independent and paired t-tests where appropriate. p values less than 0.05 were accepted as significant. The correlation between the measurements was evaluated by Pearson's correlation analysis. The intraclass correlation coefficient (ICC) (1,1) was used to describe the degree of reliability of the measurements. Pearson's correlation coefficient and ICC are recommended for continuous data, such as goniometric measures. Because the ICC relates to the degree to which repeated measurements yield the same score while accounting for systematic bias, it is the most appropriate statistic to estimate the test-retest reliability of goniometric measurements. The intraclass correlation coefficient values range from 0 to 1, with 0 being no agreement and 1 being perfect agreement. An ICC reliability coefficient greater than 0.70 has been considered an acceptable level of reliability for test-retest purposes when applied to clinical measures[12]. The ICCs for intra-tester reliability of goniometric measurements of knee flexion in the three different positions were calculated by comparing by the first and second goniometric measurements taken by each tester. The ICCs for inter-tester reliability of goniometric measurements of knee flexion in the three different positions were calculated by comparing the first and second goniometric measurements of each tester.

RESULTS

There were no significant differences between the ROM measurements among the three testing positions preoperatively, on the postoperative fifth day and at the time of discharge ($p>0.05$), and the change of measurements between the positions was less than 5°. Descriptive statistics (mean with SD) for all goniometric measurements are given Table 1.

Pearson's correlation analysis revealed that the results of the three different testing positions were highly correlated ($r>0.80$) (Table 2).

The results for each tester are presented in Tables 3, 4. There were no significant differences between the measurements recorded on the first or second occasions ($p>0.05$). The ICC values for inter-tester reliability of measurements obtained with a goniometer were between 0.963 and 0.985 for knee flexion in the three different testing positions (Tables 3, 4). Also there were no significant differences between the measurements of the first and second tester recorded on the first or second occasions ($p>0.05$), (Tables 5, 6). The ICC values for intra-tester reliability of measurements obtained with a goniometer were between 0.920 and 0.976 for knee flexion in the three different testing positions for Tester 1 (Table 5). The ICC values for intra-tester reliability of measurements obtained with a goniometer were between 0.939 and 0.993 for knee flexion in the three different testing positions for Tester 2 (Table 6).

DISCUSSION

The goal of TKA is to provide the best possible outcome for the patient[2] and one of the most challenging goals following TKA surgery is regaining knee motion[23]. Knee flexion ROM is usually the primary outcome measure, and is used to evaluate the short-term effectiveness of TKA(measured at the end of the hospital stay)[4,19]. In addition, discharge from hospital is dependent on the mobility of patients following TKA[23]. It is generally agreed that patients with TKA should achieve 65 to 70 degrees of active flexion before hospital discharge[19], and the patients in the present study, showed this value at the time of discharge (Table 1).

X-ray analysis is the recognized "gold standard" for determining ROM, but this is an expensive procedure with risk of exposure to radiation[1,11,13]. Thus, the costs and risks associated with x-ray analysis prevent its use in routine clinical practice. The preference is for quick, simple, inexpensive and minimally invasive diagnostic tests. Low technology methods are favoured in routine clinical practice: for example, universal goniometry. The usefulness of goniometric measurements for providing objective assessments of a patient's initial status and progress depends on the reliability and validity of the measurements[11]. Goniometers also allow patients to appreciate their own progress and achievements[13]. However, it has been suggested by some observers that the position of the patient significantly contributes to the measurement error[8,10,13–15,17,18].

The description and standardization of knee flexion measurements have been neglected in many experiments, and only a few studies have provided

Table 1. Mean flexion degrees of the patients

Positions	Preoperative X ± SD (range)	Postop. 5th day X ± SD (range)	At discharge X ± SD (range)
Supine (°)	105.6 ± 17.6 (40–140)	67.7 ± 14.4 (36–100)	80.2 ± 12.7 (42–110)
Prone (°)	104.4 ± 18.1 (40–140)	67.4 ± 14.1 (38–100)	79.3 ± 12.5 (42–106)
Sitting (°)	104.7 ± 18.9 (45–140)	69.0 ± 14.4 (38–104)	80.4 ± 12.7 (42–110)

Values are expressed as means ± SD

Table 2. Correlations among testing positions

	Prone vs supine			Prone vs sitting			Supine vs sitting		
	r	ICC		R	ICC		r	ICC	
Preoperative	0.982	0.981	(0.975–0.986)	0.889	0.887	(0.848–0.917)	0.887	0.884	(0.844–0.914)
Postop. 5th day	0.962	0.961	(0.947–0.972)	0.970	0.969	(0.958–0.977)	0.960	0.959	(0.944–0.970)
At discharge	0.962	0.961	(0.947–0.972)	0.968	0.967	(0.955–0.976)	0.972	0.971	(0.961–0.979)

ICC: Intraclass Correlation Coefficient, ICC with 95 % CI. r: Pearson Correlation Coefficient. r > 0.80 is considered as very reliable[36].

Table 3. Inter-tester reliability for knee flexion in test 1

Positions	Tester 1	Tester 2	p-value	ICC
Supine(°)	70.4 (60.2–80.5)	70.7 (61.0–80.3)	0.795	0.975 (0.905–0.993)
Prone(°)	70.2 (58.8–81.5)	69.9 (59.3–80.4)	0.791	0.985 (0.943–0.996)
Sitting(°)	70.8 (61.4–80.1)	70.0 (59.7–80.2)	0.251	0.983 (0.935–0.995)

Mean with 95 % CI. ICC: Intraclass Correlation Coefficient, ICC with 95 % CI.

Table 4. Inter-tester reliability for knee flexion in test 2

Positions	Tester 1	Tester 2	p-value	ICC
Supine(°)	68.4 (57.7–79.0)	70.6 (61.1–80.0)	0.121	0.963 (0.859–0.990)
Prone(°)	68.8 (56.9–80.6)	67.2 (54.8–79.5)	0.175	0.978 (0.915–0.994)
Sitting(°)	69.8 (60.2–79.3)	69.0 (58.3–79.3)	0.330	0.981 (0.926–0.995)

Mean with 95 % CI. ICC: Intraclass Correlation Coefficient, ICC with 95 % CI.

Table 5. Intra-tester reliability for knee flexion for tester 1

Positions	Test 1	Test 2	p-value	ICC
Supine(°)	70.4 (60.2–80.5)	68.4 (57.7–79.0)	0.298	0.947 (0.804–0.986)
Prone(°)	70.2 (58.8–81.5)	68.8 (56.9–80.6)	0.267	0.920 (0.713–0.979)
Sitting(°)	70.8 (61.4–80.1)	69.8 (60.2–79.3)	0.273	0.976 (0.908–0.994)

Mean with 95 % CI. ICC: Intraclass Correlation Coefficient, ICC with 95 % CI.

Table 6. Intra-tester reliability for knee flexion for tester 2

Positions	Test 1	Test 2	p-value	ICC
Supine(°)	70.7 (61.0–80.3)	70.6 (61.1–80.0)	0.739	0.993 (0.973–0.998)
Prone(°)	69.9 (59.3–80.4)	67.2 (54.8–79.5)	0.203	0.939 (0.777–0.984)
Sitting(°)	70.0 (59.7–80.2)	69.0 (58.6–79.1)	0.194	0.987 (0.949–0.996)

Mean with 95 % CI. ICC: Intraclass Correlation Coefficient, ICC with 95 % CI.

detailed methodology[1–4,6,13,19,21,24–34]. A review of the literature revealed that three types in position have been used in measurements of knee flexion of patients with TKA, including supine[1–3,6,13,24–27], prone[28], and sitting[19,29,30], although some studies/ reports gave no information about the position[4,21,31–34]. These positions have some important differences in nature. Sitting is gravity assisted, prone is gravity resisted and supine is gravity neutral. So, the roles of neuromuscular systems and subjects' efforts vary among the measurement motions[35]. For these reasons Chiu et al. concluded that direct comparison of ROM achieved in one study with that achieved in another may not be appropriate[5]. Also, Brosseau et al. concluded that in several studies ROM measurements had not been specified. These measures need to be performed and reported in a standardized manner to allow appropriate comparisons[7]. However, the results of our study clearly indicate that the position of the patient during the evaluation of the knee flexion ROM does not affect the results and different series, regardless the position of the patient, can be compared. According to Currier[36], a correlation of 0.80 to 1.00 is considered as very reliable and we found a very strong correlation ($r > 0.80$) among the different body positions (Table 2).

Several studies have examined the reliability of goniometric measurements in native knees[11,14] and replaced knees[1,3,13,18]. These studies reported that inter-tester reliability is excellent (ICC= 0.90–0.99). Intra-tester reliability was also reported to be excellent as well (ICC= 0.85–0.99)[1,3,11,13,14,18]. The intra-tester (ICC= 0.92–0.99) and inter-tester (ICC= 0.96–0.99) reliability of the measurements in the three different body position in this study were high, which mirrors the results of previous studies.

Apart from the patient position, in our opinion, studies evaluating the reliability of ROM measurements should focus on certain points. First, the study should include similar subjects, raters, and setting[13]. Second, it is not meaningful to compare ROM measurements with highly variable postarthroplasty patients, different implants, different implant fixations (cemented vs uncemented), different surgical techniques, different patient diagnose and primary versus revision procedures[5,7]. In the current study, we tried to eliminate the greatest sources of error, using similar subjects, same diagnosis, same surgical techniques, same implants, and included only cemented implants, primary procedures, inpatient arthroplasty patients, and testers with similar experience.

The experience of the testers is also a potential source of error[13]. According to Hellebrandt, experienced physical therapist measure ROM within 3.76° of error[37]. So, the results of our study may be due to the experience (8 years) of the testers, (Tables 3–6). However, studies using electrogoniometers may provide more reliable results.

In the reports on the reliability of goniometric measurements of knee flexion of TKA patients, the samples are small and to our knowledge the number of the knees in the largest series is 60[24]. In the present study, we performed measurements on 151 knees, apparently making this the largest series in the literature.

Our results can be generalized to the clinical setting, because they are derived from measuring a typical inpatient TKA patient population (age range, 47–88 years; mean 66.8 ± 8.7 years, only osteoarthritic patients).

Goniometric measurements taken in three different positions were found to be very reliable and highly correlated. Therefore, the results of this study indicate that the positions of the patient during the evaluation of range of motion of knee flexion does not affect the results and that the three different body positions used for measurements are interchangeable.

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