Reliability and Validity of Goniometric Measurements at the Knee

PREM P. GOGIA, JAMES H. BRAATZ, STEVEN J. ROSE, and BARBARA J. NORTON

The purposes of this study were to assess 1) the intertester reliability of goniometric measurements at the knee and 2) the validity of the clinical measurements by comparing them to measurements taken from roentgenograms. Thirty healthy subjects between the ages of 20 and 60 years were studied. The subjects were positioned on their right side on a roentgenographic table with their left lower extremity on a stabilizing board that was elevated 15 cm above the table's surface. For standardization of the position, an assistant placed the posterior aspect of the subject's left thigh in contact with two 15-cm pegs, which had been inserted perpendicularly into the stabilizing board. The assistant then moved the left leg to achieve an arbitrary angle of the knee joint and held the limb in that position. Two physical therapists then independently used a standard plastic goniometer to measure the knee joint angle in the sagittal plane using the greater trochanter, the lateral condyle of the femur, the head of the fibula, and the lateral malleolus as bony landmarks. A roentgenogram was taken of the extremity before the subject was moved. Pearson product-moment correlation coefficients (r's) and intraclass correlation coefficients (ICCs) were used to analyze the data. The data analysis revealed that the intertester reliability (r = .98; ICC = .99) and validity (r = .97-.98; ICC = .98-.99) were high. The results of this study indicate that goniometric measurements of the knee joint are both reliable and valid.

Key Words: Knee joint, Physical therapy.

Goniometry is a technique commonly used in physical therapy for assessing the limitation of a patient's joint motion. 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.

Reliability is the degree to which a measurement yields the same results when taken on at least two different occasions or by a minimum of two different examiners.1 Because patients often are treated and reevaluated by different physical therapists, the intertester reliability of goniometric measurement techniques is essential.

Several studies about assessing the reliability of the goniometric measurements have been published.2-9 One study emphasizes interdevice reliability;1 one is about the assessment methods used,3 and others focus on intertester and intratester reliability.4-9

Hellebrandt et al, in 1949, were the first authors to report on the reliability of goniometric measurements.4 They tested patients with a variety of disabilities and investigated intertester reliability of shoulder, elbow, radioulnar, and wrist joints. They found that well-trained physical therapists could measure the range of motion of the specified joints with a high degree of reliability and concluded that "measurements made by different physical therapists may be used interchangeably without destroying the reliability of clinical records."5(pp306-307) When intra-individual variability is known, they recommended that when interrater reliability is not known, different observers should not be used interchangeably to obtain measurements on the same patient.

Hamilton and Lachenbruch found significant variance among the seven therapists who measured the ROM of three joints of the index and middle fingers.2 They concluded that an individual therapist is capable of making accurate repeated observations to provide reliable information of joint function in the hand. Low compared estimates and measurements of elbow flexion and extension.2 In his first of two experiments, 50 observers estimated and then measured both joint motions. The mean error of the measurements was less than that of the estimates. In the second experiment, five testers measured elbow flexion on 10 separate occasions. Both interrater and intrarater variations were smaller in the second experiment than in the first experiment. Low concluded that measuring joint motion with a goniometer is more reliable than estimat-
Boone et al also found intratester error to be less than intertester error. In their study, four testers measured the movements of six different joints in both the upper and lower extremities of six healthy subjects. In each of the four measurement sessions, the movements of each joint were measured three times for each subject. They found greater reliability for three upper extremity motions than for the lower extremity motions.

In their study of 22 healthy subjects, Ekstrand et al found intratester error to be less than intertester error when measuring six motions of the lower extremity joints. Mayerson and Milano found high intertester reliability of goniometric measurements of the major joints of the upper and lower extremities. Rothstein et al found high intertester reliability in the clinical setting for flexion and extension of the elbow and for knee flexion, but poor intertester reliability for knee extension.

Validity is the degree to which an instrument measures what it is purported to measure and the extent to which it fulfills its purpose. Studies of the validity of goniometric measurements are important because of their extensive use in physical therapy and because of the conclusions based on their use. The validity of goniometric measurements has not been studied as extensively as reliability. To date, no studies have been reported that assess directly the validity of goniometric measurements that have been obtained using a "gold standard" and that have been analyzed statistically. A few articles, however, have provided some information about the validity of goniometry.

Hellebrandt et al, in Part 3 of their series on the reliability of goniometry, discuss their approach to assessing validity. Although they were assisted by an experienced roentgenologist, which is an acceptable approach for assessing validity, they did not actually compare the measurements obtained by the roentgenologist with those obtained by the other examiners. They, instead, compared the differences in the measurements recorded in the two trials by the other examiners and discussed the relative reliability of their data, but not the validity.

In their article on the reliability of goniometers, Hamilton and Lachenbruch reported using roentgenograms to assess the ability of their specially designed positioning device to place the hand in a "reproducibly static position." Although they used roentgenograms, a potential gold standard, they did not report using statistical analysis to assess the validity of their measurements. They also did not compare the measurements taken from the roentgenograms to those obtained by the examiners.

Finally, in an article comparing several methods for measuring hip flexion, Ahlbäck and Lindahl reported on measurements taken both clinically and from roentgenograms. Although they did not report any statistical analysis of the data, they concluded on the basis of differences between pairs of measurements that close agreement existed between the measurements taken with their clinical technique and those obtained from the roentgenograms.

In summary, the consensus of these investigators is that, although exceptions exist, the level of reliability in goniometric measurement generally is acceptable. Their reports, however, contain minimal information about the validity of the goniometric measurements.

The purposes of this study were to assess 1) the intertester reliability and 2) the validity of goniometric measurements at the knee joint. We chose to study the knee joint because it could be stabilized easily on a roentgenographic table.

METHOD

Subjects
Thirty volunteers (13 women and 17 men) between the ages of 20 and 60 years (X = 35 years) participated in the study. None of the subjects had a history of knee injuries. The purposes of the study and the procedure to be used were explained, and each subject signed an informed consent form.

Materials
A 60 × 90-cm piece of plywood, similar to a powder board, was used to support the left lower extremity. The board was supported by two 15-cm spacers. Two 15-cm pegs were inserted perpendicularly into the board to stabilize the thigh posteriorly (Fig. 1). One large standard plastic goniometer with the scale marked in 1-degree increments and with 30-cm arms was used to measure the angular position of the knee joint, both on the subjects and on the roentgenograms.

Procedure
The subjects were positioned on their right side on a roentgenographic table with their right lower extremity resting on the table and their left lower extremity resting on the stabilizing board. For standardization of the position, an assistant placed the posterior aspect of the subjects' left thigh in contact with the pegs projecting perpendicularly from the stabilizing board (Fig. 2). A physical therapist assistant then moved the left leg to achieve an arbitrary angle of the knee joint and held the limb in that position. The knee joint angle for all subjects was in the range of 0 to 120 degrees.

For each subject, two physical therapists (P.P.G., J.H.B.) independently and privately used a standard plastic goniometer to measure the knee joint angle in the sagittal plane and recorded the measurement on a piece of paper containing the subject's number. The knee joint measurements were obtained according to the procedure cited in the Manual of Joint Motion Measurements. The stationary arm of the goniometer was placed parallel to the long axis of the femur along a line extending from the greater trochanter to the lateral condyle, and the moveable arm was placed parallel to the long axis of the fibula in line with the head of the fibula and the lateral malleolus (Fig. 3).

Before the subject was moved, a roentgenogram of the knee joint was made by a radiology technician. The knee joint was held in the same fixed position for both measurements and for the roentgenogram. A roentgenologist drew lines on the roentgenogram parallel to the long axes of the femur and the fibula, then measured and recorded the angle formed by the intersection of the two lines (Fig. 4).

Data Analysis
Two statistical methods were used to calculate the reliability and validity of our goniometric measurements. The first method used was the Pearson product-moment correlation
coefficient \((r)\), an assessment of covariance. The second method used was the intraclass correlation coefficient (ICC: 2,1) as identified by Bartko and Carpenter.\(^{13}\) The correlation coefficients were used to compare the measurements recorded by two therapists and to compare the measurements obtained by each therapist to those derived from the roentgenograms. In addition, the means and standard deviations for all of the measurements were computed.

**RESULTS**

The joint angles used ranged from 0 to 120 degrees; their average mean and standard deviation were about 59 and 15 degrees, respectively (Tab. 1). The average correlation coefficients for intertester reliability were \(0.98\) \((r)\) and \(0.99\) (ICC). The correlation coefficients for validity ranged from \(0.97\) to \(0.98\) \((r)\) and from \(0.97\) to \(0.99\) (ICC) (Tab. 2).

**DISCUSSION**

The findings of our study agree with those of previous investigators who also demonstrated good intertester reliability.\(^{4,6,8,9}\) Hellebrandt et al found that well-trained physical therapists could measure joint motion of the upper extremity with a high degree of reliability.\(^{4}\) Boone et al also found high intertester reliability for goniometric measurements of upper extremity joint motion; however, they reported a relatively poor intertester reliability for goniometric measurements of lower extremity joint motion.\(^{6}\) Rothstein et al found poor intertester reliability for goniometric measurements of knee extension, although they found high intertester reliability for goniometric measurements of elbow flexion and extension and knee flexion.\(^{9}\) Ahlback and Lindahl\(^{11}\) reported the raw data from their study for which we calculated a Pearson product-moment correlation coefficient of \(0.82\) and a Bartko and Carpenter\(^{13}\) ICC of \(0.91\).

Several potential sources of difficulty exist, however, in obtaining reliable measurements. Some investigators have suggested that certain joint motions might be more difficult to measure than others even though both the instrument and the examiner have been shown to be reliable.\(^{4,6}\) A particular patient may be difficult to assess for specific technical reasons\(^{14}\) or therapists may use different patient positions for measuring the same joints.\(^{9}\) The subjects' measurements also may fluctuate regardless of either the patient's level of cooperation or the skills of the examiner.\(^{15}\) Both intratester and intertester reliability, therefore, should be assessed for all joints of interest. Future studies to assess the validity of goniometric measurements might include all of the joints, patients with

**TABLE 1**

<table>
<thead>
<tr>
<th>Source</th>
<th>(\bar{x})</th>
<th>(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Therapist 1</td>
<td>60.37</td>
<td>14.94</td>
</tr>
<tr>
<td>Therapist 2</td>
<td>58.73</td>
<td>15.02</td>
</tr>
<tr>
<td>Roentgenologist</td>
<td>57.30</td>
<td>14.93</td>
</tr>
</tbody>
</table>

**TABLE 2**

<table>
<thead>
<tr>
<th>Comparison</th>
<th>(r^a)</th>
<th>ICC(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Therapist 1 vs therapist 2</td>
<td>.98</td>
<td>.99</td>
</tr>
<tr>
<td>Therapist 1 vs roentgenograms</td>
<td>.97</td>
<td>.98</td>
</tr>
<tr>
<td>Therapist 2 vs roentgenograms</td>
<td>.98</td>
<td>.99</td>
</tr>
</tbody>
</table>

\(^a\) \(r\) = Pearson product-moment correlation coefficient.

\(^b\) ICC = intraclass correlation coefficient.
RESEARCH

various dysfunctions, a variety of clinical settings, and therapists with different levels of experience.

CONCLUSIONS

Both the reliability and the validity of our clinical measurement techniques are essential. In this study, we demonstrated high intertester reliability and validity for goniometric measurements at the knee joint. Based on this study, we concluded that 1) goniometric measurements obtained by different therapists to assess the position of a patient's knee can be used interchangeably and 2) measurements recorded using the specified technique reflect the actual position of the knee joint.

REFERENCES