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RADIOGRAPHIC VERIFICATION OF KNEE GONIOMETRY

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ABSTRACT. The accuracy of knee goniometry was examined by comparing goniometric measurements with radiographic bone angle measurements of six positions of the knee, namely, 0°, 15°, 30°, 45°, 60°, and 90°. Within the first 15° of knee flexion joint excursion measured by goniometry differed significantly from bone angle measurement ($p<0.01$). With 30° of knee flexion or more, no significant difference was found between goniometric measurements and bone angle measurements of knee motion. These findings suggest that within the first 15° of knee flexion, goniometric measurement of joint excursion may be remarkably wrong. On account of this, it was suggested that when range of motion is limited at the knee joint, caution should be exercised in determining movement gains or losses within the initial 15° of knee flexion.

Key words: Knee joint, goniometry, X-ray

In the last four decades, accuracy of goniometric assessment of joint motion, has been the focus of many investigations (4, 5, 10, 11, 13, 14, 17). In 1949, Hellebrandt et al. (11) examined the range of joint motion by different goniometers and tested the reliability of repeated measurements taken by numerous physiotherapists. They showed that the average physiotherapist is highly reliable in measuring range of motion at most joints but noted that when monitoring periodic changes in joint motion, the same goniometer should be used consistently. Supporting the reliability of repeated measurements taken by individual therapists, other studies (4, 5, 10, 13, 14) have shown that intratester margin of error is minimal and usually less than intertester error.

Even though these findings suggest that as long as a particular goniometer is used consistently by the same therapist range of motion measurements will be reliable, it is equally well acknowledged that reliable goniometric measurements are difficult to obtain at some joints (1) and that in some instances the axis of joint motion is either shifting continually or difficult to localize (15, 16). Therefore, accuracy of goniometric measurements at such joints remain questionable. In the course of a recent kinematic study (6), an opportunity was found to verify in vivo the accuracy of goniometric measurements taken at the knee, a joint at which the axis of motion is known to shift continually (7–9, 18). This report deals with the accuracy of knee goniometry per se: the other aspects of the study (6) which examined the reliability of surface markers in kinematic studies of knee motion will be reported elsewhere.

METHODS

Ten normal healthy adult volunteers, four males and six females, aged 21 to 35 years (mean ± standard deviation $=27.8\pm4.49$ years), verified free of any obvious musculoskeletal abnormalities, participated in this study after signing a written consent form.

With each subject lying supine, marks were made on the skin overlying the following anatomical landmarks in the right lower extremity: (i) greater trochanter—exactly 0.035 m anterior to the posterior margin, (ii) lateral epicondyle, and (iii) lateral malleolus—exactly 0.005 m anterior to the posterior border. Thereafter, subjects were made to stand beside the vertical X-ray table. With each subject firmly supported, a clinical plastic goniometer with two 0.25 m arms (Fig. 1) was used to position the experimental right limb in the desired posture. The goniometric measurements were made by placing the axis of the goniometer at the epicondylar mark with the arms pointing towards the marks at the trochanter and the malleolus.

Mediolateral radiographs of the experimental limb were then taken with the knee in six different positions, namely: 0°, 15°, 30°, 45°, 60°, and 90°. Adequate precautions were taken to ensure that each radiograph was taken at the exact angle measured. Hip abduction and hip adduction were minimized by ensuring that the subjects stood with their right hips against the X-ray table and their right knees 0.06 m away from the table.

From the 60 radiographs thus obtained, bone angles (i.e. the angle subtended by a line representing the axis of the femur and that representing the axis of the tibia) were measured in order to determine the exact change in joint angle from one position of the knee to the other. To determine the axes of the femur and the tibia, each bone was bisected longitudinally. The bisector through the femur was drawn through the center of the femoral diameter at two levels, 0.1 m and 0.22 m above the distal margin of the outline of the femur while that of the tibia was drawn through two similar points 0.1 m and 0.3 m above the distal end of the tibia. Exact change in joint angle was defined as the difference in bone angle measurements

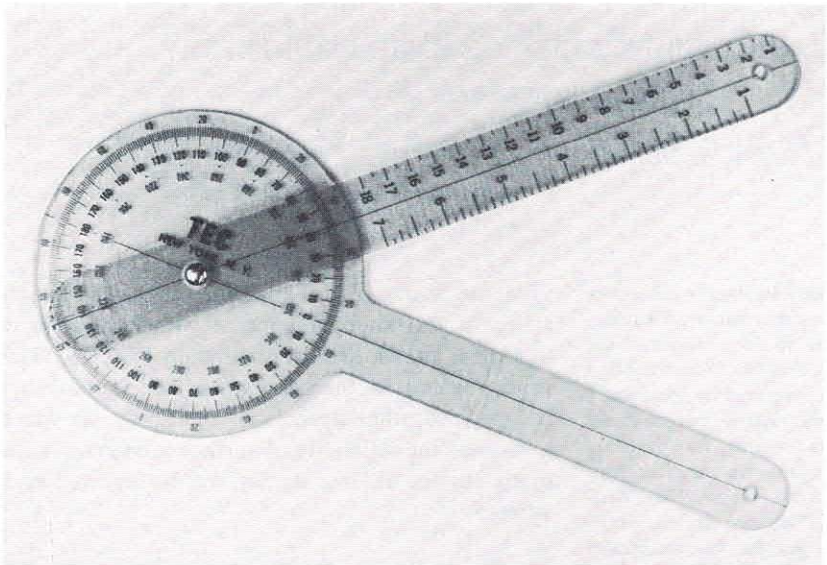

Fig. 1. The clinical plastic goniometer used for all the goniometric measurements.

obtained from radiographs of the knee in two different positions; e.g. 0° and 15°.

To determine the reliability of bone angle measurements, Pearson's correlation analysis was performed on two sets of readings obtained at two weeks interval from the 60 radiographs. Student's *t*-test was then used to test the null hypothesis that change in joint angle determined by goniometry did not differ from that obtained by bone angle measurement within the following ranges of knee flexion (*a*) 0°–15°, (*b*) 0°–30°, (*c*) 0°–45°, (*d*) 0°–60° and (*e*) 0°–90°.

RESULTS

It was shown by Pearson's correlation analysis that bone angle measurement was a highly reliable measurement procedure $r=0.999$; $p<0.001$. The difference in knee flexion measurements obtained by the two methods was significant ($p<0.01$) only within the goniometric range of 0–15 degrees. As shown in Table I, with 30° of knee flexion or more, no statistically significant difference was found between the two methods.

DISCUSSION

The significant difference between goniometric measurement and bone angle measurement in the initial 15° of knee flexion, may be explained in terms of the movements that take place within this range. The first 20° of knee flexion is usually accompanied by remarkable medial rotation of the tibia as the knee unlocks to permit flexion (2, 3, 12). Since this motion occurs in a different plane, its influence on knee flexion cannot be accounted for by a uniaxial goniometer such as the universal go niometer.

As shown in Table I, with 30° of knee flexion or more, mean difference between goniometric measurements and bone angle measurements ranged from 0.52° to 3.81°. This range falls within the limits of measurement error observed in other studies (4, 5, 11, 14). For example, under controlled conditions Hellebrandt et al. (11) observed a mean difference of 1.16° between 43 duplicated measurements of joint motion in the upper extremities. Under similar conditions, Boone et al. (4) observed a mean intratester error of 4° while Ekstrand et al. (5) and Meyerson & Milano (14) reported mean intratester errors of 3.7° and 4° respectively.

Table I. *Comparison of knee flexion measurements determined by goniometry and by bone angle*

Knee flexion determined by goniometry (degrees)	Knee flexion determined by bone angle (degrees)	*n*	df	*t*	*p*
15	19.59±4.76	10	9	−3.05	<0.01
30	33.81±5.58	10	9	−1.22	>0.10
45	46.35±6.72	10	9	−0.64	>0.10
60	60.52±6.51	10	9	0.20	>0.10
90	92.32±7.20	10	9	−0.65	>0.10

It may be pertinent to note that only changes in knee position determined by goniometry and by bone angle measurements were compared. In no instance was comparison made between actual goniometric measurements and actual bone angle measurements at each position of the knee, because such comparison would have been misleading since goniometric measurements at the knee represent the relative positions of the lateral malleolus, the lateral epicondyle and the tuberosity of the femur; while bone angle denotes the angle produced by the axes of the femur and the tibia. Because the axes of the femur and the tibia were consistently reproducible in each series of radiographs, bone angle measurement was found to be more appropriate for determining changes in joint position than measurements based on the loci of the anatomical landmarks in the radiographs. The appropriateness of this procedure is further supported by the high level of reliability demonstrated statistically.

In conclusion, it may be stated that within the first 15° of knee flexion, goniometric measurement of joint excursion may differ significantly from the actual amount of motion at the joint. Caution should thus be taken in determining movement gains or losses observed within the initial 15° of knee flexion.

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