Measurement of circumference of the knee with ordinary tape measure

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Nicholas, J. J., Taylor, F. H., Buckingham, R. B., and Ottonello, D. (1976). *Annals of the Rheumatic Diseases*, **35**, 282–284. **Measurement of circumference of the knee with ordinary tape measure.** The circumference of the knees and thighs at three locations was measured in 10 patients on two consecutive occasions by three observers. Analysis of the results for *inter*observer, *intra*observer and *among*-patient variation established that a change in circumference noted by different observers on two different days is significant if it exceeds 1·5 cm at the midpatella, 2·7 cm at 7 cm above, and 3·5 cm at 15 cm above the patella. If a single observer performs both measurements, the change need exceed only 1·0, 2·0, and 2·7 cm, respectively, to be significant.

The objective measurement of joint inflammation is a frequent research study, but often a neglected part of clinical evaluation (Boardman and Hart, 1967). The complicated equipment necessary for joint scanning and infrared photography, and even the measurement of the proximal interphalangeal and distal interphalangeal joints by jewellers' rings (Hart and Clark, 1951) and tape devices (Willkens, Gleichert, and Gade, 1973; Webb and others, 1973) undoubtedly discourage the adoption of these techniques for routine clinical evaluation. An ordinary tape measure would satisfy the need for simple, readily available equipment to measure joint circumference, an acknowledged index of joint inflammation.

The results of this study indicate that measurement of the knee with an ordinary tape measure provides reproducible results when used by both single and multiple observers.

Methods

Ten subjects were chosen at random from patients at the Rheumatology Clinic, School of Medicine, University of Pittsburgh, and showed a variety of conditions including degenerative joint disease, rheumatoid arthritis, normal knees, and knees which varied from obese to asthenic in conformation.

The measurements were performed in a quiet room, with a recording clerk and a physician present who measured and recorded dimensions of the right then the left leg in the following sequence: (1) midpatella, (2) 7 cm above the superior border of the patella, (3) 15 cm

above the superior border of the patella. Measurements were performed at these locations in the hope that they would reflect changes in fluid and synovial tissue (midpatella); muscle atrophy and fluid in the suprapatellar pouch (7 cm above the patella); and atrophy of the quadriceps muscle (15 cm above the patella). The sequence of measurements was repeated three times at each knee by the same examiner in the same order. Three physicians measured each patient at each sitting, and the entire examination was repeated approximately 2 weeks later on the same patient. Circumferential measurements were recorded to the nearest 0·1 cm with an ordinary tape measure.

An analysis of variance procedure was used to analyse the data (Sokal and Rohlf, 1969). The three sources of variability examined in this study were as follows. (1) The variability arising when a single observer made repeated measurements around the knee on the same patient, referred to subsequently as *intra*observer variation. (2) The variability arising from differences between observers making measurements, referred to subsequently as *inter*observer variation. (3) The variability arising from differences in patients, subsequently referred to as *among*-patient variation.

Results

A Table I gives the *intra*observer variation for each of the three observers. The variation is reported for each of the combinations of time period, location of measurement, and left and right knee, *e.g.* the value 0·117 cm^2 is the average intraobserver variation (averaged over the 10 patients) for observer 1, for

Table I *Intraobserver variation (cm²) for various combinations of observer, time period, location of measurement, and left and right knee*

	Observer 1	Observer 2	Observer 3	Average variation for each leg	Average variation for each time period	Average variation for each location
Midpatella						
Time 1						
Right knee	0·117	0·144	0·118	0·126		
Left knee	0·325	0·155	0·050	0·177		
Average	0·221	0·150	0·084		0·151	
Time 2						
Right knee	0·117	0·176	0·142	0·145		
Left knee	0·183	0·244	0·150	0·192		
Average	0·150	0·210	0·146		0·169	
Average period 1 and 2	0·186	0·180	0·115			0·160
7 cm above patella						
Time 1						
Right knee	0·542	0·399	0·205	0·380		
Left knee	0·158	1·831	0·250	0·746		
Average	0·350	1·115	0·228		0·563	
Time 2						
Right knee	0·608	0·756	0·208	0·524		
Left knee	1·583	0·156	0·100	0·613		
Average	1·096	0·456	0·154		0·569	
Average period 1 and 2	0·723	0·786	0·191			0·566
15 cm above patella						
Time 1						
Right knee	0·483	0·534	0·225	0·414		
Left knee	0·808	0·170	0·605	0·528		
Average	0·646	0·352	0·415		0·471	
Time 2						
Right knee	1·083	3·615	0·197	1·632		
Left knee	1·125	2·743	0·208	1·359		
Average	1·104	3·179	0·203		1·495	
Average period 1 and 2	0·875	1·766	0·309			0·983

measurements made at midpatella, on the right knee. At the midpatella location the three observers had very similar performances as reflected by the average intraobserver variation (average over time period and right and left leg); at 7 cm above the patella observers 1 and 2 are similar with respect to their intraobserver variation and both have a larger value than that for observer 3. At 15 cm above the patella observer 3 has the smallest intraobserver variation and observer 2 the largest.

B The *intra*observer variation averaged for each leg is given in Table I. With one exception, that of the location 15 cm above the knee, for the time period 2, the average intraobserver variation for the left leg was higher than for the right leg.

C The *intra*observer variation for each location and time period averaged over the two legs and the three observers is given in Table I.

D The average components of variation, that is the components reflecting *intra*observer, *inter*observer, and *among*-patient variations for each site of measurement, are given in Table II. The variability arising from differences among patients represents approximately 95 % of the total variation. The remaining two components have approximately equal shares of the remaining 5 % of the total variation. The relationship of the various components to the total variation of the measurements persists at all three sites of measurement.

Discussion

In this study the *intra*observer and *inter*observer variations were smallest at the midpatella and increased as the location of measurement moved from the midpatella to 7 and 15 cm above the

Table II *Estimated components of variance for each location of measurement* *

	Midpatella			7 cm above midpatella			15 cm above midpatella		
	A†	*B*‡	*C*§	*A*	*B*	*C*	*A*	*B*	*C*
Intraobserver variation	0·160	0·400	1·55	0·566	0·752	2·14	0·983	0·992	2.61
Interobserver variation	0·124	0·352	1·20	0·364	0·603	1·38	0·577	0·760	1·53
Patient variation	10·051	3·170	97·25	25·462	5·046	96·48	36·112	6·009	95·86
Total	10·335			26·392			37·672		

* Based upon estimates pooled over time period and left and right leg.
† Estimated component of variation (cm²).
‡ Square root of component = standard deviation (cm).
§ Percent of total variation.

superior border of the patella. The relationship of intraobserver, and among-patient variation to the total variation remained the same from location to location.

Estimates of intraobserver variation can be used to place statistical limits on a single measurement made by a physician. If, for example, such limits are wanted for a single measurement X at the mid-patella, and these limits were to include 95 % of such situations, then the limits would be $X \pm 1 \cdot 96 \sqrt{0 \cdot 16}$ or $X \pm 0 \cdot 8$. At 7 cm and 15 cm above the knee these limits would be respectively $X \pm 1 \cdot 96 \sqrt{0 \cdot 566} = X \pm 1 \cdot 5$, and $X \pm 1 \cdot 96 \sqrt{0 \cdot 983} = X \pm 1 \cdot 9$.

Two successive measurements made on the same patient by the same physician are correlated as a consequence of their having come from the same patient. However, there is no satisfactory manner in which the observations made in the present study can be paired to take into account the correlations of two successive measurements made on the same patient. If the existence of this correlation is ignored for the moment, the estimate of intraobserver variation may be applied to give *conservative* bounds for a difference in two measurements on the assumption that the only source of variation arises from intra-observer error. At midpatella, then, the absolute

difference between two measurements should exceed about 1 cm in order that this absolute difference can be considered significant statistically at the 0·05 level.*

If both intraobserver and interobserver variation are present, as in the case of individual measurements made by two different physicians, then the absolute difference between the two measurements at mid-patella must exceed about 1·5 cm.† For the locations 7 cm above the patella the corresponding values for the above situations are respectively 2 cm and 2·7 cm, and for the locations 15 cm above the patella the values are respectively 2·7 and 3·5 cm.

The observation that variation was greater more frequently in the left leg than the right may be because the right leg lay nearer the physician and was measured first. The observation that error increased as the site of observation became more superior to the patella was probably due to the cylindrical shape of the thigh, since the circumference of a cone varies significantly as one moves along the long axis.

* The standard error of the difference is $\sqrt{V(X_1 + V(X_2)}$ where $V(X_1)$ and $V(X_2)$ are the intraobserver variances attached to the two measurements. The critical value for the absolute difference is thus $1 \cdot 96 \sqrt{V(X_1) + V(X_2)} = 1 \cdot 1$.
† Based on the assumption of Gaussian distribution of errors in the differences.

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