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Verification of selected anatomical landmarks used as reference points for universal goniometer positioning during elbow joint mobility range measurements

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The paper presents the results of comparative studies on the range of active elbow joint motion based on data obtained from 50 physical education students. The measurements were made with both an electrogoniometer and a manual goniometer. An explanation of differences in measurement results has been provided based on an investigation by the photographic method of 3 elbow joints using cadaveric material.

key words: goniometry, electrogoniometry, elbow joint

INTRODUCTION

Studies of motion range in human joints provide a valuable source of information, which is used in anatomy, biomechanics, ergonomics, orthopaedics and rehabilitation. Each of these disciplines requires that the data from the study meet the criteria of reliability and accuracy of measurement. As a result there is a clear need for feasible and precise methods of evaluation of joint motion ranges. Some authors [2, 3, 5, 6] point to differences between joint motion ranges when measurements are made with different measurement methods, yet they provide no explanation of such differences. The present study has attempted to explain the differences between the results of goniometric and electrogoniometric measurements in humans. Evaluation of measurement error and corrections based on the photographic material of dissected human bodies has also been performed.

MATERIAL AND METHODS

In order to examine the reliability of goniometric and electrogoniometric measurements researchers took measurements 5 times, by means of both a manual goniometer and a Penny and Giles (P&G) electrogoniometer, of the motion ranges in the elbow joint in 30 subjects. An evaluation of reliability was made using the ANOVA method of reliability examination on the basis of the data obtained in a bifactor analysis of variance. The cadaver material was made up of 3 specimens of pectoral limbs. An elbow joint was prepared on these limbs with the preservation of the ligament apparatus and adjacent muscular insertions in the immediate vicinity of the joint. The anatomical points that determine the location of the manual goniometer [7] as well as the mechanical axis of the joint were marked with markers permanently driven into the bone [1]. The electrogoniometer was firmly fastened to the exposed humeral bone and ulna. The specimen was mounted on a measuring position prepared by the author. Next a series of photographs of each specimen was taken. The photographs were taken at every 10°, starting from the position of maximum flexion of the joint to that of maximum straightness, while the increment of the flexion angle was simultaneously measured to an exactitude of 1° with the use of the P&G electrogoniometer. On the basis of these pho-

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Table 1. A comparison of the increments of a flexion angle, for 3 specimens, made by means both the electrogoniometric method and the direct photographic method

N	$\phi 1$ [deg]	$\phi 21$ [deg]	Difference Δ [deg]	$\phi 21'$ [deg]	Difference Δ [deg]	$\phi 22$ [deg]	Difference Δ [deg]	$\phi 22'$ [deg]	Difference Δ [deg]	$\phi 23$ [deg]	Difference Δ [deg]	$\phi 23'$ [deg]	Difference Δ [deg]
1	10	12	2	11	1	12	2	10	0	12	2	10	0
2	20	22	2	21	1	22	2	20	0	22	2	21	1
3	30	32	2	31	1	32	2	31	1	32	2	31	1
4	40	42	2	41	1	42	2	41	1	42	2	41	1
5	50	52	2	51	1	52	2	51	1	52	2	51	1
6	60	62	2	62	2	62	2	61	1	62	2	61	1
7	70	72	2	72	2	71	1	71	1	72	2	70	0
8	80	82	2	82	2	81	1	81	1	81	1	80	0
9	90	92	2	91	1	91	1	91	1	91	1	90	0
10	100	101	1	101	1	101	1	101	1	101	1	100	0

tographs the increments and flexion angles were determined to an exactitude of 1° using the direct method with a protractor [4]. In addition, an evaluation was made of the corrections to the flexion angle resulting from the shift of the point where the manual goniometer was applied by distance in relation to the physical axis of the joint, applying the following formula:

$$\Delta\alpha = 2 \arccos \left(1 - \frac{d^2}{2a^2}\right)$$

a — length of the goniometer arm, d — distance known from pictures.

An evaluation was also made of the errors that resulted from the shift of the goniometer arm by segment *l* perpendicular to the axis of the long segments and which determine the flexion angle. These are expressed in the formula:

$$\Delta\sigma = \arccos \left(1 - \frac{l^2}{2a^2}\right)$$

a — length of the goniometer arm.

RESULTS AND DISCUSSION

The reliability coefficients (RC) were determined with the use of the ANOVA method on the grounds of the data obtained from the analysis of variance in factor experiments. The value of the coefficient for the manual goniometer equalled RC = 0.603, while for the electrogoniometric measurements the RC value was higher and amounted to 0.796, indicating greater measuring reliability of the electrogoniometer.

The differences between the average values of flexion motion ranges amounted to 7.3° for the left limb and were statistically significant in both cases.

The results of the investigations made on the cadaver material with use of the two methods are presented in Table 1, where ϕ_1 represents the increments of the flexion angle measured with an electrogoniometer, whereas $\phi_{21}, \phi_{22,} \phi_{23}$ are corresponding increments of the angle whose vertex is the point where the axis of the manual goniometer was applied (lateral, epicondyle), determined with the use of the direct photographic method. The increments of the angle whose vertex is an approximate point, through which the physical axis of the joint passes (capitulum of humerus), are marked with $\phi_{21',} \phi_{22'}$, $\phi_{23'}$. Taking into account the numerical error of 2° for both measurement methods, it was found that the results of the increment of flexion angles for these methods were comfortable.

Values d ranging between 6–8 mm were obtained in the measurements of the 3 specimens, which means that, with reference to the angle whose vertex coincides with the physical axis of the joint, the values of the correction of the flexion angle (not the increments of the angle) would amount to 2.8°–3.7°.

Table 2 presents the corrections of the flexion angle in the elbow, depending on the parameter d values, calculated with the use of formula (1).

The estimated values $\Delta\alpha$ are approximate to the values of the differences between those angles whose vertex is the point where the axis of the manual goniometer was applied and those whose vertex

Table 2. The flexion angle in the elbow join

The corrections $\Delta\alpha$		Simulated measuring errors $\Delta\sigma$	
d [mm]	$\Delta\alpha$ [deg]	*l* [mm]	$\Delta\sigma$ [deg]
6	2.8	2	0.9
8	3.7	4	1.8
10	4.6	6	2.6
12	5.5	8	3.5
14	6.4	10	4.4

is the point through which the physical axis of the joint passes. It must be noted that the distance d between the vertices of both angles is not large and both points determining this distance are situated on the same segment of the body. The corrections to the flexion angle are therefore small and do not depart greatly from the experimental error. This means that the corrections $\Delta\alpha$, formula (1) have little effect on the increments of the articular angle and thus on the measurement results of the active motion range in the joint as well. The difference between the averages of the measurements obtained on the live material for the motion ranges in the elbow joint by means of the manual goniometer and those obtained by means of the electrogoniometer, as well as the differences in the reliability of the measurements with these tools, could be explained by an additional, perpendicular shift of the manual goniometer arms in relation to the long axis of the segments — segment *l* formula (2) (Table 2). When the shift of the goniometer arm amounts to 8 mm, then the numerical error $\Delta\sigma + \Delta\alpha$ of such a measurement is approximately equal to 7° and is close to the measuring differences of the motion ranges in the elbow joint which were obtained on the live material.

The results of the electrogoniometric measurements of the elbow joint motion ranges are characterised by a higher degree of reliability in comparison with the manual goniometer measurement results. Therefore, it seems that the electrogoniometric method can be recommended for the measurements of joint angles in order to reduce the differences in the corresponding measurements obtained by various researchers.

Measurement differences arise, adversely affecting the reliability of manual goniometer measurements, from the inaccurate positioning of the manual goniometer axis in relation to the mechanical axis of the joint, and by the error resulting from the impossibility of holding the manual goniometer's arms at the anatomical points, thus causing a perpendicular shift of the goniometer arms towards the long segments of the body.

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