

VARIATION IN EXTENSION OF THE METACARPO-PHALANGEAL AND INTERPHALANGEAL JOINTS OF THE THUMB

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Variation in the range of movement of different joints has often been studied by special instruments, so fitted to the limbs that they give direct readings. Radiographic methods have also been used but are often unsuitable when there is movement in more than one plane. For a hinge joint, true lateral radiographs can be used to give the angle between the two bones, provided that a suitable long axis can be chosen for each bone.

The range of extension movement of the thumb joints in the two authors of this contribution was found to be strikingly different (Figs. 2 and 3) and it was thought that a study of such variations in a random sample of the European population might be of interest. Some so-called "double-jointed" individuals can hyperextend the metacarpo-phalangeal joint of the thumb, and the incidence, variation and mechanism of such hyperextension were investigated. Extension of the joints of the thumbs was also measured in a number of Indians and West Africans in order to determine any racial differences.

MATERIAL AND METHOD

The students and staff of the Department of Anatomy were the main sources of our European samples; 133 male and 100 female Europeans, 31 male Indians and 30 male West Africans formed the several groups. In each subject a lateral view of the thumbs was taken with the metacarpo-phalangeal and interphalangeal joints extended fully. The carpo-metacarpal joint was extended fully, with the thumb midway between abduction and adduction and the thumb-nail at right angles to the film.

Standard longitudinal axes for the three bones had to be found on the radiographs. In the lateral view of the thumb the posterior surfaces of the metacarpal and proximal phalanx usually present straight lines which can be used as axes (Fig. 2). Sometimes the proximal phalanx does not show a well-defined straight line posteriorly, but in such cases a line may be drawn parallel to the greatest thickness of the cortical bone.

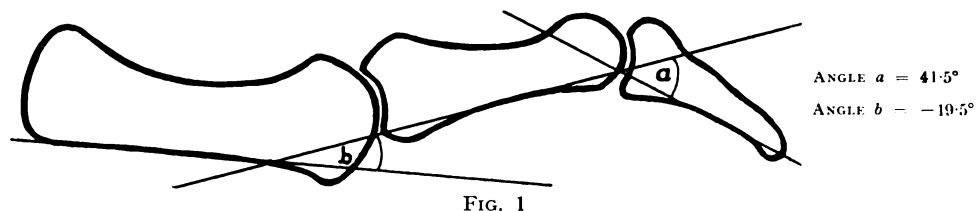


FIG. 1
The method used for measuring the interphalangeal and metacarpo-phalangeal angles.

The axis for the curved distal phalanx was more difficult to determine since the phalanx is always curved in a posterior direction. However, there is nearly always a straight line of cortical bone about one millimetre wide on the posterior aspect, and a line drawn on the posterior surface of the phalanx parallel to this was chosen as the axis. It might be argued that the greater the curvature of the distal phalanx the greater should be the angle between it and the middle phalanx. It was found, however, that the curvature did not vary enough to affect the results materially.

Once the axes were drawn, the angles between them were measured to the nearest half degree. When the two axes were parallel or in line, the angle of course was zero. A positive angle represented the number of degrees of extension beyond this position; if the axes did not reach this position, the angle was expressed as a negative figure (Fig. 1).

TABLE I
 ANGLES AT INTERPHALANGEAL AND METACARPO-PHALANGEAL THUMB JOINTS
 RECORDED BY TWO OBSERVERS MEASURING EACH ANGLE THREE TIMES

Joint	Subject	Observer I			Observer II		
		<i>a</i>	<i>b</i>	<i>c</i>	<i>a</i>	<i>b</i>	<i>c</i>
Right I.-P.	1	36	36.5	36.5	40	38	41
	6	23	23	22	22	22	21.5
	7	1	0	1	2	9	2
	8	29	30	27	28.5	30	29
	9	70	71.5	70	68.5	73	73
Right M.-P.	1	26.5	24.5	26	26	25.5	25
	6	24	23.5	23.5	24	23	23
	7	3	4	3	2	3	3
	8	0	1	0	0	0	5
	9	-8	-8	-8	-7.5	-8	-6.5
Left I.-P.	1	62	61.5	62	61	62	62.5
	6	10	13	14	11	10	11
	7	7	7	7.5	13.5	10	10
	8	36	36	36	34	35	35
	9	46	50	47	49	50.5	50
Left M.-P.	1	24	24.5	25	26	25	25
	6	8	8	9	8	7	8
	7	6	8	5	8	7	6
	8	14	14	14	14.5	14	14
	9	45	46	45	46	46	46

TABLE II
 ANGLES AT INTERPHALANGEAL AND METACARPO-PHALANGEAL THUMB JOINTS
 OF TEN SUBJECTS, EACH RADIOGRAPHED AGAIN AFTER AN INTERVAL

Subject	Right I.-P.		Right M.-P.		Left I.-P.		Left M.-P.	
1	60	63	26	27	61	62.5	25	28
2	16	17	9	4.5	21	15.5	11	9
8	28.5	33.5	0	1	35	32	14	6
11	25	26	16	17	35	35	21	18
13	42	42.5	0	0	33.5	31	1.5	4
15	30.5	28	11.5	11.5	41	41	-1.5	0
16	29	29	3.5	3.5	34	33	15	11
18	48	53	16.5	19.5	58.5	68.5	5	7.5
19	29	30	3	5.5	27	31.5	20	22
20	10	11	5	3	6.5	4	5	2.5

TABLE III
 MEAN AND STANDARD DEVIATIONS OF THE ANGLES AT THE INTERPHALANGEAL
 THUMB JOINTS OF THE EUROPEAN GROUP

Sex	Side	Mean	Standard deviation	Number of observations
Male	Right	29.16	11.65	133
	Left	32.20	11.09	133
Female	Right	23.55	9.73	100
	Left	24.85	11.40	100

In view of the possibility of variation in the observers' interpretation and readings, two observers made three separate readings on radiographs of five subjects (*a*, *b* and *c* of Table I). In order to determine the variation in radiographic technique, ten subjects were radiographed twice with an interval between each film. The results are shown in Tables I and II. It was found that these possible errors were of the order of $\pm 2.5^\circ$ and quite small as compared with the differences in the angles found in various subjects.

Many of the subjects could produce further extension of the metacarpo-phalangeal joint when the carpo-metacarpal joint was flexed; in such cases a film was taken of the thumb in what will be referred to as the "second position" (Figs. 4-7).



FIG. 2



FIG. 3

To show the range of extension movement of the thumb joints in the two authors.

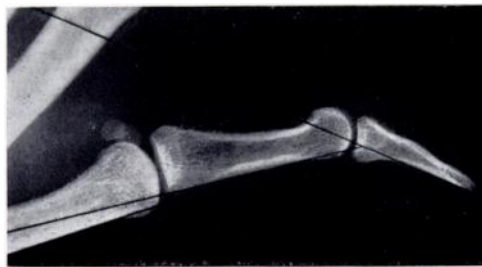


FIG. 4

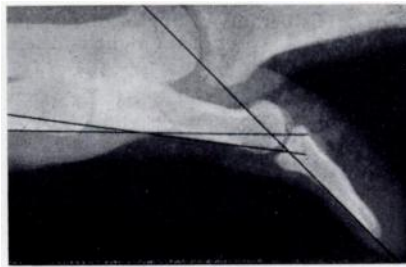


FIG. 5

Figures 4 and 5 show the common finding, that no further extension of the metacarpo-phalangeal joint occurs when the carpo-metacarpal joint is flexed.

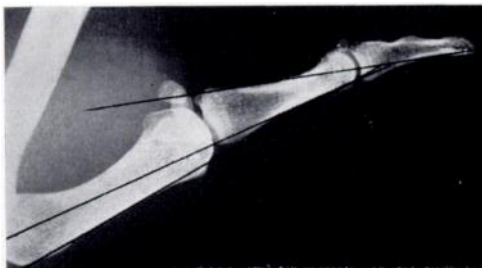


FIG. 6

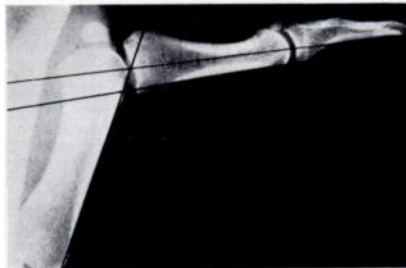


FIG. 7

Figures 6 and 7 show that in some subjects further extension of the metacarpo-phalangeal joint occurs when the carpo-metacarpal joint is flexed.

RESULTS

1) Interphalangeal joints—Figure 8 shows histograms of the angles at maximum extension of the interphalangeal joints of the right and left thumbs in European males and females. Certain conclusions can be drawn:

a) There is considerable individual variation; the greatest angle observed was 67.5° and the smallest 0° .

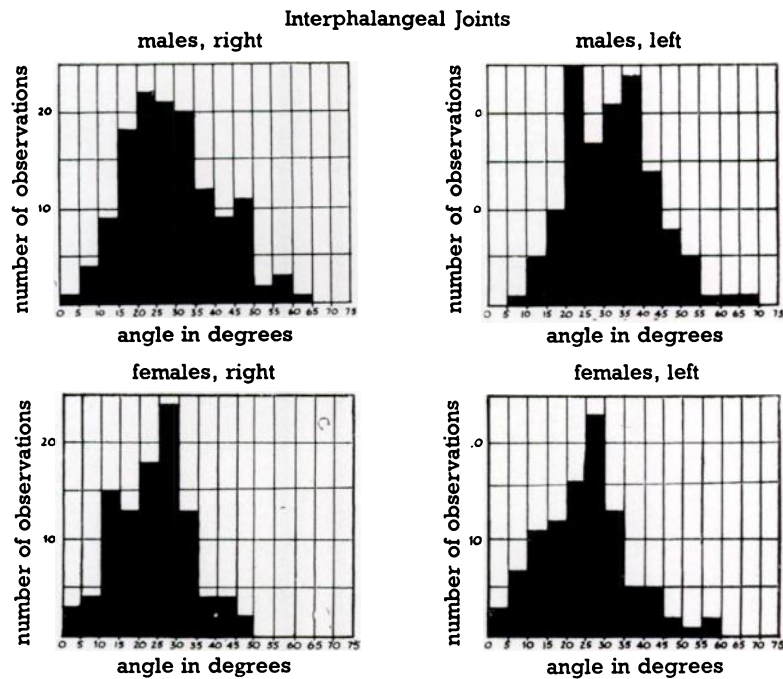


FIG. 8

Histograms of angles of maximum extension at the interphalangeal joints of the right and left thumbs in males and females.

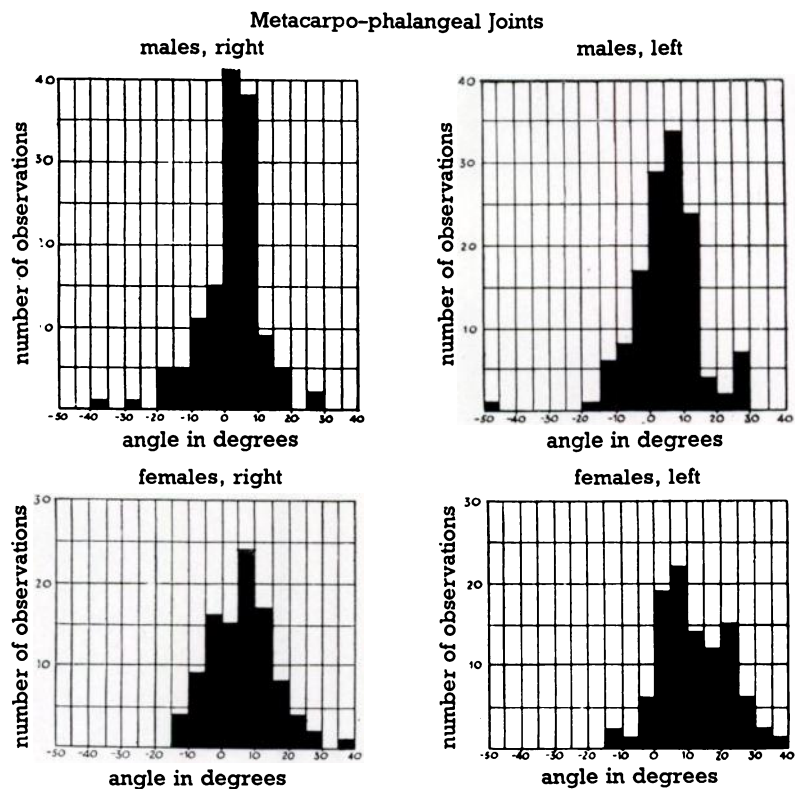


FIG. 9

Histograms of angles of maximum extension at the metacarpo-phalangeal joints (first position) of the right and left thumbs in males and females.

- b) The distribution is fairly symmetrical; the means and standard deviations of the angles for the right and left sides in both sexes are given in Table III.
- c) In the males the mean of the right is 3.04° greater than the mean of the left; this difference is barely significant. In the females the difference between the right and left is certainly not significant.
- d) In both right and left thumbs the means in the males are significantly greater than those in the females.
- e) There is a high correlation between the right and left joints in both males and females ($r=0.66$ in the males and 0.81 in the females).

2) Metacarpo-phalangeal joint—Figure 9 shows histograms of the angles of maximum extension at the metacarpo-phalangeal joints of the right and left thumbs in European males and females. The following conclusions can be drawn:

- a) There is considerable individual variation in maximum extension at this joint; the greatest angle observed was 34° and the smallest -48° .
- b) The distribution is fairly symmetrical; the means and standard deviations for the right and left sides in both sexes are given in Table IV.
- c) In the males the mean of the right is 3.30° greater than the mean of the left, and in the females it is 5.60° greater; these small differences are statistically significant.
- d) The mean of all the angles is small and the angle is often negative.
- e) In both right and left thumbs the mean for the females is significantly greater than the mean for the males.
- f) There is a high correlation in both sexes between right and left thumbs ($r=0.59$ in the males and 0.64 in the females).

TABLE IV
MEANS AND STANDARD DEVIATIONS OF THE ANGLES AT THE
METACARPO-PHALANGEAL JOINTS OF THE EUROPEAN GROUP

Sex	Side	Mean	Standard deviation	Number of observations
Male	Right	2.31	9.22	133
	Left	5.62	9.71	133
Female	Right	5.95	9.59	100
	Left	11.55	9.97	100

3) The interphalangeal compared with the metacarpo-phalangeal joints—The maximum extension at the interphalangeal joint may be related to the maximum extension in the "first position" at the metacarpo-phalangeal joint. The correlations between the two joints in the right and left thumbs of the males and females were calculated and it was found that a slight negative correlation existed in all four cases (Table V). This means that, if the maximum extension angle at the interphalangeal joint is high, the maximum extension angle at the metacarpo-phalangeal joint tends to be correspondingly smaller.

TABLE V
CORRELATIONS BETWEEN INTERPHALANGEAL AND METACARPO-PHALANGEAL JOINTS
OF THE RIGHT AND LEFT THUMBS OF THE EUROPEAN GROUP

Side	Males		Females	
	r	Observations	r	Observations
Right	-0.19	133	-0.19	100
Left	-0.20	133	-0.10	100

TABLE VI
NUMBER OF SUBJECTS SHOWING AN ANGLE OF MORE THAN 40° AT THE
METACARPO-PHALANGEAL JOINT IN THE "SECOND POSITION"

Sex	Right	Total examined	Left	Total examined
Male	5 (3.73%)	133	10 (7.5%)	133
Female	11 (11%)	100	18 (18%)	100

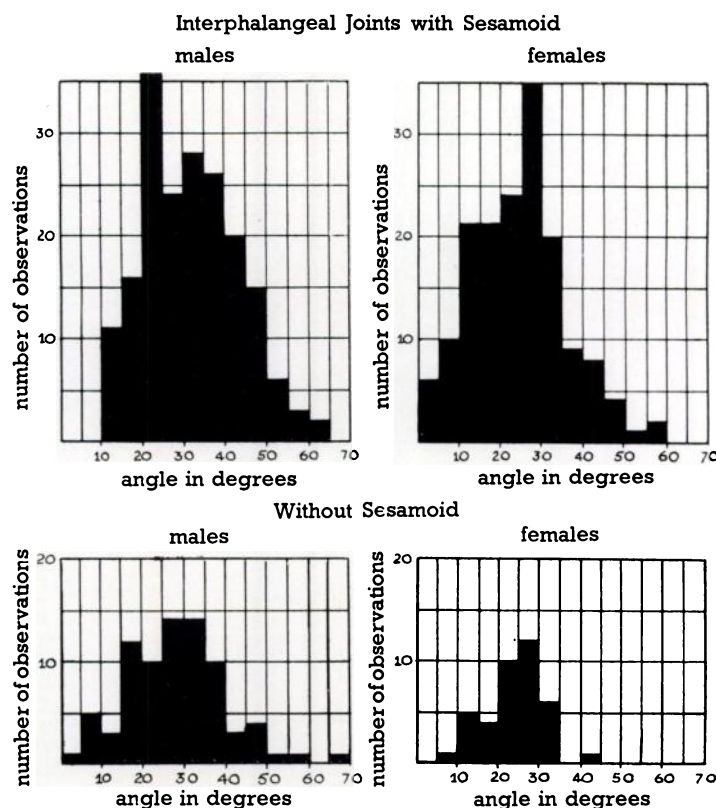


FIG. 10
Histograms of angles of maximum extension at the interphalangeal
joints of males and females with and without sesamoid bone.

4) The "second position"—An examination of the films taken with the carpo-metacarpal joint in flexion showed that, although the angle at the interphalangeal joint showed no significant change from the "first position," there was sometimes a considerable increase in the angle at the metacarpo-phalangeal joint. Some of these second positions could be described as subluxations (Fig. 7). An attempt was made to select these cases by inspection of the radiographs. It was found, however, that no sharp distinction could be drawn, either from the appearances or from measurements of the metacarpo-phalangeal angles, between extreme extension of the joint and subluxation. Extreme extension, or subluxation, was seen more often in women and more often in the left hand. This is shown in Table VI, which gives the number of cases showing an angle of more than 40°. This particular angle was chosen because such a high value was never obtained in the "first position."

5) The relation between extension at the interphalangeal joint and the presence of a sesamoid bone—Figure 10 gives the histograms of the distribution of the angles at the interphalangeal joints of the thumbs in males and females with and without a sesamoid bone.

TABLE VII
MEANS AND STANDARD DEVIATIONS OF ANGLES AT THE INTERPHALANGEAL JOINTS
WITH AND WITHOUT A SESAMOID BONE

Sex	With sesamoid			Without sesamoid		
	Mean	Standard deviation	Number of observations	Mean	Standard deviation	Number of observations
Male	31.80	11.40	187	28.14	12.05	79
Female	24.17	11.34	161	23.90	7.05	39

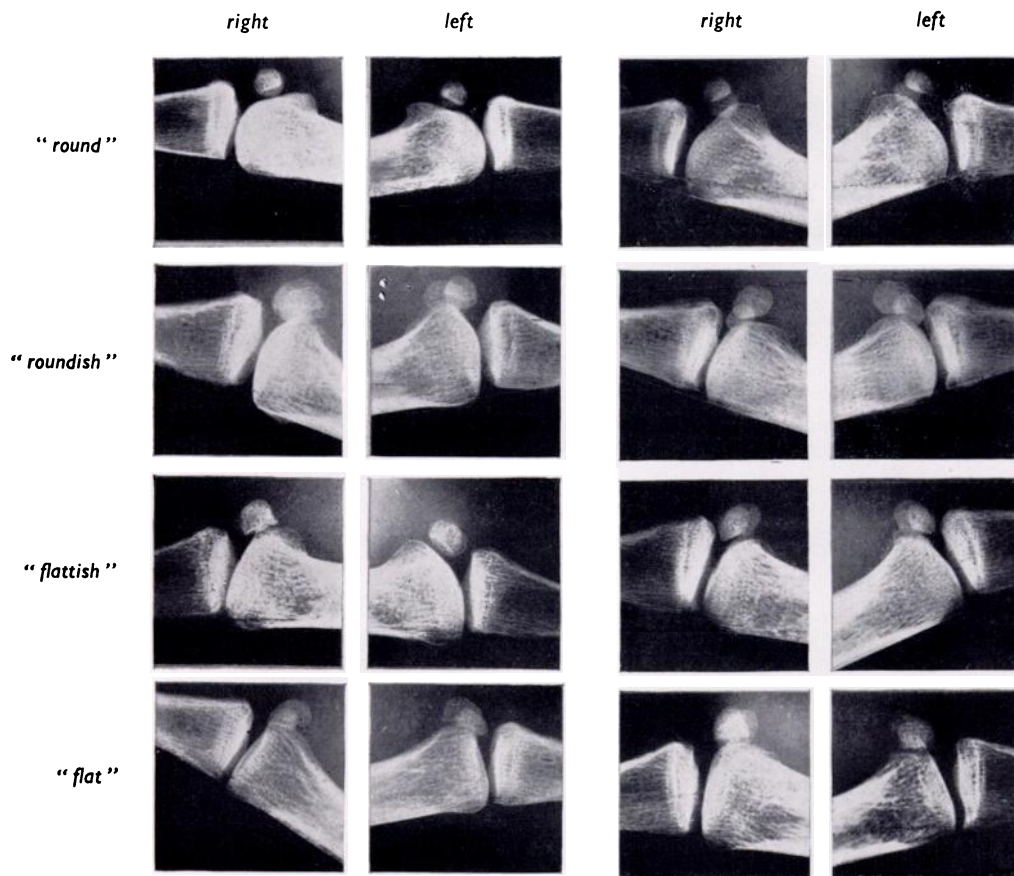


FIG. 11

Variations in the shape of the head of the first metacarpal bone.

Table VII gives the means and standard deviations of the angles with and without a sesamoid bone. The distributions are clearly very similar and the difference between the means cannot be regarded as significant.

6) Shape of the head of the metacarpal bone—The shape of the metacarpo-phalangeal joint surfaces varies considerably between “round” and “flat.” It was easier to divide the joints into four groups according to the shape of the metacarpal heads: “round,” “roundish,” “flattish” and “flat” (Fig. 11).



FIG. 12



FIG. 13

To show the difference in range of flexion at the metacarpo-phalangeal joint when the articular surfaces are round or flat in type.

Certain conclusions can be drawn about the association between the shape of this joint and its movements:

- a) The right and left thumbs usually have the same type of joint.
- b) In flat joints, increased extension in the "second position" is not found.
- c) A preliminary survey of flexion at the metacarpo-phalangeal joints suggests that in "flat" and "flattish" joints flexion is considerably limited (Figs. 12 and 13).
- d) The combined incidence of "flat" and "flattish" joints is about 10 per cent.

7) Group of 31 male Indians compared with 133 male Europeans—Figure 14 shows histograms of the angles of maximum extension at the interphalangeal and metacarpo-phalangeal joints in the "first position" of the right and left thumbs; and Table VIII shows the means and standard

deviations for these joints in the Indians. The following conclusions can be drawn:

- a) As in Europeans, both joints show a considerable variation between individuals in maximum extension in the "first position," and the distribution is fairly symmetrical.
- b) The means of the right and left interphalangeal joints are greater by 7.54° and 7.56° respectively in Indians than in Europeans; these differences are statistically significant.

TABLE VIII
MEAN AND STANDARD DEVIATIONS OF THE ANGLES AT THE INTERPHALANGEAL AND METACARPO-PHALANGEAL JOINTS IN THE INDIAN GROUP

Side	Mean	Standard deviation	Number of observations
Right	36.69	15.51	31
Left	39.76	11.45	31
Right	2.20	11.98	31
Left	10.08	13.68	31

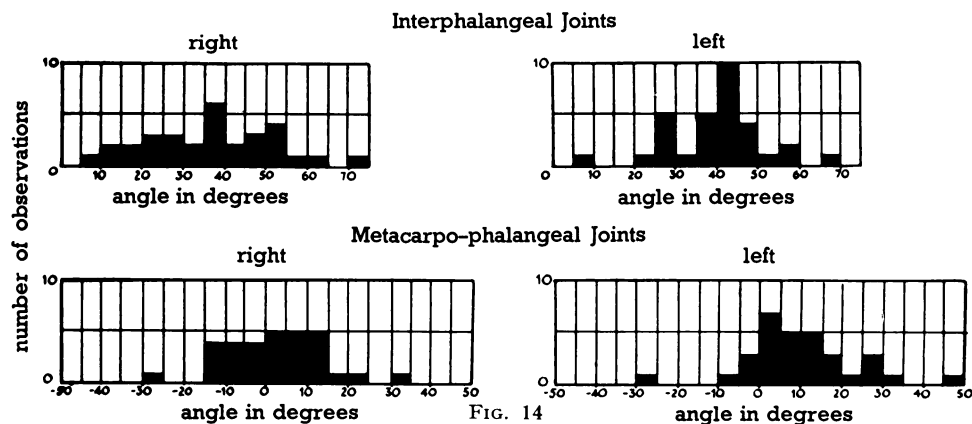


FIG. 14
Histograms of angles of maximum extension at the interphalangeal and metacarpo-phalangeal joints of the right and left thumbs in 31 male Indians.

c) The mean of the right metacarpo-phalangeal joint in Indians is 0.12° less, and the mean of the left metacarpo-phalangeal joint is 4.46° greater, than the means of the corresponding joints in Europeans; neither of these differences is significant.

d) The Indians show a significant increase in the number who have a hyperextended "second position," that is, over 40° . 16 out of 62 Indian thumbs show this as compared with 15 out of 266 European thumbs.

8) Group of 30 male Africans compared with 133 male Europeans—Figure 15 shows histograms of the angles of maximum extension at the interphalangeal and metacarpo-phalangeal joints in the "first position" of the right and left thumbs, and Table IX the means and standard deviations for these joints in Africans. The following conclusions can be drawn:

a) As in Europeans, both joints show considerable variation between individuals in maximum extension in the "first position," and the distribution is fairly symmetrical.

b) The means of the right and left interphalangeal joints are greater by 7.35° and 10.13° respectively than the corresponding means in Europeans; these differences are statistically significant. In this respect the Indians resemble the Africans.

c) The means of the angles at the right and left metacarpo-phalangeal joints in Africans are 0.15° and 0.12° respectively less than the corresponding means in Europeans; neither of these differences is significant.

d) Out of a total of 60 metacarpo-phalangeal joints there are 4 which can be grouped as hyperextensors, that is, measuring over 40° in the "second position." This proportion is much less than in Indians but similar to that found in Europeans.

TABLE IX
MEANS AND STANDARD DEVIATIONS OF THE ANGLES AT THE INTERPHALANGEAL AND METACARPO-PHALANGEAL JOINTS IN THE AFRICAN GROUP

Side	Mean	Standard deviation	Number of observations
Right	36.50	13.15	30
Left	42.33	11.45	30
Right	2.17	10.57	30
Left	5.50	9.85	30

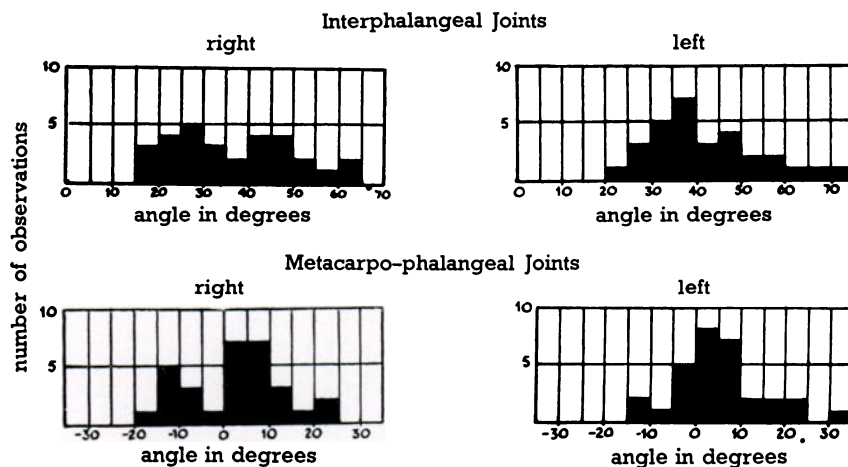


FIG. 15

Histograms of angles of maximum extension at the interphalangeal and metacarpo-phalangeal joints of the right and left thumbs in 30 male Africans.

DISCUSSION

Interphalangeal joint of the thumb—There is very wide variation in the range of extension movement in this joint. In a normal joint the range of movement is determined by the shape of the articular surfaces, by the capsule and ligaments, by the associated muscles and tendons and by the fascia and skin related to the joint. There is little variation in the shape of the articulating surfaces in different subjects, and it is probable that the observed variation is related to the capsule, to the muscles and tendons that produce the movements, or to both. If the anterior capsule is lax, more extension may occur, and clinical examination gives the impression that this is the main factor. Voluntary extension, however, may be influenced also by the ability of the flexor pollicis longus to lengthen and of the extensor pollicis longus to shorten. If this were an important factor one might have expected a change in the range of extension of the interphalangeal joint when the thumb was held in the "second position" with the carpo-metacarpal joint flexed. In most subjects, however, no such change was observed. In a few, where in the "second position" there was a very pronounced degree of extension of the metacarpo-phalangeal joint, the flexor pollicis longus was so lengthened round the front of the metacarpo-phalangeal joint that extension at the interphalangeal joint was reduced (Figs. 16 and 17). In many subjects with a large angle of extension at the interphalangeal joint of the thumb, there is evidence that the joints of the other digits can be hyperextended.

There have been many investigations and many differences of opinion on the functions of the sesamoid bones of the hand (Gillette 1872, Pfitzner 1891-92, Retterer 1918). It has been shown in this study that whatever function they may have, the presence of sesamoid bones at the interphalangeal joint of the thumb is not related to the range of extension of that joint.

Metacarpo-phalangeal joint of the thumb—Maximum extension here presents more problems. The shape of the joint surfaces is probably important in determining the range of movement at the metacarpo-phalangeal joints because on no occasion was there an increase in extension in the "second position" in a joint classified as "flat" or "flattish." On the other hand, when the metacarpal head was "round" or "roundish," increase in extension in the "second position" was often found. The term "hinge joint" in arthrology is somewhat misleading. At most joints where hinge movements take place, gliding movements also occur. If the surfaces between the bone ends are reciprocally curved, the range of movement is increased considerably. If the joint surfaces are flat, one bone is incapable of gliding round the other; it simply tilts at the front or back edges of the joint, and increased flexion or extension demands wide separation of the joint surfaces and considerable stretching of the capsule. Joints with flat surfaces are therefore associated with a limited range of movement.

The large number of muscles attached to the region of the metacarpo-phalangeal joint makes it difficult to examine their role in determining the range of extension. Only one muscle is attached near the back of the joint, namely extensor pollicis brevis. It produces extension but it is aided at full extension of the interphalangeal joint by the extensor pollicis longus. On the flexor aspect of the joint are abductor pollicis brevis, flexor pollicis brevis, the first palmar interosseous, the first dorsal interosseous, and the adductor pollicis transversus and obliquus. In full extension all these muscles are stretched and, if they were short, limited extension might be expected. A short flexor pollicis longus would also prevent full extension at this joint if the interphalangeal joint were fully extended.

The capsule may be important because a tight anterior capsule could limit extension. Another factor is the web between the thumb and index finger. If the metacarpal bone is extended fully the web is usually taut and could limit extension of the metacarpo-phalangeal joint.



FIG. 16

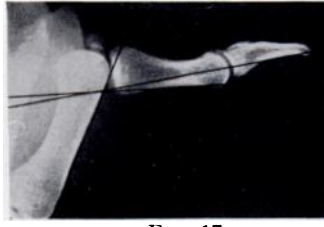


FIG. 17

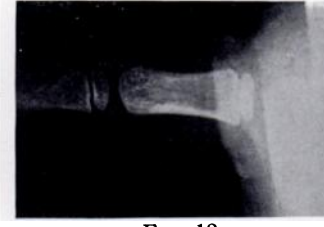


FIG. 18

To show that increased extension at the metacarpo-phalangeal joint may cause diminished extension at the interphalangeal joint.

A hyperextensible thumb in a child of one of the subjects.

If the carpo-metacarpal joint is flexed, further extension at the metacarpo-phalangeal joint does not usually take place. This failure to extend further must be due either to the shape of the joint surfaces or to the tightness of the anterior capsule, because the muscles in front of the joint and the web are relaxed. In a proportion of subjects with curved joint surfaces further extension does take place, and we suggest that laxity of the capsule is the reason. The degree of further extension is variable but it can amount almost to subluxation of the joint.

The word "double-jointed" is frequently used by laymen to describe individuals who can extend one or more joints excessively. No dictionary or standard text-book of anatomy, however, contains the word. It is clear that this ability to hyperextend is one of the phenomena referred to when the word "double-jointed" is used, but it is difficult to see what "double" signifies in this context. Many of the subjects were well aware of their ability to hyperextend the metacarpo-phalangeal joint of the thumb. It can be present from a very early age (Fig. 18). Most subjects said that practice had not increased the amount of extension; one said that, having recognised the trick in one hand, she had learned by practice to do it with the other. One or two remarked that the range of extension movement had decreased over a period of years.



FIG. 19



FIG. 20



FIG. 21



FIG. 22



FIG. 23



FIG. 24

To show the sequence of movements in one subject with hyperextensible thumbs.

Usually the movement was under complete voluntary control but occasionally attempts to extend the thumb fully were accompanied by sudden involuntary movement into the hyperextended position; and one subject said this tendency to subluxate occurred while spanning an octave on the piano.

The sequence of movements is initiated by flexion of the carpo-metacarpal joint by the flexor pollicis brevis, which may be accompanied by slight abduction of the metacarpal bone. The extensor pollicis longus and extensor pollicis brevis are then contracted, thus pulling the proximal phalanx into further extension. Beyond a certain point, it is the action of these muscles that produces full extension at the metacarpophalangeal joint (Figs. 19-24).

In a genetical and linkage study of acholuric jaundice in twenty-six families, Race (1942) noted the occurrence of hyperextensibility of the metacarpophalangeal joint. This he defined



FIG. 25



FIG. 26

A subject with marked limitation of extension at the metacarpophalangeal joint of each thumb. Note the peculiar shape of the metacarpal heads.



FIG. 27



FIG. 28

A subject with an unusual range of extension at the interphalangeal joint of each thumb.

as "ability to extend this joint, undoubtedly beyond 180° ," but his observations were clinical and not radiological. He found that about 15 per cent. of the individuals he studied could do this in one or other hand, though more often in the left than in the right. From his data it seems probable that the condition has a familial concentration, and a genetical factor may be involved. It is clear from our own studies, however, that this is not an "all or none" characteristic.

Two subjects with unusual thumb movement—Two European subjects presented unusual features. In one there was marked limitation of extension of the metacarpophalangeal joints with increased extension at the interphalangeal joints (Figs. 25 and 26). It was found that extension at the metacarpophalangeal joint was not increased even when the interphalangeal joint was fully flexed. The shape of the metacarpal head was peculiar. It was uneven and suggested that the articular surface did not extend in a backward direction

more than half-way, thus preventing full extension. It was also possible that the front part of the capsule was very tight. In the second subject (Figs. 27 and 28) there was an unusually marked degree of extension at the interphalangeal joint, and considerable extension at the metacarpo-phalangeal joint, but no increase in this extension in the "second position" when the carpo-metacarpal joint was flexed. Furthermore, he showed marked hyperextension of the joints of the rest of the digits. The range of extension of the joints in this European subject was comparable only to that found in three Indians.

Extension of the interphalangeal joint in Indians and Africans—The significant difference in extension at the interphalangeal joints between the Europeans on the one hand and the Indians and Africans on the other has already been commented on. It is presumed that this is due to increased laxity of the capsule. Compared with Africans a relatively large number of Indians can hyperextend their metacarpo-phalangeal joints, and in this respect the African group resembles closely the European group. The increased extension in both joints of the thumbs in Indians is very striking, and is in conformity with the general impression that Indians, who make such use of joint movement in their national dancing, have indeed more mobile hands than Europeans.

SUMMARY

1. The range of variation in full extension at the interphalangeal and metacarpo-phalangeal joints of the thumbs of 133 male and 100 female Europeans, and of 31 male Indians and 30 male Africans, has been investigated.
2. There is considerable variation between individuals in the maximum extension of both joints of the right and left thumbs in all groups studied.
3. The distribution for each joint in both thumbs in all groups is fairly symmetrical.
4. There is a high correlation between the right and left thumbs for both joints in all groups.
5. The mean angle of extension at the right and left metacarpo-phalangeal joints in all groups is similar. Female Europeans, however, show a significantly greater mean angle than male Europeans.
6. The mean interphalangeal angle of extension in male Europeans is significantly greater than that in female Europeans and the mean in the Indian and African groups is significantly greater than in the male European group.
7. There is slight negative correlation between the metacarpo-phalangeal angle and interphalangeal angle in each thumb in the European groups.
8. Many subjects in all groups can increase extension at the metacarpo-phalangeal joint after flexing the carpo-metacarpal joint. Marked hyperextension (over 40°) is more frequent in the left than in the right thumb, in females than in males, and in male Indians than in male Europeans and Africans.
9. Maximum extension at the interphalangeal joints is not related to the presence of a sesamoid bone in the anterior part of the capsule of the joint.
10. The surfaces of the metacarpo-phalangeal joints vary considerably in shape. Those which are flat form about 10 per cent. of the sample and do not show hyperextension.
11. The factors influencing the amount of extension at the interphalangeal joint is the degree of laxity of the anterior capsule. The problem at the metacarpo-phalangeal joint is more complex; both the capsule and the shape of the joint surfaces play important roles.

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