Europ. J. appl. Physiol. 32, 259—278 (1974)

Determination of Finger Flexibility*

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Received November 16, 1973

Abstract. Passive flexibility, defined as the range of passive movement in a joint effected by a given external torque, was determined at the metacarpophalangeal joints II to V, by means of measuring the angle of hyperextension and of spreading, respectively. Details of measuring equipment and procedure, developed for this purpose, as well as reliability of the method are reported. The tests were performed on right and left hands of 80 healthy male subjects aged 19 to 51 years, whose occupation did not require any exceptional manual achievement.

The results can be summarized as follows:

1. Passive finger flexibility varies to an extraordinarily high degree: Spreading and hyperextension showed coefficients of variation between 23 and 47 %. This is far above the variability of hand-size data and ranges of active finger movements.

2. Both hands differed significantly only in respect to the angle of hyperextension, the left hand was more flexible than the right one. A weak relation to age was to be seen, hinting a slight decrease of passive finger flexibility between 20 and 50 years. No relationship was found among the test group to different manual activity.

3. Positive correlations ranging from 0.57 to 0.90 were obtained both between right and left hand and, within each hand, between hyperextension and spreading as also between the single spreading angles.

The findings lead to the conclusion that passive finger flexibility should be recognized an independent factor in hand kinetics and, therefore, ought to be considered both in designing equipment for manual use and in judging manual adaptability to defined activities.

Key words: Functional Anthropometry — Hand Kinetics — Manual Aptitude Test — Finger Flexibility.

1. Introduction

The analysis of hand kinetics involves the assessment of finger flexibility especially if manual capacity is restricted as a result of injury or of disease of the hand. Pieper (1969), however, asserts that procedures mainly used in practice (for details see Bunnel-Böhler, 1958; Schink, 1960) are insufficient for an examination of the *function* of the hand. He

* Supported by Stiftung Volkswagenwerk.

requires methods for detecting handicaps of dexterity, since, with advancing technical development, manual skill has become particularly important and, consequently, ought to be studied using adequate methods.

Judging finger flexibility plays a ròle also with respect to aptitude, particularly for activities in which the hand does not serve as a grasping organ as a whole, but where the individual fingers perform defined movements independent of each other, such as working with typewriters and computing machines, data input devices used for electronic data processing, as well as with musical instruments, and particularly the keyed and stringed ones. The characteristic feature of all activities is that the finger tips have to be brought, simultaneously or successively, into spatially defined positions. This is accomplished principally by movements of the metacarpophalangeal joints (Carlsöö, 1964).

Experience has shown that individual capacities with keyboards vary greatly as to speed, precision and endurance. This holds too, even on a relatively high level, for technical skill with musical instruments (Wagner, 1969). In this field it has been known for a long time that the degree of finger flexibility may be a limiting factor (Trendelenburg, 1923, 1925; Ortmann, 1929). According to Guilford (1958), this also can be expected in other psychomotor performances of the hand. In his opinion, the regional psychomotor abilities depend on special anatomico-physiological properties of the body region concerned. However, there are only few experimental investigations in this field which consider more than merely morphologic data (e.g. Müller and Vetter, 1953).

Two functions which are especially important with respect to the above activities are spreading of the fingers and extension (see Fig. 1, left hand). For determining the flexibility within these two moving planes of the metacarpo-phalangeal joints II to V we developed a special measuring instrument and investigated the right and left hands of 80 healthy male subjects, aged 19 to 51 years. The purpose of this study was to obtain reference values for intercomparing professional groups such as musicians, who are required to possess special manual skills or typists who are exposed to manual stress, both intending the design of manual aptitude tests.

2. Methodology

Flexibility is commonly defined as the range of movement that can be achieved in a joint. However, it has to be distinguished between *active* and *passive* movement. The range of active movement, which depends on the subjective effort, gives little information about the level of mechanical resistance, counteracting the motive power, which influences not only the *range* of active movement but also its *process*. For this reason, it was decided to examine flexibility by means of *passive* movements effected by an external torque. This is called "passive flexibility".

Fig. 1. Mstislaw Rostropowitsch (courtesy of Erich Auerbach, London)

2.1. Measurements of Passive Hypertension of the Fingers

The measurements of finger extension were limited to the determination of the angle of *hypertension.*

2.1.1. Apparatus

Fig. 2 shows the apparatus used to measure passive hyperextension of fingers 2 to 5. On the front of a rectangular, cushioned plate (340 × 115 mm) a U-shaped frame is mounted which can be turned around a horizontal axis. While being measured, fore-arm and hand rest on this plate (see Fig. 2). The axis passing through both the ends of the frame is set 10 mm above the plate. Between the shafts of the frame is located a movable, transversal roll which can be locked at any distance from the axis. Fingers 2 to 5 are placed side by side on this roll. The supports for hand and fingers are on the very same plane. The transverse end of the frame is combined with a protractor which passes a stationary mark when the frame is swung. A string passes through a groove which is at the outer rim of the dial and is guided over a roll. To its end an exchangeable weight is attached. The radius between swivel axis and string is 150 mm. The frame with dial and finger support is counterbalanced in such a way that the torque acting on the fingers is determined exclusively by the weight. A slightly concave, cushioned bow prevents

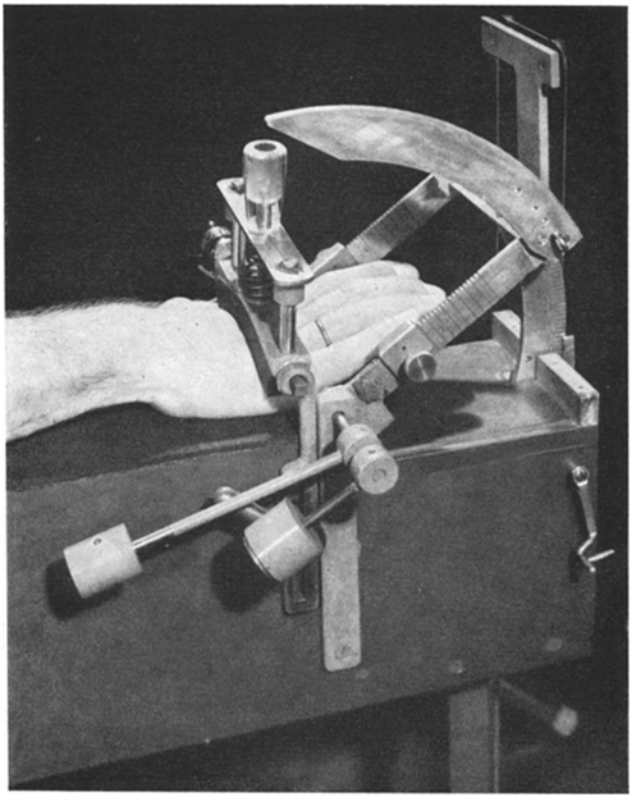

Fig. 2. Device for measuring the angle of passive hyperextension of the fingers II to V

the palm of the hand from lifting by pressing it near the metacarpo-phalangeal joints against the support, while the weight lifts the frame and thus hyperextends the fingers. Two vertical guide pins are fixed to this bow above which another adjustable bow is mounted. Between these bows is a tension spring. By lowering the upper bow down to a defined mark the lower one is pressed by a given force against the back of the hand. The lowest weight that moves the swivel frame from zero to the final position was found to be 20 g, when the device was empty.

2.1.2. Procedure

The distance between axis and finger support is adjusted to a present value and the frame is counterbalanced by removing or adding weight. The string is loaded with a defined weight. For exact orientation upon the position of the joint axis the articular spaces of the four metacarpo-phalangeal joints, which can be easily palpated through the skin, are marked with fat pencil and the hand is fixed in the apparatus in such a way that its longitudinal axis is parallel to the longitudinal axis of the device with the pivot of the basal joints approximately in the vanishing line of the swivel axis of the frame. The subject, sitting comfortably beside the apparatus, is asked to relax completely. After removing the lock the subsequent movement of the frame has to be retarded to prevent any rapid or sudden action of the force upon the fingers.

For our studies on adults a distance of 47 mm between swivel axis and finger support was chosen. Forefinger, middle finger and ring-finger of a normal hand were thus supported in the region of the middle phalanx. The fifth finger was supported in the region of the terminal phalanx. The appropriate test weight was found during preliminary investigations. Using a load of 500 g, extremely flexible hands of adults did not show full-scale reading while in the case of very inflexible hands a visible hyperextension angle could already be read. In no case did the subject complain of discomfort because of the load. Always the final value of the *momentary* extension was read disregarding the following slowly advancing post-extension.

2.2. Measurement of Passive Spreading of the Fingers

2.2.1. Apparatus

Fig. 3 shows the apparatus developed for measuring the passive spreading of the fingers, excluding the thumb. On a rectangular frame (500 × 230 mm) is mounted a flat, cushioned plate (455 × 230 mm) on which fore-arm and hand could rest during measurement (see Fig. 3). On the front of the frame are placed two sector plates which rotate around a common vertical axis, the plane of the plates being lower by 85 mm than the arm support. On each plate a vertical strut is mounted, bearing both a horizontal roll serving as finger support, and a vertical roll stopping the lateral border of the fingers measured (see Fig. 3). The supports are adjusted so that the arm and fingers are level. Provisions are made for shifting the struts along the length of the fingers and locking them at any point. Along the outer rim of each sector plate a string is conducted through a groove and fixed with one end to the plate. The string passes over a roll and is loaded with an exchangeable weight at its free end. The radius between string and axis of the sector plates is 100 mm. Directly below the sector plates is a stationary disk bearing a protractor for each sector. The edges of the sector plates which meet in zero position serve as reading marks when the plates are pulled apart by the weight. In addition to these two scales a further protractor is attached to one of the sector plates in such a way that it can slide below the edge of the other plate. This permits both the total angle of spread between two fingers and the partial angles pertaining to these fingers to be read immediately. It is possible to stop the sector plates separately so that the unilateral spread also can be read. It should be pointed out that merely putting the hand into the apparatus causes a certain spreading angle. Its amount depends on the distance between the pivot of apparatus and the vertical rolls at the top of the struts. Movements of the hand during measurement are blocked by a slightly concave, cushioned bow which presses the hand against its support. The lowest weight that moves the sector plates from zero to the final position was found to be 25 g, when the device was empty.

2.2.2. Procedure

The distance between the rolls and the axis of the sectorial plates is adusted to a given value and each string is loaded with a given weight. Then the articular spaces of the four metacarpo-phalangeal joints are marked with a fat pencil and the fingers are thoroughly dusted with talcum in order to decrease the friction with

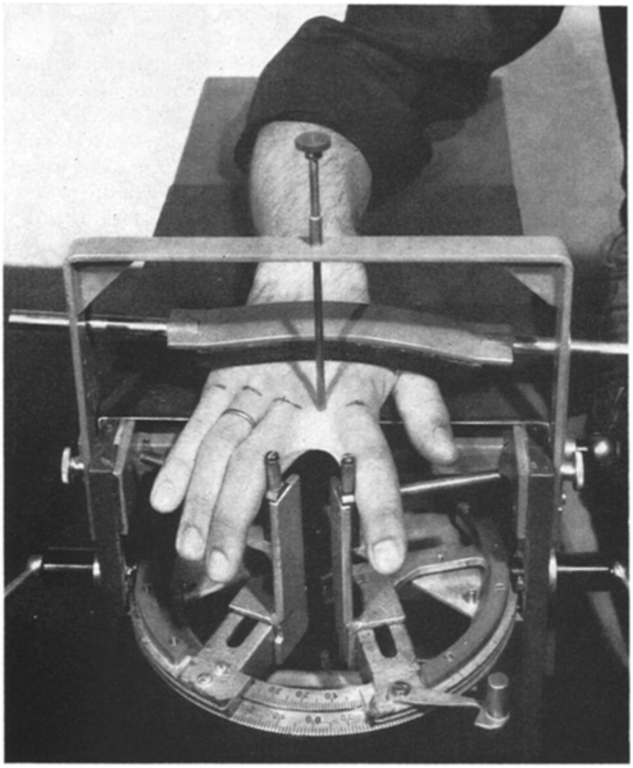

Fig. 3. Device for measuring the angle of passive spreading between the fingers II to III, III to IV and IV to V

the neighboring fingers which are pressed outwards during spreading. The hand is put in the apparatus in such a way that the median line between the proximal phalanxes of the fingers is parallel to the longitudinal axis of the apparatus and points to the zero point of the scale. The intersection of this median line with the connecting line between the articular spaces is put above the vertical pivot of the device. Exact positioning of the hand is facilitated by a pin marker which can be lowered onto the prolongation of the swivel axis (see Fig. 3). The subject sitting comfortably beside the device is asked to relax. After removing the lock, the movement of the sector plates has to be retarded to prevent any rapid or sudden action of the force upon the fingers.

For our tests a distance of 37 mm between rolls and pivot of the apparatus was chosen. Thus an angle of $2 \times 14°$ existed, as measured in the pivot, between the borders of the fingers when the sectorial plates were closed. Forefinger, middle finger and ring-finger of an average hand were thus supported in the region of the proximal interphalangeal joint. The test weight was 2×250 g. Preliminary tests had shown that this was an appropriate load for both very flexible and very inflexible hands. As in the case of hyperextension, always the final value of the momentary extension was recorded.

2.3. Subjects

With the above method right and left hands of 80 healthy men between 19 and 51 years were tested. They belonged to the following professions: administrative officials, scientists, students, technical assistants, programmers, precision mechanics, locksmiths and plumbers. There was no case of injuries or pathological alterations of the hand which might imply restricted flexibility of the metacarpo-phalangeal joints. Four of the subjects had, 6 or more years ago, suffered from tendovaginitis. There were six lefthanded persons among the 80 subjects.

2.4. Statistical Evaluation

Since in the present state of our knowledge, definite predictions upon the distribution of the variables studied could not be made, it seemed to be best to use only non-parametric methods for testing differences and correlations. Differences in the central tendency of independent samples were examined with the U-test (Mann and Whitney) considering ties (Sachs, 1969). Data on the level of significance were always based on the the two-sided test. For evaluation of correlations between the properties studied, the rank correlation coefficient was used, also considering ties (Sachs, 1969). The reliability was checked with the test-retest-correlation coefficient. For testing a trend the test of Cox and Stuart was used (Sachs, 1969).

3. Results

3.1. Reliability of the Method

The reliability of the method was tested with the first 50 subjects by measuring the left hands twice. The distribution of age and profession corresponded to that of the total of the subjects. Preceding stress or recreation as well as time of day could not be considered. The interval between both the measurements was up to 7 months. The reliability coefficients were between 0.93 and 0.97 (see Table 1).

In addition, intraindividual variation was tested by repeating the measurements with two subjects 15 times through 4 weeks. In both cases the variation was less than 5%. Because of the similarity of the results only one of the cases is listed in Table 1. Since it could have been expected from these tests that gradually an irreversible extension of the tissue surrounding the joint might occur, also a trend test was made. However, no trend could be proved within the eight time series.

3.2. Central Tendency and Variability

Fig. 4 gives an illustration of the distributions which are generally found when measuring passive finger flexibility under conditions as described above. Furthermore, it points to the difference between both hands in respect to hyperextensibility. In most of the cases, the left hand

Table 1. Test-retest reliability of the method

Measurements	Test-retest with 50 subjects Reliability coefficient	15 retests with subject B			
		Mean (°)	Standard deviation (°)	Coefficient of variation (%)	Range (°)
Hyperextension of the fingers II—V	0.97	22.5	0.9	4.1	21—25
Spreading of the fingers II—III	0.96	35.5	1.5	4.2	33—38
Spreading of the fingers III—IV	0.97	24.3	1.0	4.1	22—26
Spreading of the fingers IV—V	0.93	42.5	1.2	2.8	39—44

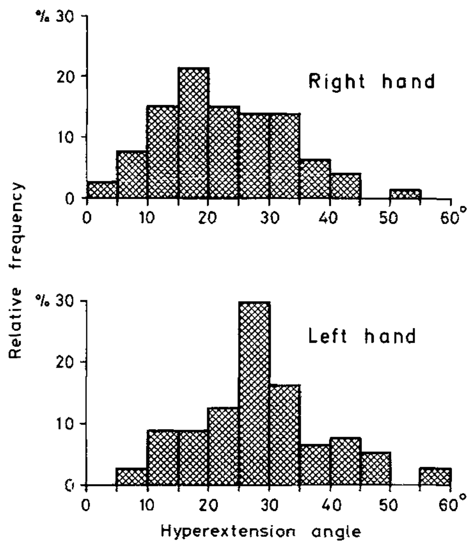

Fig. 4. Frequency distributions of the measured angles of passive hyperextension of the fingers II to V; right and left hands

seems to be more flexible than the right one. Unlike hyperextension, there was no significant difference between both hands in regard to spreading, though a tendency towards higher values of the spreading angle of the left forefinger and middle finger was noticable. Details are given in Table 2a, where means and central values, standard deviations,

Table 2a. Measurements of central tendency and variability for passive movements in the metacarpo-phalangeal joints II—V of both hands

Measurements ($N = 80$)	Mean (°)	Standard deviation (°)	Coefficient of variation (%)	Range (°)	Interdecile range (°)	Median (°)
Hyperextension of the fingers II—V						
right	21.6	10.1	46.7	3—52	8—35	20.5
left	28.2	10.6	37.5	8—58	13—42	28
Spreading of the fingers II—III						
right	33.5	8.2	24.4	21—58	22—45	32.5
left	36.0	8.5	23.6	20—65	26—47	36
Spreading of the fingers III—IV						
right	25.3	8.4	33.1	10—50	15—37	24
left	25.6	7.7	29.9	11—48	17—35	25
Spreading of the fingers IV—V						
right	37.5	9.2	24.6	22—62	26—47	36.5
left	37.4	8.4	22.5	23—68	27—47	37

Table 2b. Significance levels of differences derived from Table 2a

Measurements ($N = 80$)	Differences	Significance level $2\,\alpha$ (%)
Hyperextension of the fingers II—V	right hand vs. left hand	< 0.1
Spreading of the fingers II—III	right hand vs. left hand	> 5.0
Spreading of the fingers III—IV	right hand vs. left hand	> 5.0
Spreading of the fingers IV—V	right hand vs. left hand	> 5.0
Right hand spreading of the fingers	II—III vs. III—IV	< 0.1
	III—IV vs. IV—V	< 0.1
	II—III vs. IV—V	< 1.0
Left hand spreading of the fingers	II—III vs. III—IV	< 0.1
	III—IV vs. IV—V	< 0.1
	II—III vs. IV—V	> 5.0

variation coefficients as well as ranges and interdecile ranges for the right and left hands are listed ("Interdecile range", see Sachs, 1969, p. 69; Lienert, 1973, p. 47). Comparing the spreading angles within each hand showed that there was the smallest angle between middle finger and ring-finger. It differed significantly from the neighboring ones whereas they were essentially indistinguishable from each other. Table 2a shows the significance levels of all the differences. Evaluating the measurements of the six lefthanded subjects yielded no homogeneous results which could be opposed to the group of righthanded people. For our original problem the strikingly large variation of the properties (from 23 to 47%) was remarkable. For hyperextension it was distinctly larger than for spreading, and it was always more pronounced for the right hand than for the left one. The extremes which might occur in the individual case are shown by interdecile range and range (Table 2a). The 9th decile was about 2 to 4 times the first, and in the case of hyperextension of the right hand the maximum was as much as 17 times the minimum.

Here, of course, the question arises whether such a large variation might be caused by treating groups of different age and profession as a whole. Arranging the single values corresponding to age showed, however, that the size of variation remains nearly constant between 20 and 50 years. An example of left hand hyperextensions is given in Fig. 5, where data of 25 further subjects of the same age and profession were added, to make the graph more instructive. (They were taken from

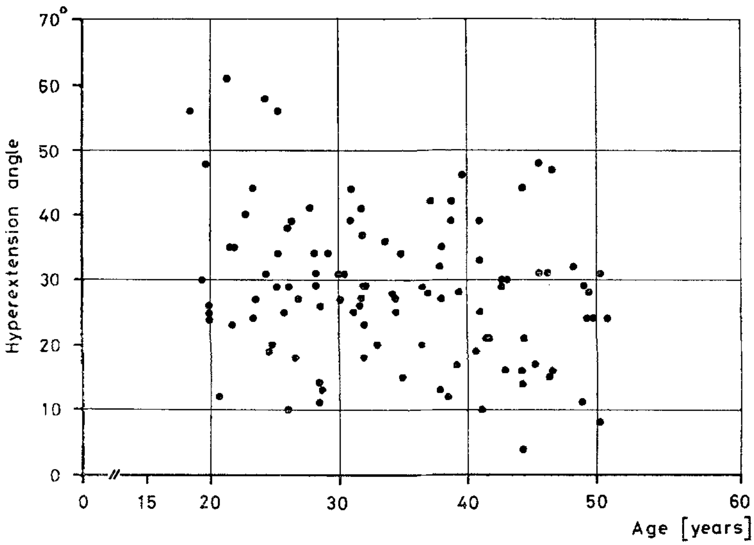

Fig. 5. Dependence of the angle of passive hyperextension of the fingers II to V upon age; left hands of 105 men

Table 3. Dependence of passive finger flexibility on age

Measurements ($N = 80$)	Rank correlation coefficient[a] Right hand	Left hand
Hyperextension of the fingers II—V	– 0.24*	– 0.12
Spreading of the fingers II—III	– 0.24*	– 0.27**
Spreading of the fingers III—IV	– 0.23*	– 0.21
Spreading of the fingers IV—V	– 0.13	– 0.17

[a] Significance level: * $2\,\alpha < 5\,\%$, ** $2\,\alpha < 2\,\%$.

another series where only left hands had been studied.) It can be seen, that a 45 year old man, for example, might have a 3 to 5 times degree of hyperextensibility as a person of 25 years, and vice versa. Similar results were obtained with the other hand and with spreading also. A common characterization of people between 20 and 50 years seems to be admissible, therefore, despite of the fact that the statistical analysis yielded low negative correlation between age and passive finger flexibility (see Table 3). In general, however, the decrease of finger flexibility appears to be rather small during that period of life — as far as this can be judged on the basis of non-longitudinal studies.

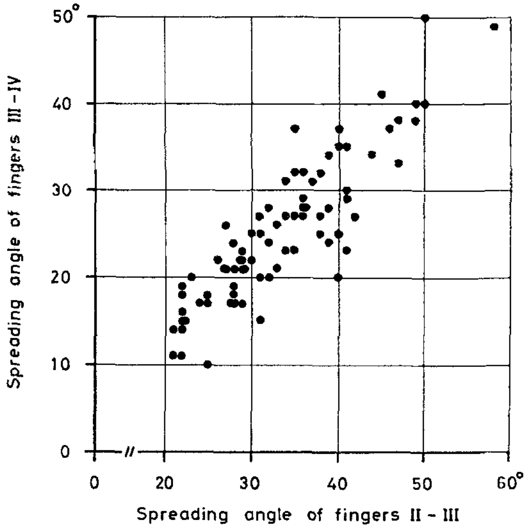

Fig. 6. Relationship between the angles of passive spreading of the fingers II to III and III to IV; right hands

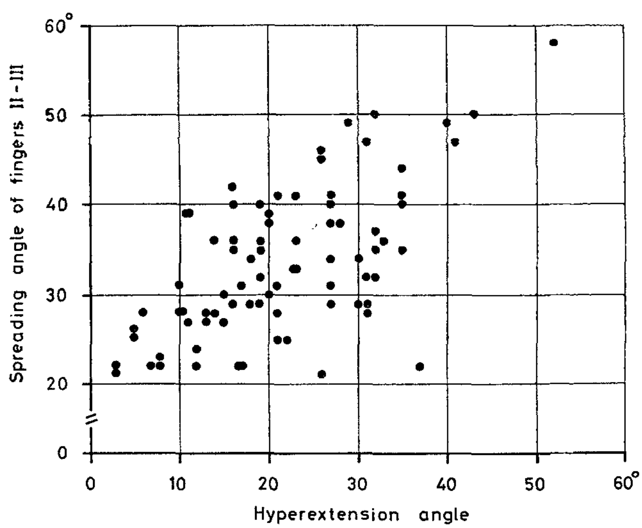

Fig. 7. Relationship between the angles of passive hyperextension of the fingers II to V and of passive spreading of the fingers II to III; right hands

Table 4. Intercorrelations of the tests of passive finger flexibility

Measurements (N = 80)	Right hand versus left hand	Right hand Spreading of the fingers			Left hand Spreading of the fingers		
		II—III	III—IV	IV—V	II—III	III—IV	IV—V
Hyperextension of the fingers II—V	0.77	0.57	0.62	0.57	0.64	0.62	0.65
Spreading of the fingers II—III	0.83	—	0.87	0.82	—	0.90	0.82
Spreading of the fingers III—IV	0.86	0.87	—	0.79	0.90	—	0.84
Spreading of the fingers IV—V	0.86	0.82	0.79	—	0.82	0.84	—

There are other conditions *before* the 20th year of age, as Ellis and Bundick (1956) and Emmerich and Schwarz (1963) have shown. With own studies, too, which shall be reported elsewhere, it was observed that a child's or adolescent's hand is far more flexible than is that of an adult. The four upper values in Fig. 5 might imply, therefore, that in these cases the development of the hand was not yet ended.

Another cause for the size of variation might be expected in the different manual demands on the subjects. Subdividing them into groups with and without manual activity, however, did not yield significant differences. The variation of each group remained on the same level as in the total group.

3.3. Correlation

It is a question of practical consequence whether passive flexibility may be considered as a generalized property of the examined joints or not. The results indicate that, in general, a common tendency towards higher or lower flexibility in these cases can be expexted. As shown by the examples in Figs. 6 and 7, there are remarkable differences, however, between the levels of correlation. All the correlation coefficients of comparing both hands as well as the properties within each hand are listed on Table 4.

4. Discussion

4.1. Discussion of Methodology

Comparing the reliability coefficients it will be noticed that the value for passive spreading between ring-finger and the fifth finger is below those of the other coefficients. Sometimes the basal joint of the fifth finger is shifted more proximally so that the hand has to be adjusted slightly diagonally in the apparatus. This necessity was probably not satisfied every time. Perhaps the reliability might be improved by shortening the interval between the two measurements and by always performing both tests at the same time of the day. Furthermore, unlike activities ought to be avoided prior to the two measurements. The level of reliability indicates, however, that these influences would not be too important.

Since comparable data on the reliability of *passive* flexibility measurements are not available some results of *active* flexibility measurements will be reported here. In their studies on trunk flexibility Matthews *et al.* (1957) obtained reliability coefficients lying between 0.87 and 0.98. McCue (1953) who investigated also leg and shoulder flexibility, reported values between 0.72 and 0.96. The majority were below 0.90. So far as known to us, similar studies on active flexibility of the hand are lacking.

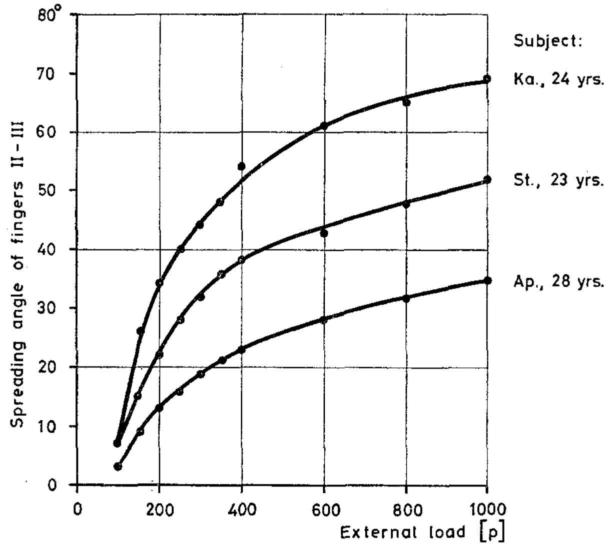

Fig. 8. Dependence of the angle of passive spreading of the fingers II to III upon the external load; right hands (the radius of the external torque was kept constant)

More important than the problem of reliability is the question of diagnostic and prognostic relevance of measuring passive flexibility, as compared with the active mode generally used. As indicated in the 2nd chapter, two independant factors limit the range of active movement of a joint:

1. The motive power, i.e. the strength of muscles acting on the joint.
2. The inhibitory power, i.e. the mechanical resistance derived from various components: the joint's body configuration, the condition of the joint-capsule, ligaments and surrounding tissues, and the extensibility of muscules and tendons inserting distal to the joint.

Measuring active flexibility gives no information on the relative effect of motive power and inhibitory power on a certain range of movement. To get insight into the biomechanical basis of hand kinetics we have to record both factors separately. This enables one to determine flexibility also within the middle sector of joint motion, which is far more important than is the extreme range, since with normal movements limiting positions are avoided as far as possible. This holds particularly for fine motor performances of the hand, as discussed elsewhere in detail (Wagner, 1972). Conditions within this middle sector cannot be derived from testing the maximum range of joint motion, as Fig. 8 may explain. It shows how the angle of passive spreading between forefinger and middle finger depends on increasing external load. (The course of the curves were not calculated but accomodated to the measured values.) In addition, it can be seen how the individual differences mentioned in the preceding chapter may influence even smaller excursions of a joint. If the operation with an apparatus comparable to our experimental setup (see for example, Fig. 1) were to necessitate a change in the angle of spread of the two fingers from 10 to 20°, this would cause, in the case of subject Ka. (Fig. 8, upper curve), an increase in the passive resistance by ca. 20%, and, in the case of subject Ap. (lower curve), by ca. 100%. Vice versa, with the same passive load as applied to subject Ka at 20°, subject Ap. would produce an angle about 7°, only. Finally these curves point to the unfavorable conditions for speed, precision and endurance when excursions of the joint exceed the middle range. Rutenfranz and Iskander (1969) have already shown for movements of the arm that unfavorable positions of the body have an increasingly inhibiting effect on learning sensumotor performances the more the joints are brought into their limiting position.

There is another reason for differentiating between motive and inhibitory powers when joint flexibility is to be judged, namely in the case if the range of active mobility of a joint is to be increased, either for adapting to an apparatus or for reestablishing normal conditions subsequent to injury or disease. Before choosing methods of training or treatment the question which of the two factors has a stronger limiting effect should be taken into consideration. Vice versa the success of such measures can be exactly judged only when active and passive powers are studied separately.

4.2. Discussion of Results

The results of this investigation characterize—at present by a single test value, only—passive flexibility of hands which perform neither very heavy nor specialized precision activities. Difference between right and left hands in respect to hyperextension as well as lack of difference in respect to spread may therefore be explained both by the anatomic structure and the normal use of the hand in daily work. Manual strain seems to reduce slightly the extensibility of the long flexors of the fingers, thus causing a lower hyperextension angle in the more used right hand. Unlike hyperextension, muscles may not account for the inhibitory power in the case of spreading, according to the topographic conditions. Different training levels of both hands would be of little effect. Therefore, probably, larger differences were not found here. In addition, one should remember that a wider spreading than normal combined with dorsal flexion of the fingers is usually not necessary. Moreover, the different anatomic conditions may explain the relatively low correlation between hyperextension and spreading. For this reason, the evaluation of passive flexibility should not be based on a single test. Starting from their measurements of active flexibility Hupprich and Sigerseth (1950) even assume specificity for each joint.

The finger flexibility measurements of Ellis and Bundick (1958), Emmrich and Schwarz (1963) and Bugyi (1965) are not immediatly comparable with our own experiments because only the passive hyperextension of the fifth finger, effected without a *defined* torque, has been studied by these authors. In contrast to our results, Emmrich and Schwarz observed a larger hyperextension angle on the right and explained this with the stronger demand on this hand. They mention also that high values were found on musicians and typists without giving detailed data. With respect to dependence on age our findings agree with those of Emmrich and Schwarz and of Ellis and Bundick. They also found a small decrease in flexibility during the middle period of life. Hertzberg (1972), too, points to this fact. The question arises whether this decrease has any functional significance on the slight decrease of finger dexterity, reported by Müller and Vetter (1953) and often complained by older people as an increasing embarrassment. For some professions, especially the musician who depends on a constant high level of fine motor abilities far beyond the 50th year, this problem has great practical importance (Piperek, 1972). Because of the high variability in passive flexibility longitudinal studies would be highly desirable. Findings as shown in Fig. 5 demonstrate nothing but the present final points of individual developments which might have deviated strongly from the mean tendency.

Although the decrease in passive flexibility is considered to be small during the middle period of life, this is only valid for the special conditions of our test. Perhaps the influence of aging would be more pronounced if other tests were used. It is remarkable, for example, how much the form of distribution of the measured values alters when varying the external torque. On 68 of the 80 subjects the angle of hyperextension was measured with 500 p as well as with 250 p. These recordings resulted in the distributions shown in Fig. 9. Whereas with 500 p 70% of the cases showed an angle of more than 25°, with 250 p only about 20% produced such a large angle. This indicates that there are only relatively few persons who are provided with a large range of joint motion at a low level of passive resistance.

According to Bugyi (1965) any heavy manual work induces a strong restriction of flexibility. Because none of our subjects could be designated as a regular "heavy worker", we cannot substantiate his findings; nevertheless, the difference between right and left hands in respect to hyperextension points in the same direction. However, it also should be

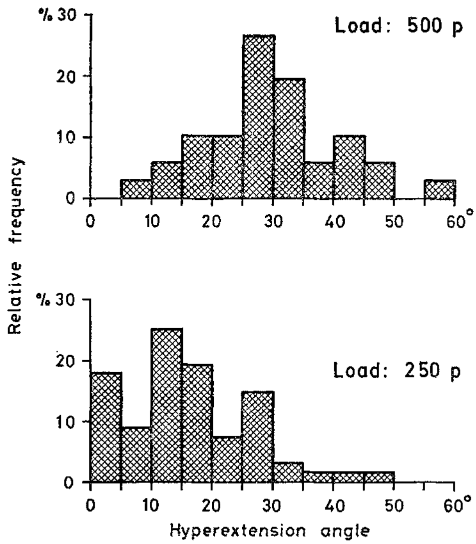

Fig. 9. Frequency distributions of the measured angles of passive hyperextension of the fingers II to V at different loading; left hands

mentioned that there were a number of cases where with entire absence of manual demand extremely low values were recorded, and vice versa, above-the-average angles of hypertension were found with relatively heavy manual activity. Excluding the conditions of extreme manual strain it appears that the degree of passive finger flexibility is determined primarily by the genetic constitution and only secondarily by influences of aging or manual activity. The results of our investigations on violin players, too, are plausible only on this supposition (Wagner, 1972). Measuring passive finger flexibility as an independant factor, therefore, might have a certain prognostic relevance when manual aptitude is to be judged at the beginning of special education.

5. Practical Conclusions

To obtain a complete picture of the possibilities of manual mobility similar investigations on the other joints are necessary as well as studies on the motive power. However at present certain practical consequences are to be seen. For the design of equipment intended for manual use data on hand-size and active mobility are recommended to be taken as a basis (Matzdorf, 1968; Garrett, 1970a, b; Hertzberg, 1972). The sizes of hands and fingers vary by 5 to 10% (Garrett, 1970) and the ten finger spans by 5 to 15%, as we learned from own studies which shall be reported elsewhere. As has been shown, *passive* flexibility of the hand, however, may vary up to nearly 50%. Therefore, measuring only handsize and active flexibility gives a partial or even an incorrect picture of the actual range of variation of functionally important properties of the hand. Ergonomic guiding principles derived from these data only, cannot in any case prevent muscular effort at a level which may affect manual performance, especially when rapid and precise movements are required. Therefore, in our opinion, appropriate reference values of passive flexibility should be regarded in this field of equipment design. Vice versa, the same applies to judging the manual adaptability to defined activities.

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