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Method for Measurement of Maximal Isometric Muscle Strength with Special Reference to the Fingers

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INTRODUCTION

In daily life, both in industrial and household work, as well as in certain leisure activities, good function of the hand and fingers is of great importance. This function depends upon several factors, of which a main one is muscle strength.

In order to study the finger function, a method has been developed for measurement of the maximal isometric muscle strength in the fingers. It has been considered of importance that the measurement procedure (including calibration and reading of the instrument) shall be easily handled by the examiner.

Methods for measurement of muscle strength have been described previously by Assmussen et al. (1959, 1961), Tornvall (1963), Bäcklund & Nordgren (1968) and Höök & Tornvall (1970), among others.

METHOD

The apparatus used is a combination of standard and laboratory-constructed equipment.

A mechano-elastic transducer (Pressduktor®, ASEA; Dahle 1954) is used as the pressure transducer. The pressduktor has been used previously in muscle strength measurements by Bäcklund & Nordgren (1968).

Measurement of finger strength: The muscle strength in the fingers varies between about 0.05 and 15 kp (i.e. ~0.5 and 150 Newton), thus including comparatively very low strengths and percentually large range of variation. The pressduktor used for measuring the finger strength has been adjusted to a pressure of 20 kp, which gives a measurement range between -20 kp (output signal -1.3 V) and +20 kp (output signal +1.3 V). The finger strength pressduktor is mounted in a holder (Fig. 1). The force applied influences the pressduktor via a lever system, where the lever for the finger force applied is 8.5 times longer than the lever for the transducer. When these low finger strengths were measured hysteresis in the system gave rise to problems.

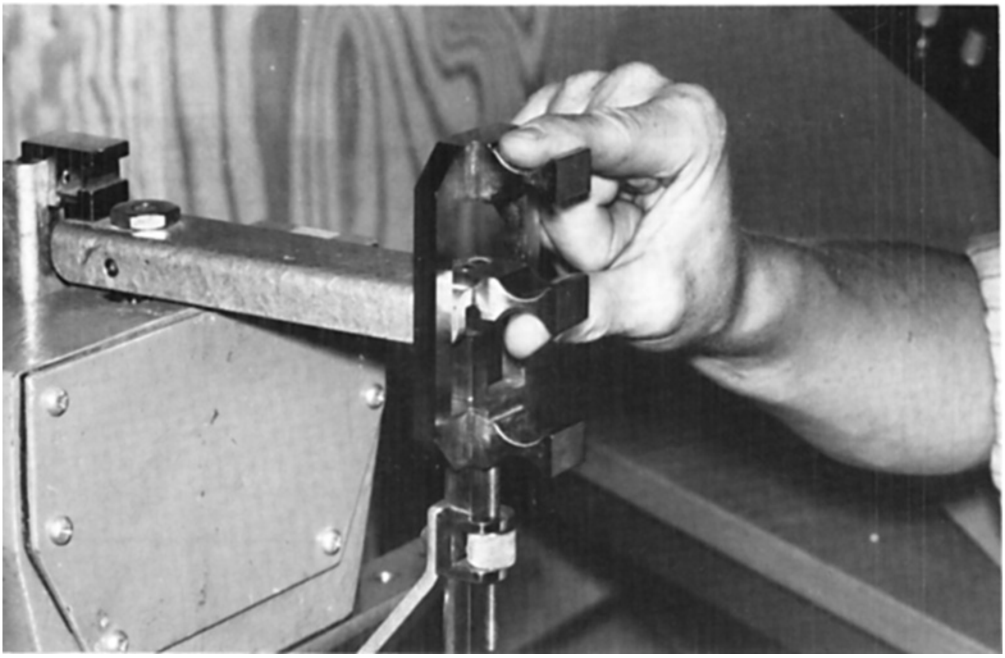

Fig. 1. To the left the pressduktor with the lever and the tightening screw-nuts; to the right the adjustable finger grip.

Several reasons for this became evident. One of them was the summation effect of several very minor backlashes, i.e. the system must have absolutely tight fittings. The use of a hinge joint on fixation of the lever gave hysteresis. Instead, therefore, grooves were made on both the lever and the holder. Into these grooves two thin steel plates were welded (one in the horizontal and one in the vertical plane). By the use of these steel plates (0.5 mm thick) for transferring the force of the lever and for suspension, a constant and defined lever length was also obtained (Fig. 2 a and b). The application of tension to the pressduktor and the tightening of the screw-nuts (Fig. 1) at the connection between the pressduktor and the lever mean that the lever's own weight has no effect on the finger force applied. Here also a thin steel plate was used for transference of force between the pressduktor and the lever.

Fig. 1 shows measurement of the strength on opposition between the thumb and index finger. The grip surfaces are grooved to fit the finger and thumb. The middle bar is attached to the lever connected to the pressduktor, while the upper and lower bars are firmly attached to one another. Their position can be varied by the screw under the lowest finger-grip bar. For testing the finger abduction strength (Fig. 3) the tested fingers are inserted between the middle bar and one of the two fixed bars, which is adjusted to give a space of a few mm between the fingers. Abduction and adduction are tested with an angle of 0^{o} in the metacarpophalangeal joint, i.e. in an extended position.

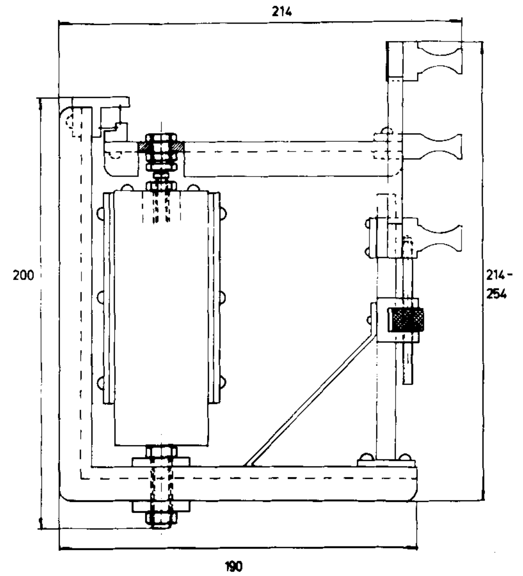

Fig. 2 a. Diagram of the pressduktor with the lever for measurement of the finger strength.

The figures are in mm.

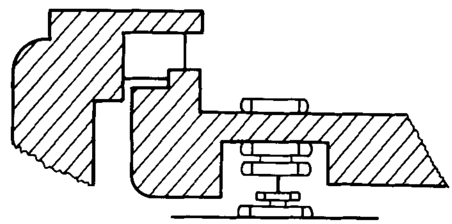

Fig. 2 b. Section of the lever illustrating transference of power in measurement of finger strength.

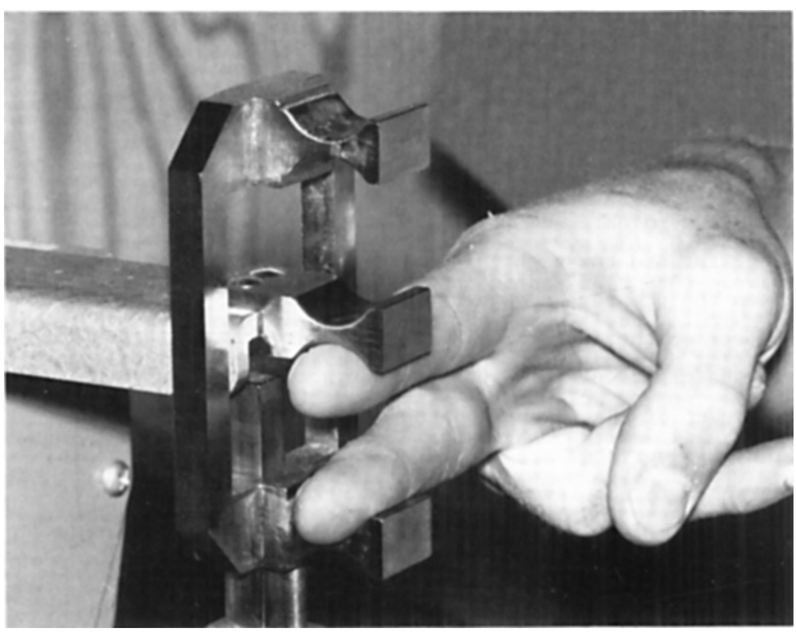

Fig. 3. Grip for measurement of the strength on opposition between digits I and II. The width of the grip is adjusted by means of the screw.

Fig.s 4 a and b show the values recorded on the potentiometer recorder (Servogor RE 520 Z) with different suspended weights (both pull (o) and push (•) sympols). The linear relationships correspond for both pull and push, with no tendency to hysteresis around the origin.

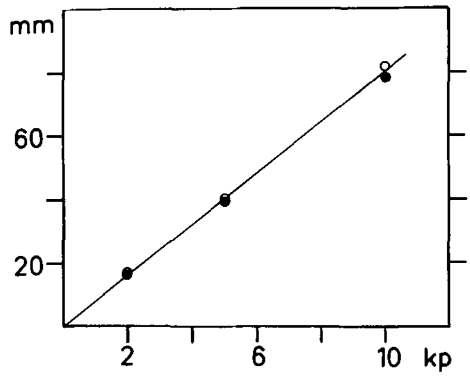

Fig. 4 a. The linearity on application of force (pull o, push •) to the pressduktor.

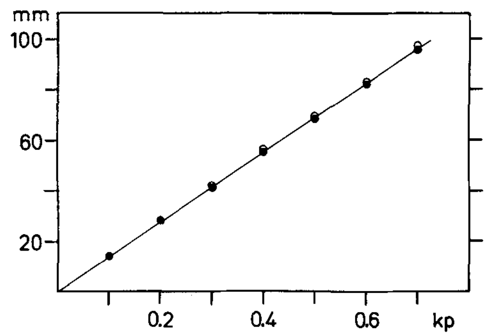

Fig. 4 b. The linearity on application of force (pull o, push •) to the pressduktor.

With forces of more than 10 kp (e.g. in several persons on opposition between the thumb and index finger) the apparatus for measurement of the hand grip can be suitably used - at such forces the finger strength pressduktor gets a slight curvilinearity. Occasional overloading of the pressduktor measuring system has not altered its properties.

APPARATUS SET-UP

The set-up of the apparatus also allows measurements of the strength of the hand grip, pro- and supination and volar flexion and dorsiextension of the hand as described by Bäcklund and Nordgren (1968).

The measurement procedure thus gives a more complete picture of the function of both the fingers and the hand and forearm.

Fig. 5 shows the apparatus set up with the recorder and selector panel (to the right on the table) for the different tests. The holder of each pressduktor is suspended on a steel wire. In this way it can be adjusted vertically and rotated around the metal tube.

The electronics are constructed such that the signals from the different pressduktors can be selected on the panel. For the finger strength three different sensitivity ranges can be chosen (the greatest degree of amplification for the adduction test). In consideration of the variations in muscle strength between the examined persons it is also possible by means of a

Fig. 5. The set-up of the apparatus.

special selector to dupulicate or halve the pen recording. There is a possibility of compensation (rotation potentiometer) in each of the five selectors. Calibration by changing the magnitude of the output signal from the respective pressduktors can be performed by means of special rotation potentiometers. The muscle strength applied is read directly on the recorder (kp; for rotatory tests kpcm) by means of graded rules.

Experience of the stability of the measurement equipment has shown that the output signal only needs to be altered twice a year, at the most.

RESULTS

Reproducibility in repeated measurements of the finger strength.

Table I presents the variation in muscle strength in the fingers at repeated measurements on the same female subject at intervals of a few days.

Table I. Repeated tests of the maximal isometric muscle strength of the fingers in the same person on four different days ($\bar{X}$ = mean).

	Right side		Left side	
	$\bar{X}$ (kp)	Range (% of $\bar{X}$)	$\bar{X}$ (kp)	Range (% of $\bar{X}$)
Opposition				
Digit. I-II	9.3	95-106	8.1	93-111
Digit. I-III	8.4	89-107	8.1	98-105
Digit. I-IV	6.1	82-111	6.1	82-115
Digit. I-V	4.2	77-132	4.3	81-127
Adduction				
Digit. I-II	8.9	97-101	7.9	86-114
Digit. II-III	4.8	80-119	4.4	76-115
Digit. III-IV	2.8	76-113	2.9	70-130
Digit. IV-V	1.7	72-114	1.6	70-114
Abduction				
Digit. I-II	1.3	91-106	1.3	85-108
Digit. II-III	1.3	89-114	1.3	89-104
Digit. III-IV	0.7	89-119	0.8	80-107
Digit. IV-V	0.9	65-131	0.9	74-116

Finger muscle strength in normal persons

Table II gives the mean values ($\bar{X}$) and standard deviations (S) in 14 men with a mean age of 34 years (range 22-55 hears) and 13 women with a mean age of 27 years (range 19-46 years), with no signs of disease.

Table II. Isometric maximal muscle strength in the fingers in a control series of healthy persons, kp, ($\bar{X}$ = mean, S = standard deviation).

	MEN				WOMEN			
	Right		Left		Right		Left	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
Opposition								
Digit. I-II	16.5	7.4	14.9	4.9	10.4	3.6	9.9	3.6
Digit. I-III	14.2	5.1	15.1	6.1	9.9	3.5	8.9	3.6
Digit. I-IV	12.1	6.4	12.9	6.0	6.7	3.6	6.8	2.5
Digit. I-V	8.9	2.6	9.8	4.0	5.5	2.0	5.2	2.5
Adduction								
Digit. I-II	7.1	2.5	6.7	2.3	5.5	1.5	4.7	1.7
Digit. II-III	2.2	1.4	2.6	1.2	2.7	1.5	2.9	2.5
Digit. III-IV	1.4	0.6	1.6	1.0	1.3	0.6	1.9	1.7
Digit. IV-V	1.2	0.8	1.3	1.0	1.2	0.5	1.3	0.8
Abduction								
Digit. I-II	1.11	0.55	1.05	0.61	0.92	0.43	0.81	0.50
Digit. II-III	1.02	0.61	0.97	0.57	0.90	0.37	0.79	0.37
Digit. III-IV	0.63	0.42	0.65	0.45	0.65	0.40	0.67	0.40
Digit. IV-V	0.63	0.48	0.60	0.20	0.64	0.33	0.64	0.34

DISCUSSION

The variation in repeated finger strength measurements on the same person (Table I) is greater on the ulnar than on the radial side, which may be an expression of the better muscular coordination on the thumb side.

Asmussen et al. (1961) measured the thumb pressure, which corresponds to adduction of digits I-II in the present study, and also pinching of digits I-II, corresponding to opposition of digits I-II in this study (Table II). They found higher values for thumb pressure than for pinching, while opposition gave higher values than adduction in the present study.

The values for adduction are lower than the values of Asmussen et al. for thumb pressure, while those for opposition are higher than the values of Asmussen et al. for pinching. The reasons for these discrepancies in the results cannot be explained with certainty, but differences in the measurement technique may be a possible reason. The movement on adduction and opposition between digits I and II merge into one another and variations in the performance of the test may therefore play a role.

The function of the finger musculature, e.g. in association with nerve injuries, can be tested with this method. Opposition and abduction of digit I, and the lumbrical muscles I-III, depend upon the median nerve. Abduction and adduction between digits II and V are dependent upon the interosseous muscle and the abductor and opponens muscles of digit V. These muscles are innervated exclusively by the ulnar nerve, and thus constitute a test of the function of this nerve.

SUMMARY

A method for measurement of the maximal isometric muslce strength in the fingers is presented. Details of the apparatus designed for avoidance of hysteresis in mechanical components on measurement of low strengths are given. The measurement of low strengths is described. The measurement procedure is simple both for examiner and for the subject. Values for finger muscle strength in normal persons are presented.

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