THE STRENGTH OF THE HAND

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INTRODUCTION

Although strength is one of the important characteristics of a normal hand, this factor is not given enough attention in reconstructive surgery as compared to other parameters of motion and sensibility. This paper presents the results of a study on strength in functional adaptations of the normal hand. A baseline of normal grip and pinch strength was obtained by testing a group of one hundred healthy persons. As it is necessary to know the normal to appreciate the abnormal, a parallel evaluation of the disabled hand could define the degree of impairment present (1,2,3,4,5).

Regnier, 160 years ago, reported the first analysis of strength of the hand measured with a personally designed dynamometer (6). Some more recent studies were made by Lewey, Kuhn, and Juditski (1947), Bechtol (1954), and Mannerfelt (1966) (7,8,9). Isometric contractions of the hand muscles were measured with pneumatic (10) or hydraulic spring-scale dynamometers. The pinch meter used in our study is an electronic device designed by Kashiwagi's Orthopaedic Department at Kobe University, Kobe, Japan (11).

The strength of the normal hand was recorded as applied in basic hand patterns: grip, chuck pinch (three-digit pinch), pulp (fingertip) pinch with separate fingers, and lateral pinch. Measurements are expressed in kilograms of force units.

METHOD AND MATERIALS

The force of grip was recorded with a Jamar hydraulic dynamometer. The strength of chuck, pulp, and lateral pinches was tested with an electronic pinch meter based on the straingage principle. The pinch object was a disk measuring 2.2 cm. dia. and 0.5 cm. thick. Changes in

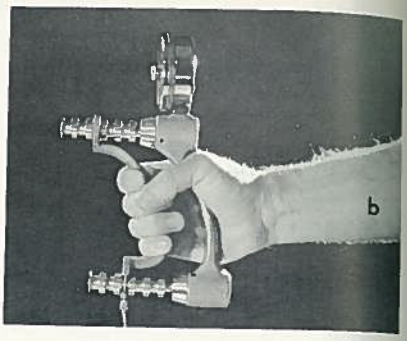

FIGURE 1.—a. Measuring devices used for evaluation of hand strength, b. using the Jamar hydraulic dynamometer.

electrical potentials were transmitted by this disk to the recording device (Fig. 1a).

The study group consisted of 50 males and 50 females (200 hands) ranging from 17 to 60 years of age. They were distributed according to occupation in three main groups: skilled (skilled craftsmen using dexterity without heavy manual labor) 36, sedentary (light clerical occupations) 16, and manual (laborers doing unskilled heavy work, such as shoveling snow) workers 48. All subjects were in good health. The tests were done at various times of the working day at a room temperature of 70 deg. F. Both the major and the minor hand were tested in a comfortable position. Little difference was noted in the strength of the grasp and pinch regardless of whether the test was performed in a standing or sitting position, or the extremity was supported or unsupported, although pinch forces in the supported position were generally somewhat lower.

The following standard measurements were taken:

1. Strength of grip
   a. without support of the extremity,
   b. with support; i.e., with the arm or elbow resting on the table or close to the body.
2. Strength of chuck pinch (three-digit pinch).
3. Strength of pulp pinch for each separate digit (II, III, IV, V) with thumb.
4. Strength of lateral pinch (between digits I and II).

Originally each of the strength tests was given three times. However, the first attempt was usually the strongest, and repeated testing proved to be unnecessary in a cooperative person. This was given consideration in this study. The various measurements were performed at short intervals and a control series was done on the same person several days later.

STRENGTH OF GRIP

The adjustable handle of the Jamar hydraulic dynamometer was spaced at 2½ in. (Fig. 1b). Most subjects were comfortable at this breadth of grip and could apply maximal force when tested. The minimal and maximal strengths of grip measured in the male group ranged from 30.4 to 70.4 kg. and 14.0 to 38.6 kg. in the female group. Table 1 shows the average strength of grip for each group studied. The skilled and sedentary males recorded very similar figures and the forces recorded by the manual workers were not significantly higher. Taken separately, manual workers recorded the highest figures, 56.1 kg. for the major hand and 49.3 kg. for the minor one. Variations in the force of grip according to age are seen in Table 2. The male group showed rather constant

TABLE 1.—*Average Strength Grip (Unsupported) Listed by Occupation*
(100 Subjects)

Occupation	Unsupported Grip, kg.			
	Male hand		Female hand	
	Major	Minor	Major	Minor
Skilled	47.0	45.4	26.8	24.4
Sedentary	47.2	44.1	23.1	21.1
Manual	48.5	44.6	24.2	22.0
Average	47.6	45.0	24.6	22.4

TABLE 2.—*Average Strength of Grip Listed by Age*
(100 Subjects)

Age	Grip, kg.			
	Male hand		Female hand	
	Major	Minor	Major	Minor
20	45.2	42.6	23.8	22.8
20–30	48.5	46.2	24.6	22.7
30–40	49.2	44.5	30.8	28.0
40–50	49.0	47.3	23.4	21.5
50–60	45.9	43.5	22.3	18.2

strength between the ages of 20 and 50 years. In the female group the maximal strength was recorded between the ages of 30 and 40 years. The grip was found to be weaker when the extremity was supported. The average figure for the supported extremity in the male group was 44.7 kg. for the major and 41.7 kg. for the minor hand. The female group registered 22.3 kg. and 20.1 kg. respectively for the supported extremities. This reduction could be explained by the fact that part of the strength was lost in stabilizing the extremity.

PREFERRED PINCH

Several small objects such as coins, screws, buttons, and keys were picked up by any method desired. The type of pinch preferred by each individual to obtain his maximum strength was noted. The grasping patterns employed could be classified in five categories: 1. Pinch with simultaneous action of digits I, II, and III (chuck pinch) was selected by 44 percent of the subjects for the major hand and 49 percent for the minor hand (Fig. 2a). 2. Simultaneous action of digits I and II was used in 29 percent of the major hands and 25 percent of the minor ones. 3. A third variety of pinch using digits I and II initially and including digit III for support during the last phase of pinch was observed in 19 percent of the subjects for both hands. 4. Another type of two-step pinch using digits 1 and III first and digit II last was recorded for 7 percent of the major and 4 percent of the minor hands. 5. Pinch between digits I and III was the fifth type of grasp preferred and was found in 1 percent of the major hands and 3 percent of the minor ones.

Table 3 shows the average strength of the chuck pinch for the various groups examined. A small difference in strength of pinch was observed between the sedentary and manual workers. The minimal to maximal strength of chuck pinch recorded for the major hand was 6.0 to 14.5 kg. in the male group and 4.0 to 10.0 kg. in the female group. The inter-

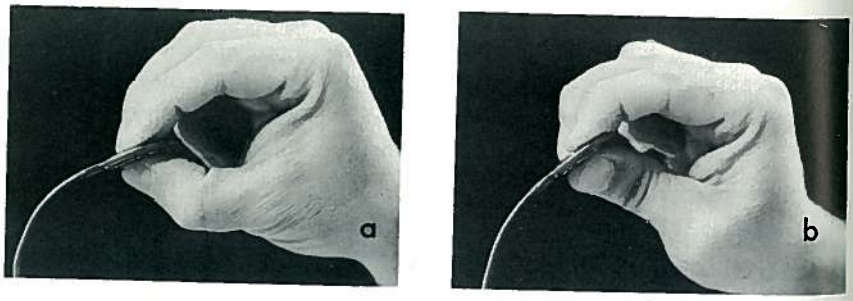

FIGURE 2.—a. Preferred pinch with digits I, II, and III (chuck pinch), b. the IP joint of the thumb becomes hyperextended when maximal chuck pinch strength is applied.

TABLE 3.—*Average Strength of Chuck Pinch by Occupation*
(100 Subjects)

Occupation	Chuck pinch, kg.			
	Male hand		Female hand	
	Major	Minor	Major	Minor
Skilled	7.3	7.2	5.4	4.6
Sedentary	8.4	7.3	4.2	4.0
Manual	8.5	7.6	6.1	5.6
Average	7.9	7.5	5.2	4.9

phalangeal joint of the thumb was hyperextended in most cases when the maximal force of chuck pinch was applied (Fig. 2b).

PINCH WITH SEPARATE DIGITS

The end device of the electronic pinch meter was squeezed with each separate digit from index to little finger using alternate hands (Fig. 3). The interphalangeal joint of the thumb became hyperextended in 88 percent of the females and 50 percent of the males (Fig. 3b). This tendency was decreased for pulp pinch with digits IV and V. Table 4 shows the average strength of pinch for each separate finger recorded in kilograms of force. The middle finger (digit III) pinch was the strongest for both hands in males and females (Fig. 3, c and d). Pinch with digit V was half as strong as pinch with digits II or III. The weakest separate pinch observed in the male group was 2.0 kg. for digit V and the strongest was 11.8 kg. for digit III. Amongst the females the weakest value was 1.3 kg. with digit V and the strongest 7 kg. with digit III. A tendency to hyperextend either the proximal interphalangeal (PIP) or the distal interphalangeal (DIP) joints was evident when maximal pinch force was applied (Fig. 3, e and f). For the PIP joint this tendency increased from the radial to the ulnar sides of the hand.

LATERAL PINCH

For this test the pinch meter was held between the pulp of the thumb and the lateral aspect of the index finger (Fig. 4). The manual group recorded the highest figures (Table 5). The maximal to minimal values of lateral pinch strength with the major hand of males were 14.5 and 6.0 kg. respectively. The female group showed a maximal strength of

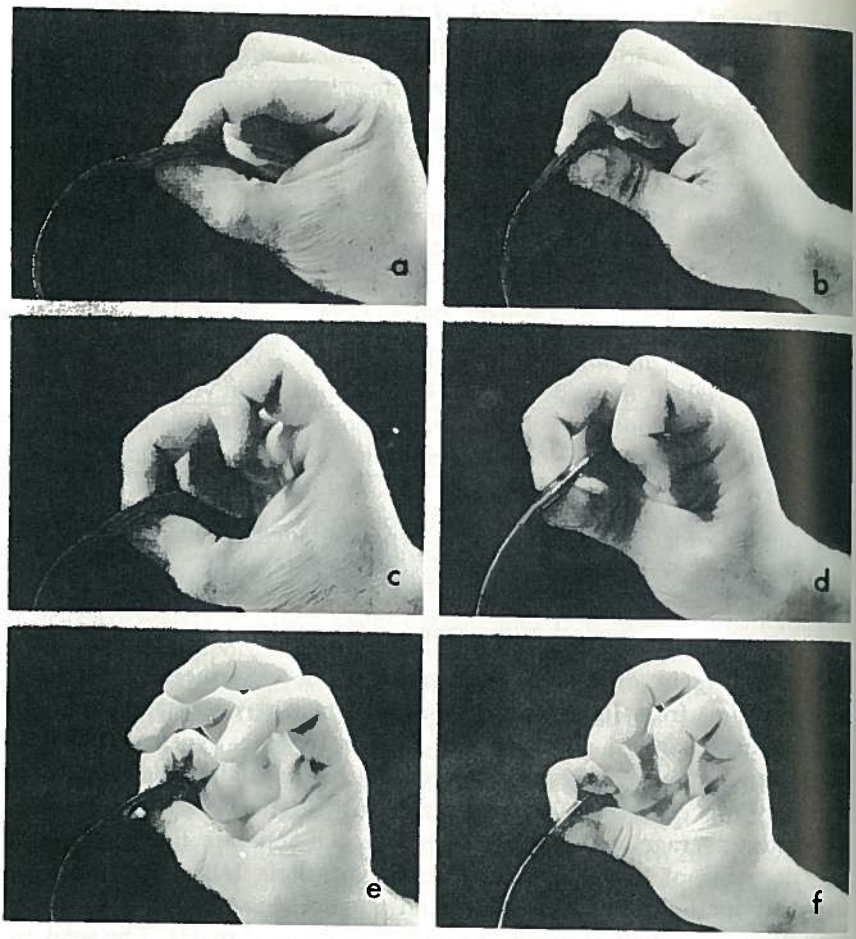

FIGURE 3.—a. Pulp pinch between digits I and II, b. hyperextension of the IP joint of the thumb occurs when maximal pulp pinch strength is applied, c, d. pulp pinch with digit III, e, f. pulp pinch with digit V showing hyperextension of the PIP joint of digit V when maximal strength is applied.

9.0 kg. and a minimal of 4.0 kg. for the major hand. As seen in Tables 3 and 5 little difference was found in average major and minor hand strengths for both chuck and lateral pinches.

COMMENTS

This study shows slightly higher strength of grip for the major hand than that reported by Bechtol and significantly stronger pinch forces with the major hand than those presented by Mannerfelt. This latter difference could be explained by the fact that Mannerfelt examined

TABLE 4.—*Average Strength of Pulp Pinch with Separate Digits*
(100 Subjects)

Digit	Pulp pinch, kg.			
	Male hand		Female hand	
	Major	Minor	Major	Minor
II	5.3	4.8	3.6	3.3
III	5.6	5.7	3.8	3.4
IV	3.8	3.6	2.5	2.4
V	2.3	2.2	1.7	1.6

TABLE 5.—*Average Strength of Lateral Pinch by Occupation*
(100 Subjects)

Occupation	Lateral pinch, kg.			
	Male hand		Female hand	
	Major	Minor	Major	Minor
Skilled	6.6	6.4	4.4	4.3
Sedentary	6.3	6.1	4.1	3.9
Manual	8.5	7.7	6.0	5.5
Average	7.5	7.1	4.9	4.7

the thumb-to-index pinch with the arm and forearm in a fixed position. We demonstrated a strength decrease of 6 percent for the major hand and 7 percent for the minor hand when the extremity examined was supported rather than free. The female group showed a similar relative decrease: 9 percent for the major and 10 percent for the minor hand.

FIGURE 4.—Measuring lateral pinch.

We were attempting to register the true maximal strength of each individual, hence the extremities were tested without support. There were no obvious differences between measurements made in the morning and in the afternoon. The strongest grips recorded for the major hand were 70.4 kg. in a 29-year-old-male surgical resident and 38.6 kg. in a 33-year-old female secretary.

COMPARISONS BETWEEN THE MAJOR AND MINOR HANDS

The gripping strength of the minor hand was the same as, or higher than, the major one in 29 percent of the individuals examined. However, the grip of the major hand was always found to be the stronger for heavy manual workers. The chuck pinch of the minor hand was as strong as, or stronger than, that of the major hand in 50 percent of the males and 54 percent of the females tested. This finding was also true of 40 percent of the manual workers examined. The same difference in strength between the major and minor hands was demonstrated for the lateral pinch. In 12 percent of the individuals examined the left hand was dominant. Of these 12 persons, 8 or 58 percent had a stronger grip with the minor hand.

On the average, grip strength of the minor hand was found to be 5.4 percent weaker in males and 8.9 percent in females. The strength of pinch of the minor hand was weaker by 4 percent in males and 6 percent in females. The data obtained in this study indicate that there is less difference in strength of the major and minor hands than has generally been thought.

SUMMARY

This study surveyed the hand strength of 100 individuals (200 hands). The basic hand patterns evaluated were: grip, three-digit pinch (chuck pinch), pinch with separate fingers (pulp pinch), and lateral pinch. A Jamar hydraulic dynamometer was used to measure grip. The strength of the various pinches was tested with an electronic pinch meter. All values were expressed as kilograms of force.

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