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SOLLERMAN HAND FUNCTION TEST

A Standardised Method and its Use in Tetraplegic Patients

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Abstract. A standardised hand function test based on seven of the eight most common hand grips is reported. The test consists of 20 activities of daily living. The test procedure and the method of scoring are described as is our evaluation of the validity and reliability of the test. Fifty-nine tetraplegic patients were evaluated using the test before reconstructive surgery to their hands. The test score correlated well with the accepted international functional classification of the patient's arm ($r = 0.76, p < 0.001$). The mean test score in the arms of patients lacking sensation was significantly lower than in those with tactile gnosis (O:1–3 compared with OCu:1–3, $p < 0.001$).

Key words: hand function evaluation, hand function test, tetraplegia.

Evaluation of hand function is of great importance in hand surgery, because the choice of treatment and the assessment of the results of treatment are dependent on the function of the hand. To assess and compare the results of reconstructive hand surgery, a standardised test that gives an index of overall hand function is needed. Such a test should be easily given during a short period of time and the results should be reproducible and correlate with other ways of assessing hand function. The test should include objective measurements of standardised tasks commonly used in activities of daily living (8). Several methods have been used for this purpose, but most of them were designed for special diagnoses and questions (2, 5, 8, 12, 13, 16, 19, 21, 27, 29).

Already in 1980 one of us (CS) designed and presented a new hand function test based on the seven most frequently used hand-grips (22). We have used this method for testing hand function since then, and present our experience, which is mainly in tetraplegic patients.

PATIENTS AND METHODS

The hand function test

In previous studies hand-grips were classified (7) and the use of eight most common hand-grips in activities of daily living was analysed (Fig. 1 and Table I) (23). A grip function test was designed based on these studies in which seven of the eight hand-grips were used. The test consists of 20 subtests, each comprising a task considered to be an activity of daily living, the performance of which could be easily scored. Each subtest is scored by the examiner on a scale from 4 to 0 points according to the guidelines for scoring shown in Table II.

The scoring rules were chosen so that subjects with normal hand function would achieve 80 points with the dominant hand and 77–79 points with the non-dominant hand. The test equipment was mounted in a box (Fig. 2), so that the test could be applied quickly and easily. The Yale-lock and the door-handle were placed on both sides of the wall in the box in order to fit both the right and the left hand. Table III shows the 20 subtests and a detailed description is given in the Appendix.

When testing hand function, the subject is seated in front of the box, which is placed on a table. In addition to information about the design and purpose of the test, the instructions to the subject state that the tasks should be done with no hurry in the way to which they are accustomed, that the subject should be seated throughout the test, but is permitted to stand if he has to (yields a lower test score), and that a free choice of grip is allowed. The manual contains a list of "normal and permitted" hand-grips for each test, however, and any divergence from these yields a lower score. The test is done with one hand at the time with the exception of subtests 11, 14, and 15 which require both hands. As the upper time limit for each subtest is one minute, the test can usually be completed within 20 minutes.

Evaluation of validity

The validity of the test results was evaluated by comparing them with the subjective estimation of hand function and with a disability rating scale in a consecutive series of patients at the division of hand surgery, comprising 47 hands in 40 patients (10

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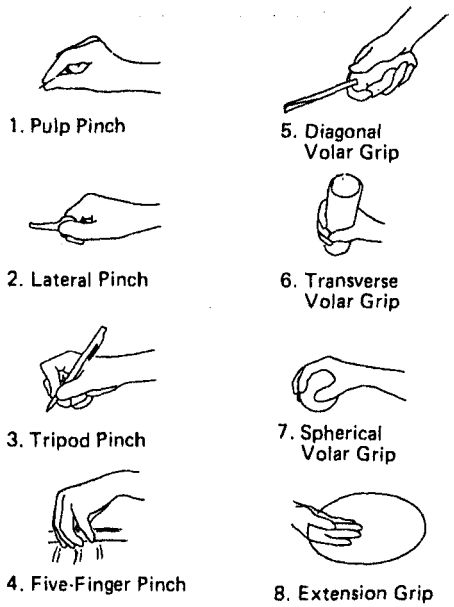

Fig. 1. Eight main hand-grips into which a normal grip pattern can be divided.
1. *Pulp pinch:* the object is held between the thumb and the index or the middle finger, or both. 2. *Lateral pinch:* the object is held between the thumb and the radial side of the index finger. 3. *Tripod pinch:* the object is surrounded by the thumb, index and middle finger. It may (but need not have) contact with the web of the thumb. 4. *Five-finger pinch:* the object is held between the thumb and the four fingers together. It has no contact with the palm. 5. *Diagonal volar grip:* the object is held with the thumb against the four fingers. It has contact with the palm and its axis is diagonal to that of the hand. 6. *Transverse volar grip:* same as 5, but the axis of the object is transverse to that of the hand. 7. *Spherical volar grip:* the object is surrounded by the thumb and the four fingers and has contact with the palm. 8. *Extension grip:* the object is held between the thumb and the four fingers, which are extended in the interphalangeal joints. It has no contact with the palm.

Table I. *The percentage use of the eight most common hand-grips in activities of daily living (23)*

Pinches (fingers)	%	Grips (hand)	%
Pulp pinch	20	Diagonal volar grip	15
Lateral pinch	20	Transverse volar grip	14
Tripod pinch	10	Spherical volar grip	4
Five-finger pinch	15	Extension grip	2

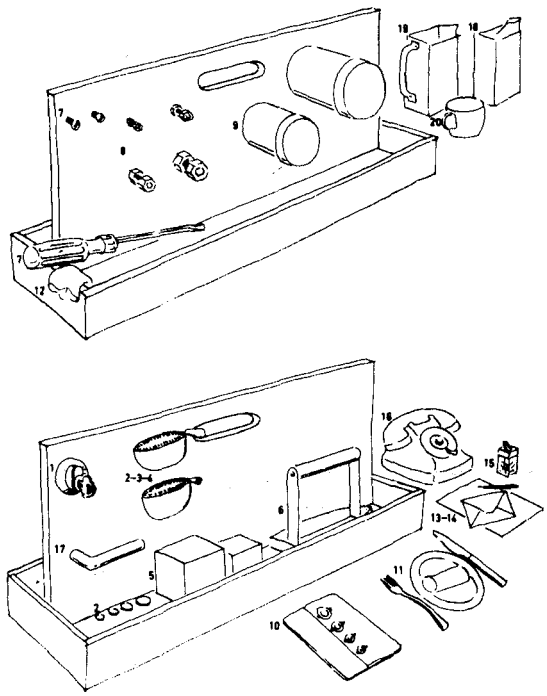

Fig. 2. The equipment of the grip function test. The figures refer to the description of the test procedure (See Table III and Appendix).

women and 30 men with a mean age of 47 (range 17–75) years) (Table IV).

In studies of perception of effort, pain, dyspnoea and force subjective rating methods were used (24). Borg designed a 10 point visual analogue scale to obtain quantitative measurements with Swedish verbal expressions for each point on the scale (3). In this study we used a modification of this scale in which the end points of a line 10 cm long were defined as "no hand function" and "full hand function" respectively (Fig. 3).

The patients were instructed to put a mark on the line somewhere between the endpoints so that the distance from these corresponded to their estimated hand function. The length (cm) from the left endpoint was used as a measure of the subjective estimation of hand function. To avoid confusion with percentage impairment of hand function the line was not graduated or numbered. Some patients knew their percentage disability that had been calculated by the insurance company and these patients might have estimated their hand function according to this figure. The result of the hand function test and the subjective estimation of hand function correlated well (correlation coefficient r = 0.68).

Impairment of hand function was also estimated by a disability rating scale. The insurance companies in Sweden have agreed on common rules for disability rating (20). Detailed tables of amputation

Table II. *Guidelines for scoring of subtests*

	Score
The task is completed without any difficulty within 20 seconds and with the prescribed hand-grip of normal quality	4
The task is completed, but with slight difficulty, or the task is not completed within 20 seconds, but within 40 seconds, or the task is completed with the prescribed hand-grip with slight divergence from normal	3
The task is completed, but with great difficulty, or the task is not completed within 40 seconds, but within 60 seconds, or the task is not performed with the prescribed hand-grip	2
The task is only partially performed within 60 seconds	1
The task cannot be performed at all	0

Table III. *The 20 subtests comprising the Sollerman grip function test*

1. Put key into Yale lock, turn 90°
2. Pick coins up from flat surface, put into purses mounted on wall
3. Open/close zip
4. Pick up coins from purses
5. Lift wooden cubes over edge 5 cm in height
6. Lift iron over edge 5 cm in height
7. Turn screw with screwdriver
8. Pick up nuts
9. Unscrew lid of jars
10. Do up buttons
11. Cut Play-Doh with knife and fork
12. Put on Tubigrip stocking on the other hand.
13. Write with pen
14. Fold paper, put into envelope
15. Put paper-clip on envelope
16. Lift telephone receiver, put to ear
17. Turn door-handle 30°
18. Pour water from Pure-pak
19. Pour water from jug
20. Pour water from cup

levels, impairment of sensation and reduced range of motion have been worked out, by which a percentage impairment of hand function can be calculated. These tables were used to calculate the impairment of hand function of the patients. The calculation was made by the examiner before carrying out the test. The correlation between test results and the hand function calculated from the disability rating tables was good with a variation from 0.78 in nerve injuries to 0.92 in amputees and with a mean of 0.88 in overall series (Table V).

Reliability and reproducibility

Two occupational therapists working at the division of hand surgery were given brief theoretical and practical information about the test method. They then participated in the study in such a way that six patients were tested by CS and one of the therapists consecutively, while four of the patients were tested by CS and both therapists. Eighteen pairs of test results were obtained and the concordance between two different observers and of two consecutive testing procedures was high (r = 0.98) (22).

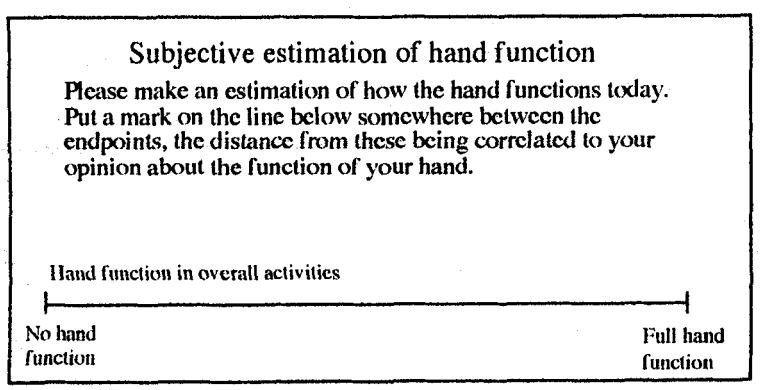

Fig. 3. The scale used for subjective estimation of hand function.

Table IV. *Diagnoses of patients in the evaluation study*

Diagnosis	No of hands	No of patients
Rheumatoid arthritis	10	5
Finger amputations	15	14
Nerve injuries	6	6
Impaired range of motion (Dupuytren's contracture, shoulder–hand-finger syndromes, effects of fractures and burns)	16	14
Total	47	39

Table V. *Correlation between disability rating scale and total test score in test series of patients*

Diagnosis	No of hands	r-value
Rheumatoid arthritis	10	0.87
Finger amputatees	15	0.92
Nerve injuries	6	0.78
Impaired range of motion	16	0.90
Total	47	0.88

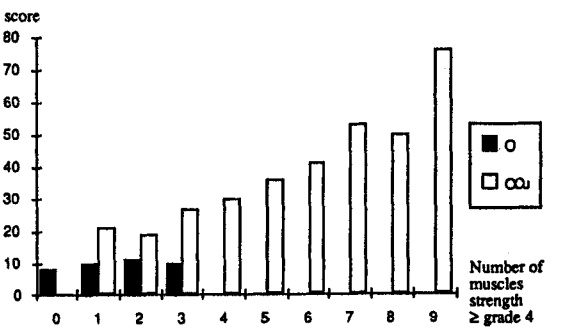

Fig. 4. Mean test score in each functional group of 73 tetraplegic arms.

Assessment of hand function

Since 1985 all tetraplegic patients admitted to the neurological rehabilitation unit at Sahlgrenska Hospital for reconstructive surgery on the arm or hand were preoperatively evaluated with the Sollerman test.

The patients also had their arms classified according to the internationally adopted classification (Table VI) (14). The classification is based on the

Table VI. *International classification for surgery of the hand in tetraplegia. Edinburgh, Scotland, 1978 (Modified in Giens, France 1984) (14)*

Sensibility O or OCu	Motor characteristics	Description (function)
0	All long muscles below elbow < grade 4	Flexion of the elbow and supination of the forearm
1	Brachioradialis	
2	Extensor carpi radialis longus	Extension of the wrist (weak or moderate)
3	Extensor carpi radialis brevis	Extension of the wrist (strong)
4	Pronator teres	Extension of the wrist and pronation of forearm
5	Flexor carpi radialis	Flexion of the wrist
6	Finger extensors	Extrinsic extension of the fingers (partial or complete)
7	Thumb extensor	Extrinsic extension of the thumb
8	Partial digital flexors	Extrinsic flexion of the fingers (weak)
9	Lacks only intrinsics	Extrinsic flexion of the fingers

Table VII. *Sollerman test score and functional group in 73 arms (59 patients)*

	O:0 ($n = 5$)	O:1 ($n = 11$)	O:2 ($n = 6$)	O:3 ($n = 4$)	OCu1 ($n = 5$)	OCu2 ($n = 4$)	OCu3 ($n = 8$)	OCu4 ($n = 11$)	OCu5 ($n = 10$)	OCu6 ($n = 2$)	OCu7 ($n = 1$)	OCu8 ($n = 5$)	OCu9 ($n = 1$)
	8	12	6	4	25	17	26	15	27	49	53	53	76
	7	11	9	13	22	21	25	33	44	32		50	
	12	21	25	11	18	20	28	25	31			51	
	5	15	9	11	25	16	34	40	28			38	
	9	8	11		16		17	37	31			57	
		2	8				29	26	55				
		10					40	21	44				
		5					16	44	37				
		13						52	24				
		9						16	35				
		4						20					
Mean	8	10	11	10	21	18	27	30	36	40	-	50	-

number of muscles in the forearm with strength equal to or above grade 4, and the absence (ocular = O) or presence of tactile gnosis (oculocutaneous = OCu). Thus an arm with classification O:1 is an arm without tactile gnosis, that is a two point discrimination exceeding 10 mm in the hand and only the brachioradialis muscle with a minimum strength of grade 4. OCu:3 then denotes an arm with tactile gnosis (two point discrimination 10 mm or less), at least in the thumb, and good strength on dorsiflexion of the wrist, indicating that both wrist extensors are of grade 4 strength. The presence or absence of grade 3 minimum muscle strength in the triceps is specified separately. All patients falling into the categories O:0–3 and OCu:0–9 are included in this study. A few patients, classified in the × category were excluded.

The patients were tested with the Sollerman test by either of two occupational therapists working at the neurorehabilitation unit or by the one of the authors (AE). The test was done on the day before reconstructive surgery, which was usually done a minimum of a year after injury and at a time when the patient has been well rehabilitated.

Statistical methods. The comparison of the Sollerman score between hands with and without tactile gnosis was by Mantel's test (11) with elimination of the influence of the number of muscles with strength grade 4 or more. Two-tailed tests were used. In patients with tactile gnosis the correlation between the number of muscles of grade 4 or more and the Sollerman score was evaluated with Pitman's test (4).

RESULTS

During the period 1985 to January 1994, 59 patients were examined, of whom 14 were evaluated in both arms making a total of 73 arms.

The number of arms in various functional classes are shown in Table VII. Seventy four % of the arms belonged to the groups O:0–3 or OCu:1–4 indicating that many patients had high level injuries. Twenty six of the hands lacked tactile gnosis and so were classified in the ocular groups 0–3.

The individual test score varied from 2 to 76, the lowest value in an arm classified as O:1 and the highest in an arm in group OCu:9. The individual test scores are shown in Table VII. The mean test score of each group of arms varied from 8 in group O:0 to maximum 50 in group OCu:8 (Fig. 3).

When comparing the test scores of the comparable groups of arms with (OCu:1–3) and without (O:1–3) tactile gnosis the latter groups showed much lower values and the difference was highly significant ($p < 0.001$). Even when comparing the test score for each corresponding group of arms there was a significant difference in two of the groups (O:1 compared with OCu:1 $p > 0.01$ and O:3 compared with OCu:3 $p < 0.01$). In the oculocutaneous groups (OCu:1–9) there was a significant positive correlation between the group of classification of the arm and the mean score in the Sollerman test ($r = 0.76$, $p < 0.001$).

DISCUSSION

The hand function test is based on the concept that the prehensile movements of the human hand can be described as variations of seven

basic grips (pulp pinch, lateral pinch, tripod pinch, five-finger pinch, diagonal, transverse and spherical volar grip). The human hand naturally has many other functions in addition to these main grips and many of these are included in the test procedure for example, manipulation (task 8, 10 and 14), tactile gnosis (task 3), precision (tasks 7 and 17), pronation (tasks 1, 9, 18, 19, and 20), supination (tasks 7 and 17) and moderate shoulder-elbow movements (tasks 1, 2, 3, and 4). The percentage use of the main grips in activities of daily living was calculated in a previous study (23) and these figures formed the basis of the test. The aim of the method is primarily to give a picture of the grip function in activities of daily living. The percentage use of the other functions of the hand has not been calculated, but as the tasks are chosen from among common activities of daily living, we presume that the testing procedure yields a good measure of overall hand function. The high correlation between test results and other methods of evaluation of hand function indicates that this suggestion is correct. As the testing procedure was designed for Swedish manners and habits, some of the tasks and scoring rules may need to be adjusted for other countries and cultures.

The grip function test yields a figure which is assumed to correspond to the function of the hand in activities of daily living. As there is no fundamental measurement for comparison, it is difficult to judge how accurate this figure is. Subjective estimation of hand function gives uncertain figures, because some subjects tend to underestimate their functional capacity while others (who are used to their disability) may tend to overestimate it. The comparison with the subjective estimation method is therefore uncertain, and the fairly low correlation coefficient of 0.68 does not give much information about the validity of the test results.

The disability rating scale gives a more reliable figure, but this corresponds to anatomical impairment rather than functional disability of the hand. The disability rating scale is used to estimate impairment of hand function mainly in relation to industrial and vocational potential, which may explain why the degree of impairment suggested by the test results is generally less than that calculated by means of the disability rating scale. Nevertheless, the correlation coefficient of 0.88 indicates a good correlation between the two methods of evaluation of hand function.

Patients with finger amputations and impaired range of motion showed a higher correlation between test score and disability rating compared with patients with rheumatoid arthritis and nerve injuries (Table V). This difference seems to indicate that the grip function test is a more valid method of evaluation of hand function in the first two diagnostic groups, but it might also be explained by the fact that the disability rating scale gives a more valid estimation of the hand function in patients with amputations and impaired range of motion than in the other groups. Rheumatoid hands with severe deformities are particularly difficult to assess with the disability rating scale, and the grip function test is likely to be a more valid method of assessing the function of the rheumatoid hand.

The Sollerman test was designed to give a good measure of overall function of the hand (not the elbow and shoulder). The purpose was to produce a true picture of grip function in activities of daily living and to reflect the most common main grips used in daily life. The test gives thus a picture of both the ability and the quality of the hand. The Rancho Los Amigos test (5) is a test of the whole upper extremity. The Jebsen test (8) uses only timing of the task, and not the quality of the grip. In review articles published during the last decade (1, 2, 9, 15) a number of other tests are mentioned but these tests are either designed for specific groups of patients (rheumatoid arthritis (10, 28) hemiparesis (30) tetraplegia (6, 27), or replantation (26)) or testing specific hand functions such as dexterity (Box and Block test (12) Nine Hole Peg test (13)). None of these test seems to fulfil the requirements set up for the Sollerman test.

Among the tetraplegic patients with arms classified in groups OCu:1–9 (those with tactile gnosis) the group of classification of the arm showed a good correlation with the average test score of each group ($r = 0.76$). It is only among the high level tetraplegic patients, especially those without sensation (groups O:0–3) where

this correlation seems to be absent. This might be because there are no measurable functional differences between these groups or that the test cannot evaluate the small differences that might exist. These might be detected with the technique recently described by Stroh Wuolle et al (25). In most tetraplegic patients the test seems to give an appropriate value on the remaining single hand function. The test does not evaluate the capability of using two-hand grips, which tetraplegic persons commonly use for many activities. This could be done with a revised scoring system, but when assessing the effects of reconstructive hand surgery it is necessary to measure each hand separately and so the test does give adequate information. In contrast to Curtin (6) we think it is important to use a test which is not specifically designed for tetraplegic patients so that we can compare the hand function of the patient with that of other groups of patients and with those with normal function. This makes it easier for laymen to understand the great difficulties that patients with injuries to the spinal cord have in activities of daily living. It is also important to use a test with good validity and reliability. The test used by Vanden Berghe et al. lacks data in these aspects.

The Sollerman test is not intended to test the function of a reconstructed elbow extensor. We prefer to evaluate the strength and endurance of an elbow extensor by measuring active range of motion and torque in the elbow.

The significant difference that we found between the comparable groups with and without tactile gnosis in the hand we interpret as a proof of the importance of sensation for hand function, which Moberg has stressed so much (17, 18). It also shows the importance of measuring the sensibility in the tetraplegic hand with a two point discrimination test as it facilitates a correct evaluation of the function of the hand.

CONCLUSIONS

The Sollerman hand function test which is based on functional ability in activities of daily living and the quality of seven main hand-grips, gives results that correlate well with a disability rating scale used by the insurance companies in Sweden. Among tetraplegic patients it also correlates well to the international classification of a patient's arm. The test is reliable and reproducible. The test is simple, takes about 20 minutes to do and can be used by occupational therapists without much experience of the method. We have found the test to be useful for the assessment of hand function and we think it is the best overall hand function test available for all patients, including tetraplegic ones.

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Appendix: *Description of tasks and testing procedures.*

Subtest 1:	Pick up key, put into Yale-lock and turn 90°.
Material:	Yale-lock with bolts mounted on a vertical wall 30 cm above bottom level. Yale-key placed on the bottom of the box.
Procedure:	Pick up the key, put it into the lock and turn 90° in pronation so that the bolts disappear.
Hand-grip:	Pulp pinch, lateral pinch.
Subtest 2:	Pick up the coins from flat surface, put into purses mounted on the wall.
Material:	Four coins of different size placed on the bottom of the box. Two purses mounted on the wall, 20 cm above bottom level.
Procedure:	Pick up the coins, one at a time, and put two coins in each purse.
Hand-grip:	Pulp pinch.
Subtest 3:	Close and open zips.
Material:	Two purses mounted on the wall with zips of different size.
Procedure:	Close the zips and then open them again.
Hand-grip:	Pulp pinch, lateral pinch.

Subtest 4: Pick up coins from purses.
Material: See subtest 2.
Procedure: Pick up the coins, one at a time from the purses and place them on the bottom of the box.
Hand-grip: Pulp pinch.

Subtest 5: Pick up wooden blocks, lift over edge.
Material: Two wooden blocks, size 7.5 cm and 10 cm, respectively, placed on the bottom of the box with edges of 5 cm.
Procedure: Pick up the blocks, lift them over the edge and place them on the table in front of the box.
Hand-grip: Five-finger pinch.

Subtest 6: Lift iron over edge.
Material: Iron, weight 3 kg, placed on the bottom of the box with edges of 5 cm.
Procedure: Lift the iron over the edge and place it on the table in front of the box.
Hand-grip: Transverse volar grip. Hand in pronation.

Subtest 7: Turn screw with screwdriver.
Material: Two screws with nuts mounted in the vertical wall, one with spring resistance, the other without resistance. Screwdriver with handle 2.5 cm in diameter.
Procedure: Pick up the screwdriver and turn the screw with resistance one turn in supination. If the subject cannot do this, he is allowed to turn the screw without spring resistance.
Hand-grip: Diagonal volar grip.

Subtest 8: Pick up nuts and put on bolts.
Material: Four bolts of different size mounted on the vertical wall. Four nuts placed on the bottom of the box.
Procedure: Pick up the nuts, one at a time, and put them on the appropriate bolts.
Hand-grip: Pulp pinch, lateral pinch, tripod pinch.

Subtest 9: Unscrew lid of jars.
Material: Two jars with screw-lids size 7.5 and 10 cm respectively, mounted on the wall. The lids are screwed on with moderate force.
Procedure: Unscrew the lids and place them on the table.
Hand-grip: Spherical volar grip.

Subtest 10: Do up buttons.
Material: Four buttons with button-holes of different size on pieces of cloth mounted on a plate.
Procedure: Do up the four buttons.
Hand-grip: Pulp pinch, lateral pinch.

Subtest 11: Cut Play-Doh (plasticine).
Material: Plate, knife and fork of commercial design. A lump of Play-Doh placed on the plate.
Procedure: Pick up the knife and fork and cut the lump of Play-Doh into four pieces.
Hand-grip: Tripod pinch, diagonal volar grip.

Subtest 12: Put elasticated tubular bandage (TubiGrip, Seton Healthcare Group, England) on the other hand.
Material: Two TubiGrip stockings of different sizes.

Procedure: Pick up the small stocking with the tested hand and draw it on to the other hand. If the subject cannot manage the small stocking he is allowed to try the bigger one.
Hand-grip: Lateral pinch, five-finger pinch.

Subtest 13: Writing.
Material: Paper and pen.
Procedure: Write the name on the paper.
Hand-grip: Tripod pinch.

Subtest 14: Fold paper, put into envelope.
Material: Paper size A4, envelope size C6.
Procedure: Fold the paper twice and put it into the envelope. The non-tested hand is used when folding the paper and to hold the envelope.
Hand-grip: Five-finger pinch, lateral pinch.

Subtest 15: Put paper-clip on envelope.
Material: Two paper-clips of different size. Envelope as above.
Procedure: Pick up the small paper-clip and put it on the envelope. If the subject cannot manage this he is allowed to try the bigger one.
Hand-grip: Pulp pinch, lateral pinch.

Subtest 16: Pick up telephone-receiver and put it to the ear.
Material: Telephone of commercial design placed on the table.
Procedure: Pick up the receiver and put it to the ear.
Hand-grip: Diagonal volar grip.

Subtest 17: Turn door-handle 30°.
Material: Door-handle of usual design mounted on the wall. The handle is placed on both sides of the wall and can be turned 30° in supination to fit both the right and the left hand.
Procedure: Turn the handle 30° in supination.
Hand-grip: Transverse volar grip.

Subtest 18: Pour water from one litre paper milk or juice package (pure-pak).
Material: Pure-pak size 1 litre filled with water, placed on the table. Empty water-jug.
Procedure: Lift the pure-pak and pour the water into the jug. If the subject cannot manage this, half of the water should be poured out.
Hand-grip: Five-finger pinch.

Subtest 19: Pour water from jug.
Material: Water-jug with handle, size 1 litre filled with water. Tea-cup size 2 dl.
Procedure: Lift the jug by the handle and pour the water into the cup. If the subject cannot manage this, half of the water should be poured out.
Hand-grip: Transverse volar grip.

Subtest 20: Pour water from cup.
Material: Tea-cup with handle without a hole, size 2 dl, filled with water. Empty water-jug.
Procedure: Lift the cup by the handle and pour water back into the jug. If the subject cannot manage this, half of the water is poured out.
Hand-grip: Pulp pinch, lateral pinch.