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STANDARDIZATION OF GRIP STRENGTH MEASUREMENTS

Effects on Repeatability and Peak Force

Dorine C. M. Spijkerman,[1] Chris J. Snijders,[2] Theo Stijnen[3] and Gustaaf J. Lankhorst[1]

From the [1]Department of Rehabilitation Medicine, [2]Department of Biomedical Physics and Technology, [3]Department of Epidemiology and Biostatistics, Faculty of Medicine and Allied Health Sciences, Erasmus University Rotterdam, 3000 DR Rotterdam, The Netherlands

ABSTRACT. The aim of our study was to test grip strength and assess the effects of various degrees of standardization on repeatability and level of peak force. Sixteen healthy persons and eight subjects with an impaired hand function have been tested using a strain-gauge dynamometer. We compared four measurement protocols: (A) the subject is free to assume a comfortable arm position; (B) the subject is also free to assume a comfortable arm position but in addition a challenging stimulus to exceed a previous maximal effort, is given; (C) the arm was held in a predescribed and partly fixated position, as recommended by the American Society of Hand Therapists; (D) the position of the dynamometer is standardized using two reference points both on the hand and on the dynamometer. We found high test–retest reliabilities for each measurement protocol without any significant difference. There were, however, significant differences in strength level. With measurements according to protocol B the highest peak values were noted. Since the measurement protocol B combined good reliability with realistic peak forces, this procedure seems most suitable for grip strength measurements.

Key words: reliability, hand, strength, standardization.

Several factors are known to influence the level of strength in grip strength measurements. Thorngren et al. (12), and Reikerås (11) studied the effect of age and the ratio dominant/non-dominant hand. The influence of wrist position on hand or finger strength has been investigated by Hazelton et al. (4), Pryce et al. (10) and Kraft et al. (5). They reported that with volar flexion of the wrist subjects exert significantly less strength than in any other position. Positional variations may be reduced by standardization of position during measurements. The American Society of Hand Therapists has recommended a standardized position with "the patient seated with his shoulder adducted and neutrally rotated, the elbow flexed in 90° and the forearm and wrist in neutral position" (3).

Motivation may also influence test results and their reproducibility. Bohannon (1) compared the results of fake efforts to those of sincere efforts. He found intra-trial variation coefficients of less than 8% for maximal efforts, whereas submaximal efforts resulted in variation coefficients usually exceeding 8%. The administration of a challenge to exceed previous efforts may help to obtain maximal efforts and might therefore improve test–retest reliability.

Test–retest correlation coefficients of grip strength have been reported by several authors (2, 4, 6, 7, 8) (Table I), but those are not very helpful in order to establish confidence limits of strength values. Furthermore, no studies about the effect of standardization on grip strength measurements could be found. The aim of the present study was to assess the effects of various degrees of standardization on reproducibility and level of peak force of grip strength measurements.

MATERIAL AND METHODS

We studied 16 healthy subjects and 8 subjects with impaired hand function (Table II). A strain-gauge dynamometer was used (9), with an accuracy of 3% in the range of 2–900 N. We compared four measurement protocols:

A: The subject is free to assume a comfortable arm position during the test.

B: A recorder (Hewlett Packard model 17501A) with a non-numerical scale and two recording pens is attached to the amplifier. One pen is used to monitor the signal produced by the dynamometer, the other pen is set by the observer to a strength level 10% higher than that of a preceding (maximal) effort, thus challenging the subject with a visual stimulus to exceed his previous effort. The subject is free to assume a comfortable arm position.

C: The forearm is stabilized in a groove, the wrist is fixated in neutral position with a velcro strap. The elbow is in 90° of flexion, the shoulder is in adduction and neutral rotation (the position recommended by the American Society of Hand Therapists). The dynamometer is suspended from the ceiling with a cord in order to eliminate the weight of the dynamometer.

D: The position of the dynamometer in the hand is stand-

Table I. *Survey of reliability studies of grip strength*

Author	Test	Number of subjects	Test–retest *r*
Cousins (2)	Grip strength right hand	10×4 ♂,♀	0.81–0.89
Hazelton et al. (4)	Finger flexion force right hand in 5 different wrist positions	30 ♂	0.88–0.97
Kroll (6)	Grip strength right hand	33 ♀	0.90
Less et al. (7)	Finger extension, adduction and abduction force	18 ♂,♀	0.89–0.97
Mathiowetz et al. (8)	Grip strength left and right hand	27 ♀	0.92 0.82

ardized, using two reference points both on the hand and on the dynamometer (the deepest point of the thumb web was put over a marking on the spacing bar and the point where hand lines coincide at the base of the hand was placed along the midline of this bar).

The testee was always seated upright in a chair, leaning against the back of the chair and with the feet supported. Verbal encouragement during the measurements was standardized. Four efforts were recorded, each lasting 5 sec, with a one minute interval in between. After each effort the display was reset to zero. The first effort was considered a trial effort. The mean values of the last three efforts were analysed. The measurements were repeated after a one week interval, at the same hour of the day. The sequence of conditions was randomized according to a 4×4 latin square design. In order to reduce errors due to fatigue the sequence of the conditions in the second session was similar to that of the first.

Statistical analysis

In preliminary analyses, carried out for each measurement protocol and group (patients or healthy persons) separately, no correlation was found between the level of recorded grip strength of an individual (averaged over two occasions) and the variability between the measurements at the two occasions. Therefore it was justified to calculate test–retest reliability (TRR) as the standard deviation of the residual component in an analysis of variance. In order to investigate differences between the initial measurements and those after one week, the *t*-test for paired observations was used (learning effect). Analysis of variance was used to assess differences in peak levels between the four different measurement protocols.

RESULTS

Neither in the group of healthy persons nor in the patient group were any significant correlations between level of grip strength and variability of the measurements (recorded at the two occasions) found. A significant 'learning effect' was found for protocols B and C for the healthy subjects (B: initial strength 45.1 Nm, after 1 week 47.2 Nm, $p<0.05$; C: initial strength 42.8 Nm, after 1 week 44.1 Nm, $p<0.05$; the subsequent calculations of test–retest reliability were corrected for this learning effect). For the patients and the remaining two measurement protocols in healthy subjects the strength measurements showed a non-significant increase. Mean peak strength values, test–retest reliability (TRR) and 95% confidence limits for each of the measurement protocols are shown in Table III. The mean strength values showed significant differences as well for the healthy persons (F (3, 15)=285.1; $p<0.001$) as for patients (F (3, 7)=18.7; $p<0.001$). The protocol in which the patient is challenged to exceed an earlier recorded value yielded the highest peak forces in both subgroups. Test–retest reliability, expressed as standard deviations, showed no significant differences between the four measurement protocols. This is also demonstrated by the overlap of the confidence intervals.

DISCUSSION

If the standard deviations of repeated grip strength measurements were proportional to the level of recorded strength, a 'relative standard deviation' or 'variation coefficient' should be used to assess

Table II. *Age and type of injury of the patients*

Subject	Age	Disability
1	35	Ulnar nerve lesion forearm level
2	17	Amputation at distal phalanx level dig I, at PIP dig II and III, fractures prox. phalanx I–III
3	18	Extensor tendon lesion dig V, amputation tip dig IV
4	42	Partial lesion profundus tendon dig III, lesion radial artery and nerve of dig III and IV, fracture distal phalanx dig II
5	29	Incomplete amputation dig II–IV, lesion ulnar nerve dig II and radial nerve dig III
6	23	Lesion median and ulnar nerve and deep and superficial tendons at wrist level
7	19	Amputation dig I at MCP level, dig II and III at CMC level, multiple fractures dig IV
8	53	Fracture proximal phalanx dig V

Table III. *Mean strength values, test–retest reliabilities (TRR) and 95 % confidence intervals for four measurement protocols*

	Total group $n=24$	Patients group $n=8$	Healthy group $n=16$
Mean age	29.5	29.5	29.5
SD	10.2	14.0	9.0
A. Mean strength (Nm)	37.7	23.5	44.8
TRR	2.2	2.6	2.1
95 % confidence interval	1.7<TRR<3.1	1.7<TRR<5.2	1.5<TRR<3.2
r	0.99	0.99	0.97
B. Mean strength (Nm)	39.2	25.3	46.2
TRR	2.7	3.3	2.4
95 % confidence interval	2.1<TRR<3.8	2.2<TRR<6.8	1.8<TRR<3.8
r	0.97	0.96	0.95
C. Mean strength (Nm)	36.6	23.1	43.4
TRR	1.8	2.5	1.4
95 % confidence interval	1.4<TRR<2.5	1.7<TRR<5.1	1.0<TRR<2.1
r	0.98	0.98	0.98
D. Mean strength (Nm)	32.6	19.3	39.3
TRR	1.8	1.6	1.8
95 % confidence interval	1.4<TRR<2.5	1.0<TRR<3.2	1.3<TRR<2.8
r	0.98	0.98	0.96

reliability (CV = SD/mean level × 100%; measurements X_1 and X_2 from the same individual at different occasions are significantly different with a 95% confidence interval if (X_1-X_2) is larger than 2 $CV/100x\sqrt{(X_1^2+X_2^2)}$. Since the standard deviation was found to be fairly constant at all strength levels, a simple absolute standard deviation can be used for the interpretation of test results (SD; if X_1 and X_2 are measurements of the same individual at different occasions, the change is significant with a 95% confidence interval if (X_1-X_2) is larger than $2\sqrt{2}$ SD. Inappropriate use of the SD would lead to *false negative* conclusions in the low strength ranges, whereas for the higher strength levels it would lead to *false positive* conclusions. For inappropriate use of the CV, the reverse is true.)

All four measurement protocols showed a similar reliability, which was remarkably high for healthy subjects. Similar results were obtained for the group of subjects with impaired hand function. Since the number of subjects in this group was small, results should be interpreted cautiously. The observation that in a free situation the reliability does not differ from other conditions may implicate that subjects, when assuming a comfortable gripping position, automatically take on their position of choice.

Our results are in agreement with the common opinion that in order to obtain a good reliability, standardization of protocols is important in grip strength measurements. Nevertheless it disagrees with the expectation that protocols with stricter conditions will enhance reliability. The levels of peak force were found different for the four measurement protocols. Protocol B, where the subjects were given a visual challenge to exceed previous grip efforts, produced significantly higher grip strength levels, compared to protocol A (in which the subject was free to assume a comfortable position), C (in which the arm position was specified), and D (in which the position of the dynamometer in the hand was made reproducible by way of reference points). In protocol D significantly lower strength was exerted.

In conclusion this study has shown that the measurement protocol, which uses a visual challenge, is best suited for grip strength measurements since it combines a good reliability with the highest, thus most realistic peak forces.

REFERENCES

1. Bohannon, R. W.: Differentiation of maximal from submaximal static elbow flexor efforts by measurement variability. Am J Phys Med *66:* 213, 1987.

2. Cousins, G. F.: Effect of trained and untrained testers upon the administration of grip strength tests. Res Quart *26:* 273, 1955.
3. Fess, E. E. & Moran, C. A.: Clinical assessment recommendations. 1981, American Society of Hand Therapists.
4. Hazelton, F. T., Schmidt, G. L., Flatt, A. E. & Stephens, R. I.: The influence of wrist position on the force produced by the finger flexors. J Biomech *8:* 301, 1975.
5. Kraft, G. H. & Detels, P. E.: Position of function of the wrist. Arch Phys Med Rehabil *53:* 272, 1972.
6. Kroll, W.: Isometric strength fatigue patterns in female subjects. Res Quart *42:* 286, 1971.
7. Less, M., Krewer, S. E. & Eickelberg, W. W.: Exercise effect on strength and range of motion of hand intrinsic muscles and joints. Arch Phys Med Rehabil *58:* 370, 1977.
8. Mathiowetz, V., Weber, K., Volland, G. & Kashman, N.: Reliability and validity of grip and pinch strength evaluations. J Hand Surg [Am] *9:* 222, 1984.
9. Pronk, C. N. & Niesing, R.: Measuring hand grip force, using a new application of strain gauges. Med Biol Eng Comp *19:* 127, 1981.
10. Pryce, J. C.: The wrist position between neutral and ulnar deviation that facilitates the maximum power grip strength. J Biomech *13:* 505, 1980.
11. Reikerås, O.: Bilateral differences of normal hand strength. Arch Orthop Trauma Surg *101:* 223, 1983.
12. Thorngren, K. G. & Werner, C. O.: Normal grip strength. Acta Orthop Scand *50:* 255, 1979.

Address for offprints:

G. J. Lankhorst
Rehabilitation Department
Erasmus University Rotterdam
P.O. Box 1738
3000 DR Rotterdam
The Netherlands