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Evaluation of instruments for measuring grip strength

Three instruments for measuring grip strength: the steel spring dynamometer, the Martin Vigorimeter and the My-Gripper, were tested in a universal testing machine to evaluate the linearity of the readings. Furthermore, a clinical study including 100 normal probands evaluated the applicability of these instruments.
It was concluded that the steel spring dynamometer was not suitable for clinical use, due to its lack of precision. The Martin Vigorimeter and the My-Gripper were both very precise instruments. The My-Gripper seems to be preferable for clinical use because it is cheap and easy to handle. Also, the instrument can accumulate the results of several trials, facilitating the calculation of average grip strength.
A nomogram showing the relationship between the dominant and the non-dominant hand is given.

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In insurance medicine, the assessment of the end-result after injuries of the upper extremity often includes the measurement of grip strength for objective evaluation (Bacorn & Kurtzke 1953, Lidström 1959, Frykman 1967). Various instruments have been designed for this purpose (Bechtol 1954, Cousins 1955, Wright 1959, Fünfgeld 1966). However, the grip strength of normal persons in the population has seldom been reported and the results are obviously closely connected to the use of particular instruments (Schmidt & Toews 1970, Kellor et al. 1971, Thorngren & Werner 1979).

The ideal dynamometer should meet the following demands: 1) The readings should be reproducible and have the same accuracy independent of high or low grip strength; 2) It should be independent of hand size; 3) It should be comfortable for the patient; 4) It should be small and easy to carry around.

The steel spring dynamometer and the Martin Vigorimeter (Figure 1) are the instruments most often used in Scandinavia. The steel spring dynamometer is a small and handy instrument, but very uncomfortable for most patients. The accuracy of this instrument has not been demonstrated. The Martin Vigorimeter is an accurate instrument (Thorngren & Werner 1979), but different balloon sizes are necessary, depending on hand size.

A new instrument, the My-Gripper (Figure 1), has been designed for measuring grip strength. This instrument is small and handy, comfortable for the patient and requires no adjustment for different hand sizes.

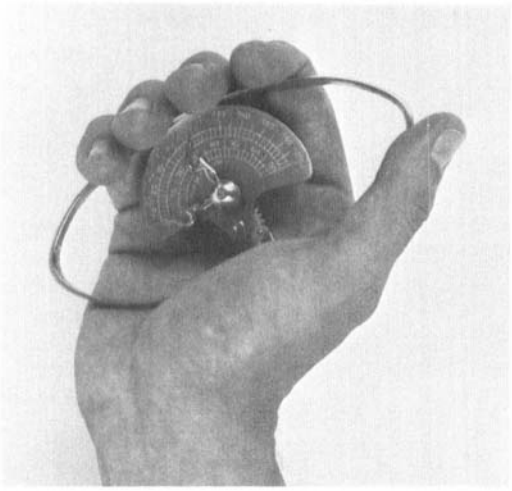
The purpose of the present investigation was to compare the steel spring dynamometer, the Martin Vigorimeter and the My-Gripper in the laboratory, testing the linearity, and to compare the precision of the instruments in the clinical situation.

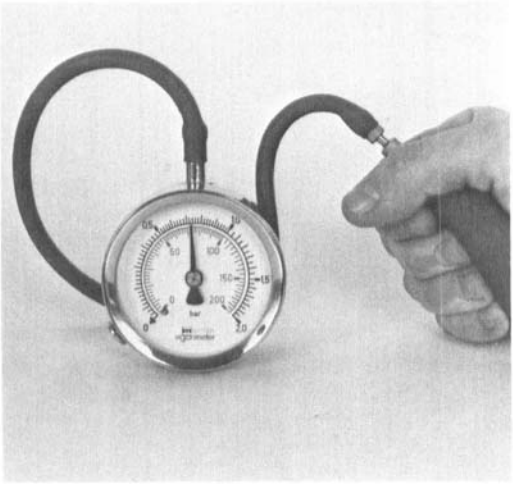
Material and methods

The steel spring dynamometer (Collin, Gebrüder Martin, W. Germany) consists of a parabolic steel spring connected to a pointer, measuring an almost isometric force.

The Martin Vigorimeter (Gebrüder Martin, W. Germany) consists of a manometer connected to a compressible balloon, available in three different sizes depending on the size of the hand.

The My-Gripper (Yamasa, Tokei, Japan) consists of two steel springs enclosed in two compressible plastic shields. As the two shields can be compressed 1–2 cm, the measured force is not purely isometric. The instrument is able to summarize several trials and the number of trials can be read from a second scale to calculate the average.





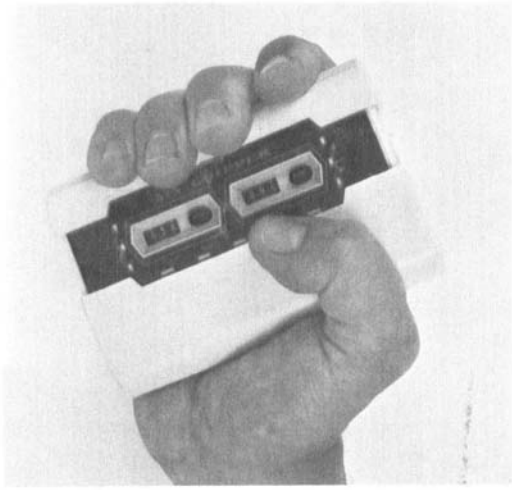


Figure 1. From top to bottom: the steel spring dynamometer, the Martin Vigorimeter, and the My-Gripper.

Machine tests

To investigate the accuracy of the dynamometers, the instruments were mounted between two incompressible traverses in a universal testing machine (1441 Zwick, Gmbh. & Co, W. Germany) with electronic measurement of force and deflection. The instruments were loaded with increasing force from 50 to 500 N. Readings were taken for every 50 N of load. The experiment was repeated five times with each instrument and the average values were used to estimate the regression lines.

Clinical study

In the clinical study, 100 probands (45 men and 55 women) were included. None had diseases or injuries of the upper extremity and all were right-handed. The median age was 45 (20–87) years. The average height of the probands was 171 (146–190) cm, and the average weight 68 (39–110) kg. The measurements were performed with the proband sitting, and the elbow flexed 90 degrees.

The experiment was performed with the steel spring, the My-Gripper and all three balloons of the Martin Vigorimeter. Each person was given five trials with each instrument and each hand, changing hand and instrument for every trial. Thus 50 measurements were obtained from each proband. The probands were allowed to rest at will to eliminate the effect of fatigue. No tendency to declining measured strength during the experiments could be demonstrated, however.

For each instrument and each hand, the average score and the standard deviation were calculated. To determine and compare the precision of the instruments, the variation coefficients ($\bar{v}$) were calculated.

Results

Machine tests

The curves for the My-Gripper and the Martin Vigorimeter with the medium balloon were almost linear, whereas the other instruments measured a lower force than expected when the performed force was high (Figure 2).

Clinical study

In accordance with the experimental study, the Martin Vigorimeter (medium balloon) and the My-Gripper had the lowest variation coefficients (Table 1). In order to evaluate whether the precision of any of the instruments was influenced by the strength of the probands, the series was divided according to grip strength,

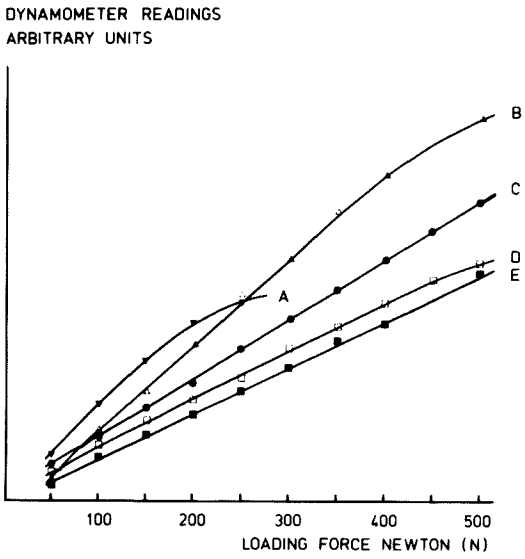


Figure 2. Dynamometer readings in arbitrary units following increasing force load in the universal testing machine. (A: Martin Vigorimeter, small balloon – B: Steel spring dynamometer – C: Martin Vigorimeter, medium balloon – D: Martin Vigorimeter, large balloon – E: My-Gripper).

so that there were 50 probands (with 100 hands) in the low and high pressure groups, respectively. For each hand and instrument a variation coefficient was calculated. In the low pressure group the My-Gripper had higher precision than the other instruments ($P < 0.01$). The steel spring dynamometer had a higher variation coefficient ($P < 0.01$), i.e. a lower precision than the other instruments. In the high pressure group the Martin Vigorimeter was superior to the My-Gripper, and also in this group the steel spring dynamometer was inferior to the other instruments.

The grip strength of the probands decreased with age and increased with height and weight. Statistical analysis of the ratio D/ND between the grip strength of the dominant and non-dominant hands showed that this ratio could not be analysed by analysis of variance, due to lack of homogeneity of the variance. However, this criterion was fulfilled for the difference $\sqrt{D} - \sqrt{ND}$. Multiple linear regression analysis showed that this difference did not correlate with age, sex, height and weight of the probands ($P > 0.5$).

On the basis of these calculations, it was found justified to develop a nomogram showing the relationship between the grip strength of a person's dominant and non-dominant hand (Figure 3).

Table 1. Variation coefficients for the Martin Vigorimeter, the steel spring dynamometer and the My-Gripper. Calculations based on 100 probands, each having five trials with each instrument

	$\bar{V}_{right}$	$\bar{V}_{left}$	$\bar{V}_{average}$
Large balloon	8.0	7.7	7.9
Medium ballon	6.1	6.8	6.5
Small balloon	6.8	8.2	7.5
Steel spring	12.6	12.8	12.7
My-Gripper	6.5	6.7	6.6

Discussion

Investigations of function after fracture of the wrist often use grip strength as an objective parameter; grip strength has been found to correlate well with the function of the hand (Sølund et al. 1983). The majority of publications, however, lack information about the method of measuring grip strength, and the accuracy and definitions of "decreased grip strength" (Bacorn & Kurtzke 1953). We found that all three instruments were approximately linear when the applied force was low, but when the load increased, the dynamometer readings of the steel spring and the small and large balloon were lower than expected. Both the My-Gripper and the Martin Vigorimeter

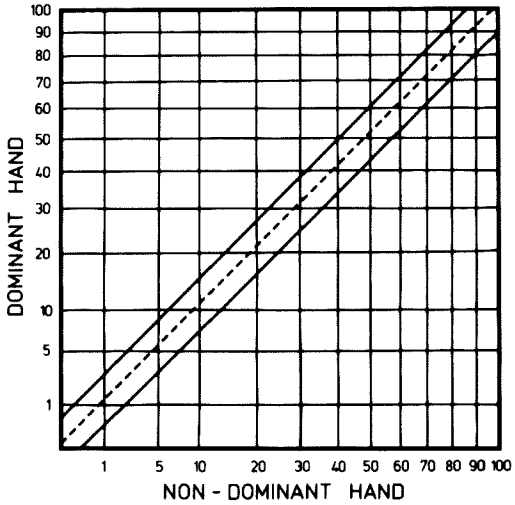


Figure 3. Nomogram of 100 probands. The units in the diagram are plotted as the square root, so that the expected force of one hand can be read directly knowing the force of the contralateral hand (average of three trials ± 2 SD, dynamometer: the My-Gripper).

with the medium balloon were highly linear.

In the clinical study, the Martin Vigorimeter with the medium balloon and the My-Gripper had the lowest variation coefficients (6–7 per cent), indicating that these instruments had the highest degree of precision. The average score of five trials was used for the calculation of a person's grip strength. The average of three trials, however, is sufficient, since further trials will reduce the standard deviation only marginally from 0.31 to 0.30 (five trials). As stressed by Henry (1967), there is no statistical basis for using the best rather than the average score. Similar methods of calculating and comparing the precision of dynamometers have been used by Clarke (1954) and by Heyward et al. (1975)

The grip strength of a person is known to correlate with age, sex, height and weight (Anderson & Cowan 1966, Schmidt & Toews 1970, Thorngren & Werner 1979), and this was confirmed here. In persons with low grip strength, the My-Gripper was superior to all other instruments. In the high pressure group the Martin Vigorimeter was superior, especially when the medium balloon was used. In all situations the precision of the steel spring dynamometer was inferior. Patients with wrist fractures are often older women with a low grip strength. Consequently, the My-Gripper and the Martin Vigorimeter with the medium balloon are both useful instruments for the measurement of grip strength in the assessment of the objective end-result, whereas the steel spring can hardly be recommended. The ease of the clinical use and the low price (one third of the Martin Vigorimeter) make the My-Gripper preferable, however. The Martin Vigorimeter is also a reliable instrument, and can also be used for measurements of pulp pinch, tip pinch and lateral grips. When it is applied in these situations, the small balloon must be used, accepting the risk of less precision. The My-Gripper and the steel spring cannot be used for measurements of finger force.

Acknowledgements

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