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COMPARISON OF THE JAMAR DYNAMOMETER AND THE MARTIN VIGORIMETER FOR GRIP STRENGTH MEASUREMENTS IN A HEALTHY ELDERLY POPULATION

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ABSTRACT. Grip strength is considered to be a good indicator of upper limb strength. The Jamar dynamometer and the Martin vigorimeter are two instruments frequently used to assess grip strength in clinical and research settings. The purpose of this study was to compare these instruments for assessing grip strength in 360 people aged 60 to 94 years, randomly selected from the electoral list. Anthropometric data were also collected. Data analyses were done using the maximum value on 3 trials with each instrument. Although the Martin vigorimeter is a pressure measure implying a dynamic movement as opposed to the static strength measure of the Jamar dynamometer, results indicate a very high correlation between the two measures. Grip strength measured by the Jamar dynamometer is even more dependent on hand anthropometry than measurements with the Martin vigorimeter.

Key words: dynamometer, vigorimeter, assessment.

Grip strength and the strength of elbow flexors are considered to be the best predictors of upper limb strength in an elderly population (37). Grip strength is easy and inexpensive to evaluate and is a good indicator of physical fitness, physiological growth, and hand dominance (12). Grip strength is also frequently evaluated as an indicator of disease evolution (36). For practical reasons, static strength is more often measured than dynamic strength and the option of measuring isometric strength is justified by studies demonstrating a good relationship with isotonic strength (6, 21, 40).

Among the apparatuses developed to measure grip strength, portable dynamometers are the most popular. They convert the mechanical energy generated by a muscular contraction into varied measurement units, depending on the particular apparatus. Some of them are frequently used in clinical setting such as the Jamar dynamometer and the Martin vigorimeter, while others, more sophisticated apparatuses (4, 9, 20–22), are used in laboratory settings.

In this study, we wanted to verify the comparability of the Jamar dynamometer and the Martin vigorimeter with healthy subjects. We also wanted to verify the relationship of these two apparatuses with hand anthropometry. We hypothesized that, since it is a measure of pressure, the Martin Vigorimeter would be more related to hand anthropometry than the Jamar dynamometer.

METHODS AND SUBJECTS

Instruments

The Jamar dynamometer which was introduced by Bechtol (8) is considered the most accurate instrument for measuring grip strength (3, 14, 24, 31, 38). It is a sealed hydraulic instrument equipped with a sensitive gauge calibrated in pounds and kilograms (Fig. 1). No movement is generated when the handle is grasped and squeezed (isometric strength). The handle is adjustable in 5 positions and a study by Fess (13) indicated that middle finger length is the most important variable for determining the best position in which to assess maximal grip. When only one span is measured, the American Society of Hand Therapists (3) and the American Society for Surgery of the hand agree that the use of the second handle position is the best. The Jamar dynamometer has been demonstrated to be strongly correlated ($r = 0.87$) with a more complex apparatus, the BTE Work Simulator, in spite of the fact that some subjects were not considered to have given their maximal effort (25).

Over the last few years, new slightly modified versions of the Jamar dynamometer have become available. It was at first presumed that these modified versions were equivalent in accuracy. However, a study by Flood-Joy & Mathiowetz (16) showed that grip strength is significantly different when measured with 3 well-calibrated models of the Jamar. These findings underline the importance of using the same model to

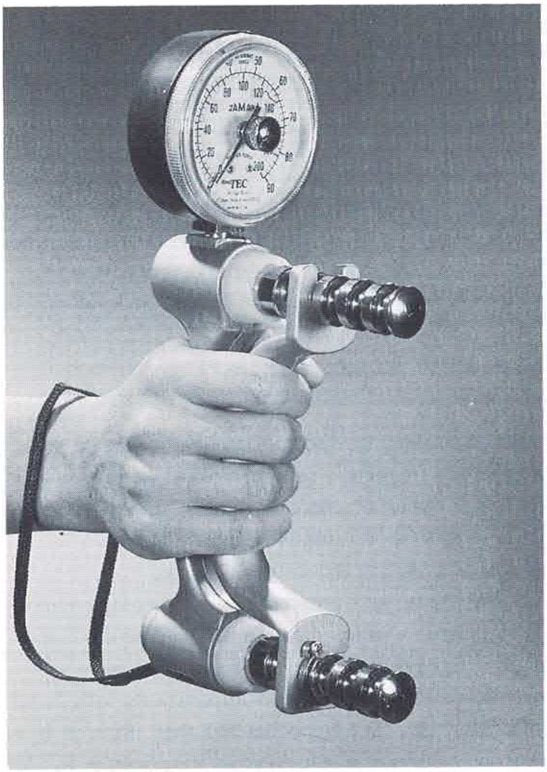

Fig. 1. Jamar dynamometer.

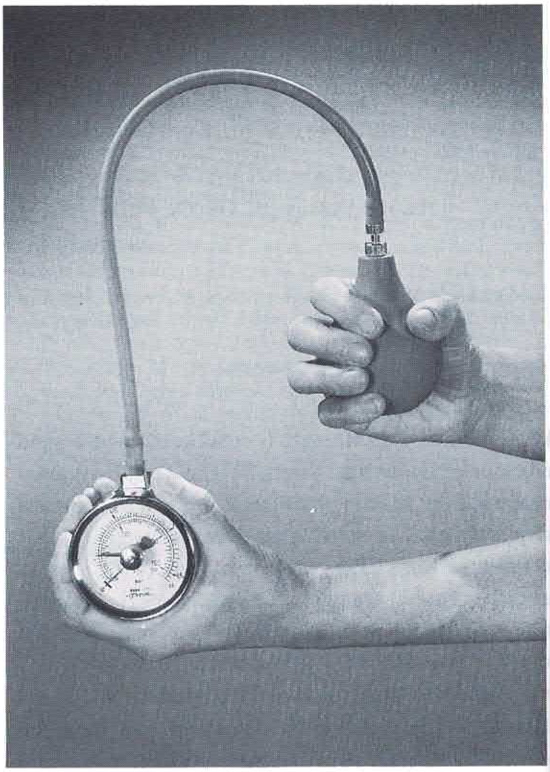

Fig. 2. Martin vigorimeter.

compare the performance of a subject to previous measurements or normative data. The precision of the calibration of the Jamar is another essential aspect to consider (14). This aspect is often neglected in clinical settings where the same apparatus may be used for many years without checking the calibration. The method most often used for testing the calibration of a dynamometer is the suspension of known weights from the center of the handle (29). Using this technique, Fess (14) developed a standardized and accurate method to check the calibration of the Jamar.

Mathiowetz et al. (31) demonstrated that standardized positions and instructions increase the reliability of grip strength measured with the Jamar dynamometer. They also reported that the mean of 3 trials shows higher test-retest reliability (Pearson's product-moment correlation coefficients: 0.89 for the right hand and 0.93 for the left) than the first measurement (0.79 and 0.86). The reliability of the highest score of 3 trials was estimated at 0.82 for the right hand and 0.92 for the left. No learning or fatigue effect was observed when 3 consecutive measurements were taken (29).

The vigorimeter and the modified sphygmomanometer are often used to evaluated grip strength (1, 15, 17, 18) despite the fact that, strictly speaking, they measure pressure and not force. They are specifically designed for an arthritic clientele in order to avoid stress on weak or painful joints (19, 31). As opposed to the Jamar dynamometer, these instruments involve isotonic muscular action because of the movement required to compress the bag or bulb. The Martin vigorimeter is a grip strength measurement instrument frequently used in Europe (17) where is was developed (39). It is composed of a rubber bulb which is grasped by the hand (Fig. 2). The pressure in the bulb is registered on a manometer via a rubber junction tube. Three sizes of bulbs are available and used depending on hand size. A recent study emphasized the stability of the Martin vigorimeter with high test-retest reliability coefficients (23). Intra-class correlation coefficients were 0.96 for the mean of 3 measures and 0.93 for only one measure with the right hand. For the left hand, the figures were 0.98 and 0.96, respectively. According to the California Medical Association committee study, devices that measure grip pressure by squeezing a bulb filled with water, fluid or air, such as the vigorimeter, can only measure grip pressure and not its force; pressure is a measure of the intensity of force over a specific area (24). Thus, with an equivalent force, a smaller hand would achieve higher grip pressure than a larger hand.

In spite of the differences between the Jamar dynamometer and the Martin vigorimeter, it is nevertheless assumed in clinical and research settings that they both measure grip strength (15, 23), that the Jamar may be awkward because of its weight, rigidity and shape, especially for an arthritic clientele (19, 31), and that the alternative instrument of these patients is the modified sphygmomanometer or the vigorimeter (11, 28).

Subjects

A random sample of citizens aged 60 years and over was drawn from the electoral pool of the city of Sherbrooke (Québec, Canada). Each subject was first contacted by mail and then by telephone to verify eligibility criteria and willingness to participate in the study. The eligibility criteria were: be lucid, be independent in activities of daily living, see sufficiently well and not have any impairment affecting upper limb function. The subjects were assessed at the Upper Limb Functional Measurement Laboratory at the Centre de recherche en gérontologie et gériatrie of the Hôpital D'Youville de Sherbrooke. Eligible subjects who refused to participate in the study were asked to reply to a general information telephone questionnaire in order to estimate refusal bias. This study was part of a comprehensive research on upper extremity performance of elderly men and women aged 60 and over.

Procedure

Subjects were seated on a regular chair without arm rests. Dominance was estimated with the Edinburgh Handedness Inventory (33) and anthropometric data were collected (weight, height, hand length, hand circumference). Hand circumference was measured at the thumb commissure following the axis of the head of the metacarpels, while hand length was measured from distal crease of the wrist to the distal extremity of the middle finger. Three grip strength measurements of each hand were taken with both instruments with a rest of about 30 seconds between each. Both hands were tested, the dominant first. Measurements were first collected with the Jamar (Model 1), and then with the Martin. Occupational therapists collected data using Mathiowetz's instructions and the American Society of Hand Therapists recommendations (31) relating to upper extremity position: shoulder adducted and neutrally rotated, elbow flexed at 90°, forearm in neutral position and wrist in light extension (0 to 30°). Calibration of the Jamar was verified according to Fess' recommendations (14) before beginning and in the middle of the study. The Jamar dynamometer was set at the second handle position and the large size bulb of the Martin vigorimeter was used for all subjects.

Data analysis

The characteristics of the subjects are described by mean, standard deviation and range for the continuous variables and by frequencies and percentages for the categorical variables. Comparison of the subjects who refused and those who agreed to participate, according to age, sex, dominance and other health information data, was done using independent *t*-test and chi-square statistics. Pearson's product-moment correlation coefficient was calculated to verify the relationship between the Jamar and the Martin. These analyses were done on the highest score obtained by each subject on 3 trials. Pearson's correlation coefficients were also calculated between grip strength scores and hand anthropometry. The statistical test of Olkin & Siotani (34) was used to verify the equality of these correlations obtained with each instrument (paired data). Finally, a test for the equality of correlations of women's and men's grip strength with hand anthropometry was done to verify sex differences.

RESULTS

The total sample consisted of 360 subjects, 179 women and 181 men. The participation rate in the study was 78%. There were no differences between those who refused and those who agreed to participate regarding age ($p = 0.47$), dominance ($p = 0.83$), height ($p = 0.06$), weight ($p = 0.11$), self-perceived health ($p = 0.19$) and current activity level ($p = 0.21$). The mean age of the subjects was 73.9. Subjects were mostly righthanded (92%). As expected, the anthropometric data of male subjects are higher than those of the female. Descriptive data on the 360 subjects are presented in Table I.

Maximal grip strength results (highest score on 3 trials) of woman and men with the 2 apparatuses are reported in Table II. As expected, the men's scores are higher than those of the women ($p < 0.0001$). For both instruments, the right hand of our largely righthanded sample is stronger than the left ($p < 0.0001$) and grip strength decreases with age ($p < 0.0001$).

Pearson's correlation coefficients between grip strength scores obtained on both instruments are 0.89 for the right hand and 0.90 for the left. The distribution of the correlation obtained with the right hand is illustrated for men and women in Fig. 3.

Correlations between grip strength scores obtained by both apparatus and hand anthropometry are detailed in Table III. Scores obtained with the Jamar and the Martin are strongly related to hand circumference and hand length ($p < 0.0001$). The Jamar dynamometer appears to be more related to these 2 hand measurements than the Martin Vigorimeter. This difference between these correlations is significant ($p < 0.05$) using the test of Olkin & Siotani (34). Correlations between grip strength and hand anthropometry are not significantly different between men and women.

DISCUSSION

Pearson's product-moment correlations between the Jamar and the Martin are very high (0.89 and 0.90) and are, in fact, superior to those observed in previous studies carried out with convenience samples. Fike & Rousseau (15) found a correlation of 0.60 and 486 subjects aged 16 to 79 of whom 33 were aged 60 and over without upper limb impairment. Only one measurement with the dynamometer (handle in the third position) and 3 with the vigorimeter (the large bulb for men and the medium one for women) were taken. It should be noted that upper limb position and the instructions given to their subjects were different from those in the present study, the recommendations of the American Society of Hand Therapists (ASHT)

Table I. *Characteristics of the subjects*

	Women ($n = 179$)	Men ($n = 181$)
Dominance		
righthanded	169 (94.4%)	161 (89.0%)
lefthanded	8 (4.5%)	14 (7.7%)
ambidextrous	2 (1.1%)	6 (3.3%)
Age	74.1* (8.2)**	73.3 (7.8)
	60–94***	60–90
Weight (kg)	60.8 (12.1)	75.0 (13.0)
	31.5–113.7	44.5–107
Height (cm)	156.4 (6.8)	169.5 (5.8)
	128–188	152–185
Hand length (cm)	17.2 (0.9)	18.9 (1.0)
	14.4–21.0	16–23
Hand circumference (cm)	19.4 (1.1)	22.5 (1.5)
	16.6–22.4	17.5–28

* Mean.
** Standard deviation.
*** Range.

Table II. *Grip strength scores (maximum value on three trials) of subjects according to sex and apparatus*

	Woman ($n = 179$)	Men ($n = 181$)
Jamar dynamometer (Kg)		
Right hand	23.0 (5.2)*	40.8 (9.5)
Left hand	21.4 (5.0)	38.8 (9.4)
Martin vigorimeter (KPa)		
Right hand	50.0 (11.4)	79.1 (19.5)
Left hand	48.4 (11.4)	77.4 (18.8)

* Mean (standard deviation).

(2, 3) not being available at the time of their study. Moreover, the medium bulb was used for their female subjects whereas, in the present study, the large bulb was used for all subjects. According to the authors, the correlation between the 2 apparatus indicates that they are fairly comparable. However, they could not be interchangeable because of the difference in measurement units and thumb position (15). Agnew & Maas (1) studied the relationship between the Jamar and the modified sphygmomanometer, which operates on the same principles as the Martin vigorimeter, with a group of 72 women and 16 men, all righthanded, aged 26 to 65, and all affected by rheumatoid arthritis. They followed ASHT recommendations with the subjects who had upper limb impairment. Correlations are similar to those obtained in the present study (0.83 and 0.84, respectively) in spite of different samples. These authors conclude that since this strong relationship appears linear, the score of one could predict the other. Based on these results, Agnew & Maas stated that the decision of which apparatus to use should be based on the grip method and on the type of strength one wants to test (isometric versus isotonic). Our results are very different from those of Lusardi & Bohannon (27) who also compared the Jamar and a modified sphygmomanometer. They obtained correlations of 0.42 and 0.51 with 34 able-bodied female subjects aged 19 to 64 years. Like Fike & Rousseau (15), these authors attributed the lack of comparability of these two instruments to the compressibility of the sphygmomanometer and hand position.

The high correlation obtained in the present study suggests that the Jamar and the Martin are comparable. In spite of their difference in measurement units, the Martin vigorimeter is therefore a valid alternative to the Jamar when it is important to decrease stress on joints and the soft tissues of the hand. In the present study carried out with healthy elderly people, subjects complained frequently about

Table III. *Pearson's correlation coefficients between hand anthropometric data and grip strength scores obtained with the Jamar dynamometer and the Martin vigorimeter*

	Right hand			Left hand		
	Jamar dynamometer	Martin vigorimeter	*p* value*	Jamar dynamometer	Martin vigorimeter	*p* value*
Hand length	0.66	0.61	0.009	0.66	0.61	0.014
Hand circumference	0.76	0.66	0.0001	0.75	0.63	0.0001

All correlations are significant at the $p = 0.0001$ level.
* Two-sided test for the equality of the correlations of the Jamar dynamometer and the Martin vigorimeter with hand anthropometry [Statistical test of Olkin & Siotani (34)].

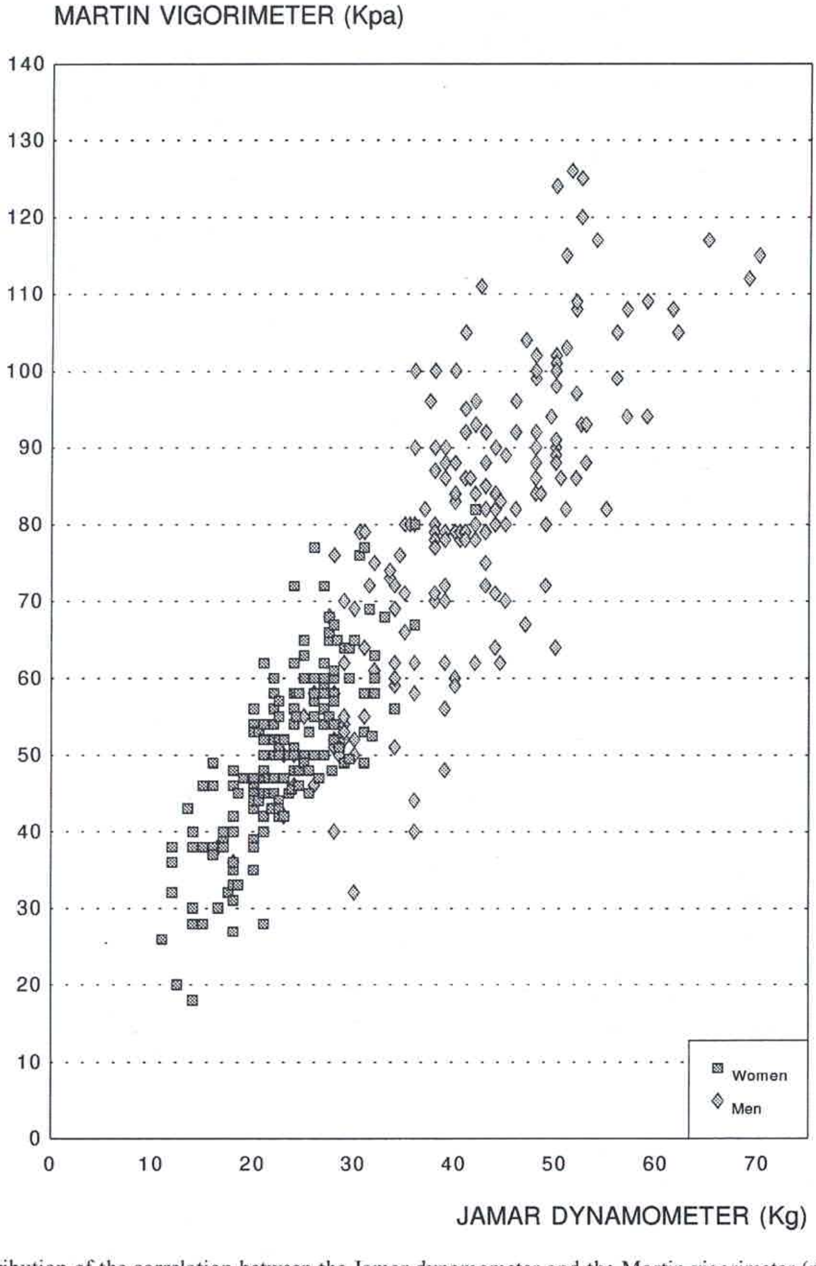

Fig. 3. Distribution of the correlation between the Jamar dynamometer and the Martin vigorimeter (right hand).

the rigidity of the Jamar as opposed to the flexibility and comfort of the Martin vigorimeter bulb. Another important aspect to consider is the movement created by squeezing the bulb, which increases feedback and therefore can improve performance. Since this study was done with subjects having no impairment affecting the upper limb function, no conclusions can be drawn regarding the two methods when applied to people with impairment.

Statistically significant correlations between grip strength and body anthropometric data were often demonstrated. Weight was the variable most frequently related to strength (10, 12, 26, 35) followed by hand width, body height and hand and finger length (12). The women achieved between 55% and 63% of the male grip strength; this is consistent with the percentages (60% to 67%) reported by Aniansson, et al. (5) and those (53% to 57%) reported by Bassey

& Harris (7). In the present study, relationships between the grip strength measured by the 2 instruments and hand anthropometry were studied in order to verify the theoretical hypothesis that the Martin is more related to hand anthropometry than the Jamar. This hypothesis is based on the fact that the Martin is a pressure measurement (force/surface) and the Jamar is a pure force measurement. The results completely contradicted this hypothesis since the Jamar was more correlated to hand anthropometry than the Martin vigorimeter. These results emphasize that hand length must be taken into account and stress the importance of the 5 handle positions available on the Jamar. However, in clinical settings, the second handle position is most frequently used. Moreover, norms developed by Mathiowetz et al. (30) which are often used by clinicians, were derived using this position. Close relationships between hand anthropometry and grip strength should encourage clinicians to change the handle position of the Jamar, as required. However, normative data would not then be useful and compromises would have to be made.

For the Martin vigorimeter, the large bulb was chosen for all subjects, in spite of the manufacturer's recommendations to use only this bulb for men and women with large hands. No bulb prehension problems were observed even for small women. In light of these results, the vigorimeter's manufacturer should modify their recommendations related to the selection of bulb size. Even though less related to hand anthropometry than the Jamar, hand circumference and hand length are also important to take into account in the Martin's grip strength measurement.

CONCLUSION

This study compared the grip strength measured with two instruments, the Jamar dynamometery and the Martin vigorimeter, and also verified their relationship to 2 hand anthropometry measures, hand length and hand circumference. Results showed a close relationship between the 2 apparatuses, with correlation coefficients higher than those reported in previous studies and significant correlations with the 2 hand measures.

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