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COMPARISON OF HAND DYNAMOMETERS IN ELDERLY PEOPLE

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Abstract: *Objective:* Some dynamometers previously tested in healthy adults showed variable degrees of practicality, weight and ergonomics. More practical models could also be used as a more suitable tool in gerontological field and clinical studies. The purpose of the present study was to evaluate the reliability of the measurements and the performance of hand grip strength dynamometers in the elderly. *Study design:* Cross-sectional study. *Setting:* A retirement home and a social day care centre for old people in Porto, Portugal. *Participants and measurements:* The accuracy of four static grip strength dynamometers (Smedlay's® Hand, Sammons Preston Rolyan® Bulb, Eisenhut® and the Jamar® Hydraulic Hand) was first tested in laboratory. The grip strength of fifty-five elderly individuals 65-99 years was measured with the four dynamometers and the Jamar® Hydraulic Hand which was used as the comparison dynamometer. *Results:* The accuracy of the four dynamometers measurements compared to known forces was excellent ($r > 0.96$). A strong association between the measurements obtained by the Jamar® Hydraulic and the other instruments evaluated was found ($r > 0.77$) but significant differences between the mean hand grip strength values evaluated with the Jamar® Hydraulic and each one of the other dynamometers were found. The Bland and Altman plots confirmed that none of the three dynamometers reflects a good agreement with the Jamar® Hydraulic. *Conclusion:* All four dynamometers showed excellent results regarding their laboratory tested accuracy. However, their application among elderly people rendered very different results. The Smedlay's® results´ were closer to the Jamar® Hydraulic, though none of these three dynamometers produced comparable results to the Jamar® Hydraulic.

Key words: Hand grip strength, dynamometers, elderly, Mini Nutritional Assessment.

Introduction

Hand grip force reflects the total force from the upper limb muscles and it is also related with the other body muscles strength (1). Hand Grip Strength (HGS) has been used as a health indicator and as a nutritional assessment technique (2) as it is sensitive in evaluating short-term changes in nutritional status (3, 4) and also shows promising results as an undernutrition screening tool (5).

Grip strength exhibits a strong predictive power for important variables in gerontological research, such as disability (4, 6), increased risk of complications (7) and mortality (8). Syddall et al have demonstrated that grip strength may prove a more useful single marker of frailty for older people than chronological age (9).

It has been shown that grip strength has numerous advantages over other biological measurements. Hand held dynamometers are rather inexpensive, portable, non invasive, quick, easy to use and do not require specialized technicians. An additional characteristic that makes this device an appealing method is that it has proved to have both low intra and inter observer variability and high test-retest reliability (3, 10).

The inter-instrument validity of some recent dynamometers have already been assessed and documented in samples of healthy adults (11-17) and hand injury patients (18) using the Jamar® Hydraulic Hand as criterion standard (11-18) recommended by the American Society of Hand Therapists as the "gold standard" for measurements of grip strength (19). However, it is not known if the Jamar® Hydraulic could be chosen as the criterion standard for measurements of grip strength in other settings where they are widely used, among the frail and undernourished older people, where their hand grip performance may be different compared to other population groups in previous studies.

Some dynamometers, previously tested in healthy adults, showed variable degrees of practicality, weight and ergonomics. More practical models could also be used as a more suitable tool in gerontological field and clinical studies. The purpose of the present study was to evaluate the reliability of the measurements and the performance of hand grip strength dynamometers in the elderly.

Methods

Study design

The accuracy of four static grip strength dynamometers was first tested in laboratory. Their reliability and performance was evaluated in an elderly sample on a cross sectional study on January 2008.

Subjects

A convenience sample was composed of fifty-five elderly individuals from a retirement home ($n = 25$) and from a day care centre for old people ($n = 30$) in Porto, Portugal. Individuals were considered eligible if they were ≥ 65 years old and were able to give informed consent. Exclusion criteria were

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upper limb deformities and incapacity to perform HGS measurements. The recruiting procedure was made by a direct and consecutive approach during the data collection days. From the 28 individuals at the retirement home and the 31 at the day care centre that fulfil the inclusion criteria, there were three from the retirement home and one from the day care centre that refused to participate. All subjects gave informed consent and the study was approved by the administration board of the two institutions.

Measurements

Four different static dynamometers were used: the Smedlay's® Hand (measurements to the nearest 0.5 kgf; mass = 0.520 kg), the Sammons Preston Rolyan® Bulb (measurements to the nearest 0.5 N; mass = 0.240 kg), the Eisenhut® (measurements to the nearest 1.0 kgf; mass = 0.102 kg) and the Jamar® Hydraulic (measurements to the nearest 1.0 kgf; mass = 0.686 kg), as the comparison dynamometer. The Sammons Preston® dynamometer data in Newtons was converted to kgf, through an equation obtained in the certified laboratory of metrology with known forces, in order to be comparable with the measurements of the other dynamometers. All instruments were previously calibrated in the aforementioned laboratory, against a pattern constituted by a unity of digital measure and a transducer of force, with a range of forces from 0.0 kgf to 100.0 kgf.

The isometric HGS was measured with the non-dominant hand in a sitting position with the elbow flexed at a 90º angle (20). Subjects used their dominant hand when they were unable to perform handgrip dynamometry with their non-dominant hand. After the procedure was explained to each individual, they performed three strength tests with each one of the dynamometers in a random order, with a one minute gap between each test, on the same day. Participants were instructed to stop the measurement if they felt pain.

The participants' anthropometric data was collected using standard procedures (21). Height was measured with the individuals wearing light clothes and without shoes to the nearest 0.001 m. When the subject had difficulties in standing up, the arm span was measured to the nearest 0.001 m, since this measurement is highly correlated with actual height (22). Mass was measured to the nearest 0.5 kg. Mass and height were used to calculate body mass index (BMI) (mass (kg)/((height (m)^2)). Wrist diameter was measured to the nearest 0.1 mm. The mid arm circumference and the calf circumference were measured the nearest 0.001 m.

Nutritional status among participants was evaluated with the Mini Nutritional Assessment (MNA) (23-25), a validated nutrition screening and assessment tool that can identify individuals aged 65 and above who are undernourished or at risk of undernutrition. It consists of 18 questions targeting three main areas: anthropometry (BMI, weight loss, mid arm and calf circumferences), global assessment (lifestyle, medication and physical and mental status), and dietary intake. An elderly patient scoring less than 17 out of 30 points is classified as undernourished, one that scores between 17.5 and 23.5 is at-risk of undernutrition and one scoring between 24 points or more is classified as well nourished (23). This tool was validated against the nutritional assessment performed by two trained physicians, as the golden standard (26). The reliability was estimated, with a kappa = 0.51 (24). The MNA was designed to be administrated by a trained health care practitioner, it usually takes less than 10 minutes to be completed and its practicability has been shown in a large number of studies (26). The participants identified as nutritionally at risk or as undernourished were referred to the person in charge of the institutions for treatment.

Social demographic, exercise practice and health status data was also collected from the participants, for the overall description of this sample.

All the measurements were obtained by the same interviewer (RG), who trained all the procedures previously in order to minimize the interviewer bias.

Data analysis and statistical methods

The calibration procedure allowed the error estimate and further data correction, which were corrected as measure (kgf) = measurement – error:

Jamar® Hydraulic: error (kgf) = - 0.047 x measurement + 1.2278

Smedlay's®: error (kgf) = 0.0604 x measurement – 1.5143

Eisenhut®: error (kgf) = 0.1821 x measurement – 7.7143

Sammons Preston®: error (kgf) = 0.153 x measurement + 0.7524

The amplitude between the grip strength measurements was calculated by subtracting the lowest value of the three consecutive measurements from the highest one.

The effect of gender, age and nutritional status on the discrepancy of grip strength measurements between the Jamar® Hydraulic and each one of the other dynamometers was also studied. The mean difference data between the Jamar® Hydraulic and the other three dynamometers were stratified for two age groups, the young-old (<75 years) and the old-old (≥75 years). Due to the small number of undernourished individuals the undernourished elders and those at risk of undernutrition were grouped.

Frequencies, medians, maximums, minimums, limits of agreement, means and standard deviations (SD) were calculated. The normal distribution of the variables was tested with the Kolmogorov Smirnov test. Differences between two means were compared with the Student's t test or with the Wilcoxon test according to the normality of the data distribution. The Friedman test was used to evaluate differences between the four dynamometers HGS data. Pearson's and Spearman's correlation coefficients were calculated to evaluate the association between the three dynamometers and the Jamar® Hydraulic. The visual agreement between the Jamar® Hydraulic and each one of the other dynamometers was evaluated with the Bland and Altman plots (27).

Significant results were considered when $p < 0.05$. All statistical analyses were carried out using the Software Package for Social Sciences for Windows, version 14.0 (SPPS Inc. Chicago, Il, USA).

Results

The association between the four dynamometers measurements and the known forces obtained in laboratory was excellent for Jamar® Hydraulic r = 0.97, Smedlay's® r = 0.98, Eisenhut® r = 0.99 and for Sammons Preston® r = 0.96.

The characteristics of study participants, 42 women (76.4%) and 13 men (23.6%), are summarized in Table 1. The subjects' age range was 65-99 years and the mean of age was 79.2 (SD = 7.2) years. Thirteen elderly (23.6%) were identified as nutritionally at-risk and two (3.6%) as undernourished. According the MNA mobility status classification 47 (85.5%) individuals had a normal mobility and 8 (14.5%) were able to get out of beds or chairs, but not to go out.

Table 1
Sample's characteristics

	Women n = 42	Men n = 13
Age (years, mean ± SD[a])	78.7 ± 6.7	80.6 ± 8.9
Height (m, mean ± SD[a])	1.51 ± 0.06	1.64 ± 0.08
Mass (kg, mean ± SD[a])	65.0 ± 12.7	69.8 ± 8.2
BMI (kg/m^2, n (%))		
18.5 - 24.9	8 (19.0)	4 (30.8)
25.0 - 29.9	19 (45.2)	7 (53.8)
30.0 - 34.9	11 (26.2)	2 (15.4)
> 35.0	4 (9.5)	0 (0.0)
Education (no. of school years, n (%))		
0	13 (31.0)	5 (38.5)
1 - 4	25 (59.5)	8 (61.5)
≥ 5	4 (9.5)	0 (0.0)
Main pathologies (n (%)[b]		
Osteoporosis	19 (45.2)	4 (30.7)
Cardiac complications	9 (21.4)	0 (0.0)
Others	35 (83.3)	6 (46.2)
MNA® (Classes, n (%))		
Without undernutrition	31 (73.8)	9 (69.2)
Nutritionally-at-risk	10 (23.8)	3 (23.1)
Undernourished	1 (2.4)	1 (7.7)
HGS[c] according to MNA status (kgf, Mean ± SD[a] (Max.; Min.))		
Without undernutrition	16.5±5.9 (29.0; 2.0)	25.3±8.6 (39.0;10.0)
Nutritionally-at-risk or undernourished[d]	12.5±4.1 (18.0; 2.0)	23.5±16.0 (47.0;10.0)

a. SD – Standard deviation; b. Total add > 100% because subjects had one or more pathologies; c. Measurements made with the Jamar® Hydraulic dynamometer; d. The nutritionally-at-risk and undernourished elderly classes were grouped.

No significant differences were found between the three measurements performed with each one of the four dynamometers, comparing the 1st measurement with the 2nd, the 2nd with the 3rd and 1st with the 3rd (Table 2).

Table 2
Three corrected measurements of HGS (kgf) evaluated with the four dynamometers

	1st measurement Mean ± SD[a]	p	2nd measurement Mean ± SD[a]	p	3rd measurement Mean ± SD[a]	p
Jamar® Hydraulic (kgf)	17.6 ± 7.6	0.825[b]	17.7 ± 8.5	0.480[d]	17.9 ± 8.8	0.467[f]
Smedlay´s® (kgf)	14.6 ± 8.1	0.560[b]	14.4 ± 7.9	0.106[d]	14.7 ± 8.0	0.745[f]
Eisenhut® (kgf)	11.0 ± 4.8	0.907[c]	10.9 ± 4.6	0.527[e]	10.8 ± 4.3	0.408[g]
Sammons Preston® (kgf)	8.9 ± 5.0	0.417[b]	9.1 ± 5.5	0.572[d]	9.2 ± 5.4	0.176[f]

a. SD – Standard deviation; b. Paired sample t- test for 1st versus 2nd measurement; c. Wilcoxon signed rank for 1st versus 2nd measurement; d. Paired sample t- test for 2nd versus 3rd measurement; e. Wilcoxon signed rank for 2nd versus 3rd measurement; f. Paired sample t- test for 3rd versus 1st measurement; g. Wilcoxon signed rank for 3rd versus 1st measurement.

Descriptive data on HGS for men and women participants and the HGS amplitude median value for each one of the four dynamometers used are presented in Table 3. The four dynamometers showed consistently higher HGS values for men.

A strong association between the measurements obtained by the Jamar® Hydraulic and the other instruments evaluated was found: Smedlay's® r = 0.83 ($p < 0.001$), Sammons Preston® r = 0.91 ($p < 0.001$) and Eisenhut® r= 0.77 ($p < 0.001$). Despite these high correlation coefficients, statistically significant differences between the mean HGS values evaluated with the Jamar® Hydraulic and each one of the other dynamometers were found (Table 3). When the Jamar® Hydraulic was compared to the Smedlay's®, we found a mean difference of 3.2 kgf (95% confidence interval for limits of agreement: -6.3-12.6 kgf). Relatively to the Eisenhut®, the mean difference found was 7.0 kgf (-3.0-17.0 kgf). For the Sammons Preston® the mean difference found was 8.7 kgf (0.9-16.5 kgf).

The discrepancy between the Jamar® Hydraulic and the other three dynamometers was studied by gender, age and nutritional status. We found lower differences between the comparison dynamometer and the Smedlay's® dynamometer for men than for women (2.1 kgf, 95% confidence interval for limits of agreement: -0.9-5.2 kgf vs. 3.5 kgf, 2.0-4.9 kgf) and higher differences between the Jamar® Hydraulic and the Eisenhut® (10.2 kgf, 6.9-13.5 kgf vs. 6.0 kgf, 4.6-7.4) and between the Jamar® Hydraulic and the Sammons Preston® (12.5 kgf, 9.5-15.4 kgf vs. 7.5 kgf, 6.7-8.4 kgf). These results show that gender influence on the discrepancy varied according to the dynamometer used.

The discrepancy observed between the two age groups (<75 and ≥75 years) is similar for both genders. We found lower differences between the Jamar® Hydraulic and the Smedlay's® for the young-old than for the old-old (2.7±5.9 kgf vs. 3.7±4.3 kgf for women and 4.0±2.3 kgf vs. 5.3±1.7 kgf for men), higher

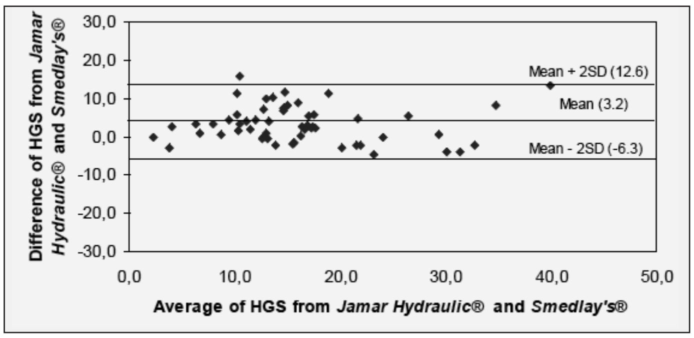
Table 3
HGS corrected measures (kgf) and amplitude[a] evaluated with the four dynamometers

	Women n = 42			Men n = 13				Amplitude[a]			
	Mean±SD[b]	Max.	Min.	Mean±SD[b]	Max.	Min.	p	Median	Max.	Min.	p[f]
Jamar® Hydraulic (kgf)	15.5±5.7	29.0	2.0	24.8±10.7	47.0	10.0		2.0	16.0	0.0	<0.001
Smedlay's® (kgf)	12.2±6.1	32.5	2.9	22.2±8.6	33.0	6.7	<0.001[c]	1.4	9.9	0.5	<0.001
Eisenhut® (kgf)	9.7±3.3	24.0	8.0	14.5±5.7	24.0	8.0	<0.001[d]	0.0	8.0	0.0	<0.001
Sammons Preston® (kgf)	8.0±4.4	16.4	0.0	12.3±6.3	23.4	2.3	<0.001[e]	1.0	6.0	0.0	<0.001

a. The amplitude is equal to the difference between the highest value and the lowest of three consecutive measurements; b. SD – Standard deviation; c. Friedman test for the mean values of HGS of the total sample for the Smedlay's® versus Jamar® Hydraulic; d. Friedman test for the mean values of HGS of the total sample for the Eisenhut® versus Jamar® Hydraulic; e. Friedman test for the mean values of HGS of the total sample for the Sammons Preston® versus Jamar® Hydraulic; f. Friedman test for the highest value versus the lowest of three consecutive measurements of the total sample.

differences between the Jamar® Hydraulic and the Eisenhut® (6.6±3.3 kgf vs. 5.8±4.9 kgf for women and 6.9±4.0 kgf vs. 5.4±1.7 kgf for men) and similar differences between the Jamar® Hydraulic and the Sammons Preston® (7.5±2.9 kgf vs 7.5±2.8 kgf for women and 5.2±3.0 kgf vs. 5.0±1.6 kgf for men).

Figure 1
Bland and Altman plot for difference against mean for HGS data from the Jamar Hydraulic® and the Smedlay's® (kgf).



Undernourished or nutritionally at-risk elders showed lower mean HGS values when compared with not undernourished (Table 1). The discrepancy between the Jamar® Hydraulic and the Smedlay's® is higher for the undernourished or nutritionally at-risk when compared with not undernourished elders (3.8±5.7 kgf vs. 2.9±4.3 kgf) and lower between the Jamar® Hydraulic and the Eisenhut® (6.5±6.3 kgf vs. 7.0±4.8 kgf) and between the Jamar® Hydraulic and the Sammons Preston® (8.2±4.9 kgf vs. 8.8±3.6 kgf). These results show that nutritional status effect on discrepancy varied according to the dynamometer used.

The highest and the lowest measurement of the three obtained with each one of the four instruments varied according to the dynamometer used. When compared (Table 3), significant differences were found. The Jamar® Hydraulic showed the biggest amplitude and the Eisenhut® the smallest.

The Bland and Altman plots of HGS from the Jamar Hydraulic® against the Smedlay's®, the Eisenhut® and the Sammons Preston® are presented in Figures 1-3. There are three characteristics that a good agreement scatter must fulfill: the dispersion of values must be uniform, the mean value for the difference between the two instruments should be close to zero and the limits of agreement between the two instruments must be small (27). The three scatters are different but none of the three dynamometers reflects good agreement with the Jamar Hydraulic®. However, the Smedlay's® dynamometer is the dynamometer whose results were closer to the Jamar Hydraulic® dynamometer. All the scatters have shown that the discrepancy between the recommended dynamometer and the others increases with the HGS values.

Figure 2
Bland and Altman plot for difference against mean for HGS data from the Jamar Hydraulic® and the Eisenhut® (kgf)

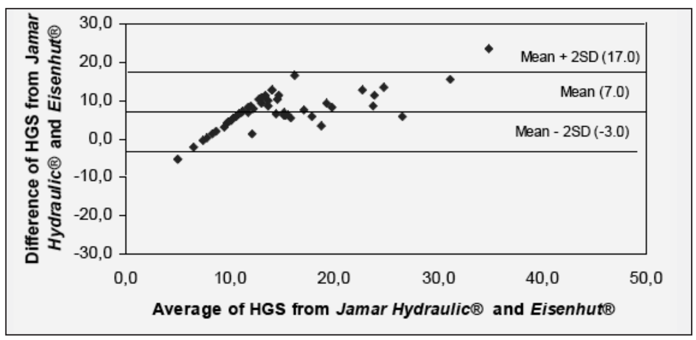
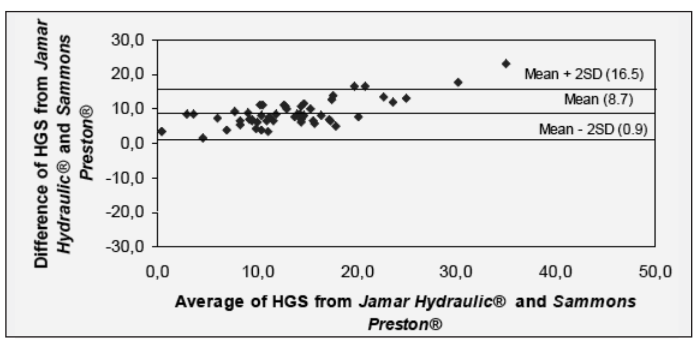


Figure 3
Bland and Altman plot for difference against mean for HGS data from the Jamar Hydraulic® and the Sammons Preston® (kgf)



Discussion

Before being applied to the elderly, the four equipments were calibrated in laboratory and their accuracy was excellent. Although the measurements carried out by elders with each of the four dynamometers were later corrected for errors quantified in the laboratory, the results were discrepant when the Jamar® Hydraulic was compared to the other dynamometers. The Jamar® Hydraulic exhibited higher mean values than the Smedlay's®, the Eisenhut® or the Sammons Preston®. The differences and the large span of the limits of agreement show that the Smedlay's®, the Eisenhut® or the Sammons Preston® dynamometers do not agree with the Jamar® Hydraulic for serial measurements on the same individual nor are these values comparable, despite the high correlation coefficients found between them.

Another relevant finding is that the highest and the lowest HGS value from the set of the three consecutive measurements varied according to the instrument used, showing that the interaction between the dynamometer and the elderly individual conditioned the amplitude of the measurement. When evaluated in laboratory the accuracy of the equipments was excellent, but the elevated amplitude obtained from repeated measurements, namely with the Jamar® Hydraulic in the elderly, reveals strong influence of individual parameters on the measurements, so its evaluation remains noteworthy. There is no mention in the literature about the within–subject variability in elderly individuals which our values can be compared to, but they are larger than previously described for adult samples. The present data suggest the need to perform at least three measurements and to use its average, when evaluating HGS in elderly subjects.

This evaluation carried out among elderly subjects showed higher differences between the Jamar® Hydraulic and the other three dynamometers, than the previously reported in healthy adults, for the comparison of Jamar® Hydraulic with other dynamometers (28-31). When the electronic dynamometer Grippit® was compared to the Jamar® Hydraulic dynamometer in a sample of 476 healthy subjects, aged between 18 and 97 years old, the results obtained revealed a mean difference of 2.2 kgf between the two instruments in spite of the large limits of agreement (-0.9 to 21.9 kgf) and the authors concluded that they cannot be interchanged (28). The comparison of the Rolyan® Hydraulic with the Jamar® Hydraulic in a sample of 60 individuals, of 20 to 50 years of age, presented excellent correlation ($r = 0.90 - 0.97$) and no significant differences between the two dynamometers were found (29). The MicroFET® 4 was also highly correlated with the Jamar® Hydraulic dynamometer ($r \geq 0.96$) although the measurements obtained with the MicroFET® 4 tended to be slightly higher (1.0-1.4 kgf) (30). On the other hand, despite the excellent concurrent validity between the DynEX® dynamometer and the Jamar® Hydraulic ($r > 0.98$) in a sample of 100 healthy subjects, aged from 20 to 40 years old, significant differences were found between the measurements made with the two dynamometers (31). In men, the HGS mean values for the Jamar® Hydraulic were 46.2 kgf and 43.6 kgf for the DynEX®, in women, the mean HGS values were 26.4 kgf for the Jamar® Hydraulic and 24.3 kgf for the DynEX® (31). Even so, the authors of this study concluded that the results obtained with the DynEX® dynamometer are comparable with those obtained with the Jamar® Hydraulic (31).

As far as we know, no previous attempts were made to assess the performance of dynamometers among an elderly sample. As the dynamometers should be assessed in the populations in which they will be used (32), the high proportion of nutritionally at risk or undernourished subjects in this sample, can be seen as a strength. Thirteen percent of elders at the day care centre were identified as nutritionally at-risk and 3.3% as undernourished, proportions within the range reported by Guigoz Y (33). At the retirement home, 36% of the elders were identified as nutritionally at-risk and 4% as undernourished, which is within the range and near the lower value, respectively, of the previously described (33, 34).

Although the low sample size does not allow to conclude about the effect of nutritional status, gender and age on discrepancy of HGS measurements, our results suggest that the discrepancy may be attributed to the interaction between the elderly and the ergonomic characteristics of each dynamometer.

Since only four individuals refused to participate and there were no exclusions, this small number of individuals does not allow us to explore possible differences in characteristics between the participants and those who did not volunteer. As a high proportion of participants have a normal mobility (85.5%), we can not infer about the generalizability of our results to elders of a different status.

As other different models of dynamometers are available, it remains to be seen if more sophisticated instruments will produce the same discrepancy when applied to elderly subjects. Another limitation is that this study did not reveal the most appropriate dynamometer to be used by the elderly. Furthermore, the present study strengthens the necessity to guarantee that dynamometers which are used in clinical practice and field studies are valid and their results are comparable.

Given that the extent of an individual impairment can be established by comparing measurements of individual performance with normative values obtained from apparently unimpaired individuals (35), caution should be used with comparisons of elderly individuals HGS measurements against normative values, if the dynamometers are not the same. The use of different models to built reference data, could partially explain the discrepant values found between HGS reference data studies (36, 37).

All four dynamometers showed excellent results regarding their laboratory tested accuracy. However, their application among elderly people rendered very different results. The Smedlay's® results´ were closer to the Jamar® Hydraulic, though none of these three dynamometers produced comparable results to the Jamar® Hydraulic.

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