Validation Study of Hand Grip Strength Measured Using Jamar Dynamometer and Aneroid Sphygmomanometer as a Diagnostic Tool for Sarcopenia

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Abstract

Background. Hand grip strength (HGS) is a tool to measure muscle strength, which is an important component in sarcopenia and frailty. Grip strength (GS) in midlife can predict physical disability in senior years and help evaluate a patient's overall health.

Objectives. The general purpose of this study is to validate the HGS using an aneroid sphygmomanometer and Jamar dynamometer as a diagnostic tool for sarcopenia. The specific aims of this study are (a) to determine the concurrent criterion validity, (b) to determine the reliability, and (c) to measure the inter-rater agreement of the aneroid sphygmomanometer against the Jamar dynamometer in measuring HGS.

Methods. This prospective validation study measures HGS using an aneroid sphygmomanometer and Jamar dynamometer obtained from seventy participants 50 years old and above. Statistical methods used in data analysis include Spearman Rho, univariate linear regression analyses, intra-class correlation, inter-rater reliability, intra-rater reliability, Bland-Altman plots, and Lin's concordance.

Results. There was a significant correlation of HGS with the Jamar dynamometer and aneroid sphygmomanometer regardless of the rater [Spearman Rho (r_s=0.762 to 0.778, p=0.001)]. Jamar GS is comparable to GS using a sphygmomanometer with the formula of [Jamar = 0.54 x sphygmomanometer (mmHg) - 45.12].

Conclusion: Aneroid sphygmomanometer can be used as an option to measure GS and has a valid value to predict the Jamar GS value. Hence, it can be an alternate tool for diagnosing sarcopenia.

Keywords: Validation Study, Grip Strength; Sarcopenia

Introduction

The loss of skeletal muscle mass is a major and well-known quantitative change associated with aging resulting in significant adverse outcomes (disturbed daily activities and decreased quality of life), disability, and mortality via influencing the physical function in older people.[1-5] Qualitative changes in skeletal muscle have been reported to correlate with aging, such as the preferential atrophy of type II muscle fibers, increased intramuscular fat, and increased extracellular water volume relative to muscle volume.[1-9] They represent important risk factors in elderly patients and are considered the main causes of invalidity and frailty.[10] Age-related loss of muscle mass is thought to be largely due to progressive loss of motor neurons (up to 50% of the motor units).[11,12] Individuals with physical dysfunction resulting from age-related skeletal muscle loss are expected to be diagnosed with sarcopenia.[3]

Sarcopenia is an important public health problem.[13] By the eighth decade of life, muscle loss is approximately 30% of peak values.[14,15] Globally, the prevalence of sarcopenia among adults aged 60 years and over is estimated to be at least 10%. It does not only predict mortality among community-dwelling and acutely ill older adults but is also related to functional decline, loss of independence, and hospitalization.[16] To overcome this issue, early prognostication is essential.

Hand grip strength (HGS) is a tool to measure muscle strength, which is an important component in sarcopenia and frailty.[16,17] Likewise, it robustly correlates with a myriad of important health variables.[32] It can be quantified by measuring the static force the hand can squeeze around a dynamometer and

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sphygmomanometer cuff. It is an indicator of overall muscle strength and power.[16,17] Among older adults, decreased handgrip strength is associated with a greater risk of frailty and loss of physical function and mobility. Frailty is also associated with sarcopenia, for which hand grip strength has been recommended for diagnostic purposes.[16] A study by R. Bohannon found that midlife grip strength (GS) can predict physical disability in senior years and help evaluate a patient's overall health.[18]

Barriers to the evaluation of grip strength include the limited availability of a dynamometer, partly due to its being relatively expensive and fragile. In contrast, the sphygmomanometer is widely available. With the above in mind, the general purpose of this study is to validate the HGS using an aneroid sphygmomanometer and Jamar dynamometer as a diagnostic tool for sarcopenia. The specific aims of this study are (a) to determine the concurrent criterion validity, (b) to determine the reliability, and (c) to measure the inter-rater agreement of the aneroid sphygmomanometer against the Jamar dynamometer in measuring HGS.

Materials and Methods

Study Design. A validation study was conducted among adult patients seen in rheumatology outpatient clinics of the University of Santo Tomas Hospital (USTH) between May 2022 and July 2022. The study was conducted and approved by the USTH Research Ethics Committee.

Participants. Seventy random participants, 50 years old and above, with no hand orthopedic problem or disability were eligible for inclusion. Exclusion criteria were those with psychiatric, psychological, and/or mental disabilities and those with unstable comorbidities that the procedure may aggravate. Participants were included after written informed consent had been secured. All enrolled patients completed the assessments, and there was no withdrawal of consent.

The sample size computation for intra-class correlation was conducted using PASS 2008 version 08.0.15. According to McGraw & Wong (1996), a null intra-class correlation (ICC_0) of 0.70 was preferred.[19] In the study of Silva et al. (2015), the estimated intra-class correlation (ICC_1) between the Jamar dynamometer and aneroid sphygmomanometer in measuring HGS was 0.83.[20] There is a minimum of two observations per subject or participant: 1 for the Jamar dynamometer and 1 for the aneroid sphygmomanometer readings and measurements. With an ICC_0 of 0.7, an ICC_1 of 0.83, a minimum power of 80%, and a significance level of 5% (two-tailed), the computed sample size was 62 participants. However, the sample size was inflated to accommodate a non-response rate of at least 10.00%, thus increasing the sample size to 70 respondents.

Apparatus and Measurement

Dynamometer Measurement. For all measurements, the grip width on the Jamar was standardized to the second position (5.0cm) regardless of age, body mass, or hand dimensions.[16] Consistent with the recommendations for handgrip by the American Society of Hand Therapy and previous research, the HGS was measured three times at 5-minute intervals to prevent fatigue. The result was obtained from the mean value after three measurements.[16,21-23]

Sphygmomanometer Measurement. The sphygmomanometer cuff was inflated to 20 mmHg, and participants were asked to squeeze the inflated cuff three times at 5-minute intervals to prevent fatigue. The result was obtained from the mean value after three measurements.[21,23]

Raters. A single investigator performed the intra-rater reliability of HGS measurements from the two apparatuses. In contrast, inter-rater reliability was measurements taken from two independent investigators blinded to each other's readings.

Inverse Regression Technique. The investigator calculated the inverse regression line to show the relationship between Jamar and Sphygmomanometer scores. From the study of Hamilton et al., the formula to convert sphygmomanometer scores to equivalent Jamar values was calculated as:[21]

JAMAR= 0.54 x sphygmomanometer (mmHg) – 45.12

Statistical Analysis. Statistical analyses were performed using STATA Statistical Software, Version 13, College Station, TX: StataCorp LP. A $p < 0.05$ was considered statistically significant. Descriptive statistics included frequency and percentage for nominal data and mean and standard deviation for continuous-level variables. The normative HGS of the participants was presented alongside its corresponding 95% confidence interval. Concurrent criterion validity used correlation analyses (Spearman Rho) while univariate linear regression analyses to determine the association between the aneroid sphygmomanometer (exposure) and the HGS using the Jamar dynamometer score (outcome).[24] The reliability of and the agreement between raters in using the Jamar dynamometer and aneroid sphygmomanometer were estimated using intra-class correlation (ICC), inter-rater reliability, and intra-rater reliability. Intra-class correlation (ICC) was utilized to determine the reliability, alongside its corresponding 95% confidence interval, and was categorized as weak (ICC<0.60), good (ICC = 0.60 to 0.79), and excellent (ICC=0.80 to 0.90).[19] Inter-rater and intra-rater reliability values were appraised using the Agreement Standard Error of Measurement (SEM) and the Agreement Minimum Detectable Change (MDC) in the HGS measurements using the Jamar dynamometer and the aneroid sphygmomanometer.

Results

Demographic and Clinical Characteristics of the Participants. Table I illustrates the demographic and clinical characteristics of the participants. Results indicated that the mean age of the participants was 65.67 years (SD=9.65). The majority of the participants were females (74.29%), had a tertiary level education (85.70%), and were employed (47.14%). The mean weight, height,

Table I. Demographic and Clinical Characteristics of the Participants (N=70)

Characteristics	Summary Statistic	Characteristics	Summary Statistic
Age (Years; x̄, SD)	65.67 (9.65)	Comorbidities (*f*, %)	
Sex (*f*, %)		*None*	16 (22.86%)
Male	18 (25.71%)	*Hypertension*	43 (61.43%)
Female	52 (74.29%)	*Diabetes Mellitus*	21 (30.00%)
Marital Status (*f*, %)		*Hyperthyroidism*	2 (2.86%)
Single	14 (20.00%)	*Hypothyroidism*	3 (4.29%)
Married	49 (70.00%)	*Osteoporosis*	4 (5.71%)
Widow	7 (10.00%)	*Asthma*	1 (1.43%)
Educational Attainment (*f*, %)		*Dyslipidemia*	5 (7.14%)
Primary Level Education	1 (1.43%)	*Systemic Lupus Erythematosus*	1 (.43%)
Secondary Level Education	6 (8.57%)	*Thyroid Nodule*	4 (5.71%)
Vocational Degree	1 (1.43%)	*Immune Thrombocytopenic Purpura*	1 (1.43%)
Tertiary Level Education	60 (85.70%)	Smoking Status (*f*, %)	
Medical Degree	1 (1.43%)	*Current Smoker*	3 (4.29%)
Masters or Doctorate Degree	1 (1.43%)	*Previous Smoker*	4 (5.71%)
Employment Status (*f*, %)		*Non-Smoker*	63 (90.00%)
Unemployed	19 (24.14%)	Alcohol Intake (*f*, %)	
Employed	33 (47.14%)	*Non-Alcohol Drinker*	69 (98.57%)
Retired	18 (25.71%)	*Alcohol Drinker*	1 (1.43%)
Weight (Kilogram; x̄, SD)	63.44 (13.74)	Exercise Status (*f*, %)	
Height (Centimeters; x̄, SD)	159.02 (9.17)	*Without Exercise*	42 (60.00%)
Body Mass Index (kg/m^2; x̄, SD)	25.03 (4.63)	*With Exercise*	28 (40.00%)

Table II. Descriptive Statistics and Correlation Analyses of the Jamar Dynamometer, Aneroid Sphygmomanometer, and Inverse Regression Scores among the Participants between the Raters (N=70)

Characteristics	Rater				rs-value	p-value (Two-tailed)
	Rater A (N = 70)		Rater B (N = 70)			
	Mean (SD)	95% CI	Mean (SD)	95% CI		
Jamar Dynamometer (kg)						
First Evaluation	19.93 (8.20)	17.97 – 21.88	20.43 (8.90)	18.31 – 22.55	0.917†	0.001
Second Evaluation	19.27 (8.34)	17.28 – 21.26	20.14 (8.82)	18.04 – 22.24	0.942†	0.001
Third Evaluation	19.56 (8.77)	17.47 – 21.65	20.14 (8.60)	18.09 – 22.19	0.922†	0.001
Mean Evaluation Score	19.59 (8.29)	17.61 – 21.56	20.24 (8.66)	18.17 – 22.30	0.961†	0.001
Aneroid Sphygmomanometer (mmHg)						
First Evaluation	109.79 (44.03)	99.29 – 120.28	117.73 (46.16)	106.72 – 128.74	0.929†	0.001
Second Evaluation	116.97 (42.87)	106.75 – 127.19	122.60 (44.51)	111.99 – 133.21	0.924†	0.001
Third Evaluation	120.67 (45.34)	109.86 – 131.48	122.36 (44.45)	111.76 – 132.96	0.938†	0.001
Mean Evaluation Score	115.81 (43.42)	105.46 – 126.16	120.90 (44.60)	110.26 – 131.53	0.951†	0.001
Inverse Regression Score	17.42 (23.45)	11.83 – 23.01	20.16 (24.08)	14.42 – 25.91	0.951†	0.001

Abbreviations: SD = Standard Deviation, 95% CI = 95% Confidence Interval
*Significant at 0.05
†Significant at 0.01

and body mass index of the participants were 63.44 kilograms (SD=13.74), 159.02 centimeters (SD=9.17), and 25.03 kg/m^2 (SD=4.63), respectively. The most common comorbidities among the participants were hypertension (61.43%) and diabetes mellitus (30.00%). In addition, 90% of the participants were non-smokers, and 98.57% were non-alcohol drinkers.

Descriptive Statistics and Correlation Analyses of the Jamar Dynamometer, Aneroid Sphygmomanometer, and Inverse Regression Scores between Raters. The descriptive statistics and correlation analyses of the study outcomes between raters are presented in *Table II*. The mean Jamar dynamometer score was 19.59kg (SD=8.29) for Rater A and 20.24kg (SD=8.66) for Rater B, while the mean HGS using the aneroid sphygmomanometer was 115.81mmHg (SD=43.42) for Rater A and 120.90mmHg (SD=44.60) for Rater B. The computed inverse regressions score for Rater A was 17.42 (SD=23.45) and 20.16 (SD=24.08) for Rater B. For correlation analyses between two raters, there was no substantial rater variations and their evaluation of Jamar dynamometer and aneroid sphygmomanometer were almost the same using Spearman Rho, of the mean Jamar dynamometer scores, the mean HGS using the aneroid sphygmomanometer scores, and the mean inverse

Table III. Concurrent Criterion Validity using Correlation Analyses and Univariate Linear Regression Analyses of the Mean Jamar Dynamometer and Mean Aneroid Sphygmomanometer Scores according to Rater (N=70)

Exposure	Mean Jamar Dynamometer Score							
	Rater A				Rater B			
	rs-value	p-value (Two-tailed)	β Coefficient	p-value (Two-tailed)	rs-value	p-value (Two-tailed)	β Coefficient	p-value (Two-tailed)
Mean Aneroid Sphygmomanometer Score	0.778†	0.001	0.834†	0.001	0.762†	0.001	0.801†	0.001

*Significant at 0.05
†Significant at 0.01

Table IV. Reliability Analyses using Intra-Class Correlation (ICC), Agreement Standard Error of Measurement (SEM), and Agreement Minimum Detectable Change (MDC) in the Mean Jamar Dynamometer and Mean Aneroid Sphygmomanometer Scores between Raters (N=70)

Variables	ICC (95% CI)	Agreement SEM	Agreement MDC	Lin's Concordance Correlation Coefficient
Mean Jamar Dynamometer Score	0.984 (0.974 – 0.990)	1.51	4.19	0.965
Mean Aneroid Sphygmomanometer Score	0.975 (0.961 – 0.985)	9.63	26.70	0.946

Abbreviations: ICC = Intra-Class Correlation; 95% CI = 95% Confidence Interval; SEM = Standard Error of Measurement; MDC = Minimum Detectable Change

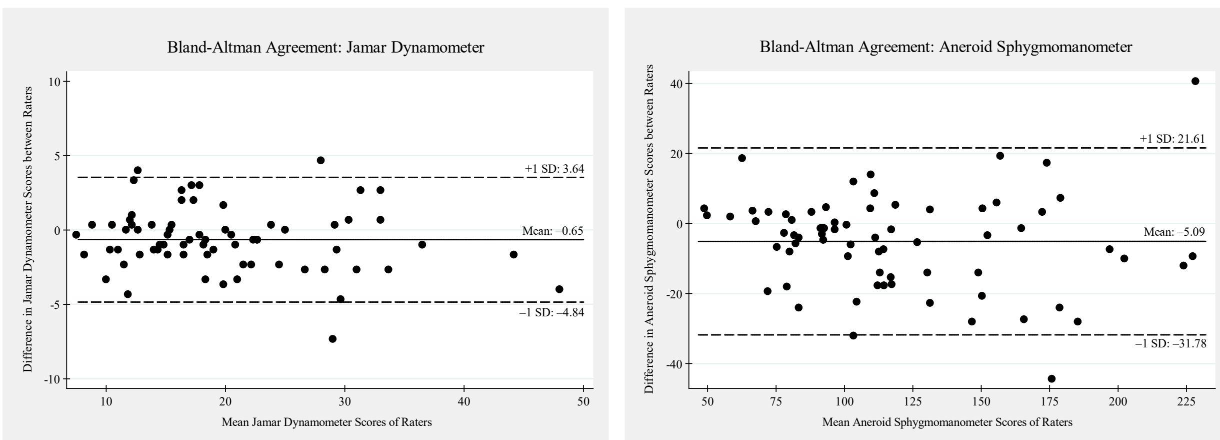

Figure 1. Inter-Rater Reliability and Agreement between Raters using Bland-Altman Plots of the Mean Jamar Dynamometer (Left Plot) and Mean Aneroid Sphygmomanometer Scores (Right Plot)

regression scores [r_s=0.961 (*p=0.001*), r_s=0.951 (*p=0.001*), and r_s=0.951 (*p=0.001*)].

Concurrent Criterion Validity of HGS measured using Aneroid Sphygmomanometer. *Table III* illustrates the concurrent criterion validity analyses of the aneroid sphygmomanometer in measuring HGS compared to the Jamar dynamometer. Correlation analyses using Spearman Rho indicated that the mean HGS measured using the aneroid sphygmomanometer had a strong and statistically significant, positive correlation with the Jamar dynamometer score (r_s=0.762 to 0.778, *p=0.001*), regardless of the rater. Similarly, univariate linear regression analyses showed strong predictive values for the Jamar dynamometer scores (*β*=0.801 to 0.834, *p=0.001*).

Reliability Analyses and Agreement of HGS measured using an Aneroid Sphygmomanometer between Raters. The reliability analyses and agreement of HGS measured using the aneroid sphygmomanometer compared against the Jamar dynamometer are illustrated in *Table IV* and *Figure 1*. The Jamar dynamometer and aneroid sphygmomanometer had excellent intra-class correlations of 0.984 and 0.975 (ICC>0.90), respectively, denoting the reliability of the two measures. In addition, the agreement SEM and MDC of the Jamar dynamometer were small compared to higher agreements with the aneroid sphygmomanometer. The agreement SEM of the aneroid sphygmomanometer denotes that the measurements on participants at different times will have a variation of 9.63 mmHg. Likewise, the agreement MDC of 26.70 denotes that a change of approximately 26.70 mmHg has less than 5% probability of occurring. These results, however, may be due to measurement error or random variation, which does not alter the patient's clinical status. Analyses of the Bland-Altman plots also showed that for both the Jamar dynamometer and aneroid sphygmomanometer, 95.71% of the data lay within their respective 95% confidence interval, and only 4.29% of the scores were one standard deviation higher or lower than the mean or were outside the 95% confidence interval. Lin's concordance correlation coefficients also showed high concordance values for the Jamar dynamometer and aneroid sphygmomanometer, suggesting a high agreement.

Discussion

Sarcopenia is an age-related muscle disease associated with higher mortality, morbidity risk, and health costs.[25] An easy and convenient sarcopenia screening test would be hugely valuable, especially for older patients. HGS is an easy, clinically-practical test for screening early sarcopenia.[25] Likewise, GS testing is likely to be more commonly used in clinical settings, for example, in the assessment of frailty and undernutrition in older people.[22] A study by Puig-Domingo et al., evaluating muscle strength and successful ageing, found it to be a helpful clinical evaluation tool and a Japanese study investigating the optimal physical or cognitive test to screen for falls risk in frail older people found that the most practical physical test was GS.[22,26]

Our results validated HGS among adult patients as a relevant diagnostic tool for sarcopenia using the two apparatuses, the Jamar dynamometer, and aneroid sphygmomanometer in hospital outpatient clinics. This determines the concurrent criterion validity of the aneroid sphygmomanometer as opposed to the well-established and already-proven Jamar dynamometer in quantifying HGS. From the accepted method of Hamilton et al., data obtained from the two instruments were used to construct a formula (Jamar = 0.54 x sphygmomanometer (mmHg) – 45.12) by which measurements on the sphygmomanometer could be converted into the corresponding Jamar (PSI) measurements.[21]

An inverse regression technique was used to make these conversions. A formula for conversion of the sphygmomanometer scores into Jamar units was developed to enhance the reporting of sphygmomanometer scores utilizing the Jamar standard.[21] Relevance of computing inverse regression scores, when measuring grip strength in the hand-disabled subjects, there are multiple advantages of the sphygmomanometer over the Jamar units: 1) ready availability of a sphygmomanometer in most clinics, 2) a soft compliant surface that may produce less discomfort to the injured hand during testing, and 3) a scale with smaller increments than the Jamar and, therefore, greater sensitivity to small changes in strength.

Most of the recent studies of GS measurement have reported the Jamar dynamometer as the most reliable and accurate device for measuring HGS.[27-30] However, the study of Hamilton et al. demonstrated the outcome ability of the aneroid Sphygmomanometer to provide acceptable levels of measuring HGS. It was similar to that of the Jamar Dynamometer.[21] These findings conform with the previous work of Mathiowetz et al., who reported a high correlation (0.80 or greater) in HGS using the Jamar Dynamometer.[29]

The information between raters found in our study showed that the generated data from the Jamar dynamometer, aneroid sphygmomanometer, and inverse regression technique with respect to association, correlation, reliability, and agreement were similar, sensitive, and can be strongly compared to each other. This is in accordance with the study of Hamilton et al., which shows that the aneroid sphygmomanometer and Jamar dynamometer exhibit good within-instrument reliability.[21] The validity of the sphygmomanometer as a grip measurement device is acceptable and reportable using the conversion formula that was developed.[21] Therefore, it can be utilized with confidence as essentially equal to the Jamar unit for grip strength measurement. This is paralleled with the study of Lusardi et al., which demonstrated good to high correlations (r = 0.823 to 0.929), not significantly different, and good to high reliability (intraclass correlation coefficients = 0.822 to 0.928) in HGS using Jamar dynamometer and sphygmomanometer.[31]

Conclusion

The results of the present study showed that the Jamar dynamometer and Aneroid sphygmomanometer in measuring HGS are equivalent. The aneroid sphygmomanometer demonstrates strong concurrent criterion validity compared to the Jamar dynamometer. Moreover, an aneroid sphygmomanometer recognized authenticity with high rater agreement and can be used to measure grip strength in a setting where a Jamar dynamometer is not available. It has a valid value for predicting the Jamar grip strength value. Hence, it can be an alternate tool for measuring muscle strength.

Limitation of the Study

The limitation of this study was that the participants were recruited from a single institution, which may affect the generalizability of our results. In addition, hand grip strength measurements for the Jamar dynamometer and sphygmomanometer are operator-dependent. Thus, it is important to conduct the measurements according to the American Society of Hand Therapy recommendations for handgrips. This is not a screening study for sarcopenia but more the validation of an aneroid sphygmomanometer as a measurement for hand grip strength.

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