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Validity and Reliability of Modified Sphygmomanometer Versus Jamar Dynamometer in Measuring Hand Grip Strength for Patients with Distal Radius Fractures

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Abstract

Background: The modified sphygmomanometer and Jamar grip dynamometer are important tools to measure the hand grip strength (HGS).

Aim of Study: Is to test the concurrent validity, interrater and test-retest reliability of bag modified sphygmomanometer and Jamar grip dynamometer.

Subjects and Methods: Seventy patients of distal radius fracture (67 colles' and 3 smith fracture) with mean age 45.03±10.45 years, were recruited to evaluate the grip strength by Jamar grip dynamometer and bag modified sphygmomanometer after being updated with the aneroid sphygmomanometer (KBM).

Validity was explained by the correlation between the strength of hand grip that was assessed by modified sphygmomanometer and Jamar dynamometer by Person Correlation Coefficient. Test-retest reliability and inter-rater reliability were expressed as Intra-class Correlation Coefficients (ICCs). All data was analyzed by (SPSS) version 25 for windows.

Results: There was a correlation between strength of hand grip that was assessed by modified sphygmomanometer and Jamar dynamometer; was strong correlation with positive significant in concurrent validity (r=0.852, p=0.001). The modified sphygmomanometer showed excellent in test-retest reliability with Intra-class correlation coefficient (ICC) was 0.996 and in inter-rater reliability with 0.993 Intra-class correlation coefficient.

Conclusion: The bag modified sphygmomanometer is a concurrently valid, test-retest and interrater reliable device to measure hand grip of distal radius fracture patients with different gender and fixation types.

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Key Words: *Distal radius fracture – Grip dynamometer –Bag modified sphygmomanometer – Pneumatic grip instruments – Hydraulic grip instruments.*

Introduction

THE distal radius fractures considered as the most common second fracture in older people after hip fractures *[1,2]*, widely occurred and estimated to increase by 50% in incidence by 2030 *[3]*. The females with distal radius fractures peak incidence happened around menopausal period of age (50-60) years group, whereas the peak incidence to males between the age (40-50) years *[4]*.

Chung et al., *[5]* assumed that distal radius fractures treatments are in 4 ways; closed reduction, percutaneous pinning, internal fixation and external fixation and there is increase in internal fixation rates in older age according to its benefits.

Hand grip strength (HGS) was an easily applied, fast and objective measure that was usually evaluated by a dynamometer of hand grip, which had been utilized in both research type; medical and scientific as a parameter of evaluation, discrimination, and prediction in a variety of population sets *[6-12]*.

Grip strength was broadly been considered as a recovery guide following distal radius fracture. That was correlated with the upper limb Disabilities of function. About half of grip strength measurement postoperatively was improved in about 3 to 6 months, and the affected side, grip strength mean at 1 year postoperative was about less than 12% of the non-affected side *[13]*.

The instruments used to measure hand grip strength as Jamar dynamometer is a hydraulic in-

strument that records grip strength and assesses the static grip strength with adjustable handles [14] and Modified sphygmomanometer uses the compression of a bag or as an air-filled bulb to evaluate the pressure of grip.

There were several benefits of use the Sphygmomanometer instead of the Jamar unit for assessing grip strength in individuals with hand impairments: (1) Ready accessibility of a sphygmomanometer in most clinics, (2) Less discomfort as it was soft compliant tool that was suitable to individuals with hand impairments through the test, and (3) A scale with minor raises than the Jamar and greater sensitivity to minute variation in strength [14,15].

Reviewing the literature showed that modified sphygmomanometer was valid and reliable in hand grip strength in stroke [16] and rheumatoid patients [17] and acceptable test retest reliability had been approved in the normal population [15]. Till the researcher's knowledge, there was no aforementioned studies applied that on patients with fractures.

Therefore, the current research intended to assess the reliability and validity of modified sphygmomanometer as grip dynamometer of Jamar in grip strength measurements of distal radius fracture patients.

Subjects and Methods

Assessment of eligibility was determined for seventy patients recruited from the orthopedic inpatient and outpatient sections at Kasr Al-Ainy Hospital, Cairo University from September 2022 to August 2023 with ethical committee No: P.T.REC/012/003951.

Sample size for intraclass correlation coefficients (ICCS) was calculated using Walter et al., [18] formula, using the minimum acceptable ICCS of 0.8, expected ICCS of 0.9, significance level 0.05, statistical power 80% and number of repetitions of measurement 3, the required sample size was about 58 subjects. Drop out patients calculated from the 58 subjects by about 15% concluded that about 9 patients. Therefore, 67 patients needed to perform this study.

The inclusion criteria for their participation were (1) Patients suffer from distal radius fractures (67 colles' and 3 smith fracture) (conservatively or surgically) from about 3 months post fracture or surgery [19,20]. (2) Females and males patients were selected [21]. (3) Age between 30-60 years [21] and the exclusion criteria were (1) Neurological defects as Parkinson's disease, multiple sclerosis, muscular dystrophy, or amyotrophic lateral sclerosis, (2) Rheumatologic, and/or orthopedic dysfunctions, such as rheumatoid arthritis except distal radius fractures [16], (3) Malunion or non union of radius fracture, (4) Median and ulnar nerve injury, (5) Complex regional pain syndrome (is an autonomic and inflammatory disorder which characterized by chronic pain state) [22], (6) Carpal ligament injury [23].

The assessment instruments were the aneroid sphygmomanometer KBM had been adapted by its cuff and outer Velcro of it removed from the bladder of equipment and, into three equal portions; the bladder was folded and fitted in a bag of cotton cloth with a zipper. The final shape of the bag modified sphygmomanometer was 12.5 cm length, 9cm width, and 1.5cm thick after being adapted [24].

After updated, the calibration of sphygmomanometer procedure was performed by inflate it to 100mmHg, its valve was closed to remove wrinkles of the inflatable portion from it, Then, the pressure was decreased to 20mm Hg and close again its valve avoiding leakage. The measurement range provided between 20-300mmHg.

Then, To put the plates of weight on the bag modified sphygmomanometer, an apparatus was built from wood to align the weights on it (Fig. 1A). All weights consistently aligned over each other in the same pattern. The plates of weight correlated with the values in mmHg as high as ($0.97 \leq r \leq 1.00$) ($p \leq 0.001$), with variation coefficient of 2-13% [25]. The calibration of bag modified sphygmomanometer correlation coefficient 0.998001 according to (Fig. 1A).

The other assessment tool was the Jamar grip dynamometer in Fig. (2) which is a hydraulic instrument with adjustable grip size.

- The testing position was sitting on a chair with back erect with the feet rested on the floor [14] the shoulder beside the body and mid position of rotation, elbow flexed to 90 degrees, forearm in a mid position of rotation, and the wrist extended between (0-30) degrees and deviated to ulnar direction in about 0 and 15 degrees.
- Neither though, the examiner or an armrest should support the arm of the patients. For measuring the grip strength, the dynamometer was holden vertically and aligned with the forearm to keep the wrist and forearm standard positions [26].
- The examiner 1 and examiner 2 performed the same steps of measurements.
- Randomly applied grip measure between the grip dynamometer and bag modified sphygmomanometer (Fig. 1B) and (Fig. 2) [16].
- The patients performed 5 seconds of maximal isometric contraction and peak contraction recorded for 3 trials for each instrument [27].
- The rest interval was provided between repetitions for 15 seconds [27] a rest period between each instrument for 2 minutes [28].

- For test-retest measurement, the test of modified sphygmomanometer was repeated.
- If after completing the first rotation of the dial, the indicator stopped at 40mmHg, the recorded measure as equal 360mmHg *[29]*.
- The nonaffected side used to be familiar to test and avoid fatigue of affected one.

Statistical analysis:

Validity was determined by the correlation between hand grip strength that was measured by modified sphygmomanometer and Jamar dynamometer through Person Product Moment Correlation Coefficient. Test-retest reliability and interrater were expressed as Intra-class Correlation Coefficients (ICCs). Repeated measurements by the same rater were used to calculate test-retest reliability.

Repeated measurements by different raters were used to calculate inter-rater reliability. Measurement error was expressed as the standard error of measurement (SEM) and the smallest detectable change (SDC). SEM = Pooled SD -V(1-ICC). The SDC was calculated as 1.96 x-V2 x SEM. The level of significance for all statistical tests was set at $p<0.05$. Statistical analysis was conducted through the statistical package for social studies (SPSS) version 25 for windows (IBM SPSS, Chicago, IL, USA).

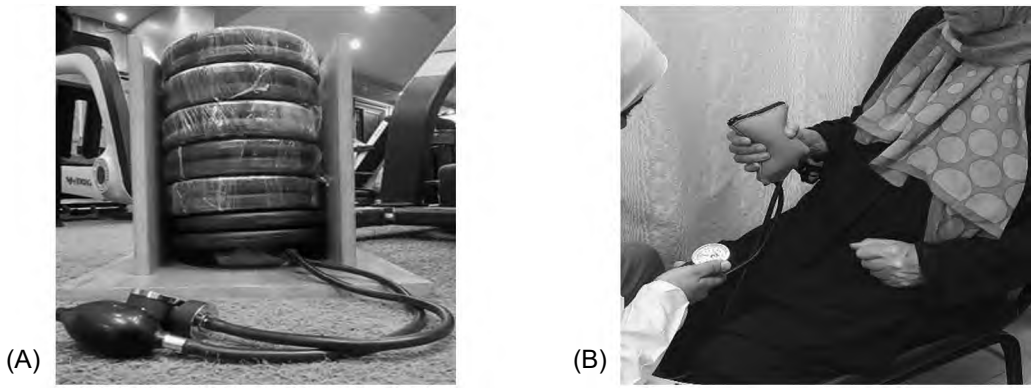

Fig. (1): (A) The calibration according to the study. (B) Bag modified sphygmomanometer on distal radius fracture patients.

Fig. (2): Jamar grip dynamometer.

Results

Subject characteristics:

Seventy patients with distal radius fractures joined in this study. Their mean age was 45.03±10.45 years, mean weight was 75.16±17.16kg, mean height was 168.96±7.33cm and mean BMI of the study group was 26.46±6.52kg/m. There were 20 (29%) females and 50 (71%) males. Table (1) shows the subject's characteristics of the study group.

Table (1): Participants characteristics.

	Mean ± SD	Maximum	Minimum	Range
Age (years)	45.03±10.45	60	30	30
Weight (kg)	75.16±17.16	124	47	77
Height (cm)	168.96±7.33	187	155.5	31.5
BMI (kg/m^2)	26.46±6.52	45.25	16.56	28.69
Hand length (cm)	19.53±1.25	22.5	16	6.5
Hand width (cm)	10.07±0.65	11.5	8.5	3
Gender:				
Females	20 (29%)			
Males	50 (71%)			
Dominant side:				
Right	69 (98.6%)			
Left	1 (1.4%)			
Affected side:				
Right	35 (50%)			
Left	35 (50%)			

SD: Standard Deviation.

The frequency distribution of cause of fracture:

The highest percentage of fractures (40%) were caused by fall onto outstretched hand while 17.1% were caused by motor car accident, 15.7% caused

by motor bicycle accident and 11.4% caused by fall from height as shown in Table (2).

Table (2): The frequency distribution of cause of fracture.

Percent	Frequency	
40	28	Fall outstretched hand
17.1	12	Motor car accident
15.7	11	Motor bicycle accident
11.4	8	Fall from height
4.3	3	Road traffic accident
2.9	2	Direct trauma
2.9	2	Flexed hand
1.4	1	Fall on ulnar side
1.4	1	Fall on hand
1.4	1	Fall downstairs
1.4	1	Fall to ground

The variability of intervention:

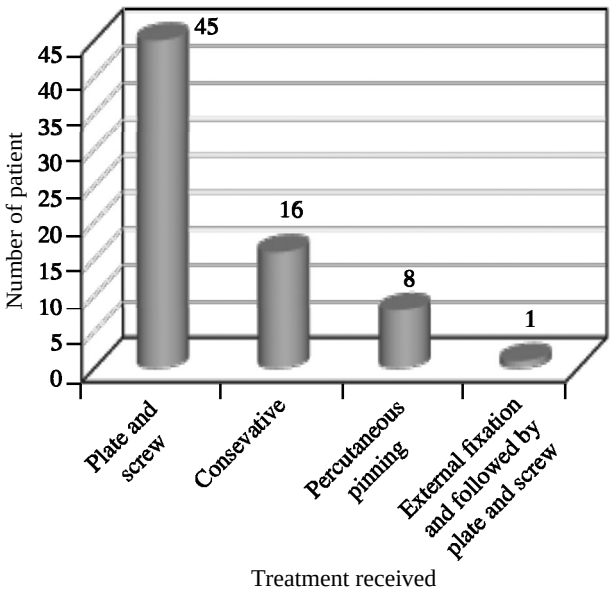

Fig. (3): The intervention variability of the patients involved in the study.

Concurrent validity:

The correlation between hand grip strength (HGS) that measured by Jamar dynamometer and modified sphygmomanometer in mmHg was strong positive significant correlation (r=0.852, p=0.001). (Table 3, Fig. 4).

The correlation between HGS that measured by Jamar dynamometer and modified sphygmomanometer in kilogram (kg) was strong positive significant correlation (r=0.752, p=0.001). (Table 3, Fig. 5).

Table (3): Correlation between hand grip strength that measured by Jamar dynamometer and modified sphygmomanometer.

Hand grip strength	*r*-value	*p*-value
Jamar dynamometer (kg):		
Modified sphygmomanometer (mmHg)	0.852	0.001
Modified sphygmomanometer (kg)	0.752	0.001

r-value: Pearson correlation coefficient.
p-value: Probability value.

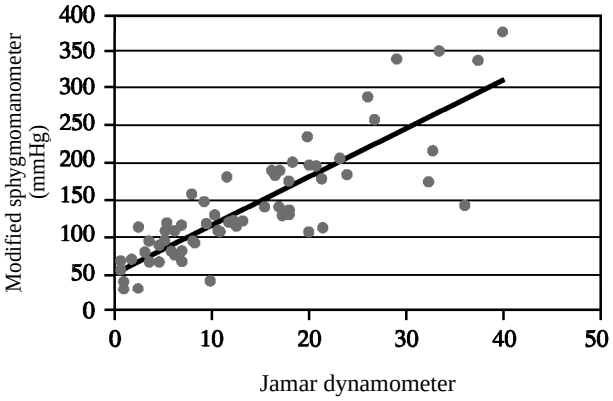

Fig. (4): Correlation between hand grip strength that measured by Modified sphygmomanometer in mmHg and Jamar dynamometer.

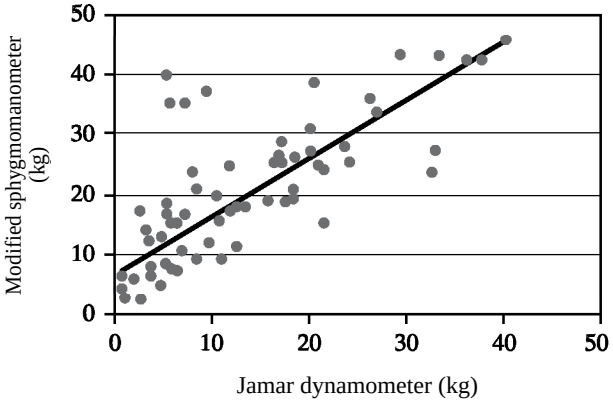

Fig. (5): Correlation between hand grip strength that measured by Modified sphygmomanometer in kilogram (kg) and Jamar dynamometer.

Reliability:

Test-retest reliability:

The modified sphygmomanometer showed excellent test-retest reliability in hand grip strength (HGS) measures; Intraclass correlation coefficient (ICC) was 0.996, with 95% Confidence Interval (CI) 0.994-0.998. The SEM was 0.71 and the SDC was 1.97. (Table 4) in kilogram measurement.

Inter-rater reliability:

The modified sphygmomanometer showed excellent inter-rater reliability in HGS measures; ICC of hand grip strength measures of was 0.993, with 95% CI 0.988-0.996. The SEM was 0.93 and the SDC was 2.58. (Table 4) in kilogram measurement.

Table (4): Test-retest reliability and Inter-rater reliability of modified sphygmomanometer in hand grip strength measures.

Hand grip strength	ICC	(95% CI) Lower bound	Upper bound	SEM	SDC
Test-retest reliability	0.996	0.994	0.998	0.71	1.97
Inter-rater reliability	0.993	0.988	0.996	0.93	2.58

ICC : Intra-class correlation coefficient value.
CI : Confidence Interval.
SEM: Standard error of measurement.
SDC: The smallest detectable change.

Discussion

The goal of the current study was to demonstrate the validity and reliability of the bag modified sphygmomanometer in comparison to the Jamar dynamometer which is a gold standard tool since 1954 in measure the grip strength of distal radius fractures patients *[30]*.

The results of statistical analysis of this study found that there was an excellent correlation coefficient in test-retest, interrater reliability and strong concurrent validity between bag modified sphygmomanometer and grip dynamometer in distal radius fracture patients.

This study found that the concurrent validity between hand grip strength measured by modified sphygmomanometer in mmHg and Jamar dynamometer had a strong positive significant correlation of 0.852.

While in Test–retest reliability in this study; The modified sphygmomanometer showed excellent measurement of hand grip strength; Intraclass correlation coefficient (ICC) was 0.996 with 95% Confidence Interval (CI) 0.994–0.998, In addition to that interrater reliability 0.993 with 95% Confidence Interval (CI) 0.988–0.996.

These results mirror those of the previous studies that had explained by Hamiliton et al., *[15]* who had recruited 29 normal healthy female patients whose dominant

hand had no known orthopedic problem to join in that study of mean age of 23.8±4.9, had assumed that the test-retest reliability of the modified sphygmomanometer of 0.85 and the construct validity of modified sphygmomanometer and the Jamar grip dynamometer had a correlation coefficient of 0.75.

While in stroke patients, 33 patients of subacute stage (17 men of mean age was 50-74 years and time after stroke was 3 to 4.5 months) while 44 patients in the chronic stage (24 men of mean age was 45-75 years and time after stroke was 3 month to 13 years) patients had recruited by Martins et al., *[28]* and measured hand grip strength by bag modified sphygmomanometer and grip dynamometer correlated them to the measurements of the paretic upper limb global strength, which had showed a significant correlations from moderate to high as the Modified sphygmomanometer values (subacute to chronic) had correlated by $0.66<rs<0.78$ respectively to global muscle strength and the grip dynamometer values (subacute to chronic) had correlated by $0.66<rs<0.78$ respectively to global muscle strength.

Therefore, there was a significant positive correlation between the bag modified sphygmomanometer grip strength values with handgrip dynamometer grip strength values for both paretic upper limb global strength in stroke patients in the two stages.

61 patients (51 women and10 men) with average age range was 22 to 75 years and average duration of the rheumatoid disease range was 1 to 43 years that showed intertrial reliability of Jamar dynamometer and bag modified sphygmomanometer measurements of no significant difference of range from 0.987 to 0.993 in grip strength. The relation between the scores of instruments was respectively strong (Pearson r=0.818 and 0.851) for the dominant and nondominant hands *[29]*.

As an example of the alternative way for measuring the grip strength of Duchenne muscular dystrophy from Jamar dynamometer which is a heavy weight about 2.5g, high cost, undetectable to the small interval in measurement, unsuitable for the decreased hand mobility specially in the progressed phase of the disease, to the modified sphygmomanometer which presented a steadiness in reading all over the 18 months, a lightweight, low cost and the marks in the device was graded in small interval *[31]*.

de Souza et al., *[31]* concluded that there was a high correlation between the Jamar dynamometer and the modified sphygmomanometer in that study of (r=0.977; p<0.001).

Another example presented by Silva et al., *[32]* who assessed the reliability and validity of modified sphygmomanometer of hand grip strength in Parkinson's disease. The concurrent criterion validity was correlated by moderate magnitude of ($r\geq0.45$) while the intraclass correlation coefficient of the reliability of modified sphygmomanometer showed by high magnitude of 0.7 *[32]*.

The importance of all those findings that modified sphygmomanometer has validity and reliability to a gold standard Jamar grip dynamometer with several advantages of the Sphygmomanometer over the Jamar device: (1) A large variation in price between Jamar grip dynamometer which is more expensive than the bag modified sphygmomanometer (KBM aneroid sphygmomanometer made in JAPAN code number 63550). (2) Light weight for therapist tool bag and packaging space in clinic and (3) Now it is valid and reliable for normal, rheumatoid, stroke and distal radius fracture patients. All these advantages added to previously mentioned one ***[14,15]***.

It can thus be suggested that the modified sphygmomanometer can be as replacement for Jamar grip dynamometer, (1) In a variety of distal radius fracture types (67 Colles' and 3 Smith fracture), (2) In a variety of gender of 20 female patients and 50 male patients and (3) With different types of fixations (plate and screw, conservative, percutaneous pinning and external fixation).

The limitations of the study were (1) Little diversity of types of distal radius fractures but not represented in the study at the time of patients collection, (2) Many patients suffered from complications of surgical approach as infection, complex regional pain syndrome that have be excluded from the study, (3) Small test retest interval that need to be for 3 months, 6 months, 9 months, 12 months from fracture follow-up, (4) Low of compliance of many patients to attend measurement session after a lot of arrangement and (5) Age limitation according to peak of distal radius fracture.

It is concluded that the bag modified sphygmomanometer is a valid and reliable device versus to Jamar dynamometer which is a gold standard device in measuring the hand grip of distal radius fracture patients.

Conclusion:

The bag modified sphygmomanometer is a concurrently valid, test-retest and interrater reliable device to measure hand grip of distal radius fracture patients with different gender and fixation types.

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صلاحية وموثوقية مقياس ضغط الدم المعدل مقابل الجامر ديناموميتر فى قياس قوة قبضة اليد لمرضى كسور مفصل الرسغ

الخلفية: مقياس ضغط الدم المعدل والجامر ديناموميتر يعتبروا من الأدوات الهامة لقياس قوة قبضة اليد.

هدف الدراسة: أجريت الدراسة لاختبار الصلاحية المتزامنة وموثوقية الاختبار وإعادة الاختبار وموثوقية ثبات النتائج مع تغيير المقيمين لحقيبة مقياس ضغط الدم المعدل والجامر ديناموميتر.

أساليب البحث: اشتملت هذه الدراسة على سبعين مريضاً بمتوسط عمر 45.03±10.45 عامًا لتقييم قوة قبضة اليد بمقياس الجامر ديناموميتر وحقيبة مقياس ضغط الدم المعدل بمقياس يبلغ ١٢,٥ سم طول و ٩ م عرض و ١,٥ سم سمك مع سحاب و تم معايرته فى علبة مع طارات وزن و تم اختبار هدف الدراسة من حيث الصلاحية بمعامل ارتباط بيرسون ومن حيث الموثوقية الاختبار وإعادة الاختبار وثبات النتائج مع تغيير المقيمين بمعاملات الارتباط داخل الطبقة (ICCs). وقد تم تحليل جميع البيانات بواسطة برنامج (SPSS) الإصدار ٢٥ لنظام التشغيل.

النتائج: احصائياً تم اثبات العلاقة الترابطية بين مقياس ضغط الدم المعدل والجامر ديناموميتر على انها إيجابية من حيث الصلاحية المتزامنة ($p = 0,001, r = 0,852$) وقياس ضغط الدم المعدل اظهر نتائج رائعة من موثوقية الاختبار وإعادة الاختبار بمعاملات الارتباط داخل الطبقة ب ٠,٩٩٦ و موثوقية ثبات . النتائج مع تغيير المقيمين ب ٠,٩٩٣

الاستنتاج: حقيبة جهاز ضغط الدم المعدل تمتلك صلاحية متزامنة وموثوقية الاختبار وإعادة الاختبار وموثوقية ثبات النتائج مع تغيير المقيمين لقياس قوة قبضة اليد لمرضى كسور مفصل الرسغ مع اختلاف أنواع الثبيت و الجنس.