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ORIGINAL RESEARCH

Reliability and validity of a load cell device for hand grip strength assessment

Confiabilidade e validade de um dispositivo de célula de carga para avaliação da força de preensão palmar

Fiabilidad y validez de un dispositivo de célula de carga para evaluar la fuerza de prensión palmar

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ABSTRACT | The grip strength is a complex measure influenced by factors such as gender, age, motivation, muscle training, handedness, height, weight, socioeconomic variables, and participation in specific sports or professions. It can be measured by dynamometers or by tension meters such as load cells (strain gauges). Reliability and validity are important psychometric properties, which analyze consistency and applicability of an instruments' measurement. Thus, the aim of this study was to evaluate the test-retest reliability and construct validity of a load cell device in isometric grip force measurements using a sample of asymptomatic subjects and patients with wrist and hand dysfunctions. Standardized methods of the upper limb positioning and randomization of the sample order were used. Statistical analysis of reliability was conducted by the ICC (Intraclass Correlation Coefficient) and the construct validity by Pearson correlation coefficient (r), with $p<0.05$, 95% CI, using SPSS version 20®. The sample consisted of 24 healthy volunteers with an average age of 22.25 years old, all college students, and 21 volunteers with upper extremity and hand disorders, from both genders. The test-retest reliability for the asymptomatic group was ICC 0.90 (0.78-0.95) and for the group of patients was 0.94 (0.87-0.97), both considered excellent. The Bland and Altman graphics showed that although the reliability has displayed excellent levels and low standard error values of measurement, some discrepant data were found. Pearson correlation coefficients were high, both for the asymptomatic group (r=0.85), and for the patients group (r=0.83). Conclusion: based on these findings, it is suggested that this load cell is a reliable and valid device for isometric grip strength measurement and its use is suitable for future clinical trials and practice.

Keywords | Muscle Strength; Reproducibility of Results; Validity of Tests; Hand Strength.

RESUMO | A força de preensão palmar é uma medida influenciada por diversos fatores como sexo, idade, motivação, treinamento muscular, dominância, altura, peso, variáveis socioeconômicas, participação em esportes específicos ou profissões. Pode ser mensurado por meio da dinamometria ou por medidores de tensão como as células de carga (*strain gauges*). Confiabilidade e validade são importantes propriedades psicométricas que avaliam a reprodutibilidade da medida de um instrumento e sua aplicabilidade. Desse modo, o objetivo deste estudo foi avaliar a confiabilidade teste-reteste e a validade de constructo de uma célula de carga para medida da força de preensão palmar isométrica, em voluntários assintomáticos e portadores de disfunções no punho e mão. Foram utilizados métodos padronizados de posicionamento do membro superior e realizada aleatorização da ordem das coletas. A análise estatística de confiabilidade foi realizada pelo ICC e a validade de constructo pelo coeficiente de correlação de Pearson (r), com $p<0,05$, com IC de 95%, utilizando o SPSS versão 20®. A amostra constou de 24 voluntários saudáveis com

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idade média de 22,25 anos, todos universitários, e 21 voluntários portadores de disfunções do membro superior e mão, de ambos os sexos. A confiabilidade teste-reteste para o grupo dos indivíduos assintomáticos foi ICC 0,90 (0,78-0,95), no grupo dos portadores de disfunções do punho e mão o ICC encontrado foi 0,94 (0,87-0,97), ambos considerados excelentes. Os gráficos de Bland e Altman mostraram que, embora a confiabilidade apresentasse níveis excelentes e com baixos valores de erro padrão de medida, alguns dados discrepantes foram encontrados. Os coeficientes de correlação de Pearson foram altos tanto para o grupo de indivíduos assintomáticos (r=0,85), como para o grupo de pacientes (r=0,83). Conclusão: baseado nos achados da amostra analisada é sugerido que a célula de carga seja um dispositivo confiável e válido para a medida de força de preensão palmar isométrica da mão, podendo ser utilizado em futuros estudos e na prática clínica.

Descritores | Força Muscular; Reprodutibilidade de Resultados; Validade dos Testes; Força da Mão.

RESUMEN | La fuerza de prensión palmar es una medida influida por diversos factores tales como, sexo, edad, motivación, entrenamiento muscular, dominio, altura, peso, variables socioeconómicas, participación en deportes específicos o profesiones. Se la puede medir mediante la dinamometría o por medidores de tensión como las células de carga (*strain gauges*). La fiabilidad y la validez son importantes propiedades psicométricas que evalúan la reproducibilidad de un instrumento de medición y su aplicabilidad. De esa manera, este estudio tuvo la pretensión de evaluar la fiabilidad test-retest y la validez del constructo de una célula de carga para medir la fuerza de prensión palmar isométrica, en participantes asintomáticos y en portadores de trastornos de la muñeca y de la mano. Se utilizaron métodos estandarizados de posicionamientos del miembro superior y se llevó a cabo la aleatorización del orden de la recolección de datos. El análisis estadístico de fiabilidad fue realizado por el ICC y la validez del constructo por el coeficiente de correlación de Pearson (r), con p<0,05, con IC de 95%, utilizando el SPSS en la versión 20®. El muestreo contó con 24 personas saludables con un promedio de 22,25 años de edad, todos universitarios, y 21 personas portadoras de trastornos del miembro superior y de la mano, de ambos los sexos. La fiabilidad test-retest para el grupo de sujetos asintomáticos fue de ICC 0,90 (0,78-0,95), en el grupo de los portadores de trastornos de la muñeca y de la mano el ICC encontrado fue de 0,94 (0,87-0,97), ambos considerados excelentes. En los gráficos de Bland y Altman se mostró que aunque la fiabilidad presente niveles excelentes y con bajos valores de error estándar de medida, se encontraron algunos datos divergentes. Los coeficientes de correlación de Pearson fueron altos tanto para el grupo de sujetos asintomáticos (r=0,85) como para el grupo de portadores (r=0,83). Con base en los resultados de la muestra evaluada se propone que la célula de carga puede ser un dispositivo fiable y válido para medir la fuerza de presión palmar isométrica de la mano, y que puede utilizarla futuramente en investigaciones y en la práctica clínica.

Palabras clave | Fuerza Muscular; Reproducibilidad de Resultados; Validez de las Pruebas; Fuerza de la Mano.

INTRODUCTION

Analysis of hand grip strength is an essential parameter in functional physical evaluation both to determine the effectiveness of therapeutic strategies and to assess the patient's ability to return to functional activities[1]. It is often used in the clinical sphere as an indicator of the general physical strength and health of the individual[2].

Muscular strength is a complex measure influenced by factors such as sex, age, motivation, muscular training[3,4,5,6]. Incel et al.[7] reported the dominant hand is significantly stronger in right-handed individuals, while there was no significant difference when evaluating left-handed ones.

One of the ways to measure the isometric hand grip strength is by dynamometry, Jamar® from the hydraulic category being one of the most used ones[8], being considered a device of excellent reliability[9,10], simple handling and easy use, recommended by the American Society of Hand Therapists, as well as by the Brazilian Society of Hand Therapists[11].

Load cells are part of another category in which strength is obtained electronically, amplified, and transmitted to a monitor for recording. These are voltage meters usually employing newtons as units of force, as well as the electronic digital dynamometer of type *Statham*, the Isometric Strength Testing Unit (ISTU), and other hand grip devices that work with voltage meters developed for specific studies[12]. Load cells are also used for muscle strain analysis in tasks with use of the upper limb, proving to be an important tool in the evaluation of strength components of the hand[13].

Hydraulic dynamometers only measure the value of grip strength and are not able to obtain the data regarding the reason of the development of strength. Unlike these traditional devices, the load cell coupled to a handle allows for the analysis of grip strength, variability of strength and of the time taken to reach fatigue, being associated with measures such as muscle activation using softwares[14,15].

Reliability and validity are important criteria in the analysis of the consistency of the measure and in the ability of the instrument to measure that for which it is utilized in the process of a physical and functional evaluation[6,16,17].

Thus, the hypothesis of this study is that the load cell can be a reliable and valid instrument in the assessment of isometric hand grip strength, compared to Jamar® hydraulic dynamometer.

Our objective, therefore, was to evaluate the test-retest reliability and construct the validity of a load cell, considering an hypothesis of moderate to high correlation of the load cell with the Jamar® dynamometer for measuring isometric hand grip strength of fingers in healthy individuals and in patients with wrist and hand lesions.

METHODS

The study included 24 asymptomatic individuals and 24 patients with dysfunctions resulting from wrist and hand lesions and changes in muscle strength of hand grip. Sample calculation was carried out by means of the software GraphPad StatMate 2 based on a previous pilot study.

Collections of asymptomatic individuals were carried out in the Laboratory of Clinical Research on Hand and Upper Limb of the University of São Paulo, Ribeirão Preto, Brazil, while the collections of patients with hand dysfunctions were conducted at the Rehabilitation Center of the University Hospital of the School of Medicine of Ribeirão Preto of the University of São Paulo (CER-HCFMRP-USP).

Inclusion and exclusion criteria

For the asymptomatic group, we included volunteers of both sexes, aged 18 years or older, with no orthopedic, rheumatological, neurological, metabolic or vascular dysfunctions of the upper limb, regardless of sport and/or labour activities with the hand or of dominance.

For the group of patients, we recruited volunteers who reported a history of previous trauma, with dysfunctions of wrist, hand, or fingers and that were in the process of rehabilitation, which allowed us to perform isometric muscle strengthening exercises of gripping with fingers at the CER-HCFMRP-USP.

The volunteers who agreed to participate in the study signed an informed consent form. The study was approved by the HCRP Research Ethics Committee No. 13049/2013 on January 6, 2014.

Procedure

The positioning of volunteers to assess isometric hand grip strength followed the recommendations of the American Society of Hand Therapists (ASHT) and the Brazilian Society of Hand and Upper Limb Therapists (SBTM)[11]: sitting on a chair without armrest, shoulder adduction, elbow bent at 90º, forearm in neutral position, radio-carpal joint between 0º and 30° of extension, ulnar deviation between 0° and 15°, feet totally supported in the floor, and hips and legs at 90º of flexion near the back of the chair (Figures 1-A and 1-B).

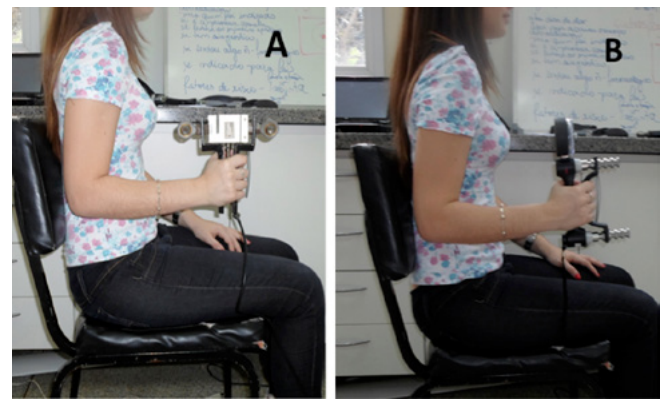

Figure 1. Model positioning according to the American Society of Hand Therapists (ASHT) and the Brazilian Society of Hand and Upper Limb Therapists (SBTM)[11]: A - with load cell adapted to a handle that was specially developed for the study; B - with the Jamar® dynamometer

The forces measured by the load cell model MM-50 (Kratos®) were exerted with a specially developed handle for the study (Figure 1-A) coupled to it and with the Jamar® hydraulic dynamometer pre-calibrated at the second position (Figure 1-B). The handle of the load cell included two handgrips (Figure 2-A) with distance equivalent to the distance used in the Jamar® hydraulic dynamometer at the second position (Figure 2-B). This

referred handle was connected to the Miotool® software developed by Miotec®, which allowed us to register grip strength values of the right hand of the asymptomatic group and of the injured hand of patients for future analysis. The initial measurement was conducted and the retest was carried out after 7 days.

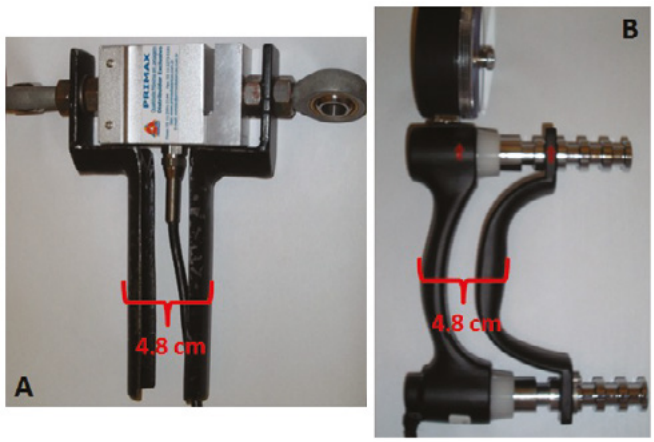

Figure 2. Detail of the standardized distance in the handle for hand grip: A - load cell; B - Jamar® dynamometer

Statistical analysis

The Intraclass Correlation Coefficient (ICC) was used to calculate the test-retest reliability by the mean and standard deviation of three measures for Jamar® dynamometer and Kratos® load cell, both in Kgf. Reliability was considered excellent for ICC values higher than 0.75, moderate when higher than 0.40, and lower than 0.75, and weak if lower than 0.40[17].

To calculate construct validity, we used the Pearson correlation coefficient (r), which varies between -1 and 1. Values close to 1 indicate maximum direct correlation, while those close to -1 indicate maximum negative – or inverse – correlation between the variables under analysis. To interpret the magnitude of the correlations found, we adopted the classification proposed by Dancey & Reidy[18] as 1=Perfect, 0.7 to 0.9=Strong, 0.4 to 0.6=Moderate, 0.1 to 0.3=Weak, and 0=nonexistent.

Additionally, the SEM (Standard Error of Measurement) was calculated both for load cell and for Jamar® dynamometer. The limit of agreement was analyzed graphically between both instruments, as described by Bland and Altman[19,20].

The data of this study was analyzed using the programs SPSS version 20® and MedCalc® with confidence interval of 95% and level of significance at $p<0.05$.

RESULTS

The 24 asymptomatic volunteers had average age of 22.25 years (SD±2.57), were university students, only one of them showing left dominance. The average age of volunteers with upper limb and hand dysfunctions was 43.48 years (SD±13.56), 62.5% were men, and 3 did not attend the retest. Demographic characteristics can be observed in Table 1.

Table 2 illustrates the mean values measured in Kgf of the load cell and Jamar® for both groups of asymptomatic individuals and patients.

Concerning test-retest reliability of the load cell for the group of asymptomatic volunteers, the ICC found was 0.90 (0.78-0.95), being considered excellent. As for the group of patients with upper limb and hand dysfunctions, the ICC found was 0.94 (0.87-0.97), a value also considered excellent.

The limits of agreement by the Bland and Altman method[19,20] for the groups of asymptomatic volunteers

Table 1. Characteristics of the volunteers with wrist and hand dysfunctions

Volunteer	Age (years)	Sex	Dominance	Cause of dysfunction	Affected side	Occupation
*1	27	Male	R	Fracture of the distal radius	R	Downspout/gutter/ leader installer
2	28	Male	R	Fracture of the distal radius	R	Construction worker
3	45	Male	R	CCW in zone VI	R	Merchant
4	13	Female	L	CCW in zone V	R	Student
5	36	Male	R	Olecranon and head of radius fracture	R	Installing technician
6	50	Male	R	CCW in dorsal region of the forearm, lesion of the venter of the extensor muscles of the fingers	L	Electrician

continua...

Table 1. Continuação

Volunteer	Age (years)	Sex	Dominance	Cause of dysfunction	Affected side	Occupation
7	50	Female	R	Bilateral lesion of the rotator cuff Tenosynovitis in the 4th and 5th fingers of right hand	Bilateral (predominance of R)	Cooker
8	29	Male	R	Fracture of the distal radius	L	Watchman
9	31	Male	R	Fracture of the radius styloid	L	Painter
10	70	Male	R	Fracture of the distal radius Fracture of the humeral shaft	R	Retired
11	48	Female	R	Carpal tunnel syndrome	Bilateral (predominance of L)	Assistant of services
12	42	Male	R	Carpal tunnel syndrome	R	Trucker
13	46	Female	R	Semi amputation of the distal phalanx of the 3rd finger of the R hand)	R	Cleaning Assistant
14	64	Female	R	Fracture of the distal radius on the right	R	Pedagogue
15	57	Female	R	Lesion of the long extensor of thumb	R	Biomedical scientist
*16	28	Male	R	Galeazzi fracture	R	Pool surveyor
17	55	Female	R	Carpal tunnel syndrome	Bilateral (predominance of R)	Administrative Officer
18	52	Female	R	Fracture of base of proximal phalanx of thumb	L	Seamstress
19	46	Male	R	Carpal tunnel syndrome	R	Civil engineer
20	56	Male	R	Rhizarthrosis on the L	L	Assistant of services
*21	35	Male	L	Carpal tunnel syndrome	R	Merchant
22	45	Male	L	Rolland syndrome; Bilateral epicondylitis Carpal tunnel syndrome worse on the L	Bilateral	Construction worker
23	60	Female	R	Carpal tunnel syndrome on the L	L	Housewife
24	44	Male	R	CCW on venter of forearm, lesion of venter of flexors of fingers	R	Loading and unloading of trucks

CCW: cut-contusion wound with lesion of flexor tendons, artery and ulnar nerve whose level of severity varied according to each patient. R: right, L: left
*Patient whose re-test was not performed

(Figure 3-A) and of patients (Figure 3-B) graphically illustrate that, although the tests showed excellent test-retest reliability, with low values for SEM, some dispersive values are observed particularly in the group of patients.

Regarding the convergent construct validity, we observed a strong direct correlation between the Jamar® and the load cell, with values of r=0.85 and r=0.83, respectively, for groups of asymptomatic individuals and of patients.

Table 2. Mean values in Kgf, standard deviation, and confidence interval (95%) of the load cell and Jamar® for the groups of asymptomatic individuals and of patients

	Groups							
	Asymptomatic individuals				Patients			
	Mean	SD	CI (95%)	SEM	Mean	SD	CI (95%)	SEM
Jamar®	31.31	8.79	27.91-34.84	2.75	20.27	9.56	16.55-24.08	3.0
Load cell	26.08	7.92	22.81-29.00	2.49	18.77	7.55	15.87-21.83	2.3

SD: standard deviation; CI: Confidence interval; SEM: Standard Error of Measurement; Values in Kgf

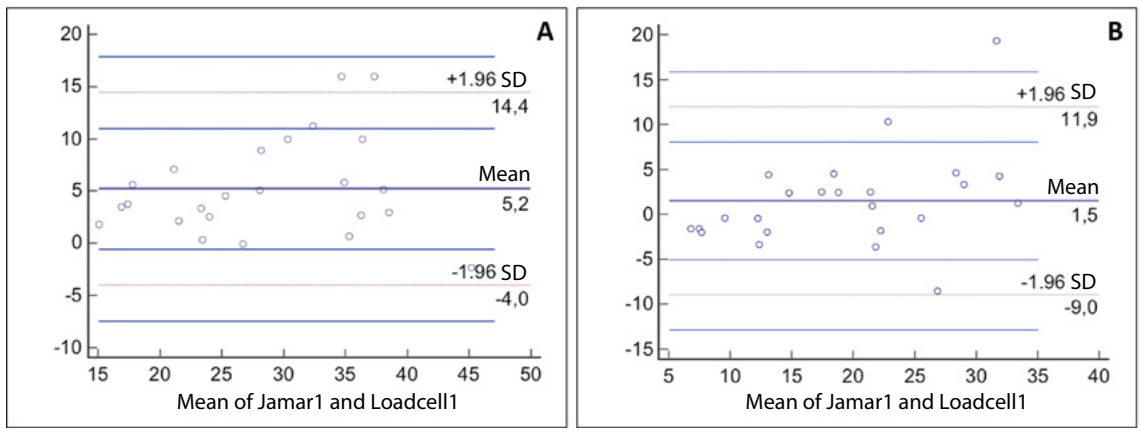

Figure 3. Graphical representation, according to the Bland and Altman Method[19,20], of the difference between the values in the ordinate (y), and mean of the values in the abscissa (x) of the isometric grip strength with Jamar® and load cell; A - data for asymptomatic volunteers and B - data for volunteers with dysfunctions of upper limb and hand

DISCUSSION

Analysis of the measures for isometric handgrip strength of fingers showed excellent test-retest reliability and construct validity for the load cell handle specially developed for this study, both for individuals with of upper limb and hand dysfunctions and for healthy volunteers.

Hand grip strength measures are important in the evaluation of several hand and upper limb dysfunctions[6,8,12,21]. Irwin and Sesto[14] examined the reliability of three devices capable of measuring grip strength using load cells: the Baseline dynamometer, a vigorimeter, and the Multi-Axis-Profile (MAP), finding high reliability for all instruments, especially for the MAP. This study had the participation of 28 volunteers, 14 aged less than 30 years and 14 aged more than 65 years. ICC for the MAP dynamometer ranged from 0.94 to 0.99, close to the values found in this study, despite the difference concerning the shape of the load cell handle. In addition, our sample also included 21 individuals with dysfunctions resulting from lesions of the upper limb musculoskeletal system with alterations of the grip muscle strength, which demonstrates the actual reproducibility of the instrument for clinical cases. On the other hand, Wimer et al.[22] used a pair of load cells to measure grip strength in normal subjects, whose handle was cylindrical, but found no correlation between the grip strengths measured with the load cells and with the Jamar® dynamometer. This may suggest that the grip strength measured may suffer alterations in reproducibility for measuring instruments with cylindrical handles[23]. In our study, the handle was developed in a semi-cylindrical format with similar diameters in relation to Jamar®, in two coupled parts, without altering the ability to grip with the fingers.

According to the COSMIM[19] group, studies on the reliability of devices and instruments of quantitative measures are required for future concomitant use with other tools. Complementarily, the use of load cell enables the measuring of grip strength development in various dysfunctions together with electromyography (or electrogoniometry[24]), with analysis of strength and time to reach fatigue. Therefore, it is possible to analyze muscular function[25] and the different types of physical exercises and intervention programs[26], complementing the functional analysis of wrist and hand.

The measure of agreement between the two instruments according to the method of Bland and Altman[19,20] showed some discrepancy in few cases, despite excellent reliability and low values of SEM.

LIMITATIONS OF THE STUDY

The study showed limitations on the commitment of some volunteers in returning to perform the re-test, as well as regarding the reading of the load cell handle, which in one of the situations failed to work properly.

CONCLUSION

The results showed excellent consistency of load cell measurements in relation to the Jamar® dynamometer, both for the group of asymptomatic individuals and for the group of patients with upper limb and hand dysfunctions, suggesting that this device is valid, reproducible, and can be utilized to measure the isometric hand grip strength in future clinical studies and in clinical practice.

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