Artículo original

Comparing the Camry dynamometer to the Jamar dynamometer for use in healthy Colombian adults

Comparación del dinamómetro Camry con el dinamómetro Jamar para su uso en adultos colombianos saludables

Comparação dos dinamômetros Camry e Jamar para seu uso em adultos colombianos saudáveis

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Abstract

Objective: Hand grip strength can provide an objective index of general upper strength, but hand dynamometer has not been validated for use in Colombia. The objective was to determine the interchangeability between Camry electronic and Jamar hydraulic hand grip dynamometers in a population found on the campus of the Universidad Nacional de Colombia and the elderly living in a community.

Methods: This was a cross-sectional concordance study on 18-88-year-old males and females. Data regarding their demographics, health, and anthropometric variables were collected/measured and the Lin concordance correlation coefficient (CCC) along with Bland-Altman plots were used for evaluating concordance regarding both devices.

Results: One hundred and thirty-three subjects participated in this study (average age 47±20.74 years-old). Right hand (RH) grip strength was 32.15±9.96 kg with the Jamar dynamometer and 29.95±9.18 kg with the Camry device. It is worth highlighting that the Jamar instrument presents higher values than the Camry instrument ($p < 0.05$). CCC was only significant at the population level and for the 40-59-year-old age group. Bland-Altman plots had narrow limits of agreement.

Conclusion: We concluded that the Camry dynamometer could replace the Jamar dynamometer in the 40-59-year-old age group; furthermore, it would be appropriate for medical use in patient monitoring or follow-up due to the close values observed.

Keywords: hand strength, upper extremity, muscle Strength Dynamometer, cross-sectional study, biostatistics.

Resumen

Objetivo. La fuerza de agarre de la mano puede proporcionar un índice objetivo de la fuerza de los miembros superiores, pero no se dispone de un dinamómetro de mano validado para su uso en Colombia. El objetivo fue determinar la intercambiabilidad entre los dinamómetros hidráulicos Jamar y el dinamómetro electrónico Camry en una población que se encuentra en el campus de la Universidad Nacional de Colombia y personas mayores que viven en una comunidad.

Métodos. estudio transversal de concordancia realizado en hombres y mujeres de 18 a 88 años de edad. Se recolectó información sobre variables demográficas, de salud y antropométricas. El coeficiente de correlación de concordancia de Lin (CCC) y los gráficos de Bland-Altman se utilizaron para evaluar la concordancia entre ambos dispositivos.

Resultados. Participaron 133 sujetos (edad promedio de 47 ± 20,74 años). La fuerza de agarre de la mano derecha fue de 32,15 ± 9,96 kg con el dinamómetro Jamar y de 29,95 ± 9,18 kg con el dispositivo Camry, destacando que el equipo Jamar presenta valores superiores al Jamar (p<0.05). La CCC solo fue significativa a nivel de la población y para el grupo de edad de 40 a 59 años. Los gráficos Bland-Altman presentaron límites de acuerdo estrechos.

Conclusión. Concluimos que el dinamómetro Camry podría reemplazar el dinamómetro Jamar en el grupo de edad de 40-59 años; además, sería apropiado para uso médico en el monitoreo o seguimiento de pacientes debido a los valores cercanos observados.

Palabras clave: fuerza de la mano, extremidad superior, dinamómetro de fuerza muscular, estudio transversal, bioestadística.

Resumo

Objetivo. A força de agarramento manual pode fornecer um índice objetivo da força dos membros superiores, mas um dinamômetro manual validado não está disponível para uso na Colômbia. O objetivo foi comparar os dinamômetros hidráulicos Jamar com o dinamômetro eletrônico Camry e establecer a possibilidade de equivalência no seu uso, na população do campus da Universidad Nacional de Colombia e em idosos que moram em uma comunidade.

Métodos. estudo de concordância transversal realizado em homens e mulheres de 18 a 88 anos de idade. Foram coletadas informações sobre variáveis demográficas, sanitárias e antropométricas. O coeficiente de correlação de concordância de Lin (CCC) e os gráficos de Bland-Altman foram utilizados para avaliar a de equivalência entre os dois dispositivos.

Resultados. 133 sujeitos participaram (idade média de 47 ± 20,74 anos). A força de preensão da mão direita foi de 32,15 ± 9,96 kg com o dinamômetro Jamar e 29,95 ± 9,18 kg com o dispositivo Camry, destacando que a equipe do Jamar possui valores maiores que o Jamar (p < 0,05). O CCC foi significativo apenas no nível populacional e na faixa etária de 40 a 59 anos. Os gráficos de Bland-Altman apresentaram limites estreitos de concordância.

Conclusão. Concluímos que o dinamômetro Camry poderia substituir o dinamômetro Jamar na faixa etária de 40 a 59 anos; Além disso, seria apropriado para uso médico no monitoramento ou acompanhamento de pacientes devido aos valores próximos observados.

Palavras-chave: força da mão, membro superior, dinamômetro de força muscular, estudo transversal, bioestatística.

Introduction

A hand dynamometer can be used for measuring upper extremity strength by hand grip test thereby evaluating upper extremity muscular strength and function (1). Hand grip strength is useful as a diagnostic and prognostic tool in clinical settings and can be used for determining treatment efficacy (2,3). It can be measured from age four onwards (3,4) since it is a simple method which is recommended for evaluating muscular function in a clinical setting (5) and can be used for determining the strength of muscular, neuronal and skeletal systems (3).

Despite its advantages, grip strength is not routinely assessed in clinical practice because the procedure remains unknown (mostly due to difficulty regarding hand grip dynamometer selection) (2), high reference device cost and greater accessibility concerning less costly yet-to-be validated devices.

A wide array of dynamometers is available; they can be discriminated by their measuring mechanism and how the outcome is presented. The Jamar hydraulic dynamometer is the currently recognized device for measuring hand grip strength (1,6) and is referred to as the gold standard or reference device for other dynamometer validation by The American Society of Hand Therapists and The American Society for Surgery of the Hand (1,4,6). The Camry electronic dynamometer is a new device, meaning that no information is currently available allowing its interchangeability with the Jamar dynamometer.

To the best of the authors' knowledge, no reports regarding validation, comparison or correspondence between the hydraulic Jamar and electronic Camry hand grip dynamometers have been published to date; this study was thus aimed at evaluating the degree of interchangeability when comparing a Camry to a

Jamar dynamometer in a sample of Colombian population aged between 18 and 88 found on the campus of the Universidad Nacional de Colombia and the elderly living in a community.

Methods

Study design

This was a cross-sectional concordance-correspondence study involving 18-88-year-old males and females. The participants at the time (September 2015) were students or staff members of Universidad Nacional de Colombia and the elderly living in a community.

Human subjects were used in this research according to the Declaration of the World Medical Association and the Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects. This study was considered to involve minimum risk according to Colombian Ministry of Health Resolution 8430/1993 and was approved by the Ethics Committee of Universidad Nacional de Colombia-School of Medicine; each participant voluntarily agreed to take part in this study and provided informed verbal consent.

Subjects

The inclusion criteria stated that males and females aged between 18 and 88 years-old who could maintain an upright standing position without the aid of a cane or crutches could participate in the study. Such individuals had to be in good health and with no limitations affecting their upper extremity functionality. The exclusion criteria had to do with subjects who stated that they suffered an autoimmune disease, pregnant women or subjects having a hospitalization history of more than three days during the past six months.

The sample size was calculated according to Lin (7): 0.995 expected precision, 0.01 precision loss, 0.125 standard deviations (SD) regarding change of location and 0.9 change in scale. This gave n=20 sample size for each subgroup, i.e. three age subgroups (18-39, 40-59 and 60-88) and two gender subgroups (male/female).

Sampling was non-probabilistic, by intention or willingness to participate. Tests for the 18-39 and 40-59 age groups were performed in a public place within Universidad Nacional de Colombia until the number of participants per group was met; the 60-88 age group was evaluated in a social group of elderly sampling by intention to participate.

Procedure

Information regarding demographics (gender, age, and occupation) and health state was collected, as well as body mass index (BMI) data. The amount of physical activity engaged in was established through verbal interview.

The devices used were the Jamar hydraulic hand dynamometer (Model J00105, Lafayette Instrument Company. USA: 90 kg capacity, 727 g weight) and the Camry electronic hand dynamometer (Model EH101, Zhongshan Camry Electronic Co. Ltd. China: 90 kg capacity, 356 g weight). The devices were calibrated by gradually applying standardized weights (concurrent validity); the dynamometers were suspended from a bracket and masses were directly applied in the center of their handles (8).

Right Hand (RH) and left hand (LH) grip strength were evaluated with each dynamometer, using three repetitions, according to Coldham *et al*. (9). The device to be used by each participant was randomly assigned by a computer-generated number to randomize the effect of fatigue and effort which might have influenced the results; each repetition was evaluated with one-minute rests between measurements. The mean and SD from three measurements were used for statistical analysis.

Subjects were standing with both legs relaxed involving equal weight distribution on both feet for each hand grip strength measurement. Their feet were placed apart according to shoulder width breadth and shoulders were in vertical adduction with neutral rotation; elbows were flexed at 90° and forearms in a neutral position, wrists between 0°-30° dorsiflexion and 0° to 15° ulnar deviation. To ensure comparable grip length between both devices, the Jamar dynamometer was adjusted in the second position of the handle and the third position was used for the Camry device. Verbal encouragement stimulation was provided at the time of measurement, according to Mathiowetz *et al*. (10). Subjects' weight and height were measured standing up, using calibrated equipment which was suitable for research. The mean and SD from three measurements were used for statistical analysis.

Statistical analysis

Frequencies and percentages were used for describing the following variables: gender, occupation, physical activity, dominant hand, and first dynamometer evaluated. Averages and SD were used for describing age, BMI and hand grip strength. The analysis was performed according to gender, dynamometer device, hand and age subgroups (18-39, 40-59 and 60-88 years).

A Shapiro-Wilk test of normality had been used for assessing normal distribution, assuming $p < 0.05$ as being statistically significant. A Mann-Whitney U-test was used for comparing RH and LH grip strength and Student's T-test or Wilcoxon signed-rank test (i.e. a paired difference test) for comparing the dynamometers..

Interchangeability was measured by Lin concordance correlation coefficient (CCC) and Bland-Altman plots. The CCC was used for quantifying concordance-correspondence between both dynamometers, assuming significance from CCC>0.9; Bland-Altman plots were used for verifying the agreement between both devices. STATA 12.0 (Data Analysis and Statistical Software, College Station, Texas USA) was used for statistical analysis.

Results

One hundred and thirty-three 18-88-year-old subjects (47±20.7 mean age) participated in this study (50.4% were female). Regarding participants' health status, diabetes, hypertension, and gastritis had the highest disease prevalence. Average BMI came within normal parameters and 45.86% of the studied population stated that they had not engaged in physical activity within the last month (Table 1).

Table 1. Population description

Variables	18 to 39	40 to 59	60 to 88	Total
	n=50	n=40	n=43	n=133
Gender: [a]				
Male	23 (46)	20 (50)	23 (53.5)	66 (49.6)
Female	27 (54)	20 (50)	20 (46.5)	67 (50.4)
Age. in years [b]	24.34 (5.82)	49.47 (5.93)	71.12 (8.22)	47.02 (20.74)
Occupation: [a]				
Student	34 (68)	2 (5)	0	36 (27.07)
Professional	11 (22)	3 (7.5)	1 (2.33)	15 (11.28)
Professor	1 (2)	20 (50)	5 (11.63)	26 (19.55)
Works at home	0	4 (10)	25 (58.14)	29 (21.80)
Retired	0	0	5 (11.63)	5 (3.76)
Secretary	1 (2)	10 (25)	2 (4.65)	13 (9.77)
Other	3 (6)	1 (2.5)	5 (11.63)	9 (6.77)
Phy y: [a]				
Does not practice	25 (50)	19 (47.5)	17 (39.53)	61 (45.86)
Yes	25 (50)	21 (52.5)	26 (60.47)	72 (54.14)
Comorbidities: [a]				
No	36 (72)	25 (62.5)	13 (30.23)	74 (55.64)

Table 1. Population description

Yes	14 (28)	15 (37.5)	30 (69.77)	59 (44.36)
Health status: [a]				
Diabetes	0	0	13 (30.95)	13 (16.46)
Hypertension	1 (5.56)	1 (5.26)	17 (40.48)	19 (24.05)
Cholesterol	0	2 (10.53)	2 (4.76)	4 (5.06)
Triglycerides	0	1 (5.26)	3 (7.14)	4 (5.06)
Hypothyroidism	0	6 (31.58)	2 (4.76)	8 (10.13)
hypoglycemia	4 (22.22)	0	0	4 (5.06)
Gastritis/ulcer	7 (38.89)	1 (5.26)	0	8 (10.13)
Other	6 (33.33)	8 (42.11)	5 (11.90)	19 (24.05)
BMI. in kg/m2 [b]	23.23 (3.42)	25.57 (3.14)	26.56 (4)	25 (3.79)
Nutritional status: [a]				
Slender	3 (6)	0	8 (18.6)	11 (8.27)
Normal	29 (58)	19 (47.5)	22 (51.16)	70 (52.63)
Overweight	16 (32)	17 (42.5)	10 (23.26)	43 (32.33)
Obesity	2 (4)	4 (10)	3 (6.98)	9 (6.77)

[a]: Values are frequency and percentage
[b] : Values are means and Standard deviation (SD)

The devices calibrated with standardized weights indicated that both devices had concurrent validity; the Jamar dynamometer had 0.999 CCC (CI 95% 0.999 to 1.000) and the Camry dynamometer 0.998 CCC (CI 95% 0.995 to 1.000).

It was found that 88% of the population was right-handed and that 51.1% started the test with the Jamar dynamometer. Average handgrip strength was higher with the Jamar dynamometer than the Camry dynamometer in both hands; In both dynamometers, RH grip strength was equal to that for LH ($p>0.1$). (Table 2).

The Concordance-correlation coefficient (CCC) between both devices was statistically significant for the entire population (CCC 0.933 CI 95% 0.911-0.955 in both hands) and for the 40-59-year-old sub-group (RH: 0.960 CI 0.934-0.985; LH 0.964 CI 0.934-0.981).

Bland-Altman agreement analysis gave negative mean differences when comparing the Camry dynamometer to the Jamar device (-3.9 to -0.48 mean differences regarding sub-groups). All limits of agreement were negative regarding the lower limit. The lowest limits of agreement rank were in the female 18-39-year-old sub-group and the highest rank in the male 18-39-year-old sub-group (Table 3).

Table 2. Handgrip strength description for sub groups.

Group	Device	Right hand			Left hand			p value [c]
		Male	Female	Total	Male	Female	Total	
Population studied	Jamar [a]	39.99 (7.76)	24.43 (4.12)	32.15 (9.96)	38.02 (7.9)	22.95 (4.1)	30.43 (9.81)	0.157
	Camry [a]	37.2 (6.96)	22.8 (4.04)	29.95 (9.18)	35.04 (7.57)	21.46 (3.68)	28.2 (9.02)	0.119
	p value [b]	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*	
Age group 18 to 39	Jamar [a]	43.89 (7.19)	26.48 (4.29)	34.49 (10.48)	41.56 (8.05)	24.8 (4.21)	32.51 (10.47)	0.347
	Camry [a]	39.98 (6.26)	24.69 (4.15)	31.73 (9.27)	38.05 (7.92)	23.23 (3.71)	30.05 (9.54)	0.376
	p value [b]	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*	
Age group 40 to 59	Jamar [a]	39.67 (7.13)	23.63 (3.38)	31.65 (9.81)	37.81 (6.48)	21.71 (3.62)	29.76 (9.66)	0.388
	Camry [a]	38.5 (6.55)	23.14 (3.3)	30.82 (9.31)	36.04 (5.9)	21.53 (3.27)	28.78 (8.73)	0.316
	p value [b]	0.093	0.33	0.049*	< 0.001*	0.728	0.009*	
Age group 60 to 88	Jamar [a]	36.36 (7.25)	22.47 (3.43)	29.89 (9.06)	34.66 (7.63)	21.71 (3.61)	28.63 (8.89)	0.516
	Camry [a]	33.3 (6.42)	19.9 (2.88)	27.07 (8.43)	31.16 (7.09)	19 (2.59)	25.5 (8.19)	0.386
	p value [b]	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*	

[a] values presented as averages and (standard deviation)
[b] p value for the contrast between dynamometers
[c] p value for the contrast between hands total
* significance to p value < 0.05

Table 3. Values of the Bland-Altman charts

Population Mean Differences (SD)	Right hand [a]			Left hand [a]		
	Mean Difference (SD)	Limits of agreement	Rank of the limits of agreement	Mean Differences (SD)	Limits of agreement	Rank of the limits of agreement
Whole population	-2.204 (2.767)	-7.627 a 3.218	10.845	-2.231 (2.699)	-7.522 a 3.060	10.582

Table 3. Values of the Bland-Altman charts

Male	Age group 18 to 39	-3.910 (3.477)	-10.726 a 2.905	13.631	-3.512 (3.790)	-10.939 a 3.916	14.855
	Age group 40 to 59	-1.168 (2.953)	-6.956 a 4.621	11.577	-1.768 (1.980)	-5.648 a 2.112	7.76
	Age group 60 to 88	-3.062 (2.445)	-7.853 a 1.730	9.583 *	-3.498 (2.331)	-8.067 a 1.072	9.139
	Total	-2.783 (3.154)	-8.964 a 3.398	12.362	-2.979 (2.914)	-8.690 a 2.733	11.423
Female	Age group 18 to 39	-1.791 (2.014)	-5.740 a 2.157	7.897 *	-1.567 (2.031)	-5.548 a 2.415	7.963
	Age group 40 to 59	-0.488 (2.183)	-4.767 a 3.790	8.557 *	-0.182 (2.303)	-4.696 a 4.332	9.028
	Age group 60 to 88	-2.567 (2.046)	-6.577 a 1.443	8.02 *	-2.710 (1.841)	-6.319 a 0.899	7.218
	Total	-1.634 (2.202)	-5.949 a 2.681	8.63 *	-1.495 a 2.259	-5.921 a 2.932	8.853
Age groups	18 to 39	-2.766 (2.953)	-8.544 a 3.022	11.566	-2.461 (3.098)	-8.533 a 3.610	12.143
	40 to 59	-0.828 (2.586)	-5.897 a 4.241	10.138	-0.975 (2.267)	-5.418 a 3.468	8.886
	60 to 88	-2.831 (2.255)	-7.252 a 1.589	8.841 *	-3.131 (2.131)	-7.307 a 1.044	8.351

[a] Values are in Kg
* Narrow limits of agreement < 10 kg
SD: standard deviation

Discussion

To the best of our knowledge, this is the first study involving adults comparing concordance between the digital Camry dynamometer and the hydraulic Jamar hand dynamometer (currently the gold standard in Colombia). These findings could stimulate the measurement of grip strength in routine clinical practice, such as older people wards or geriatrics home.

Significant CCC values were observed when evaluating their concordance for the entire study population; nonetheless, such values were not observed at all subgroup levels, suggesting that variables such as age and gender could be a confounding variable when validating hand dynamometers. For the above, other statistical methods can be used to control confounding variables when assessing concordance-correspondence, such as analysis of variance components or generalized estimation equations (11).

The concordance-correspondence between both devices could have been due to four differing factors: handle ergonomics (the Jamar dynamometer have smooth handle surface compared to the Camry dynamometer's handle having clefts for placing each finger), device weight (Camry weighed less), transmission mechanisms and result presentation. Regarding the presentation of results, the Camry device's LCD screen enabled rapid, accurate reading of hand grip values while the Jamar dynamometer's clock or dial demanded more time and effort for reading it.

Regarding handle ergonomics and device weight, in agreement with Amaral *et al.* (8), handle design defined how to hand articulations were positioned and different strengths were thus applied, depending on the design of the device quantifying hand grip strength.

Concerning transmission mechanism, devices having hydraulic mechanisms should be comparable to the Jamar hand dynamometer, as stated by Mathiowetz regarding the Rolyan hydraulic dynamometer (12). Research concerning non-hydraulic systems has concluded that such devices are not interchangeable with the Jamar hand dynamometer (13-15); however, standardized weights evaluation (concurrent validity) of the digital device was high in this study, suggesting that both devices measured in a similar way.

Another explanation to the findings of concordance-correlation between both devices for the entire population and for the 40-59-year-old sub-group is the variability or heterogeneity of the grip strength inside each age-sub-group. In men and women, the grip strength increase up to 39 years old and decreased markedly from 60 years, in both periods, the variability or heterogeneity of the grip strength is large (4,16); On the other hand, across the 40-59-age-year, the grip strength no modify significantly and present not much variability respect to another age-groups (4). This variability can alter the concordance between devices, thus, the age is a confounder variable in this type of studies and need to be monitored and measured by small age-sub-groups (e.g. five-year-age periods).

Bland-Altman plot comparison with other reports contrasting the Jamar dynamometer with other devices revealed that the current findings have a small mean difference between both devices. Limits of agreement were narrow, thus suggesting that the Camry dynamometer could be used for specific purposes such as patient monitoring or hospital follow-up after arm surgery, as has been suggested by Hogrel (17). Hogrel's study compared measurements obtained with MyoGrip and Jamar dynamometers, giving 4.12 kg mean difference for the Jamar-Myogrip dynamometer (-4.13 to 12.37 kg limits of agreement) and the present study's results were similar to those reported by Hogrel.

Other studies by Amaral *et al*. (8) and Massy-Westdropp *et al*. (18), have highlighted high mean differences and an ample limit of agreement between the Jamar and other devices, concluding that devices were not interchangeable with the Jamar dynamometer. Massy-Westdropp *et al*. (18), compared an electronic dynamometer (Grippit; AB Detektor) with the hydraulic Jamar device, finding a 22 N mean difference and limits of agreement were 86-129 N; Amaral *et al*. (8), found a 17 kg mean difference between the Jamar and Takei dynamometers (10-44.8 kg limit of agreement).

The findings of the research have a restriction in the population investigated, so, results can not be easily extrapolated to other types of population. Therefore, future research has to focus on geriatric home, under 18 years, sports players and/or clinical patients.

As the Jamar and Camry dynamometers differ regarding ergonomics, weight and presentation of results, the Camry dynamometer is thus recommended for future studies concerning its use in hospital settings, weak patient or patient follow-up, due to its weight and reported values being close to those when using the Jamar dynamometer. Future research should be oriented towards evaluating concordance-correspondence between the devices when used on hospitalized population and with subjects of less than 18 years of age.

Conclusion

The digital Camry dynamometer can be interchanged with the hydraulic Jamar hand dynamometer in the 40-59-year-old sub-group. The Camry device is lighter and has different ergonomics compared to the Jamar dynamometer and would be appropriate for patient monitoring, particularly regarding older people and hospitalized adults. Further studies (including a hospitalized population) must thus be performed to ascertain such affirmations.

Authors' contributions

GD participated in the study design, data collection, analysis of information, article writing and approval of the final article. SC participated in study design, data collection, analysis of information, article writing and approval of the final article.

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Conflicto de intereses

Ninguno declarado por los autores.

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