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Original article

Comparison of two electronic dynamometers for measuring handgrip strength

Sebastian Keller Rolsted [a,b], Kasper Dyrmose Andersen [a,b], Gustav Dandanell [a,b], Christian Have Dall [a,c,d], Camilla Kampp Zilmer [a], Kasper Bülow [b], Morten Tange Kristensen [a,d,*]

[a] Department of Physical and Occupational Therapy, Copenhagen University Hospital, Bispebjerg and Frederiksberg, Copenhagen, Denmark
[b] Centre for Health and Rehabilitation, University College Absalon, Slagelse, Denmark
[c] Department of Cardiology, Copenhagen University Hospital, Bispebjerg and Frederiksberg, Copenhagen, Denmark
[d] Department of Clinical Medicine, Faculty of Health and Medical Sciences, University of Copenhagen, Copenhagen, Denmark

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ABSTRACT

Introduction: Handgrip strength (HGS) is a strong predictor and easily applicable assessment, indicating a person's physical condition and health. However, many dynamometers are available; therefore, it is essential to ensure that the results of HGS testing using different dynamometers can be used interchangeably. The primary purpose of this study was to investigate the inter-instrument agreement and criterion validity of the Baseline BIMS Digital Grip Dynamometer in comparison with the Jamar electronic dynamometer (Jamar+).
Methods: Seventy participants, aged between 23–88 (five men and five women in each decade from 20 to 80+), performed three attempts with each dynamometer (30-sec break between attempts) in a randomized order and separated with a 5-minute break between dynamometers. Intraclass correlation coefficient (3.1), standard error of measurement and minimal detectable change were used for comparison of the strongest and average strength measured with dynamometers. Jamar+ and Baseline BIMS Digital Grip Dynamometer were new dynamometers and considered calibrated by the manufacturer.
Results: The overall Intraclass correlation coefficient was excellent (0.98). An average (SD) difference of 0.68 (2.2) kg (p = 0.04) was seen for the comparison of the strongest attempt for Baseline BIMS minus Jamar+, Correspondingly, for the average of three attempts, it was 0.37 (2.29, p = 0.2) kg. The standard error of measurement (%) and minimal detectable change (%) of the strongest attempt was 1.64 kg (4.2%) and 3.55 kg (9.0%), respectively.
Conclusions: Findings indicate low measurement error with high agreement and criterion validity for the comparison of Baseline BIMS Digital Grip Dynamometer and Jamar+ and that results of the two dynamometers can be used interchangeably.

1. Introduction

Handgrip strength (HGS) is a relevant proxy for measuring a person's physical function and general health status [1–7]. HGS is also acknowledged to be the best test for assessing general muscle strength in daily clinical practice [8], and reference values have been reported according to gender and age group in several countries, from Australia to Canada [9–15]. Correspondingly, below-normal HGS in the elderly is associated with increased risk of premature and cardiovascular death, disability, type-II diabetes, dementia, fracture and depressive symptoms [2–6]. HGS can be used to index biological ageing or age-related diseases such as sarcopenia, where HGS is part of the diagnostic criteria in the European Working Group on Sarcopenia in Older People 2 (EWGSOP2) [16]. Therefore, clinicians may use HGS testing in clinical practice to identify people with signs of sarcopenia and as a measure of physical health in the general population [7,17]. HGS has shown strong association with lower-limb strength [18], but weaker association with the 30-sec Sit-To-Stand test (STS) in older community-dwelling adults [19]. However, the association between HGS and the STS test has been less examined in adults of all ages.

* Corresponding author.
E-mail address: morten.tange.kristensen@regionh.dk (M.T. Kristensen).

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Different strength dynamometers are used to measure HGS worldwide (10): GripAble [20], Camry [21], K-Force [22], Smedley Spring [23], Saehan [24], Jamar [25], and the hydraulic Baseline [26]. Of these, Jamar has been suggested as a gold-standard for HGS testing [8,27] and is available as both a hydraulic and electronic dynamometer (Jamar+). The Baseline BIMS digital grip dynamometer (BIMS) and the Saehan DHD-1 digital hand dynamometer (Saehan) are other dynamometers used for the same purpose.

A prerequisite for comparing HGS results in research and clinical practice is to know whether test results are comparable between dynamometers. Another issue that influences choice of dynamometer is the price. Therefore, the primary objective of this study was to compare the agreement and criterion validity of the digital versions of the less expensive BIMS dynamometer versus the more costly Jamar+ and Saehan devices, in adults with no functional or neurological impairment. The secondary objective was to examine performance stability over three HGS trials and the association between HGS and 30-sec STS results.

2. Methods

2.1. Design

An observational cross-sectional agreement design was used for the study, and the GRRAS checklist for agreement studies for appropriate reporting [28]. The project was evaluated by the Scientific Ethics Committees for the Capital Region of Denmark, which decided that, according to Danish legislation, the project could be carried out without further permission (Journal-nr: F-23077862).

2.2. Participants

Seventy home-dwelling adult volunteers (35 men and 35 women, aged 23–88 years) were enrolled from October to November 2022. Inclusion criteria were: 1) 18 years or older, 2) ability to give written informed consent, 3) ability to read and speak Danish, 4) no functional impairment in arms or legs, and 5) no skin-wounds on hands, and 6) no neurological disease. The participants were hospital staff, members of an exercise club for the elderly and acquaintances of the authors, recruited by social media, email, telephone or personal contact. Seven age decades were pre-specified, with 10 participants (5 men and 5 women) in each [7,29]. Each participant received written and verbal information about the study and signed a written informed consent form. The following patient data were collected: age, gender, height and weight to calculate body mass index (BMI), smoking habits, diseases, dominant hand, occupation, sports activities, health-related quality of life (on EQ-5D-5L and EQ-VAS, 0–100 points) [30] and weekly physical activity. Physical activity was assessed on a questionnaire by the Swedish National Board of Health and Welfare [31], comprising three questions: 1) How much time on average during a regular week do you take exercise that leaves you short of breath (e.g., running, fitness or ball games)? 2) How much time on average during a regular week are you physically active other than exercises (e.g., cycling or gardening)? 3) How much time do you spend sitting down on a regular day? Participants answered in categories of minutes from 1 to 6 for the first two questions (from 0 min in category 1–120 min or more in category 6) and from 1 to 7 (from "more or less all day" to "never") for the third, and a score between 3 and 18 was calculated by multiplying the score for the first question by two and adding the score for the second question. To fulfil the WHO recommendation for weekly physical activity, a score of $\geq$11 was necessary [31], as used in a recent study of younger patients with hip fracture [32].

2.3. Hand grip strength testing procedure

The HGS tests were performed over four weeks in two very similar rooms. The rooms were bright, quiet and well-ventilated. Two of the authors were in the room with the participant during each session; one was the tester and the other noted the results. These roles were the same throughout all the tests. Participants were seated comfortably in a standard chair with a back and armrests (chair seat height 46 cm in the front and 44.5 cm at the back), feet flat on the ground next to each other, buttocks against the back of the chair, hip and knee flexed at 90°, forearm in neutral rotation and resting on the armrest with only the wrist clearing the armrest, and the opposite hand resting on the opposite thigh [7]. All participants were given the opportunity to hold each dynamometer before testing to check that the handle was in the right position and to perform a sub-maximal test before the three attempts in which study data were recorded. For a full description of instructions to participants before performing the HGS test, see the manual in Appendix 1. A computer-generated randomization of the three dynamometers was made for the 10 participants in first age decade (18–29 years), and this dynamometer test order was copied to the other six age decades. The randomization ensured that each dynamometer was used in 1st, 2nd and 3rd place an equal number of times. Participants were given a 30-second break between each attempt and a 5-minute break between each dynamometer, as recommended in the literature [33]. The tester was blinded until end of study, with one of the authors removing the dynamometer between each attempt, recording the result (kg to one decimal place), and resetting the device to zero before handing it back to the tester.

2.4. 30-sec STS

During the first 5-minute break, a 30-sec STS test was performed [7,34]. Participants were seated in the same chair as for HGS testing and instructed to sit in the middle of the chair with back straight, feet flat on the ground shoulder width apart, and arms crossed at the wrists over the chest and hands flat on the chest throughout the trial. During each valid repetition, the participants were instructed to extend their knees and hips when standing fully and to get down and touch the chair with their buttocks. Before the 30-sec STS test, the participants had two or three attempts at chair stands. Verbal instruction was given: "Do as many correct stand-ups as possible in 30 s. Are you ready? Ready, set, go!" No verbal encouragement was given during testing (see Appendix 2 for a full description of the 30-sec STS test). During the second 5-minute break, the EQ-5D-5L and EQ-VAS 0–100-point questionnaires were filled out by the participants.

2.5. Calibration

The Jamar+ and BIMS were new dynamometers, while Saehan had been used in clinical practice for some time and was not re-calibrated by the manufacturer before start of study. Calibration of the three dynamometers was tested with weights before, halfway through and after the complete series of tests. Weightlifting discs of 10, 20, 30 and 40 kg plus a strap were weighed on electronic scales (Seca GmbH & Co KG 704) and used for all three dynamometers. The average of three measurements per weight was used to calculate the difference between weights and for the subsequent assessment on the three dynamometers (see picture of the calibration setup in Appendix 3). Also, each dynamometer's average difference was calculated based on the mean score from all measurements. This control test showed that, over all assessments, BIMS, Jamar+ and Saehan gave an average difference of −0.1, 0.46 and 0.94 Kg, respectively, with respect to the electronically determined weight of the four discs (+strap). Because the Saehan dynamometer was used clinically before this study, and due to its lack of calibration, we decided not to include it in the comparison with the two other dynamometers, but still included it in the secondary assessment of participants' performance stability over the three attempts with each dynamometer.

2.6. Statistical analysis

Data distribution was tested visually with Q.Q-plots and on Kolmogorov-Smirnoff test; both indicated a normal distribution of all continuous variables. Accordingly, continuous data are presented as mean (SD) and analyzed with the appropriate statistics.

The highest value of the three assessments with each dynamometer was used to compare results. Corresponding analysis for systematic differences were made using the average of the three assessments for each dynamometer.

A repeated-measures ANOVA was used to assess systematic differences in participant performance over the three attempts with each of the three dynamometers. The intraclass correlation coefficient (ICC, 3.1) with 95% confidence interval (2-way mixed effects, absolute agreement, single rater/measurement), standard error of measurement ($SEM = SD * \sqrt{1-ICC}$, and SEM% = SEM/mean*100) and minimal detectable change ($MDC = 1.96 * \sqrt{2} * SEM$ and MDC% = MDC/mean) were used to assess agreement between the BIMS and Jamar+ dynamometers [21] and were illustrated in Bland–Altman plots. The SD used for calculation of the SEM was the pooled SD of all attempts. For interpretation of results, Koo et al. [35] used ICC values of 0.5, 0.5–0.75, 0.75–0.9 and >0.9, respectively, to indicate poor, moderate, good, and excellent relative reliability.

To establish the suitability of devices for clinical use through criterion validity [36], the following criteria were proposed: Bland-Altman plot showing minimal outliers and a narrow limits of agreement (LoA), ICC > 0.75, SEM% <10%, and a MDC percentage <30% [21].

An alpha value of 0.05 was set to determine significant difference. Bonferroni correction was used to correct for multiple comparisons by multiplying the p-value by the number of comparisons (in this case, 3) [37]. All statistical tests were performed using IMB SPSS statistics software, version 28.

3. Results

The 70 participants had a mean (SD) age of 54.2 (19.4) years; other characteristics are presented in Table 1. Physical activity level was high, with 83% fulfilling WHO recommendations for weekly physical activity. Correspondingly, EQ-5D-5L and EQ-VAS indicated high health-related quality of life. Mean overall HGS on BIMS, Jamar+ and Saehan was respectively 39.79 (11.0) kg, 39.11 (10.6) kg, and 38.71 (11.0) kg, and is presented stratified by gender in Table 1.

3.1. Agreement

3.1.1. Strongest of three HGS attempts

Using the strongest of the three attempts on the BIMS and Jamar+ dynamometers, the average difference between the two was 0.68 (2.2) kg ($p < 0.05$) (Table 2; Fig. 1A).

ICC between BIMS and Jamar+, overall and for women, was excellent (0.98) and only slightly lower in the subgroup comparison for men (ICC = 0.91) (Table 2). Overall SEM and SEM% was 1.64 kg and 4.2%, respectively (Table 2).

3.1.2. Average of three HGS attempts

Analysis of the average of the three attempts for each dynamometer showed a non-significant difference of 0.37 (2.29) kg ($p = 0.2$) between BIMS and Jamar+ (Table 3, Fig. 1B).

Subgroup analysis for men and women showed a similar pattern, with no significant difference between BIMS and Jamar+ (Table 3).

3.2. Secondary outcomes

Evaluation of performance stability for the three attempts for each dynamometer showed that participants, on average, performed their best at the first attempt and the poorest at the third (Fig. 2). A significant difference between attempts 1 and 3 was seen for all three dynamometers, with a mean difference of 1.72 (2.25) kg ($p < 0.001$), 1.26 (2.39) kg ($p < 0.001$), and 1.31 (3.62) kg ($p = 0.01$), respectively, for BIMS, Jamar+ and Saehan. Also, a significant difference of 1.01 kg ($p = 0.002$) was seen between BIMS attempts 1 and 2, where 42 (60%), 22 (31%) and 6 (9%) of participants performed their best at the 1st, 2nd and 3rd trials, respectively. Performances of the HGS and 30-sec STS results stratified by decade for all participants and for men and women separately are presented in Table 4. There was a significant association between HGS and STS performances for women ($r = 0.552$, $p < 0.001$) and men ($r = 0.366$, $p = 0.03$), using the strongest attempts with BIMS.

4. Discussion

4.1. Overall findings

We found excellent relative reliability, high agreement and low measurement error, with only a few outliers, between the BIMS and Jamar+ dynamometers. Thus, we consider that performance with the two dynamometers was comparable and acceptable for clinical practice and research, as differences in terms of SEM% and MDC% were below 10% at both group and individual level [21]. However, there was a small but systematic overall higher performance for BIMS compared to Jamar+ (mean 0.68 kg) using the strongest of three attempts, while no significant difference was seen using the average of three attempts.

4.2. Detailed comparison

The present differences between BIMS and Jamar+ match the findings of a study in 2000 by Mathiowetz et al. [38] comparing results of the hydraulic versions, with a mean difference of 1.08 and 1.1 kg for men and women, respectively, and corresponding ICCs of 0.95 and 0.94. Likewise, in 2019 Conforto et al. [33] evaluated intra-device agreement between a new electronic dynamometer (Labin) and the hydraulic Jamar, and reported an ICC of 0.91 for each, which was lower than the inter-device ICC of 0.98 in the present study. Absolute agreement was also better in the present study than the SEM% and MDC% values reported by Conforto et al.: respectively, 11% and 16% for Jamar and 16% and 19% for Labin [33].

The calibration test showed that, on average, Jamar+ measured 0.46 kg above the electronically determined weight, while BIMS measured −0.1 kg lower. The Jamar+ and BIMS devices were brand new dynamometers, and a variation of 0.56 kg over several calibration tests with different weight discs is considered acceptable. During the dynamic tests the BIMS measured an average 0.68 kg higher than Jamar+, using the strongest of the three attempts. A possible explanation for this could be the difference in the grip size and material of the dynamometers, the

Table 1
Characteristics and performances of participants, N = 70.

Variables	All (N.70)	Men (N.35)	Women (N.35)
Age (Years), mean (SD)	54.2 (19.4)	54.09 (19.7)	54.29 (19.4)
Hight (cm), mean (SD)	172.6 (8.9)	179.1 (5.5)	166.03 (6.6)
Weight (kg), mean (SD)	72.8 (12.6)	80.15 (10.8)	65.51 (9.8)
BMI, mean (SD)	24.4 (3.4)	25.02 (3.6)	23.72 (3.01)
Dominant hand:			
Right:	64 (91)	33 (94)	31 (89)
Left:	6 (9)	2 (6)	4 (11)
Smoker			
Yes	5 (7)	3 (8)	2 (6)
No	44 (63)	23 (66)	21 (60)
Ex-smoker	21 (30)	9 (26)	12 (34)
Comorbidity (possibly more than one):			
Heart disease	8 (11)	2 (6)	6 (17)
Diabetes	1 (1.4)	0 (0)	1 (3)
Rheumatic	6 (9)	4 (11)	2 (6)
Cancer	9 (13)	7 (20)	2 (6)
Psychological	3 (4.3)	2 (6)	1 (3)
None of above	49 (70)	24 (69)	25 (71)
Occupation:			
Inn work	32 (46)	17 (49)	15 (43)
Student	8 (11)	4 (11)	4 (11)
Retired	27 (39)	13 (37)	14 (40)
Job seeker	3 (4)	1 (3)	2 (6)
Days per week with sport, mean (SD)	2.8 (1.7)	2.83 (1.54)	2.8 (1.88)
Physical activity per week (sport):			
0 min (does not participate in sports)	7 (10)	3 (8)	4 (11)
Less than 30 min	3 (4)	0 (0)	3 (8)
30–59 min	4 (6)	2 (6)	2 (6)
60–89 min	4 (6)	2 (6)	2 (6)
90–119 min	14 (20)	6 (17)	8 (23)
120 min or more	38 (54)	22 (63)	16 (46)
Everyday activity per week:			
0 min (no activity)	0 (0)	0 (0)	0 (0)
Less than 30 min	1 (2)	1 (3)	0 (0)
30–59 min	3 (4)	2 (6)	1 (3)
60–89 min	8 (11)	5 (14)	3 (9)
90–119 min	7 (10)	2 (6)	5 (14)
120 min or more	51 (73)	25 (71)	26 (74)
Sitting during the day:			
Almost all day	0 (0)	0 (0)	0 (0)
13–15 h	4 (6)	3 (8)	1 (3)
10–12 h	9 (13)	5 (14)	4 (11)
7–9 h	20 (28)	10 (29)	10 (29)
4–6 h	27 (39)	10 (29)	17 (48)
1–3 h	10 (14)	7 (20)	3 (9)
Never	0 (0)	0 (0)	0 (0)
Physical activity questionnaire:			
Physical activity per week, 3–18 points, mean (SD)	15.17 (3.5)	15.6 (3.3)	14.7 (3.7)
Complies with WHO recommendations (≥11.0 points):			
Yes	58 (83)	31 (89)	27 (77)
No	12 (17)	4 (11)	8 (23)
EQ-5D-5L index, mean (SD)	0.957 (0.07)	0.961 (0.05)	0.954 (0.08)
EQ-VAS 0–100, mean (SD)	87.57 (9.4)	87.34 (9.1)	87.8 (9.7)
30-sec Sit-to-Stand test, number of stand-ups, mean (SD)	23.2 (7.2)	23.37 (7)	22.97 (7.4)
Hand grip strength (kg), mean (SD) of strongest attempt:			
Baseline BIMS	39.79 (11.0)	48.53 (6.8)	31.06 (6.6)
Jamar+	39.11 (10.6)	47.38 (6.6)	30.85 (6.6)
Saehan	38.71 (11.0)	47.19 (6.9)	30.24 (7.2)

Data are presented as numbers (%), unless otherwise stated. Standard Deviation (SD), Kilograms (kg), European Quality of Life - 5 Dimensions (EQ-5D-5L), European Quality - visual analogue scale (EQ-VAS).

grip circumference of BIMS being 0.2 cm larger than for Jamar+. Likewise, the texture on the BIMS grip creates slightly more friction than Jamar+. These differences in size and texture could explain the better results using BIMS compared to Jamar+, supported by the previous study comparing the hydraulic versions of the dynamometers [38]. This seemed to be especially the case for men, who generally have bigger hands than women, and on average performed around 1 kg better on the BIMS than the Jamar+, while minor differences were seen for women. Still, comparing the average of the three attempts, no significant differences were seen between BIMS and Jamar+.

4.3. Performance stability

Performance stability over the three trials indicated the participants' fatigue levels. The first attempt, with all three dynamometers, was significantly better (between 1.26 kg and 1.72 kg) than the third attempt. Thus, two attempts may be enough to obtain a person's maximum HGS. On the other hand, some participants performed their best on the 3rd attempt. This finding was supported by Reijnierse et al. in 2017 [39], who concluded that at least three HGS attempts are needed when used with a cut-off value to classify states such as dynapenia, as the

Table 2
Agreement, relative and absolute inter-instrument reliability for the comparison of the Baseline BIMS and Jamar+ dynamometers using the strongest of 3 attempts for each device.

	N	Mean (SD) of both	Mean diff. (SD)	SEM (%)	MDC (%)	$ICC_{3.1}$ (95%CI)
BIMS – Jamar+:						
All	70	39.45 (10.8)	0.68 (2.2)*	1.64 (4.2)	3.55 (9.0)	0.977 (0.962–0.986)
Men	35	47.95 (6.9)	1.15 (2.7)*	2.05 (4.3)	3.97 (8.3)	0.906 (0.805–0.954)
Women	35	30.95 (6.6)	0.21 (1.5)	1.03 (3.3)	2.81 (9.1)	0.976 (0.953–0.988)

Data are presented as kilograms (kg,), apart from the ICC values. Standard Deviation (SD), Standard Error of Measurement (SEM), Minimal Detectable Change (MDC), Intraclass Correlation Coefficient (ICC).
* $P < 0.05$.

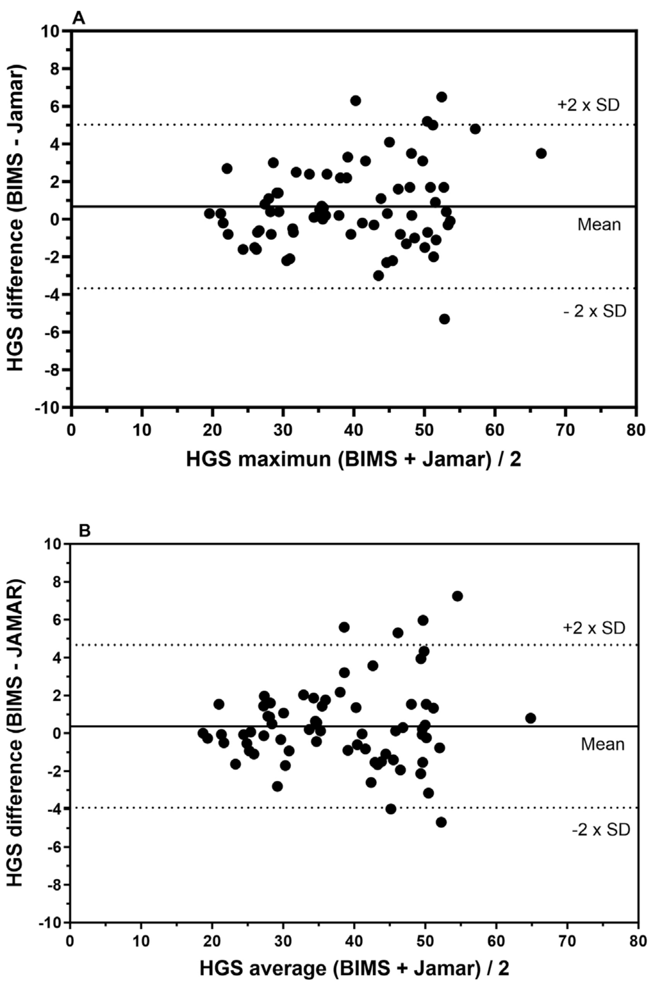

Fig. 1. Bland-Altman plot of the maximum (A) and average (B) HGS performance of the 2 dynamometers.

number of subjects misclassified with only two attempts was too high [39]. Further, there is also some disagreement in the literature about the adequate rest time between attempts in the HGS test. In 2005, Watanabe et al. [40] concluded that a 1-minute break was sufficient to maintain maximal HGS in three attempts, while, in 1985, Reddon et al. [41] reported a significant decrease in HGS over 10 attempts with a 30-second break, although only 12 subjects were tested. In contrast, in 1990, Mathiowetz et al. [42] found no decrease in HGS over three trials with a 15-second rest period, while Conforto et al., in 2019 [33], used a 30 s break, as in the present study. Taken together, these findings indicate a need for further evaluation of break-time between attempts for subjects to perform their best.

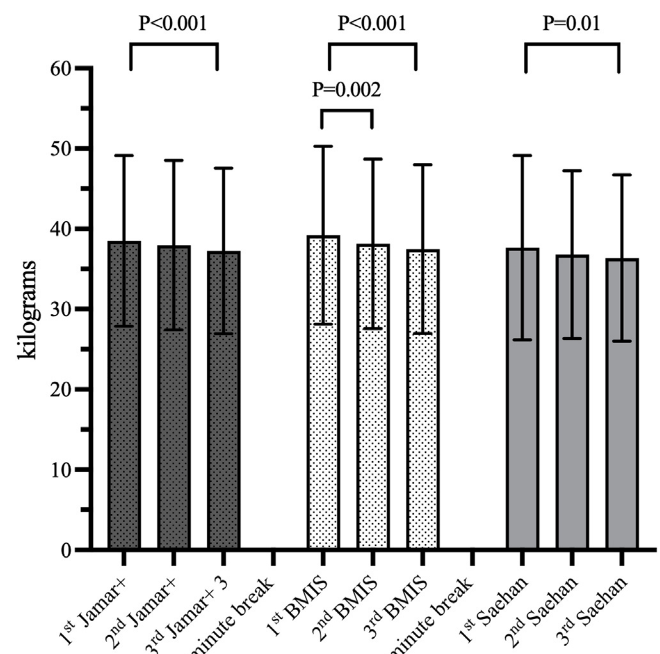

Fig. 2. Performance stability using the strongest of 3 attempts for each of the 3 dynamometers.

Table 3
Agreement, relative and absolute inter-instrument reliability for the comparison of the Baseline BIMS and Jamar+ dynamometers using the average of 3 attempts for each device.

	N	Mean (SD) of both	Mean diff. (SD)	SEM (%)	MDC (%)	$ICC_{3.1}$ (95%CI)
BIMS – Jamar+:						
All	70	38.08 (10.5)	0.37 (2.3)	1.10 (2.9)	2.9 (7.6)	0.989 (0.982–0.993)
Men	35	46.35 (6.3)	0.64 (2.8)	1.42 (3.1)	3.3 (7.1)	0.949 (0.899–0.974)
Women	35	29.82 (6.5)	0.10 (1.2)	0.62 (2.1)	2.2 (7.4)	0.991 (0.982–0.995)

Data are presented as kilograms (kg,), apart from the ICC values. Standard Deviation (SD), Standard Error of Measurement (SEM), Minimal Detectable Change (MDC), Intraclass Correlation Coefficient (ICC).

Table 4
Handgrip strength measured with Baseline BIMS Digital Grip Dynamometer (strongest of three attempts) and the 30-second Sit-to-Stand test, overall, by gender, and by age decade (5 men and 5 women in each).

Age decade	Handgrip Strength, kg			30-sec Sit-To-Stand Test, number of stand-ups		
	All, N = 70	Men, n = 35	Women, n = 35	All, N = 70	Men, n = 35	Women, n = 35
3rd Decade (18–29 years)	42.03 (10.2)	50.30 (3.5)	33.76 (7.1)	33.5 (4.0)	34.8 (1.3)	32.2 (5.4)
4th Decade (30–39 years)	40.85 (9.4)	47.92 (4.2)	33.78 (7.5)	26.6 (5.2)	25.8 (6.1)	27.4 (4.7)
5th Decade (40–59 years)	45.70 (11.9)	55.50 (8.4)	35.9 (3.1)	26.3 (4.1)	26 (2.6)	26.6 (5.6)
6th Decade (50–59 years)	42.29 (10.3)	50.98 (3.2)	33.6 (6.4)	20.8 (3.8)	18.6 (3.4)	23.0 (2.9)
7th Decade (60–69 years)	39.20 (10.3)	47.80 (4.2)	30.6 (6.1)	19.4 (5.9)	20.4 (6.8)	18.4 (5.3)
8th Decade (70–79 years)	35.58 (10.9)	44.76 (6.6)	26.4 (3.3)	20.4 (5.2)	21.6 (3.6)	19.2 (6.7)
9th Decade (≥80 years)	32.90 (11.9)	42.44 (9.0)	23.56 (3.5)	15.2 (3.7)	16.4 (4.6)	14.0 (2.6)

Data are presented as mean (SD).

4.4. Participants

There were 5 men and 5 women in each of the 7 decade groups, from 18–29 to +80 years, as in a similar study evaluating agreement between two shoulder strength dynamometers [29].

83% of participants in the present study fulfilling WHO recommendations for weekly physical activity, and this should be considered when interpreting both the HGS and the 30-sec STS test performances. Thus, a recent study of younger patients with hip fracture showed a moderate association between weekly physical activity and HGS [32]. The HGS and 30-sec STS performances, although slightly better in the present study, were comparable to population-based reference values for Danish subjects according to Suetta et al. [14], who reported mean HGS of 46.98 (10.22) kg and 29.17 (7.75) kg for men and women respectively using Jamar+, in comparison to 47.38 (6.6) kg and 30.85 (6.6) kg in the present study. On the 30-sec STS test, Suetta et al. reported a mean 21.31 (7.16) chair stands for men and 20.30 (7.46) for women, compared to respectively 23.37 (7.0) and 22.97 (7.4) in the present study. However, the small number of participants in each decade in the present study calls for caution in interpreting these comparisons. Furthermore, the present series comprised active subjects with no functional or neurological impairment and the results cannot be directly extrapolated to individuals with physical disabilities or medical conditions.

4.5. Strengths and limitations

One strength of the study was the use of standardized procedures (Appendices 1 and 2) recommended in Denmark for HGS and STS testing [34], and similar to international recommendations [27]. This was reinforced by using the same chair and setup for all participants, with the same tester providing instructions in all cases. Another strength was the blinding of the tester and participants until end of the study, which ensured constant motivation for all tests.

One limitation could be that the dynamometers did not undergo calibration by the manufacturers before being used in the study, but both the Jamar+ and the BIMS were brand new products and could therefore be considered calibrated by manufacturer on purchase. Another limitation was that we did not ask participants, independently of their results, which of the dynamometers they felt most comfortable using, as was done in the study by Conforto et al. [33]. This could have provided useful information regarding our hypothesis regarding the influence of the BIMS grip, improving performance, especially for men, compared to the Jamar+.

5. Conclusion

A strong agreement with low measurement error was found between BIMS and Jamar+ for measuring HGS in adults with no functional or neurological impairment, indicating high criterion-related validity and agreement for these dynamometers. Although minor differences were found, the present findings indicate that the results using these two dynamometers are comparable and can be used interchangeably. We suggest that future research should investigate how long the optimal rest time is for the HGS test, as there is no clear evidence.

Human and animal rights

The authors declare that the work described has been carried out in accordance with the Declaration of Helsinki of the World Medical Association revised in 2013 for experiments involving humans as well as in accordance with the EU Directive 2010/63/EU for animal experiments.

Informed consent and patient details

The authors declare that they obtained a written informed consent from the patients and/or volunteers included in the article and that this report does not contain any personal information that could lead to their identification.

Disclosure of interest

The authors declare that they have no known competing financial or personal relationships that could be viewed as influencing the work reported in this paper.

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Author contributions

All authors attest that they meet the current International Committee of Medical Journal Editors (ICMJE) criteria for Authorship.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.hansur.2024.101692.

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