GRIP WORK MEASUREMENT WITH THE JAMAR DYNAMOMETER: VALIDATION OF A SIMPLE EQUATION FOR CLINICAL USE

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Abstract: *Objectives:* Previously, we developed and validated an easy test to measure muscle fatigability during sustained maximal handgrip contraction in older persons using a Martin Vigorimeter device. This study aimed at validating the equation to estimate grip work (GW) during sustained maximal handgrip contraction, by monitoring continuously the grip strength (GS) decay using a Jamar Dynamometer-like (JD) device. *Design:* Cross sectional, explorative study. *Setting:* Data collection took place at The National Research Centre for the Working Environment in Copenhagen, Denmark. *Participants:* 962 subjects, belonging to a subgroup of the Copenhagen Aging and Midlife Biobank, were enrolled. *Methods:* GS was recorded continuously during sustained maximal contraction until it dropped to 50% of its maximum and fatigue resistance (FR, time to fatigue) was noted. GW, area under the force-time curve, was compared to its estimate which was calculated as $GW_{estimated}=GS_{max}*0.75*FR$. *Results:* Excellent correlation was found between $GW_{estimated}$ and $GW_{measured}$ (R^2=0.98 p<0.001). The equation slightly overestimated GW by 6.04 kg*s (95% CI[-0.08, 12.15]) with a coefficient of variation method error of 6%. *Conclusion:* GW estimation is a valid parameter reflecting muscle work output during a sustained maximal grip effort in healthy middle-aged community-dwelling persons when using a JD. GW estimation is a promising outcome parameter in comprehensive geriatric assessment and its validation for commonly used instruments in geriatric practice will increase its clinical implementation.

Key words: Grip work, validity, Jamar Dynamometer, muscle fatigue, grip strength.

Introduction

Due to sarcopenia, older persons function is closer to their maximal physical capacity. Consequently, continuing and completing functional tasks necessitate sustained muscle contractions at a nearly maximal intensity, leading to muscle fatigue. Increased muscle fatigability might explain the occurrence of fatigue, one of the major characteristics of frailty in older persons. Assessment of fatigability may serve an alternative clinical tool providing a more precise identifier of older people in risk of rapid decline in physical function. Muscle fatigability can be easily assessed in older patients by measuring the time during which grip strength (GS) drops to 50% of its maximum during a sustained maximal contraction (fatigue resistance, FR)[1]. FR allows the calculation of grip work (GW, $GW=GS_{max}*0.75*FR$)[2] which is a parameter reflecting the work output delivered by the muscles during the fatigue test. FR (time to fatigue) and GW are developed and validated for the Martin Vigorimeter (1-8) (MV; KLS Martin Group, Tuttlingen, Germany), a device consisting of a rubber bulb connected via a rubber airtight junction to a manometer. However, many researchers and clinicians use more classic devices such as the Jamar Dynamometer (JD; Sammons Preston, Rolyon, Bolingbrook, IL), which is designed to measure isometric GS and is characterized by its rigid iron handle. GS measures obtained by the MV have been shown to be well correlated with those obtained with the JD[9]. Although FR is now being used by several researchers and clinicians using JD (10, 11), the GW equation – which is based on the assumption that the strength drop during the FR test is linear – is not yet been validated for the JD. Thus this study aimed at validating the equation to estimate GW during sustained maximal handgrip contraction, by monitoring continuously the GS decay using a JD-like device (dynamometer G100 system, Biometrics Ltd, Newport, UK).

Methods

Participants

This study included 962 subjects, belonging to a subgroup of the Copenhagen Aging and Midlife Biobank (CAMB), which has been described extensively elsewhere (12). In summary, CAMB is based on a merger of 3 established cohorts: the Metropolit Cohort (MC) (10171 men born in Copenhagen in 1953), the Copenhagen Perinatal Cohort (CPC) (8102 men and women born at the National University Hospital in Copenhagen in 1959-61) and the Danish Longitudinal study on Work, Unemployment and Health (DLWUH) (11082 men and women, born 1949 and 1959, constituting a random sample of the Danish population in 1999). When these cohorts were merged, 4604 individuals had died or had previously asked to be excluded from cohort follow-ups. This left 24751 persons

eligible for invitation into CAMB, but 6814 individuals (28% of those eligible) who lived in the Western part of Denmark (too far from the study clinic) were excluded. Thus 17937 persons were invited to participate in CAMB. A total of 5575 participants (31%) came to a study clinic for physical testing. Compared to non-participants, CAMB participants did not differ substantially with regard to educational level (except that there were fewer persons with few years of education and more with higher education compared with non-participants) and the two groups are comparable in overall health (except that the all-cause mortality was higher among non-participants in the period April 2009 to December 2012) (12). Muscle endurance was measured with a JD-like device in a subset of 962 subjects of the cohort who were consecutively enrolled between November 2010 and March 2011. The local ethical committee has approved the CAMB as a database combining the 3 cohorts (No: H-A-2008-126). CAMB has also been registered at the Danish Data Protection Agency as a combined database (No: 2008-41-2938).

### Grip strength, fatigue resistance and grip work

All handgrip tests were executed with the dominant hand using a JD G100 system, consisting in an adjustable handgrip handle (standard JD configuration) equipped with in-build compression load cell (capacity=0-90kg, accuracy=<1% of rated load) and connected via a strain gauge amplifier (National Instruments, type SCC-SG24) to a computer. This device allows continuous monitoring and recording of the force exerted on the handgrip handle. All data were sampled at 100Hz (low pass filtered, 10Hz) and stored on a computer for further analysis. The system was calibrated prior to the start and checked during the study by applying a 20 kg load to the JD handle. Before each assessment session a zero-calibration was performed in order to adjust for environmental conditions (ambient temperature). In order to avoid in-between assessment zero-calibrations, the handgrip handle was calibrated in position 2 (middle grip position) and maintained in that position for all participants. GS, FR and GW were assessed as described previously (1, 2). Subjects were asked to squeeze the handle as hard as possible for 3 times with 30 seconds interval. Afterwards, subjects were instructed to maintain this maximal pressure as long as possible. The time (in seconds) during which GS dropped to 50% of its maximum was recorded as FR and the maximal GS value reached during the test as GSmax. GW, a parameter reflecting the total effort produced during the FR test, was first estimated as described previously (2, 5). This parameter (equation 1) corresponds to the area under the curve when assuming a linear decrease of the GS during the FR test (figure 1):

$$GW_{estimated}=GS_{max}*0.75*FR \quad (equation\ 1)$$

With GWestimated=estimated grip work, GSmax=maximal grip strength (in kg), FR=fatigue resistance (time in seconds during which GS dropped to 50% of its maximum).

Figure 1
Schematic presentation of GW (A) and the strength drop during a sustained maximal contraction for a randomly selected participant (B). A: FR=fatigue resistance: the time during which GS decreases to 50% of its maximum value. The bold line represents the estimate of the evolution of GS with time during sustained contraction. GW is calculated as FR multiplied by 75% of the GSmax, corresponding to the area under the curve (gray shaded) (2). B: the strength drop during a sustained maximal contraction for a randomly selected participant. The black line connects the GSmax with 50% of its maximum value (linear pattern)
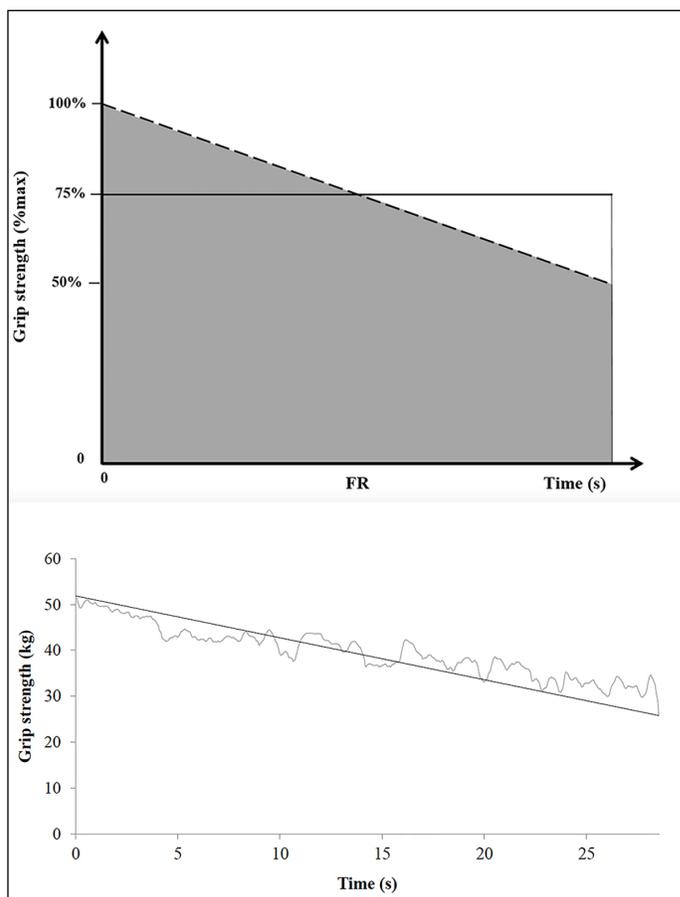
The observed area under the curve was calculated by integrating the actual GS at each time interval (i.e. 0.01 second) based on the measurements recorded during the drop of GS to 50% of its maximum value (equation 2).

$$GW_{measured}=\sum_{(GSmax-GS50\%)}GS*t \quad (equation\ 2)$$

With GWmeasured=real grip work, GS=grip strength, t=time-interval (at 100Hz=0.01 second), GSmax=maximal grip strength, GS50%=50% of GSmax.

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Table 1

Participants' characteristics

| Parameter | Males | | | Females | |
	MC N=175	DALWUH N=41	CPC N=319	DALWUH N=59	CPC N=368
Age (y)	57.9±0.3[a,b]	56.6±5.1[b]	50.1±0.8	56.8±5.1[b]	50.0±0.8
Height (m)	1.8 (1.8-1.8)	1.8 (1.7-1.8)[c]	1.8 (1.8-1.8)[c]	1.7 (1.6-1.7)	1.7 (1.6-1.7)
Body mass (kg)	85.7±14.7	83.7±14.3[c]	86.9±15.0[c]	71.5±14.4	71.0±14.0
GSmax (kg)	43.7±8.4[a,b]	47.3±8.2[c]	48.0±8.5[c]	27.9±5.5	29.5±5.5
FR (s)	33.4 (24.3-44.6)	35.2 (26.9-46.1)	34.6 (27.0-47.2)	33.7 (20.4-48.6)	36.3 (25.4-53.7)
GWmeasured (kg*s)	1176.6 (834.3-1573.5)[b]	1251.6 (976.3-1726.1)[c]	1335.5 (975.8-1744.6)[c]	735.6 (436.7-1022.2)	804.2 (529.1-1147.2)
GWestimated (kg*s)	1122.1 (759.8-1591.2)[b]	1218.5 (885.2-1745.0)[c]	1277.0 (919.2-1733.1)[c]	726.9 (439.3-1052.5)	806.3 (512.1-1152.9)

Values expressed as mean ± SD for continuous variables with normal distribution and as median (P25-P75) for continuous variables with not-normal distribution; MC=Metropolitan Cohort; DALWUH=Danish Longitudinal Study on Work Unemployment and Health; CPC=Copenhagen Perinatal Cohort; significantly different from aDALWUH, bCPC (One-way ANOVA with Bonferroni post-hoc test for male and unpaired t-test for female for continuous variables); csignificantly different from female participants (unpaired t-test for continuous variables, p<0.05)

Data processing and statistical analysis

The Statistical Package for the Social Sciences (SPSS version 25; Chicago, Ill., USA) was used for all analyses. Values are reported as mean ± SD for continuous variables with normal distribution and as median (P25-P75) for continuous variables with not-normal distribution. Differences between groups were assessed by one-way analysis of variance (ANOVA) and Bonferroni post-hoc testing for males and unpaired t-test for females for continuous variables. Differences between male and female participants were assessed by an unpaired t-test for continuous variables. Significance was set a priori at p<0.05.

Validation analysis of the GWestimated (as calculated by equation 1) consisted in comparison with GWmeasured (as calculated by equation 2) using Spearman's correlation coefficient, the calculation of the mean difference and 95% confidence intervals, the calculation of the method error (ME, ME=SD/√2 with SD=standard deviation of the difference scores between estimated and GWmeasured) and its associated coefficient of variation (CVME, CVME=2*ME/[mean GWestimated + mean GWmeasured]).

Results

Participants' characteristics are shown in table 1. Figure 1B shows the strength drop during sustained maximal contraction for a randomly selected participant. As can be seen, the GS decay followed an almost linear pattern. As shown in figure 2, an excellent correlation was found between GWestimated and GWmeasured for all participants as well as for each subgroup separately. Next to the Spearman's correlation, we also performed a Deming regression analysis - taking increasing variances with measured grip force into account- which gave fairly equal results (R2 = 0.94 compared to 0.98 when using Spearman's correlation coefficient).

In general, the mean difference between both calculations for GW was 6.04 kg*s (95% CI[-0.08, 12.15]) with a CVME of 6% (ME=68.36).

Figure 2

Validity of GW estimation during sustained maximal contraction; GW (corresponding to the area under the curve in a force-time plot during the FR test) was estimated based on a simplified formula (equation 1) as described previously (2, 5, 7). The real GW was calculated based on the actual GS measured at 100Hz using a digital pressure gauge (equation 2). Triangles represent males participated in MC study (n=175), vertical dashes represents participants of the DALWUH study (black = males n=41; gray=female n=59) and horizontal dashes represents participants of the CPC study (black=males n=319; gray = female n=368). Excellent correlation was found between both measures (r=0.99 for respectively all participants, MC males, DALWUH males, CPC males, DALWUH females and CPC females; all p<0.001)
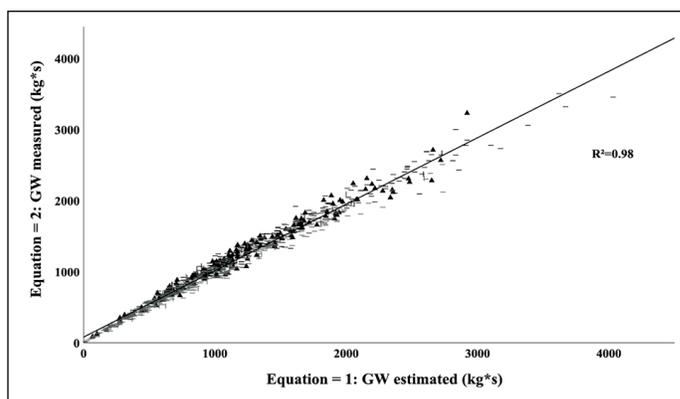
Discussion

The objective was validating an equation to estimate GW during sustained maximal handgrip contraction using the JD as a measure of muscle fatigability. The excellent correlation between GWestimated and GWmeasured in our sample of 962 subjects, as well as for each subgroup separately confirms the validity of our equation. Only a slight overestimation of 6.04 kg*s (95% CI[-0.08, 12.15], CVME=6%) was noted, which can be considered as acceptable. Previously (7) we found similar results for the MV where we observed an overestimation of GW of 247.69 kPa*s (95% CI[-614.98, 1110.36]; CVME=10%). The lower CVME observed in the current study could be related to the fact that here a homogeneous group consisting of primarily healthy community-dwelling middle aged persons was enrolled, while in our previous study we used a diverse sample of young (23±3 years) and older (74±5 years) subjects as well as hospitalized geriatric patients (83±5 years). In addition, recently (6) we reported differences in strength decay during a sustained maximal handgrip effort according to age and clinical condition. Finally, the fact that data was sampled at 100Hz for the JD, compared to 1Hz in the study for the MV might have allowed a more accurate continuous monitoring and recording of the strength decay and consequently a lower ME.

Conclusion

Based on the results of this study we can conclude that GW estimation is a valid parameter reflecting muscle work output during a sustained maximal grip effort in healthy middle-aged community-dwelling persons when using a JD. The results of our current study confirm the validity of our equation, when using another often used handgrip device, namely the Jamar Dynamometer. We believe that the grip work estimation is a promising outcome parameter in comprehensive geriatric assessment and its validation for commonly used instruments in geriatric practice will increase its clinical implementation.

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