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Assessment of maximal handgrip strength: how many attempts are needed?

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Abstract

Background Handgrip strength (HGS) is used to identify individuals with low muscle strength (dynapenia). The influence of the number of attempts on maximal HGS is not yet known and may differ depending on age and health status. This study aimed to assess how many attempts of HGS are required to obtain maximal HGS.

Methods Three cohorts (939 individuals) differing in age and health status were included. HGS was assessed three times and explored as continuous and dichotomous variable. Paired *t*-test, intraclass correlation coefficients (ICC) and Bland–Altman analysis were used to test reproducibility of HGS. The number of individuals with misclassified dynapenia at attempts 1 and 2 with respect to attempt 3 were assessed.

Results Results showed the same pattern in all three cohorts. Maximal HGS at attempts 1 and 2 was higher than at attempt 3 on population level ($P < 0.001$ for all three cohorts). ICC values between all attempts were above 0.8, indicating moderate to high reproducibility. Bland–Altman analysis showed that 41.0 to 58.9% of individuals had the highest HGS at attempt 2 and 12.4 to 37.2% at attempt 3. The percentage of individuals with a maximal HGS above the gender-specific cut-off value at attempt 3 compared with attempts 1 and 2 ranged from 0 to 50.0%, with a higher percentage of misclassification in middle-aged and older populations.

Conclusions Maximal HGS is dependent on the number of attempts, independent of age and health status. To assess maximal HGS, at least three attempts are needed if HGS is considered to be a continuous variable. If HGS is considered as a discrete variable to assess dynapenia, two attempts are sufficient to assess dynapenia in younger populations. Misclassification should be taken into account in middle-aged and older populations.

Keywords Muscle strength; Sarcopenia; Aged; Geriatric assessment; Reproducibility of Results

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Introduction

Handgrip strength (HGS) is frequently measured as a proxy for global muscle strength. Low muscle strength, also known as dynapenia, is highly prevalent in old age.[1] Approximately 25% of all 80 year olds have a HGS of more than 2.5 standard deviations (SD) below the gender-specific peak mean of HGS in a general population.[2] Dynapenia is associated with cognitive decline, impaired functional status and mortality,[3] and is therefore an important indicator of health status.[4] In addition, HGS is one of the diagnostic criteria for sarcopenia, which is also highly prevalent in the older aged.[5–7]

A standardized protocol measuring maximal HGS is currently lacking, leading to considerable variation in assessments.[8,9] Most studies take between one and three repeated measurements of HGS and report the maximal effort. The risk with taking too few measurements is that an individual may be misclassified as dynapenic. Few studies have examined the influence of the number of attempts on maximal HGS; these have generally been performed in patients with hand trauma[10,11] or in healthy adults.[12,13] In an older community-dwelling population, one attempt was found to be sufficient to determine maximal HGS, which significantly decreased after more attempts.[14] However, this result was based on population level using intraclass correlation coefficients (ICC) and did not take individual variance into account. Furthermore, the optimal number of HGS attempts may differ depending on age, health status and on the use of HGS as a discrete (cut-off value, mostly for clinical use) or continuous variable (for research).

This study aimed to assess how many attempts of HGS are required to obtain an optimal estimate of maximal HGS in three cohorts: young and old healthy individuals from the MyoAge cohort, middle-aged and old individuals from the Grey Power cohort, and geriatric outpatients.

Methods

Study design

This study included three cross-sectional cohorts-based studies including 939 individuals with different age and health status. This study has been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

MyoAge cohort

The European multicenter MyoAge study included healthy young (n = 182, aged between 18 and 30 years) and old individuals (n = 322, aged between 69 and 81 years). Study rationale and design have been described in detail elsewhere.[15] Exclusion criteria were aimed to ensure a selection of healthy individuals free from major diseases: dependent living status, inability to walk a distance of 250 m, morbidity (neurologic disorders, metabolic diseases, rheumatic diseases, recent malignancy, heart failure, severe chronic obstructive pulmonary disease and coagulation disorders), use of specific medication (immunosuppressive drugs and insulin), immobilization for one week during the previous 3 months and orthopaedic surgery during the past 2 years or still causing pain or functional limitation. Physical assessments were performed at local study centers according to unified and standardized operation procedures. For the present analyses, data from the Netherlands (Leiden), Finland (Jyvaskyla), France (Paris) and the UK (Manchester) were included. Data from Estonia were excluded because HGS was only performed on the right-hand side. Local medical ethical committees of the participating medical centers approved the study, and all individuals gave written informed consent.

Grey Power cohort

The Grey Power cohort included 256 community-dwelling (aged between 20 and 91 years) individuals recruited from the Grey Power debate events, which took place in November 2014 at the VU University Medical Center, Amsterdam, the Netherlands. The Grey Power debates were freely accessible lectures for the general population to promote healthy ageing. Visitors were offered to participate in the Grey Power study to test age-related and muscle-related parameters and physical activity. No exclusion criteria were applied. For the present analyses, the cohort was divided into middle-aged individuals (n = 173) and old individuals (n = 89) using a cut-off value of 70 years. Because of missing HGS data, two middle-aged individuals and three old individuals were excluded. This study was reviewed and approved by the Medical Ethical Committee of the VU University Medical Center (Amsterdam, the Netherlands). All individuals gave written informed consent.

Geriatric outpatients

This cohort consisted of 299 geriatric outpatients (aged between 48 and 97 years) who were consecutively referred to a middle-sized teaching hospital (Bronovo Hospital, The Hague, the Netherlands) between March 2011 and January 2012 for mobility problems. No exclusion criteria were applied; inclusion was based on referral. A comprehensive geriatric assessment (CGA) was performed by trained nurses and medical staff, including questionnaires and measurements of physical and cognitive performance. For the present analyses, 19 outpatients (6.4%) were excluded because of missing HGS data. The need for individual informed consent was waived by the Medical Ethical Committee of the Leiden University Medical Center (Leiden, the Netherlands).

Characteristics of the different cohorts

Age, gender, presence of diseases and use of medication were assessed by questionnaires in the MyoAge cohort and Grey Power cohort and by medical charts in geriatric outpatients. Living status was assessed in the MyoAge cohort and in geriatric outpatients but not in the Grey Power cohort. Independent living status was defined as not living in an assisted home or nursing home. In all cohorts, body weight was assessed to the nearest 0.1 kg and height to the nearest 0.1 cm. Body composition was measured using dual-energy X-ray absorptiometry in the MyoAge cohort (UK: Lunar

Prodigy Advance, version EnCore 10.50.086; France: Lunar Prodigy, version EnCore 12.30; the Netherlands: Hologic QDR 4500, version 12.4; Finland: Lunar Prodigy, version EnCore 9.30) and using direct segmental multi-frequency bioelectrical impedance analysis (DSM-BIA) in the Grey Power cohort (In-Body 230; Biospace Co., Ltd, Seoul, Korea) and in geriatric outpatients (In-Body 720; Biospace Co., Ltd, Seoul, Korea). DSM-BIA has been shown to be a reliable measure for body composition compared with dual-energy X-ray absorptiometry.[16] In the geriatric outpatients, data on body composition was available in 144 consecutive outpatients because of a protocol amendment in which the DSM-BIA was added at a later stage. Gait speed was assessed using the 6 min walking test in the MyoAge cohort[15] and using the timed 4 m walking test in the Grey Power cohort and in geriatric outpatients. During the 4 m walking test, individuals were asked to walk at normal pace from a standing start. Gait speed was expressed in meters per second.

Assessment of handgrip strength

Handgrip strength was assessed three times on each hand alternately using the Jamar hand-held hydraulic dynamometer (Jamar hand dynamometer; Sammons Preston, Inc., Bolingbrook, IL, USA). Handle width was adjusted to hand size. Individuals were standing with their arms parallel to their trunk and were encouraged to squeeze the dynamometer as hard as possible. The following variables of HGS were used for analysis: (i) maximal HGS at attempt 1, (ii) maximal HGS at attempt 2, (iii) maximal HGS at attempts 1 and 2; and (iv) maximal HGS at attempt 3. Maximal HGS of the different attempts were of either the right-hand or left-hand side. Results are not stratified by dominant hand because it is known that maximal HGS is not always reached in the dominant hand.[17]

Statistical analysis

Continuous variables with a Gaussian distribution were presented as mean (SD) and those with non-Gaussian distribution as median [interquartile range (IQR)]. A paired Student's *t*-test was performed to compare HGS between attempt 1 vs. attempt 2, attempt 1 vs. attempt 3, attempt 2 vs. attempt 3 and maximal HGS at attempts 1 and 2 vs. attempt 3. A two-tailed *P*-value of less than 0.05 was considered statistically significant.

Single measure ICC were calculated to assess the reproducibility of HGS between attempt 1 vs. attempt 2, attempt 1 vs. attempt 3, attempt 2 vs. attempt 3, maximal HGS at attempts 1 and 2 vs. attempt 3 and attempt 1 vs. maximal HGS at attempts 1, 2 and 3. ICC values were calculated using a two-way mixed model of absolute agreement.[18] ICC values below 0.8 were considered insufficient, values between 0.8 and 0.9 were considered moderate and values above 0.9 were considered high.[19] Bland–Altman plots were used to assess the reproducibility of HGS at the individual level.[20] Mean differences were calculated with the 95% limits of agreement (LOA) (mean difference $\pm$ 1.96 SD). The number of individuals with a higher HGS at attempt 2 compared with attempt 1 was calculated and the number of individuals with a higher HGS at attempt 3 compared with the maximal HGS at attempts 1 and 2.

Finally, the influence of the number of attempts on the diagnosis of dynapenia was examined. Dynapenia was defined using gender-specific cut-off values; male $<$ 30 kg, female $<$ 20 kg.[21] Misclassified as dynapenic was defined as a maximal HGS below the gender-specific cut-off value at attempts 1 and 2 but a HGS above the gender-specific cut-off value at attempt 3, dependent on the order of attempts. True-positives were defined as those classified as dynapenic at any of the 3 attempts, but above the gender-specific cut-off value on at least one of the three attempts, independent on the order of attempts.

Data were analysed using STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES, version 23 (SPSS Inc. Chicago, IL, USA). Visualization was performed using GRAPHPAD PRISM 5.01.

Results

Characteristics of the different cohorts

Table 1 shows the characteristics of the three different cohorts, stratified by age. The prevalence of multimorbidity was higher in older age. Polypharmacy was more present in geriatric outpatients compared with the other cohorts. Gait speed and HGS were lower in geriatric outpatients compared with the other cohorts. The majority of the individuals was right-handed. Maximal HGS was reached by the dominant hand in 59.6 to 79.9% of the individuals.

Reproducibility at population level in three cohorts

Handgrip strength at attempt 1 was higher than at attempt 2 in healthy old individuals from the MyoAge cohort ($P < 0.01$) and not statistically significant higher in the other cohorts. Maximal HGS at attempts 1 and 2 was higher than the HGS at attempt 3 in all cohorts: on average, 1.5 kg in healthy young individuals and 0.6 kg in healthy old individuals (MyoAge cohort), 1.3 kg in middle-aged individuals and 1.1 kg in old individuals (Grey Power cohort), and 0.9 kg in geriatric outpatients ($P < 0.001$ for all cohorts). Supporting Information *Figure* S1 shows maximal HGS of either the right-hand or left-hand side of the three cohorts on population level, stratified

Table 1 Characteristics of the three cohorts, stratified by age

	MyoAge cohort		Grey Power cohort		Geriatric outpatients
	Healthy young $n = 139$	Healthy old $n = 258$	Middle-aged $n = 173$	Old $n = 89$	$n = 280$
Sociodemographics					
Age, years, median [IQR]	22.9 [21.0–25.4]	73.7 [71.7–77.1]	62.6 [52.9–66.7]	74.5 [72.5–78.1]	82.8 [78.3–87.2]
Male, *n* (%)	67 (48.2)	130 (50.4)	55 (31.8)	34 (38.2)	96 (34.3)
Independent living, *n* (%)	139 (100)	258 (100)	n/a	n/a	227 (82.2)
Health characteristics					
Multimorbidity[a], *n* (%)	0	38 (14.7)	15 (8.7)	20 (22.5)	94 (35.5)
Polypharmacy[b], *n* (%)	0	22 (8.5)	4 (2.3)	10 (11.4)	151 (56.1)
Body composition					
BMI, kg/m^2	22.8 (3.0)	25.4 (3.3)	25.1 (3.7)	26.2 (3.8)	25.9 (4.5)
Fat mass, %	23.1 (9.4)	30.4 (8.1)	28.3 (8.5)	32.5 (8.0)	30.5 (10.8)
Physical performance					
Gait speed, m/s	1.85 (0.33)	1.50 (0.22)	1.46 (0.20)	1.39 (0.21)	0.73 (0.27)
Handgrip strength, kg					
Males	52.8 (10.0)	40.4 (7.7)	48.4 (10.1)	38.7 (9.5)	33.5 (6.4)
Females	33.7 (4.9)	25.9 (5.0)	31.8 (6.4)	27.0 (6.1)	21.0 (4.9)
Hand dominance					
Right-handed, *n* (%)	81 (89.0)[c]	159 (97.0)[d]	151 (87.3)	83 (93.3)	249 (90.5)[e]
Max. $HGS_{dominant}$[f], *n* (%)	68 (74.7)[c]	131 (79.9)[d]	123 (71.1)	53 (59.6)	164 (59.6)[e]

All values are presented as mean (SD) unless indicated otherwise. IQR, interquartile range, BMI, body mass index; HGS, handgrip strength.
[a]Defined as ≥2 diseases including: MyoAge cohort—hypertension, cardiovascular events, noninsulin-dependent diabetes mellitus, mild chronic obstructive pulmonary disease (COPD), osteoarthritis, arterial surgery and thyroid disease; Grey Power cohort and geriatric outpatients—hypertension, myocardial infarction, stroke, diabetes mellitus, COPD, cancer, Parkinson's disease and rheumatoid arthritis/osteoarthritis.
[b]Defined as ≥5 medicaments.
Data available in a subgroup of
[c]$n = 91$,
[d]$n = 164$,
[e]$n = 275$.
[f]Maximal HGS reached by the dominant hand.

Table 2 Intraclass correlation coefficients and mean differences between maximal handgrip strength, stratified by cohort and age

	MyoAge cohort		Grey Power cohort		Geriatric outpatients
	Healthy young $n = 139$	Healthy old $n = 258$	Middle-aged $n = 173$	Old $n = 89$	$n = 280$
ICC (95% CI)					
Attempt 1 vs. 2	0.96 (0.95–0.97)	0.97 (0.96–0.98)	0.95 (0.94–0.97)	0.96 (0.94–0.98)	0.94 (0.93–0.96)
Attempt 1 vs. 3	0.95 (0.93–0.96)	0.96 (0.95–0.97)	0.95 (0.93–0.96)	0.97 (0.95–0.98)	0.94 (0.92–0.95)
Attempt 2 vs. 3	0.97 (0.96–0.98)	0.98 (0.97–0.98)	0.96 (0.95–0.97)	0.98 (0.96–0.98)	0.97 (0.96–0.98)
Attempt 1, 2 vs. 3	0.96 (0.92–0.98)	0.97 (0.97–0.98)	0.95 (0.92–0.97)	0.97 (0.93–0.99)	0.95 (0.92–0.97)
Attempt 1 vs. 1, 2, 3	0.98 (0.90–0.99)	0.97 (0.82–0.99)	0.96 (0.87–0.98)	0.97 (0.90–0.99	0.96 (0.82–0.98)
Mean difference (95% LOA)					
Attempt 1 vs. 2	0.30 (−6.37–6.97)	−0.52 (−5.23–4.20)	−0.03 (−6.41–6.36)	−0.21 (−5.26–4.83)	−0.29 (−5.41–4.84)
Attempt 1 vs. 3	0.39 (−6.99–7.76)	−0.59 (−5.73–4.54)	0.12 (−6.73–6.97)	0.04 (−4.52–4.61)	−0.16 (−5.67–5.36)
Attempt 2 vs. 3	0.09 (−6.03–6.21)	−0.08 (−4.14–3.98)	0.15 (−5.37–5.67)	0.26 (−3.77–4.29)	0.13 (−3.79–4.05)
Attempt 1, 2 vs. 3	1.52 (−4.65–7.68)	0.60 (−3.55–4.75)	1.32 (−4.87–7.50)	1.10 (−2.48–4.69)	0.92 (−3.59–5.43)
Attempt 1 vs. 1, 2, 3	−1.66 (−5.82–2.50)	−1.70 (−5.35–1.94)	−1.75 (−6.33–2.84)	−1.35 (−4.95–2.25)	−1.50 (−5.09–2.09)

ICC, intraclass correlation coefficient; CI, confidence interval; LOA, limits of agreement.

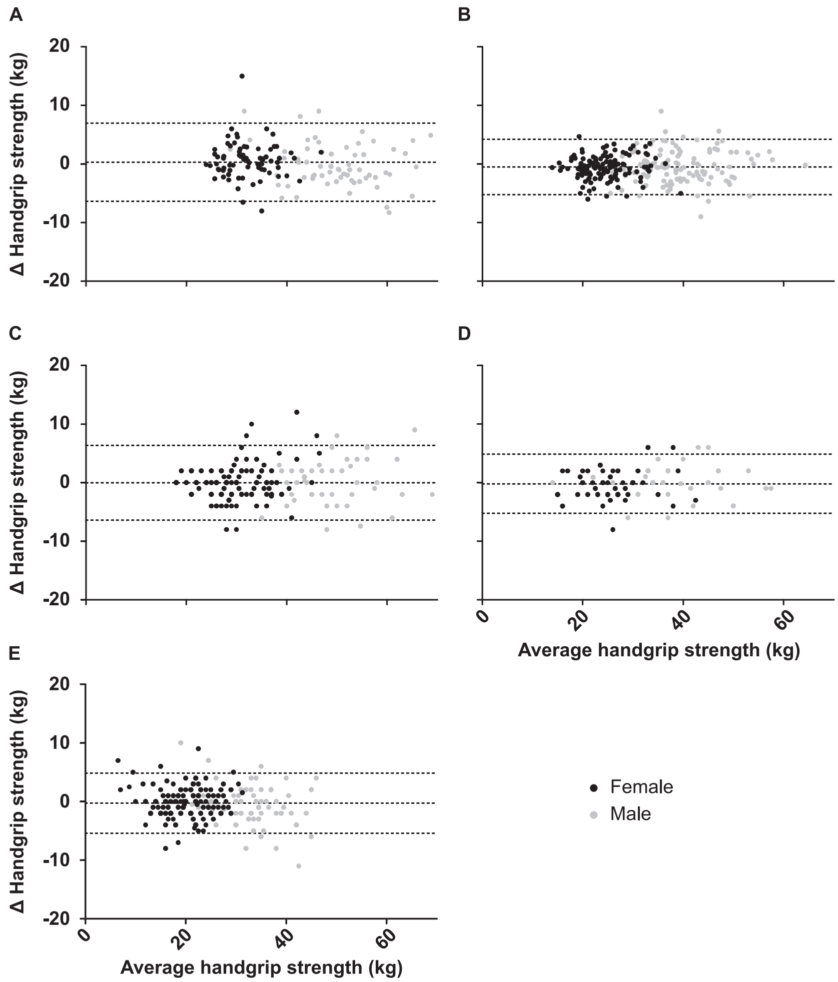
by age. Stratification by hand side showed the same results as the total group (Supporting Information *Figure* S2).

Table 2 shows ICC values and the mean differences with the 95% LOA between maximal HGS of different attempts, stratified by cohort and age. ICC values between all attempts were above 0.8 or 0.9, indicating moderate to high reproducibility. In all cohorts, the 95% LOA of maximal HGS at attempts 1 and 2 vs. attempt 3 were higher than the 95% LOA between attempt 1 vs. attempt 2, attempt 1 vs. attempt 3, attempt 2 vs. attempt 3 and attempt 1 vs. maximal HGS at attempts 1, 2 and 3. ICC values and the mean differences with the 95% LOA stratified by hand side showed the same results as when analysed as a total group (Supporting Information *Table* S1).

Reproducibility at individual level in three cohorts

Figure 1 shows Bland–Altman plots of HGS at attempt 1 vs. attempt 2. *Figure* 2 shows Bland–Altman plots of HGS at

Figure 1 Bland–Altman plots of handgrip strength at attempt 1 vs. attempt 2. Results are stratified by cohort and age: MyoAge cohort ((*A*) healthy young, (*B*) healthy old), Grey Power cohort ((*C*) middle-aged, (*D*) old) and geriatric outpatients (*E*). The dashed lines represent the mean difference in handgrip strength with the upper and lower 95% limits of agreement (mean difference ± 1.96 SD). Grey dots represent males and black dots represent females. Δ = difference.



attempts 1 and 2 vs. attempt 3. Supporting Information *Figure* S3 shows Bland–Altman plots of HGS at attempt 1 vs. maximal HGS at attempts 1, 2 and 3. It shows that a considerable number of individuals did not reach maximal HGS at attempt 1: MyoAge cohort healthy young individuals 60.4, healthy old individuals 70.9; Grey Power cohort middle-aged individuals 52.0, old individuals 49.4; geriatric outpatients 57.1%.

Table 3 shows the number of individuals classified as dynapenic assessed at different attempts, stratified by cohort and age. The percentage of individuals with a maximal HGS above the gender-specific cut-off value at attempt 3 compared with attempts 1 and 2 ranged from 0 to 50% with higher values in middle-aged and older populations and therewith higher dynapenia misclassification in populations with higher age. The percentage of true-positives was higher using three attempts compared with using two attempts in all three populations.

MyoAge cohort

In healthy young individuals, a higher HGS of on average 2.3 kg (SD 1.9) at attempt 2 was found in 67 (48.2%) individuals compared with attempt 1. A higher HGS at attempt 3 compared with the maximal HGS at attempts 1 and 2 was found in 41 (29.5%) individuals with an average of 1.8 kg (SD 1.7). None of the healthy young individuals were classified as dynapenic using the maximal HGS at attempts 1, 2 and 3 dependent on the order of attempts.

In healthy old individuals, a higher HGS of on average 2.0 kg (SD 1.6) at attempt 2 was found in 152 (58.9%) individuals compared with attempt 1. A higher HGS at attempt 3 compared with the maximal HGS at attempts 1 and 2 was found in 96 (37.2%) individuals with an average of 1.4 kg (SD 1.0). Using the maximal HGS at attempts 1 and 2, 23 (8.9%), individuals were classified as dynapenic of which 4 (17.4%) had a maximal HGS above the gender-specific cut-

Figure 2 Bland–Altman plots of handgrip strength of maximal handgrip strength at attempt 1 or attempt 2 vs. attempt 3. Results are stratified by cohort and age: MyoAge cohort ((*A*) healthy young, (*B*) healthy old), Grey Power cohort ((*C*) middle-aged, (*D*) old) and geriatric ooutpatients (*E*). The dashed lines represent the mean difference in handgrip strength with the upper and lower 95% limits of agreement (mean difference ± 1.96 SD). Grey dots represent males and black dots represent females. Δ = difference.

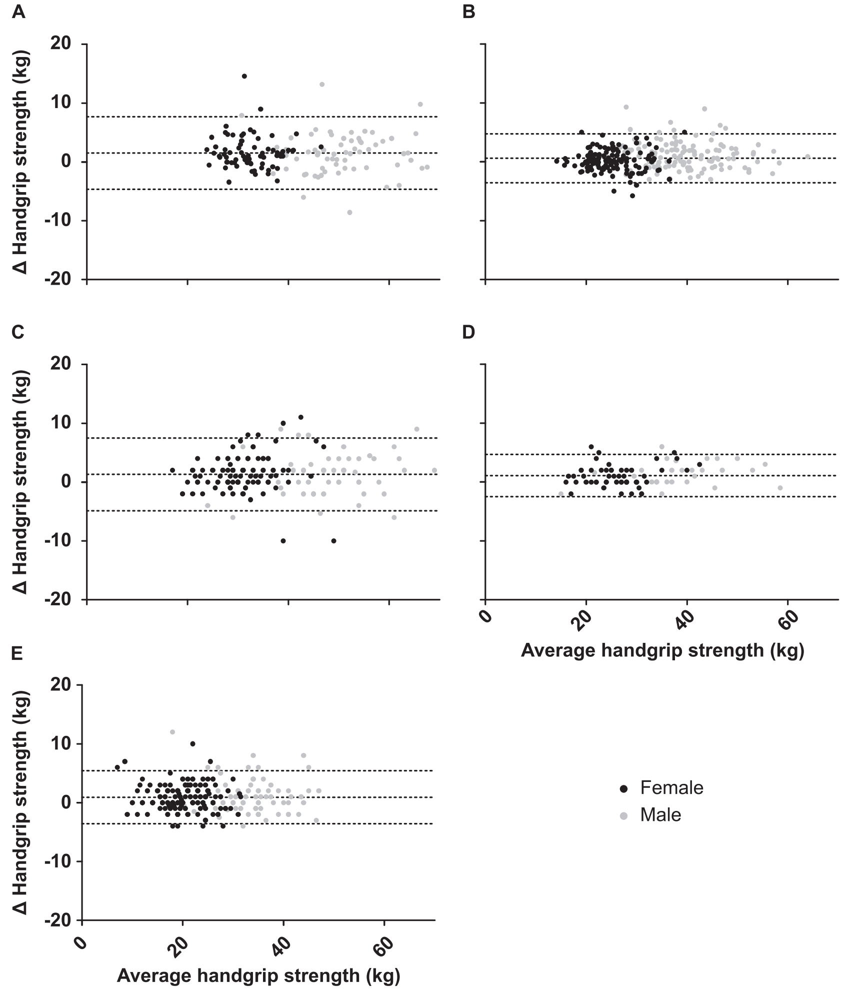


Table 3 Number of individuals classified as dynapenic dependent on the number of attempts, stratified by cohort and age

	MyoAge cohort		Grey Power cohort		Geriatric outpatients
	Healthy young *n* = 139	Healthy old *n* = 258	Middle-aged *n* = 173	Old *n* = 89	*n* = 280
Dynapenia in order of attempts					
Attempt 1	0	39 (15.1)	7 (4.0)	12 (13.5)	122 (43.6)
Attempt 1 and 2	0	23 (8.9)	6 (3.5)	10 (11.2)	99 (35.4)
Attempt 1, 2 and 3	0	19 (7.4)	3 (1.7)	10 (11.2)	88 (31.4)
True–positives[a]					
Attempt 1 and 2	2 (1.4)	25 (9.7)	3 (1.7)	4 (4.5)	31 (11.1)
Attempt 1, 2 and 3	3 (2.2)	34 (13.2)	6 (3.5)	7 (7.9)	51 (18.2)

All variables are presented as n (%).
Dynapenia was defined using gender specific cut–off values; males <30 kg, females <20 kg.
[a]True–positive defined as those classified as dynapenic at any of the 3 attempts, but above the gender specific cut–off value on at least one of the three attempts, independent on the order of attempts

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off value at attempt 3, which was higher compared with attempts 1 and 2 and would therewith be misclassified as dynapenic by use of 2 attempts.

Grey Power cohort

In middle-aged individuals, a higher HGS of on average 2.9 kg (SD 1.7) at attempt 2 was found in 71 (41.0%) individuals compared with attempt 1. A higher HGS at attempt 3 compared with the maximal HGS at attempts 1 and 2 was found in 35 (20.2%) individuals with an average of 2.7 kg (SD 2.2) higher HGS. Using the maximal HGS at attempts 1 and 2, 6 (3.5%), individuals were classified as dynapenic of which 3 (50.0%) had a maximal HGS above the gender-specific cut-off value at attempt 3, which was higher compared with attempts 1 and 2 and would therewith be misclassified as dynapenic by use of 2 attempts.

In old individuals, a higher HGS of on average 2.5 kg (SD 1.6) was found in 38 (42.6%) individuals compared with attempt 1. A higher HGS at attempt 3 compared with the maximal HGS at attempts 1 and 2 was found in 11 (12.4%) individuals with an average of 1.6 kg (SD 0.5) higher HGS. Using the maximal HGS at attempts 1 and 2, 10 (11.2%) individuals were classified as dynapenic of which 1 (10.0%) had a maximal HGS above the gender-specific cut-off value at attempt 3, which was higher compared with attempts 1 and 2 and would therewith be misclassified as dynapenic by use of 2 attempts.

Geriatric outpatients

A higher HGS of on average 2.4 kg (SD 1.7) at attempt 2 was found in 124 (44.3%) individuals compared with attempt 1. A higher HGS at attempt 3 compared with the maximal HGS at attempt 1 and 2 was found in 69 (24.6%) individuals with an average of 1.7 kg (SD 0.9). Using the maximal HGS at attempts 1 and 2, 99 (35.4%) individuals were classified as dynapenic of which 11 (11.1%) had a maximal HGS above the gender-specific cut-off value at attempt 3, which was higher compared with attempts 1 and 2 and would therewith be misclassified as dynapenic by use of 2 attempts.

Summary of results

On population level, maximal HGS at attempts 1 and 2 was significantly higher than attempt 3. On individual level, 12.4 to 37.2% of the individuals reached the highest HGS at attempt 3 compared with the maximal HGS at attempts 1 and 2 with an average of 1.4 kg to 2.7 kg higher HGS.

Discussion

Maximal HGS was found to be dependent on the number of attempts in all three cohorts. At least three attempts are needed if HGS is considered as a continuous variable. If HGS is used as a discrete value with a cut-off value to assess dynapenia, the percentage of individuals misclassified as dynapenic by use of two attempts compared with the use of three attempts was higher in middle-aged and older populations.

Maximal HGS at attempts 1 and 2 was significantly higher on population level than attempt 3 in all three cohorts. Despite the moderate to high ICC values, a significant number of individuals had a higher HGS at attempts 2 and attempt 3 compared with attempt 1. Previous studies yielded contrasting results on how many attempts of HGS should be assessed to obtain maximal HGS.[10–14] Some studies concluded that one attempt should be sufficient because ICC values between the efforts were high[10–12,14] and maximal HGS decreased significantly at attempts 2 and 3[14] or a significant increase in pain was seen after several HGS attempts.[11] In contrast, we conclude that one attempt is insufficient because approximately half of the individuals had a higher HGS at attempt 2 compared with attempt 1. One previous study has concluded that three attempts are needed because this gave the highest test–retest reliability assessed with Pearson product moment correlation coefficient analysis.[13] Some of these previous studies were performed in individuals with hand trauma on the affected side[9,10] that represent a particular participant group and thus the results may not be generalizable to the wider older population. Two of the previous mono-centre studies were performed in healthy individuals[12,13] but included only limited number of individuals (n = 33 and n = 27, respectively). A limitation of all aforementioned studies[10–14] is that Bland–Altman analysis was not performed; consequently, the variance at the individual level was not analysed. It can therefore not be ruled out that in the previous studies, a similar number of individuals did obtain the highest HGS at attempt 3.

The number of attempts to assess HGS depends on the goal that is pursued. If an underestimation of the HGS value is undesirable and HGS is considered as a continuous variable, we recommend to measure HGS at least three times to avoid underestimation of HGS. This underestimation is relevant as a recent meta-analysis showed a significant association of even 1 kg difference in grip strength and mortality in older cohorts.[3]

One of the strengths of this study is that HGS was tested in different cohorts thereby making the results generalizable to populations differing in age and health status. Another strength is the fact that HGS was analysed both as a continuous value and as a discrete variable. Pain during the assessment of HGS was not registered, which forms a limitation of the study. Another limitation is that it cannot be excluded whether individuals would reach an even higher maximal HGS after more than 3 attempts.

Conclusions

Maximal HGS is dependent on the number of attempts, independent of age and health status. If HGS is considered as a continuous variable, HGS should be performed three times. The percentage of individuals misclassified as dynapenic by use of two attempts is higher in middle-aged and older populations compared with younger populations. If HGS is considered as a discrete variable to assess dynapenia, two attempts are sufficient in younger populations; in middle-aged and older populations, the percentage of misclassification should be taken into account when using two attempts. Future research should focus on other aspects of standardization of the assessment of HGS such as the influence of pain, posture and hand dominance. In addition, other reproducibility such as day-to-day or month-to-month variation should be assessed in a longitudinal design.

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Online supplementary material

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table S1. Intraclass correlation coefficients and mean differences between handgrip strength for the right and left hand, stratified by cohort and age

Figure S1. Handgrip strength values (either the right or left hand side), stratified by cohort and age: MyoAge cohort (a: healthy young, b: healthy old), Grey Power cohort (c: middle-aged, d: old) and geriatric outpatients (e). Attempt 1, 2 is the maximal handgrip strength measured at attempt 1 or attempt 2. Values are presented as mean. Error bars represent 1 standard deviation. * = p-value $<$0.05, ** = p-value $<$0.01, *** = p-value $<$0.001 determined with paired Student's t-test.

Figure S2. Handgrip strength values (either the right or left hand side); results are stratified by cohort and age: Results are stratified by cohort, age and hand side: MyoAge cohort (a: healthy young, b: healthy old), Grey Power cohort (c: middle-aged, d: old) and geriatric outpatients (e). Attempt 1, 2 is the maximal handgrip strength measured at attempt 1 or attempt 2. Values are presented as mean. Error bars represent 1 standard deviation. Grey bars represent left hand side, black bars represent right hand side. * = p-value $<$0.05, ** = p-value $<$0.01, *** = p-value $<$0.001 determined with paired Student's t-test.

Figure S3. Bland–Altman plots of handgrip strength of attempt 1 versus maximal handgrip strength at attempt 1, 2 and 3. Results are stratified by cohort and age: MyoAge cohort (a: healthy young, b: healthy old), Grey Power cohort (c: middle-aged, d: old) and geriatric outpatients (e). The dashed lines represent the mean difference in handgrip strength with the upper and lower 95% limits of agreement (mean difference $\pm$ 1.96 SD). Grey dots represent males and black dots represent females. Δ = difference

Conflict of interest

None declared.

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