REVIEW

A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach

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Abstract

Background: the European Working Group on Sarcopenia in Older People has developed a clinical definition of sarcopenia based on low muscle mass and reduced muscle function (strength or performance). Grip strength is recommended as a good simple measure of muscle strength when 'measured in standard conditions'. However, standard conditions remain to be defined.
Methods: a literature search was conducted to review articles describing the measurement of grip strength listed in Medline, Web of Science and Cochrane Library databases up to 31 December 2009.
Results: there is wide variability in the choice of equipment and protocol for measuring grip strength. The Jamar hand dynamometer is the most widely used instrument with established test–retest, inter-rater and intra-rater reliability. However, there is considerable variation in how it is used and studies often provide insufficient information on the protocol followed making comparisons difficult. There is evidence that variation in approach can affect the values recorded. Furthermore, reported summary measures of grip strength vary widely including maximum or mean value, from one, two or three attempts, with either hand or the dominant hand alone.
Conclusions: there is considerable variation in current methods of assessing grip strength which makes comparison between studies difficult. A standardised method would enable more consistent measurement of grip strength and better assessment of sarcopenia. Our approach is described.

Keywords: *grip strength, measurement, protocol, sarcopenia, elderly*

Introduction

The European Working Party on Sarcopenia in Older People (EWGSOP) has recently reported a consensus approach to the definition and diagnosis of sarcopenia [1]. The diagnosis of sarcopenia requires low muscle mass and low muscle function (strength or physical performance) and a wide range of tools were reviewed. Grip strength was the only assessment technique recommended for the measurement of muscle strength, and was the simplest method for assessment of muscle function in clinical practice. Longitudinal studies confirm that grip strength declines after midlife, with loss accelerating with increasing age [2] and through old age [3]. As an assessment measure grip strength has been shown to have predictive validity and low values are associated with falls [4], disability, impaired health-related quality of life [5] and prolonged length of stay in hospital [6] as well as increased mortality [7, 8].

Grip strength can be measured quantitatively using a hand dynamometer. However, the methods used to characterise grip strength varies considerably, for example with regard to the choice of dynamometer or the measurement protocol used. This has the potential to introduce measurement error. The EWGSOP report recognised the challenge

of determining how best to measure variables such as grip strength.We therefore conducted a literature review to evaluate the extent of variation in the method of assessment of grip strength, and the potential effect on values reported.

Methods

A literature search of Medline, Web of Science and Cochrane Library databases was conducted by two researchers independently and then combined. The search terms used were (i) grip strength and frail/elder/protocol/measurement/methods/jamar, (ii) hand grip and frail/elder/protocol/measurement/methods/jamar, (iii) dynamometer and (iv) jamar. The full texts of all potentially relevant papers were obtained. Papers were included in the review if they described measurement of hand grip strength of human subjects aged 16 years or more and were written in English. The search included papers, conference proceedings and e-publications registered with the databases up to 31 December 2009, and the bibliographies of these articles were checked for additional relevant papers. The search terms were used until no further papers were identified. Findings on the measurement of grip strength are presented with regard to the equipment used, variation in measurement protocol and clinimetric properties of the value reported.

Results

Search results

A total of 11,604 papers were identified by the searches. The titles and abstracts of these papers were screened. In all, 189 were found to be possibly relevant and retrieved in full for detailed evaluation. One hundred and forty-seven were excluded, either because they were from a population aged 15 years or younger, or focussed on detection of insincerity of effort or grip endurance, rather than maximal strength testing. When several papers were identified that covered the same research question, the most recent paper was chosen for clarity and brevity, except once when the results were conflicting. Forty-two studies were included in the final review.

Equipment

Choice of dynamometer

Table 1 indicates the main features of the different types of dynamometer. The Jamar hand dynamometer (Lafayette Instrument Company, USA) is the most widely cited in the literature and accepted as the gold standard by which other dynamometers are evaluated [9,10]. It has the most extensive normative data [11], although data are available for other instruments such as the BTE Work Simulator [12] and the Martin Vigorimeter [13]. Excellent concurrent validity of the Jamar with known weights is reported ($r = 0.9998$ [14]; $r > 0.96$ [15]).

A review [14] of the reliability and validity of the Jamar in comparison with other grip strength measurement devices concluded that excellent inter-instrument reliability exists between the Jamar, Dexter and Baseline dynamometers, which all measure grip strength in pounds and kilograms and could be used interchangeably. There was also similar evidence between the Jamar and Rolyan hydraulic dynamometers.

Moderate to excellent reliability was found between the Jamar, the Baltimore Therapeutic Equipment (BTE) work

Table 1. Key features of hand dynamometers

Instrument type	Hydraulic	Pneumatic	Mechanical	Strain
Measures	Grip strength	Grip pressure	Grip strength	Grip strength
Based on	A sealed hydraulic system that enables grip strength to be read off a gauge dial	The compression of an air-filled compartment, e.g. a bag or bulb	The amount of tension produced in a spring	The variation in electrical resistance of a length of wire due to the strain applied to it
Example of instrument	Jamar	Martin Vigorimeter	Harpenden dynamometer	Isometric Strength Testing Unit
Units	Kilograms (kg) or pounds of force (lbf)	Milimeters of mercury (mmHg) or pounds per square inch (psi) (lb/in^2)	Kilograms (kg) or pounds of force (lbf)	Newtons of force (N)
Advantages	Portable, economical, large amount of normative data available	Gentler on weak or painful joints	No evidence for superiority presented in the literature	Are not subject to leaks (of oil/water/air), which can compromise accuracy
Limitations	Can cause stress on weak joints. Can develop slow leaks and hysteresis	These instruments measure grip pressure, which is dependent on the surface area over which the force is applied. Hand size can therefore influence the measurement	Reproducibility of the grip force measurements is limited due to difficulties in exactly replicating the grip position and in calibrating the device	Can be expensive and heavy

Information in the table is taken from [11, 61–63].

simulator and the BTE Primus and the Martin Vigorimeter, but they use different units of measurement and the BTE is not a portable machine. Similar reliability was found between the Jamar and the MicroFET 4 [16] and DynEX [17] dynamometers. Low inter-instrument reliability scores were reported between the Jamar, the sphygmomanometer and the Vigorimeter. It is unclear whether the electronic Grippit dynamometer and the Jamar can be used interchangeably [18]. Since it is the most widely used this review will now focus on the Jamar dynamometer.

Jamar dynamometer

The Jamar is small and portable but relatively heavy at 1.5 lb. The dial reads force in both kilograms and pounds, with markings at intervals of 2 kg or 5 lb, allowing assessment to the nearest 1 kg or 2.5 lb. It requires 3–4 pounds of force to make the indicator needle move, which may be inappropriate when measuring grip strength in very weak patients [19] and the reading error is reported to be greater at lower loadings. The calibration accuracy should be checked on new machines [20] and the manufacturers recommend annual or more frequent calibration if used on a daily basis.

Measurement protocol

Hand size and nail length

The Jamar is a variable hand span dynamometer with five handle positions. As shown in Table 2, most studies have used the second position for all participants. This has been assumed to be the most reliable and consistent position [10] and is the position advocated for routine use. However, hand size is important and only 60% of 214 volunteers demonstrated maximal grip strength at position two [21] and 56 healthy volunteers self-selected position two or three for maximal grip strength [22]. Handle positions one [23] and five [24] have been found to be significantly less reliable than the other positions, but for people with very small hands position one may be required [25]. Grip strength measured using the second handle position has been shown to be reduced in women with fingernails extending 1 cm or more beyond the fingertip, and for those using handle position one, grip was reduced even with finger nails projecting just 0.5 cm [26].

Hand dominance

The 10% rule used by therapists treating patients with injured hands states that the dominant hand has a 10% stronger grip than the non-dominant hand [27]. Among American and Greek volunteers this was true for right-handed people but for left-handed people grip strength was equal in both hands [21, 28], which may influence the final value where only one hand is assessed. Similarly, a review

Table 2. Examples of grip strength measurement protocols employed in studies using a Jamar dynamometer

Author and year of publication	Population (n)	Handle setting	Body position	Encouragement/instructions	Hands tested	Measure used
Bohannon and Schaubert 2005 [48]	Community-dwelling elders, USA (21)	2nd	ASHT recommendations	Not stated	Both	Single trial
Desrosiers et al. 1995 [13]	Community-dwelling elders, Canada (360)	2nd	ASHT recommendations	Standardised instructions according to Mathiowetz et al. (1984)	Both	Highest of three
Fried et al. 2001 [64]	Community-dwelling elders from the Cardiovascular Health Study (5,317)	Not stated	Not stated	Not stated	Dominant	Mean of three
Massy-Westropp et al. 2004 [65]	Healthy adults, Australia (419)	2nd	ASHT recommendations	Not stated	Both	Single trial
Mathiowetz et al. 1985 [66]	Healthy adults, USA (628)	2nd	ASHT recommendations	Standardised instructions according to Mathiowetz et al. (1984)	Both	Mean of three
Sayer et al. 2007 [67]	Community-dwelling elders from the Hertfordshire Cohort Study, UK (2,677)	Most comfortable	Subjects seated, forearms rested on the arms of the chair, wrist just over the end of the arm of the chair in a neutral position, thumb facing upwards, feet flat on the floor	Standardised encouragement given	Both	Highest of three
Werle et al. 2009 [68]	Community-dwelling adults, Switzerland (1,023)	2nd	ASHT recommendations	Standard instructions at a constant volume	Both	Mean of three

of 10 studies found that right dominant subjects were stronger with their right hand, whereas among left dominant subjects the results were equivocal [29].

Body position

Wrist and forearm

Richards et al. [30] found that varying the position of the forearm between neutral, supinated and pronated altered the grip strength. The supinated position produced the strongest force, whereas the force was weakest in the pronated position.

Elbow

Higher grip strength has been reported sitting with the elbow in 90° flexion rather than fully extended [31], and a significant difference has been reported between 45° and 90° of elbow flexion [10]. However, Su et al. [32] found significantly higher grip strength in 160 Chinese subjects with the elbow fully extended rather than flexed regardless of shoulder position. A Canadian study of 49 healthy right-handed Canadian men aged 60–84 years found significantly higher grip strength in the non-dominant hand with the elbow flexed to 90° rather than fully extended, but no such difference was found for the dominant hand [33].

Shoulder

Su et al. [34] evaluated grip strength with the elbow fully extended and 0°, 90°and 180° of shoulder flexion, and also with the elbow flexed to 90° and 0° of shoulder flexion. The highest mean grip strength was found with the shoulder in 180° of flexion, and the lowest was found with the shoulder in 0° flexion and the elbow flexed to 90°.

Posture

One study reported no significant difference in grip strength with subjects in either sitting or standing positions [35], but Balogun et al. [36] showed higher grip strength with college students standing rather than sitting. Hillman [37] found that readings with subjects' elbows unsupported were significantly higher than when they were supported.

The American Society of Hand Therapists (ASHT) recommends standardised positioning: subject seated, shoulders adducted and neutrally rotated, elbow flexed at 90°, forearm in neutral and wrist between 0 and 30° of dorsiflexion [38]. The need for a standard protocol to improve the validity of assessment is illustrated by Spijkerman et al. [39], who found that allowing subjects to assume a comfortable position produced significantly different readings from the ASHT protocol. Table 2 summarises some of the variation in measurement protocol between studies using a Jamar hand dynamometer to measure grip strength.

Effort and encouragement

Most studies either do not report how much encouragement they give or report differing amounts (Table 2). Different methods of instruction and/or verbal encouragement can affect the performance [40] and thus introduce measurement error, as may the volume of instruction [41]. Mathiowetz et al. [42] have a set of standardised instructions: 'I want you to hold the handle like this and squeeze as hard as you can'. The examiner demonstrates and then gives the dynamometer to the subject. After the subject is positioned appropriately, the examiner says, 'Are you ready? Squeeze as hard as you can'. As the subject begins to squeeze, the examiner says, 'Harder!… Harder!… Relax'.

Interval between measurements

Watanabe et al. [43] compared the mean of two readings for each hand, measured repeatedly without rest or taken at 1 min intervals in 100 participants. During repeated measurement grip strength decreased gradually, whereas there was no change during interval measurement for either gender or hand.

Time of the day

Young et al. [44] reported similar values on testing grip strength in the morning and afternoon but Jasper et al. [45] showed a circadian rhythm in grip strength, with a minimum around 06:00 h and a maximum around 18.00 h.

Training of assessors

There is little literature on training individuals to measure grip strength, but there is evidence that assessment of grip strength by different hand therapists can be considered interchangeable, if they follow the same protocol [46]. Currently, research staff are trained prior to measuring grip strength [47] but this is typically poorly documented and not standardised across studies.

Clinimetric properties

Reliability and reproducibility

Measurements of grip strength taken with the Jamar dynamometer have evidence for good to excellent $(r > 0.80)$ test–retest reproducibility [42] and excellent $(r = 0.98)$ inter-rater reliability [46]. High test–retest reproducibility has been shown among older American community-dwelling volunteers (mean age 75 years) tested repeatedly over a 12-week period [48].

Number of assessments and summary measures reported

The ASHT protocol uses the mean of three trials of grip strength in each hand [38], which had higher test–retest reliability among female students than either one trial alone

Table 3. Comparison of ASHT and Southampton grip-strength measurement protocols

	ASHT	Southampton protocol
Posture	Subject seated	Subject seated, same chair for every measurement
Arm position	Shoulders adducted and neutrally rotated, elbow flexed at 90°, forearm in neutral	Forearms rested on the arms of the chair
Wrist position	Wrist between 0 and 30° of dorsiflexion	Wrist just over the end of the arm of the chair, in a neutral position, thumb facing upwards
Lower extremity position		Feet flat on the floor
Encouragement		'I want you to squeeze as hard as you can for as long as you can until I say stop. squeeze, squeeze, squeeze, stop' (when the needle stops rising)
Number of trials		Three trials on each side, alternating sides
Score to use		Maximal grip score from all six trials used

or the maximum of three trials [42]. However, Hamilton *et al.* [23] found similar test–retest reliability with one trial alone, the mean of two or three trials and the maximum of three trials. A recent UK study found that one trial was as reliable and less tiring than three trials [49].

Responsiveness

Nitschke *et al.* [50] evaluated test–retest reliability in the maximum grip strength of 32 healthy women and pain-free grip in 10 disabled women. The measurement variation between tests was ±5.7 and ±5.9 kg for the healthy and disabled women, respectively. They proposed a minimal significant change of 6 kg. Similarly, studies identifying recovery after stroke estimate the difference in repeat measures of hand grip strength to be between 4.7 kg [51] and 6.2 kg [52].

However, significant clinical change may be obscured by measurement variation. The clinical meaning of change in grip strength over time has been evaluated using the standardised mean response, calculated as the mean change in score/standard deviation of that change [53]. Other authors have similarly used the effect size, calculated as the difference between the mean (median) values of grip strength 'after' and 'before', divided by the standard deviation (inter-quartile range) of the 'before' measurement [54]. For both measures a value of 0.2–0.5 is considered a low responsiveness, 0.51–0.8 is moderate and >0.8 shows a high level of responsiveness.

Discussion

This review consisted of a wide search using many terms, conducted by two independent researchers. The search included original articles as well as reviews, reports and conference proceedings, though these were restricted to articles written in English language. It demonstrated that the choice of equipment and measurement protocol for assessing grip strength varies widely between studies. The Jamar hand dynamometer is the most widely cited instrument in the literature, appears to be generally accepted as the gold standard by which other dynamometers are evaluated, and has the most normative data.

The absolute values and precision of grip strength measurements can be influenced by aspects of the protocol such as allowance for hand size and dominance, posture, joint position, effort and encouragement, frequency of testing and time of day, and training of the assessor. In addition, inconsistencies in the number of assessments and variable use of the maximum or mean grip strength as a summary measure limit comparison of results between epidemiological studies. For example, with multiple attempts, the maximum grip strength will be greater than the mean value.

Differences in protocol and summary measures used in different studies may affect not only the precision and reproducibility of the measurements but also the ability to compare absolute values reported for grip strength between different study populations. A recent systematic review published in this journal highlights the problems of drawing conclusions from studies where physical capability measures and outcomes have been assessed and categorised in different ways [55].

Grip strength testing is likely to be increasingly used in clinical settings, for example in the assessment of sarcopenia [1, 56], frailty and undernutrition [15] in hospitalised older people. A study by Puig-Domingo *et al.* [57], evaluating muscle strength and successful ageing, found it to be a helpful clinical evaluation tool and a Japanese study investigating the optimal physical or cognitive test to screen for falls risk in frail older people found that the most practical physical test was grip strength [58]. However, the use of differing protocols in research studies can lead to confusion among clinicians regarding what constitutes best practice, and the feasibility and acceptability of measuring grip strength in different healthcare settings is not established [59]. The development of accurate and standardised reference values is essential as clinicians aim to identify individuals at increased risk of adverse outcomes within a given population [60].

We suggest that a standardised method is needed to enable more consistent measurement of grip strength and better assessment of sarcopenia. This has been previously proposed by the American Society of Hand Therapists [38]

Figure 1. Southampton protocol for adult grip strength measurement.

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(1) Sit the participant comfortably in a standard chair with legs, back support and fixed arms. Use the same chair for every measurement. (2) Ask them to rest their forearms on the arms of the chair with their wrist just over the end of the arm of the chair—wrist in a neutral position, thumb facing upwards. (3) Demonstrate how to use the Jamar handgrip dynamometer to show that gripping very tightly registers the best score. (4) Start with the right hand. (5) Position the hand so that the thumb is round one side of the handle and the four fingers are around the other side. The instrument should feel comfortable in the hand. Alter the position of the handle if necessary. (6) The observer should rest the base of the dynamometer on the palm of their hand as the subject holds the dynamometer. The aim of this is to support the weight of the dynamometer (to negate the effect of gravity on peak strength), but care should be taken not to restrict its movement. (7) Encourage the participant to squeeze as long and as tightly as possible or until the needle stops rising. Once the needle stops rising the participant can be instructed to stop squeezing. (8) Read grip strength in kilograms from the outside dial and record the result to the nearest 1 kg on the data entry form. (9) Repeat measurement in the left hand. (10) Do two further measurements for each hand alternating sides to give three readings in total for each side. (11) The best of the six grip strength measurements is used in statistical analyses so as to encourage the subjects to get as high a score as possible. (12) Also record hand dominance, i.e. right, left or ambidextrous (people who can genuinely write with both hands). Equipment: Model J00105 JAMAR Hydraulic Hand Dynamometer.

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but not universally adopted, as can be seen from Table 2. A standardised protocol could improve the measurement of grip strength by not only increasing the precision of measurements within any given study (thereby increasing statistical power to detect associations between grip strength and clinical characteristics), but also enabling the generalisability of results across study populations.

We have a well-established protocol for measurement of grip strength in large epidemiological studies of older people which is based on the ASHT protocol. Our protocol additionally standardises for leg and forearm position, encouragement and assessor training and clearly states the summary measures used (Table 3, Figure 1). We share this protocol to stimulate discussion towards a consensus for the measurement of grip strength.

Key points

- A consensus approach to the definition and diagnosis of sarcopenia has recently been proposed and includes the measurement of grip strength.
- There is considerable variation in current methods of assessing grip strength, which makes comparison between studies difficult.
- A standardised method would enable more consistent measurement of grip strength and better assessment of sarcopenia. Our approach is described.

Supplementary data

Supplementary data mentioned in the text is available to subscribers in *Age and Ageing* online.

References

The very long list of references supporting this review has meant that only the most important are listed here and are represented by bold type throughout the text. The full list of references is available as a supplementary data on the journal website http://www.ageing.oxfordjournals.org/ as Appendix 1.

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