Journal of Frailty, Sarcopenia and Falls

Short Communication

The impact of variation in the device used to measure grip strength on the identification of low muscle strength: Findings from a randomised cross-over study

Rachel Cooper[1]*, Carli Lessof[2]*, Andrew Wong[3], Rebecca Hardy[4]

[1]*Department of Sport and Exercise Sciences, Musculoskeletal Science and Sports Medicine Research Centre, Manchester Metropolitan University, Manchester, UK;*
[2]*National Centre for Research Methods, University of Southampton, Southampton, UK;*
[3]*MRC Unit for Lifelong Health and Ageing at UCL, London, UK;*
[4]*Cohort and Longitudinal Studies Enhancement Resources (CLOSER), UCL Social Research Institute, London, UK*
** equal contribution*

Abstract

Grip strength is commonly used to identify people with low muscle strength. It is unclear what impact the type of dynamometer used to measure grip strength has on the identification of low muscle strength so we aimed to assess this. Study participants were 118 men and women aged 45-74y from a randomised, repeated measurements cross-over study. Maximum grip strength was assessed using four hand-held dynamometers (Jamar Hydraulic; Jamar Plus+ Digital; Nottingham Electronic; Smedley) in a randomly allocated order. EWGSOP2 cut-points were applied to estimate prevalence of low muscle strength for each device. Agreement between devices was compared. Prevalence of low muscle strength varied by dynamometer ranging between 3% and 22% for men and, 3% and 15% for women. Of the 13 men identified as having low muscle strength by at least one of the four dynamometers, only 8% were identified by all four and 54% by just one. Of the 15 women classified as having low muscle strength by at least one of the four dynamometers, only 7% were identified by all four and 67% by only one. Variation in the measures of grip strength acquired by different hand-held dynamometers has potentially important implications when identifying low muscle strength.

Keywords: Cut-points, Hand-held dynamometer, Grip strength, Low muscle strength, Sarcopenia

There is increasing recognition of the important role of skeletal muscle for health and disease. This is exemplified by a growing awareness of the clinical importance of sarcopenia[1] - 'a progressive and generalised skeletal muscle disorder that involves the accelerated loss of muscle mass and function'[2] – which in the last 5 years has been assigned an ICD-10 code[3].

Despite progress, there remain well-documented challenges for clinical practice and research on sarcopenia[1,2]. One of the most important is the ongoing debate relating to how sarcopenia should be operationally defined[1]. Of a number of consensus definitions proposed over the last decade, the European Working Group on Sarcopenia in Older People's (EWGSOP) definition has gained considerable traction[4]. It was therefore noteworthy when an extended working group, EWGSOP-2, published a revised definition in 2019 to reflect updates to relevant evidence[5].

In working towards the aim of a true consensus definition and improved understanding of sarcopenia, each time a new definition is proposed it is important to compare this with

The authors have no conflict of interest.

Corresponding author: *Professor Rachel Cooper, Department of Sport and Exercise Sciences, Manchester Metropolitan University, All Saints Building, Manchester, M15 6BH, UK*

E-mail: *r.cooper@mmu.ac.uk*

Edited by: *George Lyritis*

Accepted *17 May 2021*

existing definitions[6-9]. Work has thus been undertaken to compare the EWGSOP-2 definition with the EWGSOP and other definitions[10-14]. These comparisons have highlighted that prevalence estimates vary markedly and often have limited overlap i.e. identify different groups of people within a population as sarcopenic. This is a well-recognised challenge; a systematic review in 2019 reported that estimates of sarcopenia prevalence varied between 9.9 and 40.4% depending on the definition used and emphasised the lack of agreement between definitions[9].

The differences that these comparison studies highlight have important implications that need to be resolved. However, alongside these differences, it is also important to consider the impact of variation in how the core measures on which any one definition is based are assessed; this has been given considerably less attention. Identification of low muscle strength is an important step in the case-finding of sarcopenia as defined by EWGSOP2 and other groups. The EWGSOP2 propose doing this via assessment of handgrip strength or chair rises[5]. A number of sources of variation in the protocols commonly used to assess grip strength have been documented[15-18] one of which is the type of hand-held dynamometer used. Some studies have shown variation in the grip strength achieved by individuals when tested using different makes and model of hand-held dynamometer[19-22]. However, only one study, of community dwelling Japanese adults aged 69-89 years, has considered the implications of this for the case-finding of low muscle strength. In this comparison of two types of hand-held dynamometer (Jamar hydraulic and Smedley), there was marked variation in the prevalence of weakness identified[22].

In another recent cross-over study, measurements of maximum grip strength achieved by the same community-dwelling individuals assessed in a random order using four different makes and model of commonly used hand-held dynamometer, including electronic devices not previously examined were compared. Mean differences in maximum grip strength of between 4 and 5 kg were found when comparing hydraulic or spring-gauge devices with electronic devices[23]. In this report, we aimed to assess the impact of these measurement differences on the case-finding of low muscle strength to help inform future work on sarcopenia definitions.

We utilise data from a randomised, repeated measurements cross-over study, full details described elsewhere[23]. In summary, participants were 118 men and women, aged 45 to 74 years, who had previously taken part in a market research study, resided in London or the South East of England and who agreed, on invitation after checks to ensure their eligibility, to participate in a trial to compare different devices commonly used to measure grip strength, blood pressure and lung function. This study received ethical approval from the local UCL ethics committee (ref: 6338/001) and all participants gave written informed consent.

During attendance at a research office in London between October 2015 and January 2016, study participants completed a 2-page questionnaire on sociodemographics and health status. This included questions on whether they had arthritis or other musculoskeletal conditions that affect their hands and have difficulty because of long-term health problems holding something heavy like a full kettle or removing a stiff lid from a jar. They then had their grip strength, blood pressure and lung function assessed by a trained researcher.

Grip strength was assessed using four types of hand-held dynamometer in a randomly allocated order, with 5-10 minutes between each set of grip strength measurements to prevent participant fatigue. These devices were those most commonly used in UK longitudinal studies: Jamar Hydraulic; Jamar Plus+ Digital; Nottingham Electronic; Smedley. The same standardised protocol[15,23] was used for each set of measurements (see Appendix 1). After each test, the strength (kg) achieved was recorded. For each device, two measurements were assessed in each hand. The use of a standardised protocol and assessments in both hands ensured that any variations in grip strength measurements observed could be attributed to dynamometer type and not to other factors (such as handedness or position during testing).

After identifying the maximum grip strength achieved (from all four measures, two in each hand) by each individual using each device we applied the EWGSOP2[5] recommended cut-points for low muscle strength of <16 kg for women and <27 kg for men. We then summarised the prevalence of low muscle strength for each device and assessed the agreement between pairs of devices using kappa statistics.

Among the 118 community-dwelling men and women who participated in this study, 20 (17%) reported arthritis or another musculoskeletal condition that affects their hands and 24 (20%) reported some or a lot of difficulty holding something heavy. Prevalence estimates of low muscle strength varied by dynamometer type with a range of 3% to 22% for men and 3% to 15% for women (Table 1).

Of the 13 men identified as having low muscle strength by at least one of the four dynamometers, only one participant was identified by all four dynamometers and seven by just one device (and in all cases this was the same device) (Table 2 and Appendix Supplementary Figure 1). When comparing pairs of devices, kappa statistics ranged from 0.22 to 0.55 suggesting poor to moderate agreement. Agreement between devices among women was lower with kappa statistics ranging from 0.13 to 0.46; of the 15 women classified as having low muscle strength by at least one of the four dynamometers, only one was identified by all four and ten by only one.

In a study comparing four commonly used hand-held dynamometers, we have shown that identification of low muscle strength is influenced by the type of dynamometer used to assess grip strength. The differences in prevalence

	Men (N=59)	Women (N=59)
Age (y) – mean (SD)	59.3 (7.7)	59.9 (8.4)
Low muscle strength* – n (%)		
Jamar Hydraulic	5 (8.5)	9 (15.3)
Jamar Plus+ Digital	2 (3.4)	3 (5.1)
Nottingham Electronic	2 (3.4)	9 (15.3)
Smedley	13 (22.0)	2 (3.4)
Maximum grip strength (kg) – mean (SD)		
Jamar Hydraulic	35.2 (8.5)	20.5 (5.7)
Jamar Plus+ Digital	39.4 (8.5)	25.2 (5.3)
Nottingham Electronic	40.9 (10.3)	24.4 (6.9)
Smedley	32.4 (7.4)	22.9 (5.0)

** Low muscle strength defined as maximum grip strength <27 kg for men and <16 kg for women[5].*

Table 1. Prevalence of low muscle strength and mean maximum grip strength (kg) by dynamometer type.

Classified as low muscle strength by:	Men	Women
All 4 dynamometers	1	1
3	1	1
2	4	3
1 dynamometer	7	10
At least 1 dynamometer	13	15

Table 2. Number of men and women classified as low muscle strength by number of dynamometers.

estimates and the limited overlap in case-finding between devices that we have identified are likely to have important implications for research and clinical practice that need to be carefully considered in future work on sarcopenia.

Our findings concur with those from a previous study of older Japanese adults which compared two of the four devices we assessed[22]. As we were unable to compare the strength of associations between low muscle strength, identified by each of the four devices, and important health outcomes due to limited statistical power and no longitudinal assessment of relevant health outcomes, further research is required to clarify the implications of our findings. As our study population were aged 45 to 74 years, additional research is also required to establish whether these results are generalizable to older populations where sarcopenia is more prevalent.

It has previously been argued that differences in the absolute measures of grip strength recorded when using different makes and models of hand-held dynamometers may not be a major concern when pooling grip strength data for use in epidemiological studies of association on the assumption that different devices rank people equivalently[24,25]. However, these new findings highlight that when applying absolute cut-points to grip strength measures, systematic measurement differences between different types of dynamometer are a cause for concern. This suggests that there may be benefits of avoiding the application of cut-points and instead using continuous measures in research whenever possible.

The application of cut-points is necessary for case-finding in clinical practice and so cannot always be avoided. Research is ongoing to validate cut-points for grip strength and other measures required for sarcopenia case-finding. Our findings suggest that more work is also required to understand how best to standardise the measurement of each of the different components of any one sarcopenia definition to which these cut-points are applied. For low muscle strength, it is important to recognise that there are a number of potential sources of variation in the measurement of grip strength that may have an impact on case-finding[15,17,26-28]. While excellent work has been done to highlight some of these factors and promote the standardisation of assessments[15], it may be unrealistic to expect that all research and clinical facilities will ever have access to exactly the same measurement devices and be able to follow precisely the same protocols. In recognition of this, options to consider include the development of correction factors that can be applied to take account of measurement differences between devices. Alternatively, it may be necessary to consider developing different reference values and cut-points for different types of measurement device. However, whether this is feasible remains to be seen, especially as it can be expected that existing measurement devices will be updated and new devices will continue to be developed and introduced. Creating standard protocols that are followed to validate initial results prior to a diagnosis being confirmed and interventions being implemented,

similar to those followed in diagnosing hypertension could also have value[29]. This could involve taking initial grip strength measurements using whatever device is available and, where low muscle strength is indicated undertaking additional assessments of muscle strength using a gold-standard method.

Funding

This project was funded by CLOSER (www.closer.ac.uk), whose mission is to maximise the use, value and impact of longitudinal studies. The CLOSER consortium is currently funded by the Economic and Social Research Council (award reference: ES/K000357/1). CLOSER was funded by the Economic and Social Research Council and the Medical Research Council between 2012 and 2017. CL is supported by an ESRC Doctoral Training Programme grant (ES/J500161/1) with supervision from Patrick Sturgis and Dave Martin. AW is supported by the UK Medical Research Council (MC_UU_12019/06). RH is Director of CLOSER.

Acknowledgements

With thanks to all those who volunteered to participate in the study. Thanks to Diana Kuh, Seif Shaheen, Rebecca Bendayan and Anna Hansell for their contributions to the study's development and to Cosetta Minelli and George Kyriakopoulos for guiding sampling decisions. We also thank Maria Popham and Hayley Cheshire who carried out sample recruitment and Aradhna Kaushal, Rishi Caleyachetty, Theodore D. Cosco, Ahmed Elhakeem and Stella G. Muthuri who contributed to the data collection.

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APPENDIX 1
Grip strength measurement protocol

Four different types of dynamometer will be used during the calibration study: the Nottingham electronic; Jamar hydraulic; Jamar digital; Smedley. Wherever possible, four measures will be ascertained using each device (2 measures in each hand (in the order: Left 1, Right 1, Left 2, Right 2)).

To ensure comparability of measures across devices a standard protocol will be used when performing each set of grip strength tests (see Roberts et al, Age and Ageing 2011;40(4):423-9). This standard protocol is described below.

Equipment:
- Dynamometer
- A standard straight backed chair with solid arms

Checks before performing the first set of grip strength measurements:
Exclusion criteria.
- swelling or inflammation, severe pain or recent injury in their hands
- surgery to the hand in the last 6 months (if there is a problem with one hand only use just take measurements on the other hand)
- blood pressure over ≥200 mmHg for systolic or ≥120 mmHg for diastolic.

If the participant has any of these, explain to the participant that they cannot do the grip strength tests as it would not be safe

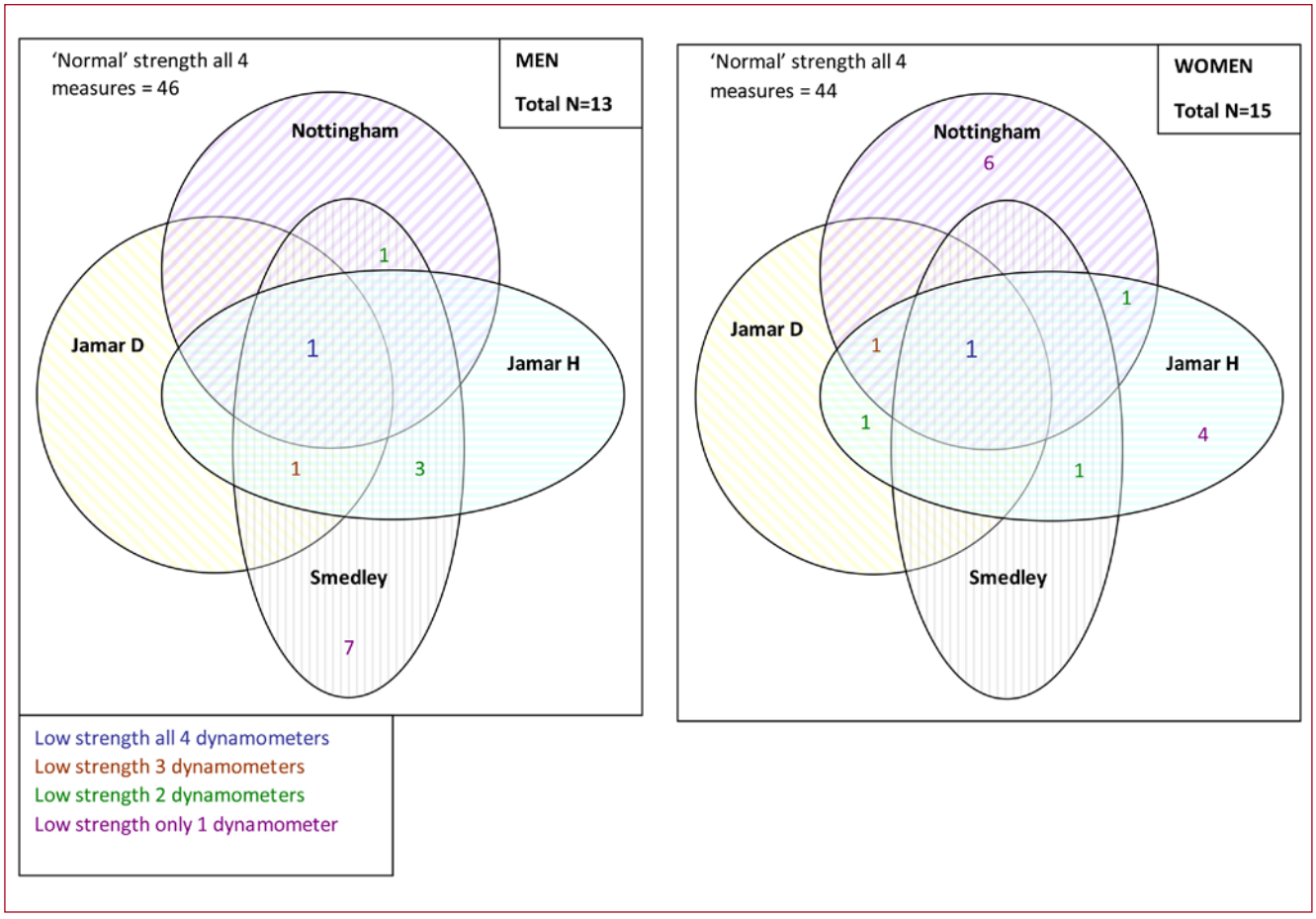
EXPLAIN THE TEST:
READ OUT:
"We would like to assess the strength of your hand in a gripping action. This test will be done using 4 different machines and each time I would like to take 2 measurements in each hand."

NOTE: *The participant should have use of both hands as a screening question will have been asked before recruitment. However, if the participant only has use of one hand please record this and perform the two measurements in that hand.*

READ OUT:
"Which is your dominant hand?"
Proceed with the tests (if participant has use of both hands the order of the tests for each device will be: Left hand, Right hand, Left hand, Right hand)

GENERAL PROTOCOL:
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 the participant to rest their left forearm on the arm of the chair in the mid-prone position (i.e. with the thumb facing upwards) and their wrist just over the end of the arm of the chair in a neutral but slightly extended position.
3. Place the dynamometer handle in their left hand (and when using either of the Jamar devices carefully place the wrist strap around the participant's left wrist)
4. 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. Large rings may need to be removed.
5. Tell the participant that after I say 'And Go' I will need you to squeeze the handle of the device as hard as you can, just for a couple of seconds until I tell you to stop and then let go. Make it clear that gripping very tightly registers the best score.
6. Once you are happy that the participant's arm is positioned correctly and that the device is ready to record you are then ready to take the measure.
7. Say '**And Go!**' at which point the participant should squeeze as hard as they can for a couple of seconds and then release quickly. You should provide verbal encouragement by telling the participant to '**Squeeze, squeeze, squeeze**' and then you should tell them after a few seconds to stop.
8. During the test please make sure that the participant's arm remains in position resting on the arm of the chair.
9. Record the value on the display to the nearest 0.1kg (for the Jamar digital and Nottingham Electronic devices), 1kg (for the Jamar hydraulic device) or 0.5kg (for the Smedley device).
10. Once the value for the left hand is recorded carefully take the dynamometer from the participant and repeat the test in the participant's right hand.

NOW REPEAT THE INSTRUCTIONS ABOVE AND TAKE A SECOND MEASUREMENT IN THE LEFT HAND, FOLLOWED BY A SECOND MEASUREMENT IN THE RIGHT HAND



Appendix Supplementary Figure 1. Overlap between men and women classified as low muscle strength by four different hand-held dynamometers (Jamar Hydraulic (Jamar H); Jamar Plus+ Digital (Jamar D); Nottingham Electronic; Smedley).