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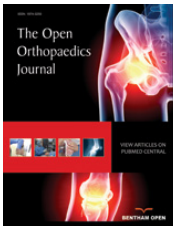

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REVIEW ARTICLE

A Review of Handgrip Strength and its Role as a Herald of Health

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Abstract:

Measurement of grip strength using a handheld dynamometer is frequently performed as part of an orthopedic upper extremity examination. We review the technique of grip strength measurement and evaluation of the possible submaximal effort. What constitutes normal grip strength in one part of the world is not necessarily normal elsewhere. Additionally, there is considerable evidence, most of which is outside the orthopedic literature, that diminished grip strength is a proxy for poor health and a predictor of increased mortality.

Keywords: Grip strength, Dynamometer, Sarcopenia, Disability, Morbidity, Mortality.

Article History	Received: March 18, 2021	Revised: October 20, 2021	Accepted: November 17, 2021

1. INTRODUCTION

In 1954, Charles O. Bechtol reported grip strength testing using a hydraulic dynamometer with adjustable settings [1]. At least since then, measurement of grip strength is commonly performed as part of a hand examination, typically with a hand-held hydraulic dynamometer. The device described by Bechtol is given the name Jamar dynamometer and has been called the "gold standard" against which all other dynamometers are measured, as well as the most widely cited in the literature [2 - 4]. It is considered reliable and valid [5]. Other devices have been used to measure grip strength, for example, pneumatic bulbs and spring gauges, but hydraulic dynamometers are near-ubiquitous pieces of equipment in the offices of hand and orthopedic surgeons, and grip strength measurements are routinely obtained [2].

Obtaining grip strength measurement is easy and straightforward. The hydraulic dynamometer described by Bechtol and its subsequent iterations have a smooth handle, always adjustable, with 5 settings. A dial, facing away from the patient, records force of grip in pounds or kilograms. The handles do not move when squeezed and therefore, by design, provide no feedback to the patient.

The patients are instructed to squeeze as hard as they can, and a number is generated. However, what to make of this measurement, is it helpful and if so, in what way? Since Bechtol's 1954 paper, many studies have been undertaken to answer these and other questions related to the measurement of grip strength.

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Positioning during grip strength measurement can range in terms of how the handle is held, as well as how the upper extremity is otherwise positioned. In Bechtol's 1954 report, subjects were shown how to grasp the dynamometer and were requested to grasp with maximum force at each of the five handle settings, alternating right and left hands. Subjects were instructed to sit in a straight-backed chair, with feet flat on the floor, shoulder adducted with neutral rotation, elbow flexed at 90 degrees, and the forearm and wrist in the neutral position [5].

Switching handle settings and recording measurements at each of 5 different positions take time. Firrell *et al*. noted that, in a busy clinic, to save time, when using the Jamar dynamometer, typically only one setting (position) is used [6]. They evaluated 288 normal asymptomatic hands of 4 to 78-year-old individuals at 5 dynamometer settings. Eighty-nine percent had maximum strength at the second setting. They recommended grip strength measurement at position 2, regardless of age, weight, or hand dimensions.

Trampisch *et al*. supported this recommendation further using a Jamar dynamometer (with digital readout) to evaluate optimal handle position by measuring grip strength 3 times at each of the 5 handle positions for 50 study participants [5]. Position 1 was the closest and position 5 was the widest spread. They found that the handle at position 2 was the best position (maximal grip strength) for 70% of participants. They found the mean difference between grip strength at position 2, and each participant's best position was 0.8kg (2% of mean maximal grip strength). They, therefore, recommended position 2 for measuring grip strength with the Jamar dynamometer having the advantage of being easier and faster as well as

DOI: 10.2174/18743250-v16-e2201100, 2022, *16*, e187432502201100

"sufficiently accurate" as compared to the measurements at multiple different positions.

Mathiowetz *et al*. evaluated the effect of elbow position on grip strength and found significantly greater grip strength with the elbow flexed at 90 degrees compared to elbow fully extended [7]. Additional recommendations are for the shoulder to be adducted and neutrally rotated and for the forearm to be neutral [8].

The ideal number of grip strength measurements and how to interpret repeated trials have also been explored. The American Medical Association (AMA) Guides to the Evaluation of Permanent Impairment, 5th edition, used in California and other states to determine disability, recommends 3 measurements which are then averaged [9]. Coldham *et al.* evaluated the reliability of one *vs*. three grip trials in symptomatic and asymptomatic subjects using the Jamar dynamometer [10]. Their findings suggest that one maximal trial is as reliable as taking 3 measurements, either the best of 3 or the mean of 3 measurements. In contrast, Mathiowetz *et al.* believed that the mean of 3 trials generated the highest reliability [11].

So, from the above studies, when using the Jamar dynamometer, one maximum grasp at setting 2 with the elbow flexed at 90 degrees can provide a reliable measure of grip strength.

Submaximal effort during grip strength testing is an apparent popular topic in the literature. Various terms have been used to describe this scenario, such as "feigned hand weakness," "submaximal grip effort," "faked hand weakness," "voluntary control of submaximal grip strength," "sincerity of effort," and "low effort" [12 - 17]. The words "malingering" and "malingerers" also appear in the literature [18 - 20].

In Bechtol's 1954 report under a paragraph headed "failure to exert full effort during a grip test," he described "repeated tests" as a basis for determining submaximal effort. According to Bechtol, if a subject exerts full effort, scores on repeated tests will vary less than 20 percent and usually less than 10%. With submaximal effort, repeated tests will vary greater than 20% [1].

Afterward, other techniques have been tried in an attempt to identify submaximal effort. Using the Jamar dynamometer, it has been observed that grip strength measurements obtained at all 5 handle positions produced a bell-shaped curve, with maximum grip strength at the second or third handle set, and lower strength with a handle set wide and narrow [17, 19]. Stokes, in 1983, proposed that a patient who is voluntarily trying to demonstrate weakness will, when tested at all 5 handle positions, generate a straight-line graph instead of a bell-shaped curve [19]. This conclusion has been challenged by others [12, 15, 16, 21]. For example, Niebuhr and Marion reported that subjects, with proper instruction as to the amount of effort to exert, can produce feigned submaximal efforts similar to sincere, maximal efforts of injured people [15].

Hildreth proposed a rapid exchange test to detect submaximal effort [20]. The test is performed by having the patient maximally grip the dynamometer, switching right to left hands, and comparing results with static tests. Hildreth *et al*. stated that there is no set number of exchanges, but the testing continues until the examiner has determined if the results are positive or negative. A rapid exchange test score greater than the static test score is a negative result. A positive rapid exchange test, one which, while not proof of "malingering" can "alert" and "sensitize" the physician to the possibility of submaximal effort. Like the 5 handle position grip test, the rapid exchange grip test has its critics [13]. Tredgett and Davis stated that rapid, repeated measurement of grip strength could not be relied on to discriminate between maximum effort and feigned hand weakness [14].

The AMA Guides to the Evaluation of Permanent Impairment, 5th Edition, recommends both the rapid exchange grip technique and the 5 handle setting technique to help detect less than maximal effort [9]. These methods are not foolproof. Determining conclusively that one is not putting forth maximal effort is difficult. Additionally, it should be noted that malingering is often considered a conscious or willful effort to "deceive," and in the absence of some extraordinary proof, a physician should use caution before labelling someone as a malingerer.

Normative data and demographic context are important considerations when analyzing grip strength measurements and their implications. A reference grip strength chart is available in the AMA Guides. Furthermore, Wang *et al*. have recently published normative reference values for grip strength for 1232 individuals of 18 to 85 years of age residing in the United States (Table **1**) [22]. The data were obtained from the United States National Institutes of Health Toolbox project and, as the authors stated, can be used to interpret grip strength measurements obtained from adults in the United States.

Table 1. Summary of hand-grip strength measurements by side, sex, and age-group strata.

-	-	Percentile				
Hand/Sex/Age, years	**Strength, lb***	**10**	**25**	**50**	**75**	**90**
Dominant: Male						
18-24 (n = 36)	103.6 ± 17.9	79.8	91.3	105.4	112.9	127.6
25-29 (n = 35)	109.6 ± 25.6	74.3	95.5	108.7	131.0	145.9
30-34 (n = 29)	102.5 ± 26.7	68.8	80.2	101.6	124.3	139.1
35-39 (n = 41)	103.8 ± 26.2	66.8	87.5	110.5	119.7	134.0
40-44 (n = 47)	103.0 ± 25.8	75.6	88.0	101.2	119.9	139.1
45-49 (n = 32)	94.4 ± 24.0	68.6	78.9	89.7	106.3	130.5
50-54 (n = 46)	97.0 ± 22.7	67.0	86.0	98.8	115.3	125.0
55-59 (n = 27)	89.7 ± 22.9	62.2	71.4	85.3	105.4	124.1

(Table 1) contd.....

60-64 (n = 33)	84.7 ± 22.7	51.4	67.0	88.8	99.0	115.7
65-69 (n = 22)	81.1 ± 23.1	39.2	69.4	80.7	101.0	110.5
70-74 (n = 39)	76.5 ± 19.8	36.8	64.6	80.0	90.8	100.5
75-79 (n = 24)	72.1 ± 22.3	40.6	57.1	73.9	80.7	95.9
80-85 (n = 38)	61.9 ± 20.1	34.4	47.4	65.0	76.3	84.2
Dominant: Female						
18-24 (n = 54)	61.9 ± 15.7	38.8	49.4	62.6	74.5	83.8
25-29 (n = 102)	65.3 ± 15.4	44.5	56.0	65.3	74.1	87.5
30-34 (n = 109)	63.7 ± 13.7	45.2	52.7	65.7	72.8	81.8
35-39 (n = 90)	64.4 ± 13.7	44.1	54.0	66.8	72.8	83.8
40-44 (n = 88)	65.9 ± 13.7	50.3	58.4	67.0	74.5	82.5
45-49 (n = 52)	63.5 ± 15.9	39.0	55.6	63.3	75.8	82.9
50-54 (n = 65)	62.2 ± 13.9	43.4	54.2	62.2	72.1	77.6
55-59 (n = 30)	55.3 ± 13.7	37.3	45.6	53.1	66.6	71.0
60-64 (n = 58)	52.0 ± 14.3	35.1	42.3	53.8	61.9	70.1
65-69 (n = 29)	48.7 ± 14.6	25.8	42.5	48.9	55.1	68.8
70-74 (n = 43)	47.4 ± 11.2	33.5	43.0	49.6	52.7	60.6
75-79 (n = 17)	43.2 ± 13.2	27.8	34.6	40.1	49.4	61.3
80-85 (n = 46)	43.9 ± 9.7	32.0	36.6	43.0	48.1	59.5
Nondominant: Male						
18-24 (n = 36)	99.0 ± 17.2	78.7	83.8	98.1	111.1	121.7
25-29 (n = 35)	102.5 ± 21.2	68.6	86.9	104.1	124.3	132.1
30-34 (n = 29)	101.0 ± 24.9	62.8	81.6	99.2	123.9	132.5
35-39 (n = 41)	100.3 ± 24.3	75.6	82.7	104.1	115.3	129.6
40-44 (n = 47)	99.0 ± 25.8	70.8	85.5	94.1	115.5	135.4
45-49 (n = 32)	90.8 ± 22.0	65.3	75.8	89.1	102.5	127.2
50-54 (n = 46)	93.3 ± 23.4	59.7	84.4	97.7	107.4	121.5
55-59 (n = 27)	84.9 ± 21.2	60.4	67.7	82.0	93.7	121.9
60-64 (n = 33)	82.0 ± 20.1	51.6	70.3	81.8	98.8	108.7
65-69 (n = 22)	78.0 ± 22.7	38.1	61.7	82.7	94.8	105.8
70-74 (n = 39)	75.0 ± 20.9	45.2	65.9	76.1	89.5	100.8
75-79 (n = 24)	66.8 ± 21.8	32.0	54.0	66.6	79.4	88.6
80-85 (n = 38)	59.7 ± 20.7	31.3	44.1	60.2	70.5	88.2
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25-29 (n = 102)	61.5 ± 14.6	45.0	52.2	60.6	70.1	84.2
30-34 (n = 109)	61.1 ± 13.0	43.2	53.1	60.8	67.9	77.6
35-39 (n = 90)	61.7 ± 13.2	43.4	52.2	60.8	70.5	80.2
40-44 (n = 88)	63.7 ± 14.1	47.8	55.6	64.6	74.1	81.1
45-49 (n = 52)	60.4 ± 15.4	37.7	50.3	59.3	73.6	80.5
50-54 (n = 65)	58.4 ± 14.3	39.0	49.2	58.2	70.3	76.7
55-59 (n = 30)	52.0 ± 14.1	32.2	40.6	51.8	62.2	68.6
60-64 (n = 58)	50.5 ± 13.9	34.8	38.8	49.8	62.2	67.5
65-69 (n = 29)	46.3 ± 14.6	33.1	35.7	47.2	56.9	67.5
70-74 (n = 43)	44.5 ± 12.1	30.2	36.8	46.1	51.8	61.7
75-79 (n = 17)	41.2 ± 12.8	23.6	31.7	41.0	48.5	60.4
80-85 (n = 46)	42.8 ± 8.8	30.6	38.1	42.5	46.3	54.0

*Values are mean ± Standard Deviation; lb = pounds.

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Bechtol, in his 1954 paper, provided results of grip strength testing in "unselected patients" with charts showing the distribution of grip strength in more than 400 men and women [1]. Since then, and as noted by Wang *et al.*, grip strength measurements, described as normative data, have been reported from all over the world [22]. For example, normative data, for handgrip strength has been studied in Australians, Spanish population, Greek population, Canadians aged 6-79 years, South Korean population, 6 to 19-year-old individuals in a 7 county Milwaukee area, "elderly Singaporeans," "older adults" in Singapore, Nepalese, Saudis, Iranian, and individuals residing in the United States of 18 to 85 years of age [22 - 33].

Sometimes, it has been observed that the reference values will provide a basis for comparison when testing individuals [34]. Often, no goal is given other than establishing reference values or normative data. However, we can compare the grip strength measurement of one individual to a large group of similar people. Mitsionis *et al*. believed that grip strength is a reliable way to assess the impact of an injury on the hands to evaluate the effectiveness of the surgical intervention [25]. However, comparing grip strength to the uninjured hand might be a better way. Generalizing from one group to another has been questioned. For example, Werle *et al*. evaluated normative data in a healthy adult Swiss population, found significant differences from other populations, and concluded that applying normative data internationally is “questionable” [35]. Ong *et al*. reported that older adults in Singapore had weaker grip strength than older adults from Western and other Asian countries [30].

Dodds *et al*., in 2016, reviewed studies on grip strength from different countries. They performed a systematic review and meta-analysis of reports on grip strength throughout the world (96, 517 grip strength observations). From their data, and as one might expect, grip strength peaked between ages 20 to 40 years. One of their main findings was that grip strength measurements were substantially lower in developing world regions, such as Africa, America (excluding North America), and Asia (excluding Japan), compared to developed world regions. As a result, they questioned whether a single set of normative data could be used across different countries. Therefore, what constitutes low grip strength or weak grip may need different “cut points” for different geographic regions [36].

Moreover, as noted by Roberts *et al*., there is often insufficient information about the protocols used in many studies which makes comparisons difficult [3].

2. GRIP STRENGTH AS A MEASURE OF HEALTH

Orthopedic surgeons and hand surgeons often document grip strength after injury or surgery. It is one way of monitoring deficit, recovery, and return of functions. However, perhaps unknown to most surgeons, grip strength is often used as a proxy for fitness and well-being, and a predictor of future health and mortality.

Grip strength measurement is a tool to assess for sarcopenia, which is a “progressive and generalized skeletal disorder associated with increased likelihood of adverse outcomes, including falls, fractures, physical disability, and mortality” [37]. Sarcopenia is characterized by low muscle strength, low muscle quantity or quality, and low physical performance.

Gale *et al*., in 2007, investigated the relationship between grip strength, body composition, and cause-specific and total mortality in 800 men and women aged 65 and older living in Britain. They found that poor grip strength was associated with increased mortality from all causes, cardiovascular disease, and cancer in men, but not in women [38]. Grip strength, in their determination, is a long-term predictor of mortality in men.

Bae *et al*. in a prospective observational study conducted in Korea involving middle-aged and older adults, found a relationship between weaker handgrip strength and higher all-cause mortality in both men and women. Considering this finding, they concluded that assessing and monitoring handgrip strength during adulthood protects against premature death in the population of Korean adults [27].

Rantanen *et al*. investigated whether handgrip strength measured during mid-life predicts old age functional limitations and disability in initially healthy men. Their 25-year prospective cohort study involved more than 6,000, 45 to 68-year-old Japanese-American men living in Hawaii. They found that handgrip strength was highly predictive of functional limitation and disability 25 years later. They surmised that good muscle strength in middle age may protect people from old age disability [39].

Giampaoli *et al*., in a population-based prospective study, followed 140 Italian men aged 71 to 91 years who reported no disability in performing activities of daily living. After four years, their functional status was re-evaluated. Poor grip strength predicted disability in men 77 years or older [40].

In a longitudinal study conducted on Japanese men and women, Sasaki found grip strength “an accurate and consistent” predictor of all causes of mortality in middle-aged and elderly subjects [41].

Al Snih *et al.* evaluated the association between grip strength and mortality in older Mexican American men and women in a five-year prospective cohort study involving 2,488 subjects aged 65 and older. In this study, it was found that lower handgrip strength was a strong predictor of mortality [42].

Ling *et al.* performed a prospective population-based study on all 85-year-old inhabitants of Leiden, Netherland (total 555 participants). Handgrip strength was measured at baseline and again at age of 89 years. They found, after adjusting for possible co-founders, a significant elevation in risk for all-cause mortality in subjects in the lowest tertile of handgrip strength at 85 years and the lowest two tertiles of handgrip strength at age 89 years. Subjects with high relative loss of handgrip strength over 4 years also showed significantly increased mortality. It was reported that handgrip strength is a surrogate measure of overall muscular strength. They acknowledged that they could not determine whether the relation between muscle strength and mortality is direct or whether muscular strength is a “surrogate marker” of other factors [43].

Lera *et al*., in a study on Chileans over 60 years, noted an increased risk of all-cause mortality in subjects lower than the 25^{th} percentile. As in other studies, they noted that they could not discard the influence of other “nonmeasured parameters” on the association between grip strength and mortality [44].

Bohannon performed a literature review to assess the predictive value of grip strength. He found that low grip strength was associated with a greater likelihood of premature death. Additionally, low grip strength was associated with the development of disability and an increased risk of complications or prolonged length of stay after hospitalization or surgery [45].

Bohannon, in a recent and extensive review, described grip strength as "an indispensable biomarker for older adults" and as "an explanator of concurrent overall strength, upper limb function, bone mineral density, fractures, falls, malnutrition, cognitive impairment, depression, sleep problems, diabetes, multimorbidity, and quality of life." Also, Bohannon reported, "a predictive link between grip strength and all-cause and disease-specific mortality" [46].

It should be noted that most of the studies that focused on grip strength and mortality have reported an association without proving a causal relationship. However, one recent study by McGrath *et al*. provided some support to suggest causality through a robust matched cohort study [47]. Their group evaluated grip strength and mortality in more than 19,000 Americans of at least 50 years old and divided them into groups defined as weak, not weak, and strong. They defined weak grip as < 26 kg for men and < 16 kg for women. They found a higher hazard for mortality in the weak cohort. Those in the weak cohort had a 40% and 54% greater risk for early mortality relative to the not-weak and strong control groups, respectively, despite these cohorts being balanced on modifiable and nonmodifiable factors associated with mortality. The authors stated that their findings "may indicate" a causal association between muscle weakness and mortality [47].

Interestingly, in addition to association with overall mortality, more recent studies have also demonstrated an association between asymmetric handgrip strength and multimorbidity. Klawitter *et al*. studied handgrip strengths, which were asymmetric by >10% between dominant and non-dominant hands of individuals aged 40 years and greater [48]. They found asymmetric handgrip strength to be linked to chronic morbidity status, with these individuals demonstrating 1.31 (95% confidence interval (CI): 1.03 – 1.67) greater odds for multimorbidity, as well as 1.22 (CI: 1.04 – 1.44) greater odds for accumulating morbidities compared to individuals without handgrip asymmetry. They suggested that healthcare providers encourage healthy, physically active behaviors, which will reduce asymmetries, thus improving muscle function and mitigating morbidity risk in the future.

Although causality cannot be proven by the currently available literature, the robust body of evidence available makes it clear that an important association exists between grip strength and overall health.

CONCLUSION

Something seemingly so limited and circumscribed as grip strength measurement has significance beyond what many of us are aware. The evidence, almost all of which is not in the orthopedic literature, supports this simple objective test as having value and usefulness beyond what most of us have known. Bohannon recommended routine grip strength measurement for older adults in healthcare settings. Orthopedic surgeons have the opportunity to measure grip strength as a routine part of an orthopedic examination and it is reasonable to do so in order to identify at-risk patients who then can be referred to primary care physicians and geriatricians for additional evaluation and appropriate care. By utilizing this ubiquitous tool diligently and communicating these findings to our primary care and geriatric colleagues, we can further support our patients' overall health, well-being, and potentially even longevity.

CONSENT FOR PUBLICATION

Not applicable.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

Declared none.

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