SQUEGG™

Smart Dynamometer and Hand Trainer

Normative Grip Strength Reference Values for the Squegg® Smart Dynamometer and Hand Grip Trainer

Authors |

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Introduction

The measurement of grip strength holds immense importance in a variety of health-related contexts. Grip strength, evaluated using dynamometers, serves as a fundamental metric for quantifying nature and severity of injury and disease affecting hand function, and for tracking rehabilitation progress and effectiveness.[1,2] Extensive literature spanning several decades has also demonstrated a strong relationship between weak grip strength and poor health-related quality of life and elevated risks of heart attacks, diabetes, stroke, and cognitive decline, especially among the elderly.[3–5] Grip strength decline, often a natural part of aging, may go unnoticed until it hampers everyday activities.[6] Longitudinal studies, thus underline the significance of regular grip strength assessment, to allow for timely interventions and preserving functional independence. Therefore, precise grip strength assessment with accurate and reliable dynamometers is vital for enabling valid clinical interpretations for diverse patient populations.

Traditionally, grip strength assessment has been conducted in person using analog devices such as hydraulic dynamometers. This can both increase time burden for physicians, and reduce access for those with transportation and mobility limitations, including economically disadvantaged individuals, aging adults, disabled individuals, and rural community residents. The need for remote assessment devices has gained further prominence, with the rise of teletherapy, and expansion of CPT codes facilitating remote therapeutic monitoring in occupational and physical therapy settings.[6] Among the existing tools, the Jamar® Hydraulic Hand Dynamometer (also referred to herein as "Jamar") has been widely regarded as the gold standard due to its excellent test-retest and interrater reliability, and decades of use in both clinical and research settings.[3,6,7]

Nonetheless, the Jamar dynamometer has several inherent limitations. It lacks capabilities such as display or record of rapid grip and release handgrip force data, or measurement of sustained handgrip force, crucial for comprehensive assessment.[8] Moreover, its mechanical nature necessitates regular recalibration and poses challenges in handling due to its weight,and it is insensitive for measuring low forces.[3,7,8] As technology continues to advance, there is a growing need for innovative solutions that address these limitations of traditional in-clinic dynamometry, and ensure accurate, convenient, and efficient grip strength measurement in various healthcare contexts.

One such innovative solution, is the Squegg® Smart Dynamometer and Hand Grip Trainer which is a class II, 510(k)-exempt and HIPPA compliant medical device (also referred to as Squegg®; Squegg Inc, Plantation, FL). Squegg® has an oblong egg-shaped body, with an outer silicone shell for comfortable gripping and guidance of finger placement via finger indentations. The device can connect via Bluetooth to any smart mobile device or tablet, and comes with companion physician (Squegg Pro) and patient facing (Squegg Core) applications to facilitate administration of standardized grip strength assessments, and game-based exercise programs. Three recent studies assessed the concurrent validity and reliability of Squegg relative to gold standard Jamar dynamometry.

Stamate et al. conducted a study in forty middle-age and older adult volunteers, and concluded that Squegg has good to excellent inter-instrument reliability (overall intraclass correlation = 0.912), agreement (Pearson correlation coefficient = 0.85), and concurrent validity, with the Jamar dynamometer.[1] Bairapareddy et al. conducted a similar study in 30 adults aged 18-40 yrs of age, and reported excellent intra-rater reliability for Squegg (ICC >0.99), and 'good' concurrent validity with Jamar (ICC= 0.844, Pearson correlation coefficient = 0.72).[2] Amin et al. conducted a study in 595 volunteers, and noted significant correlation (Spearman's rank correlation = 0.67 – 0.73), and 'good' concurrent validity between Jamar and Squegg.[3] Additionally, test-retest reliability for Squegg was reported to be 'good-to-excellent' for the right hand, and 'excellent' for the left hand [between trials ICC = 0.911 and 0.928 respectively].

In addition to establishing validity and reliability, the identification of grip-strength impairments using a new tool also requires normative reference values to which an individual patient's measurements can be compared. This is particularly important since absolute values of grip-strength have been shown to be device-specific, and impacted by factors such as size, weight, material, and technological characteristics.[3,7,11]

Furthermore, normative grip strengths values are also influenced by patient demographic characteristics such as age and sex. Therefore, the purpose of the present study was to provide: (a) normative reference values of Squegg measured Maximal Grip Strength (MGS) for individuals 18 to 80+ years of age, and (2) qualitative comparison of normative trends for Squegg with those reported in literature using other dynamometers.

Methods

Data Collection

Majority of data included in this study were obtained from general Squegg users, who had purchased the device on their own, and who could perform the assessments at any time in a self-guided manner based on instructions built-in the mobile (Squegg Core) application. The user is provided options for which hand is to be evaluated (Left/Right), while hand dominance, age and gender information is collected as part of patient profile creation. Each assessment consists of 3 grip strength measurement trials per alternating hands, which are averaged to obtain the grip strength associated with that specific assessment . At the time of grip strength assessment, the user is given the following standard instructions in the mobile application, along with relevant images for clarity. These instructions align with the recommendations of the American Society of Hand Therapists.[12]

- Sit in upright position.
- Keep your feet uncrossed and, on the floor, keep your elbow tucked at your side.
- Flex your elbow 90 degrees so that it is parallel to the floor Do not rest your arm on the armrest.
- Hold the Squegg comfortably in your hand so that your thumb is up, and your fingers are on the 4 indentations.

During each trial of an assessment, the user is asked to squeeze the device for a brief period (prompted by "grip" and "release" instructions, and a progress bar), and the highest measured grip strength value is recorded. The user is prompted to switch hands between each trial, and may also take a rest in between trials. After measuring the grip strength 3 times, the user is given an option to repeat any of the trials if required.

Data for all the 3 trials, along with the average value, is recorded in the database. For further reference, only the average of the 3 is considered and referred to as an assessment of maximal grip strength. Squegg users can assessment their grip strengths any number of times in the application. Results across multiple assessment, were averaged to obtain maximal grip strength for that user.

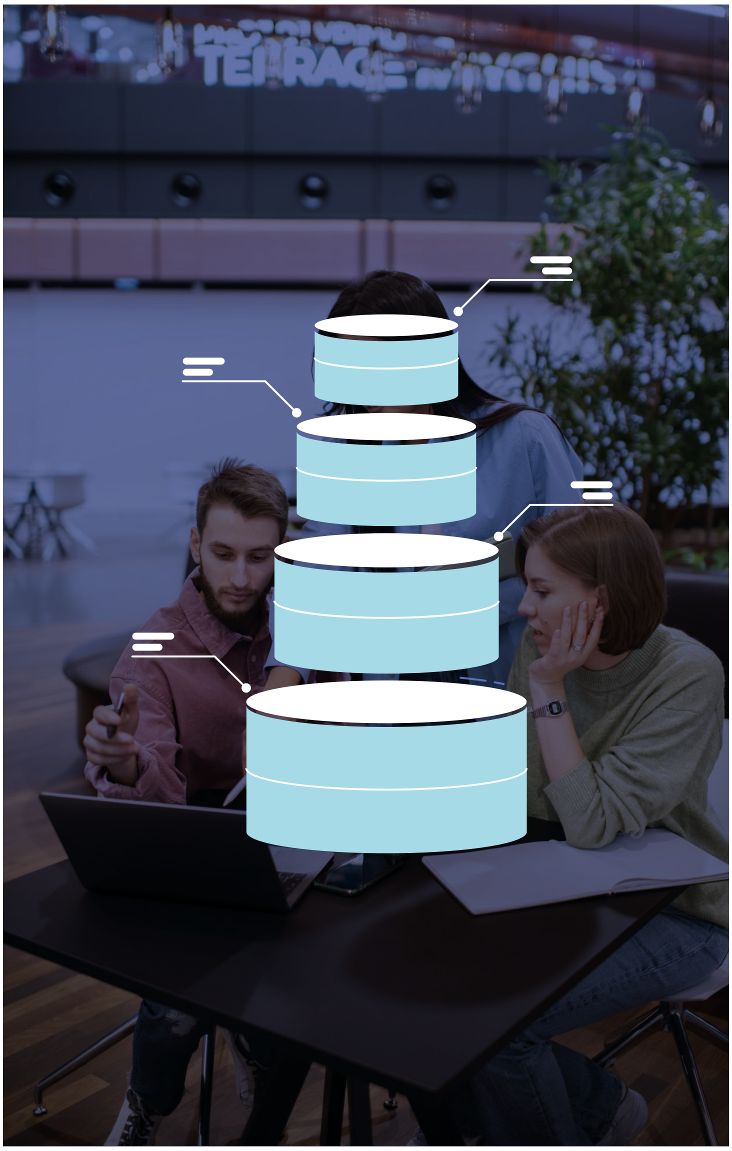
Data Filtering

The initial dataset, contained 1800 users with following associated fields: id, age, grip_strength, grip_hand (left/right), dominant_hand, sex, country. Out of this initial dataset, 577 users were removed because of missing data in one or more fields. To ensure similar racial makeup, geographic location was limited to North America (US, Canada), Europe, Australia or New Zealand, leading to filtered set of 870 users.

A total of 13 age categories spanning 18 to 87 years were considered ('18-24', '25-29', '30-34', '35-39', '40-44', '45-49', '50-54', '55-59', '60-64', '65-69', '70-74', '75-79', '80+').

Users with age outside of these categories, along with 84 users with between-side differences in grip strength larger than 30% [(abs(dominant-non-dominant) >30% of dominant grip strength) were dropped.[13] Also removed were 15 additional male and 5 female users with grip strength values that were outliers relative to their age category and overall distribution of grip strength.

In the end, data from 465 general Squegg users were included in the analysis. These data were combined with data for 37 subjects from prior validation study by Stamate et al.[6], resulting in 502 subjects in total for the final analysis.



The 37 subjects from study by Stamate et. al., were older adults without neuromuscular, or orthopedic dysfunction affecting hand function. Out of the 465 general Squegg users, "reason for use" information was available for 450 users (96.7%). None of the users selected "recovering from hand injury" or "recovering from stroke" as a reason for use. Majority of users (81.1%) reported using Squegg to improve grip performance (endurance, strength, coordination or reaction time), with smaller proportions using Squegg to "regulate blood pressure" (12.2%), and for "other" (6.7%) reasons.

Qualitative Comparison to Literature

For qualitative comparison of Squegg MGS with values reported for other dynamometers, we conducted a search of English language literature in PubMed, using search terms that involved combinations of "normative", and "grip strength", "hand-grip strength", or "handgrip strength". A total of 352 studies were identified via the search. Further filtering of relevant studies based on manual review of abstract and text was carried out as per following criteria.

Studies involving populations from North America (US, Canada), Europe, Australia or New Zealand were included to maintain parity with geographic locations of Squegg users in the present study. For inclusion in the comparison, a study had to report mean or median grip strength values for general non-disease specific cohorts, with data for male and female subjects provided as a function of age either in tabulated or graphical format. The device used should have been a grip-based dynamometer. Additionally, data had to be collected within the last 20 years (year 2003 cut-off) to maintain relevance to current populations. Studied with duplicated sources of grip strength data were excluded. Based, on the above criteria a total of 14 suitable studies, were identified for comparison of normative MGS values.[3,4,13,-24]

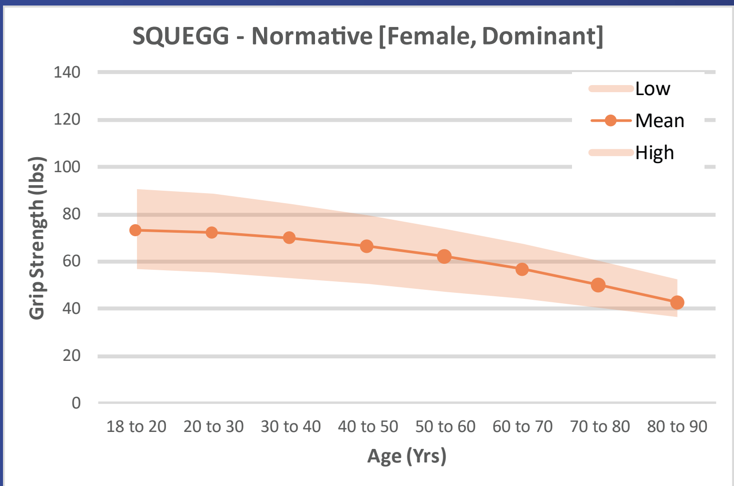
Results

Squegg Normative Data

Squegg grip strength data from a total of 502 individuals (245 males, and 257 females) was included in the final analysis. The geographic distribution of Squegg users was; 329 from US, 12 from Canada, 37 from Romania, 19 from Great Britain, 12 from Belgium, 10 from Italy, and 83 from Australia. Table 1 summarizes Squegg maximal grip strength by age group, sex, and side (dominant/non-dominant). Three-way ANOVA analysis, confirmed that age ($p < 0.0001$), sex ($p<0.0001$), and side ($p = 0.0038$), had significant effect on Squegg MGS. Interaction effects between the 3 factors were not found to be significant.

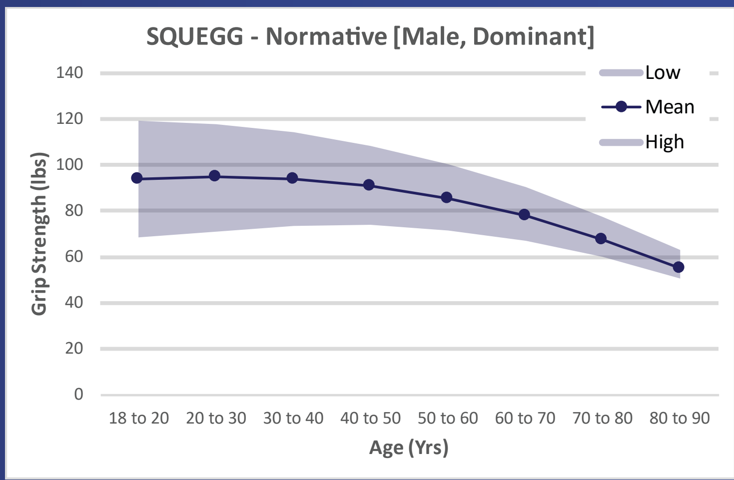
Overall, there was a slight difference in grip strength between dominant and non-dominant sides, with non-dominant side on average being 5-6% lower. As expected, females showed lower grip strength compared to males across all age groups (~26% lower than males). Figure 1, which shows graph of MGS as function of age, demonstrates continual reduction in MGS with age for both male and female sexes, following a quadratic pattern. The quadratic fit, further shows that the downward trend in grip strength is more pronounced after 40-50yrs of age.

Figure 01



Mean grip strength for dominant hand of female subjects, along with low (25th percentile) and high (75th percentile) ranges.

Mean grip strength for dominant hand of male subjects, along with low (25th percentile) and high (75th percentile) ranges.



NORMATIVE GRIP STRENGTH DATA (lbs)

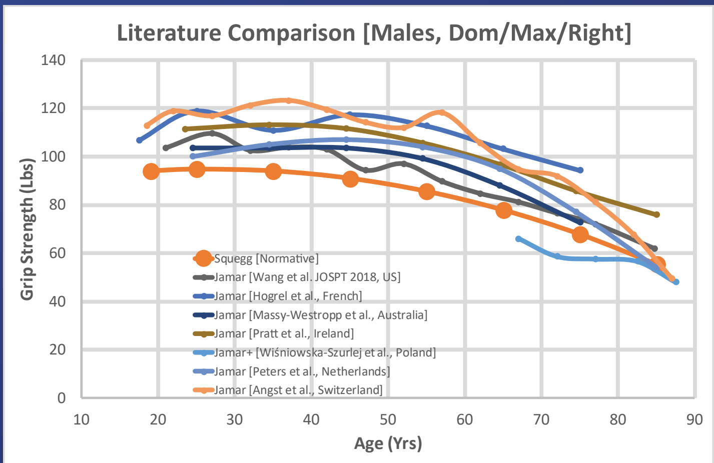
		Males		Females	
Age (yrs)	Side	Mean (lbs)	Range (lbs)	Mean (lbs)	Range (lbs)
18 to 20	Dom	94.0	68.4 – 119.0	73.4	56.8 – 90.7
	Non-Dom	89.6	69.5 – 111.1	68.2	53.5 – 79.4
20 to 30	Dom	94.7	71.1 – 117.9	72.5	55.5 – 88.6
	Non-Dom	89.5	70.7 – 110.2	67.8	52.1 – 80.4
30 to 40	Dom	94.0	73.7 – 114.3	70.0	53.1 – 84.4
	Non-Dom	88.2	71.3 – 107.1	66.0	49.9 – 80.1
40 to 50	Dom	90.9	73.8 – 108.5	66.5	50.4 – 79.5
	Non-Dom	85.0	70.0 – 102.0	63.0	47.5 – 77.4
50 to 60	Dom	85.5	71.6 – 100.5	62.1	47.4 – 73.8
	Non-Dom	79.8	66.9 – 94.8	58.8	45.1 – 72.4
60 to 70	Dom	77.8	67.0 – 90.1	56.6	44.1 – 67.4
	Non-Dom	72.6	61.9 – 85.4	53.4	42.5 – 65.0
70 to 80	Dom	67.7	60.0 – 77.6	50.1	40.5 – 60.3
	Non-Dom	63.5	55.0 – 74.0	46.7	39.9 – 55.2
80 to 90	Dom	55.3	50.6 – 62.8	42.7	36.6 – 52.4
	Non-Dom	52.4	46.4 – 60.6	38.8	37.2 – 43.1

*This range represents 25-75th percentile.

Qualitative Comparison to Literature

A total of 14 studies reporting normative grip strength data for healthy populations from North America (US, Canada), Europe (Ireland, France, Netherlands, Switzerland, Germany, Great Britain, Poland, Northwest Russia), and Australia were identified for qualitative comparison with normative values for Squegg. Six studies used a Jamar dynamometer, [3,13,16,19,21,23] one study used a Jamar plus + dynamometer, [22] three studies used a Smedley dynamometer,[17,18,24] one study used a Takei dynamometer,[4] one study used Tracker Freedom dynamometer,[20] one study used a DK-50 dynamometer,[14] and one study included a mix of different dynamometers.[15]

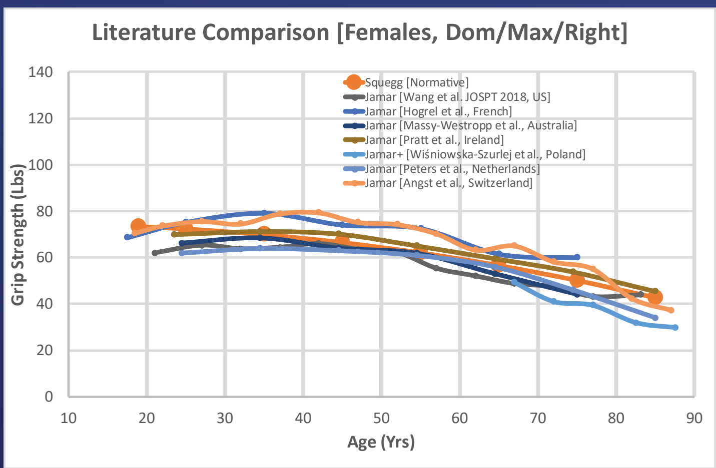
Figure 02



Comparison of normative grip strength of male subjects measured using Squegg to values reported in literature using other dynamometers

Note - *only comparison with Jamar studies shown here.

Figure 03



Comparison of normative grip strength of female subjects measured using Squegg to values reported in literature using other dynamometers

Note - *only comparison with Jamar studies shown here.

Figure 2, shows an overlay of grip strength for males reported across the various prior studies from literature, and the Squegg MGS values from the present study. Squegg MGS for males showed quadratic trend of reducing values with age very similar to those observed in literature for Jamar and other dynamometers. Although following very similar trend, Squegg MGS values for males were slightly lower than the range of values measured in most of the studies.

Figure 3, shows overlay of MGS for females as reported across the various studies in literature, and the Squegg MGS values from the present study. Squegg MGS for females also showed quadratic trend of reducing values with age very similar to those reported in literature with Jamar and other dynamometers. Additionally, Squegg MGS values for females were within the range of values measured with other devices.

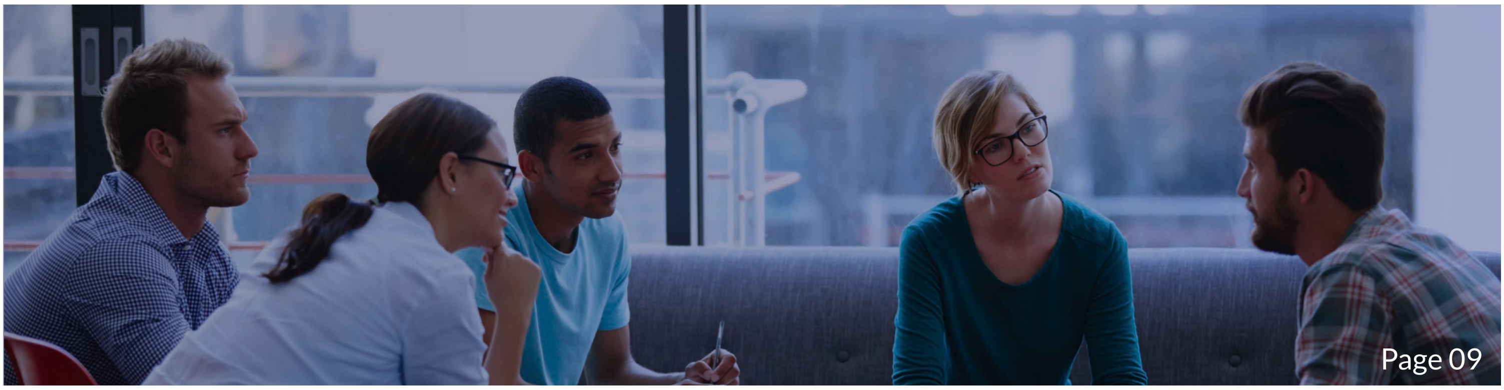
Discussion

The present study is the first report of normative MGS values for a new digitally connected dynamometer, namely the "Squegg® Smart Dynamometer and Hand Grip Trainer". Previously, the validity and reliability of Squegg relative to gold standard Jamar dynamometry was demonstrated in both older and younger adults in three different studies.[6,9,10] The normative values presented herein, together with these prior validation studies, will facilitate practical clinical usage of this new technology by enabling physicians to benchmark severity of hand impairment at initial presentation and track improvements during the course of rehabilitation. Overall, Squegg MGS normative values followed trends that were qualitatively very similar to those reported in literature for other dynamometers. This included a quadratic trend of reducing MGS with age, for both male and female subjects, with female MGS being significantly lower than that of males [~26% lower on average]. In particular, the downward trend for MGS was more pronounced after about 50 yrs of age. This is consistent with the findings of other studies. For example, Pratt et al. observed, grip strength in both sexes to be relatively stable during early adulthood (18–39 years), peak between 30-39 years of age, before stabilizing for a brief period followed by progressive deterioration beyond 45-50 (sooner in females) years of age.[16] Looking across 12 British studies, Dodds et al. observed grip strength to peak in early adult life, followed by period of a broad maintenance through mid-life, prior to decline with increasing age thereafter.[15] Similarly, Wong et al. found a curvilinear relationship between grip strength and age, with grip strength increasing from childhood through adolescence, peaking in mid-adulthood (~30-49yrs) and declining thereafter.[17] McGrath et al. noted decline in absolute HGS at around 30 years of age, with accelerated reduction starting around 70 years of age.[4] These age-related trends of MGS also underly the rapidly increasing prevalence of weak grip strength with age. For example, Kim et al. described prevalence of weak grip strength in Korean adults to increase from <5% for age <50 yrs, to over 30% for age >70yrs (weak MGS defined as 2 standard deviations below young adult mean).[5] Pratt et al. noted prevalence of weak grip strength in Irish adults to increase from <5% for age <50 yrs to over 25% for age >70yrs.[16] Similarly, Dodds et al. noted prevalence of weak grip strength in British adults to increase from <5% for age <50 yrs to over 20% for age >70yrs.[15]

In addition to sex and age, side (dominant/non-dominant) also affected grip strength, albeit the effect was much smaller. Squegg MGS for non-dominant side in both sexes was ~5-6% lower than the values for dominant side. This was similar to the ~4-7% difference between dominant and non-dominant sides for Jamar measured MGS noted by Wang et al.[13] and Mohammadian et al.,[25] and Takei dynamometer measured MGS by McGrath et al.[4] Comparing absolute MGS values for Squegg, with values for other dynamometers in literature, Squegg MGS for males was lower, while Squegg MGS for females was well within the range of literature values.

Measurements of grip-strength have been shown to be device-specific, and impacted by factors such as size, weight, material, and technological characteristics.[3,7,11] For example, King et al. found Jamar hydraulic to measure 10% higher GS than Jamar PLUS+ its digital equivalent from the same manufacturer.[11] Hogrel et al. reported 14% difference between MyoGrip dynamometer compared to the Jamar.[5] Mutalib et al. reported GripAble dynamometer's measurement to be approximately 69% of Jamar Plus+ MGS output.[7] Magni et al. reported K-Force dynamometer to measure ~80% of Jamar Hydraulic dynamometer output.[26] Considering the above, differences between Squegg and Jamar normative MGS values appear to be well within the range reported for other devices relative to Jamar hydraulic dynamometer.

Squegg dynamometer is currently is offered in a single size. The relative similarly between Squegg and Jamar normative MGS values for females, and somewhat lower Squegg MGS values for males relative to Jamar, could indicate that the current Squegg size offering is optimal for female hands and somewhat small for the male hands. This hypothesis relating device size and MGS is supported by studies such as Petrofsky et al. who concluded that for each individual there existed one handgrip size at which he or she could exert the greatest isometric strength.[27]



Some limitations of the present study are important to note. The data was obtained from users residing in a few specific countries, and therefore results may not be fully extrapolatable to all populations/countries. This limitation can be overcome in future with continual expansion of the normative dataset. While majority of the data was obtained from users performing remote, self-directed grip strength assessments, a small proportion of the data (7.4%) was obtained from an in-person study conducted by Stamate et al.[6] This variation in data sources could introduce heterogeneity in the normative dataset. Another limitation was that user height and weight information were not available, therefore height/-weight or body mass index adjusted norms could not be reported. This limitation can be addressed in future with help of recently updated version of the Squegg application, wherein self-reported subject height/weight information is collected. Direct quantitative comparison of Squegg MGS to literature values for other dynamometers was limited by variability in collection and reporting protocols across studies. For example, while some studies reported grip strength for dominant vs. non-dominant side, others reported values for left vs. right hand. Similarly, some studies reported single maximum grip strength value measured across either hand of the subject, while other reported values separately for each side (left/right or dominant/non-dominant). These limitations notwithstanding, Squegg normative grip strength values showed sex, age, and sidebased trends consistent with those reported for other devices across the various studies.

Conclusion

The study provides the first report of normative values for MGS for a new smart dynamometer, namely the "Squegg® Smart Dynamometer and Hand Grip Trainer", which was previously shown to have good-to-excellent test-retest repeatability, concurrent validity, and agreement with gold standard Jamar dynamometer.[6,9,10] The normative values for Squegg, demonstrated age and sex related trends consistent with those reported for variety of other devices. These trends included ~26% lower MGS for females, quadratic trend of reducing MGS values with age for both sexes, and ~5-6% lower MGS values for non-dominant side relative to the dominant side. The combination of prior validation studies, and the normative values reported herein, will enable physicians to use this new technology for benchmark severity of patient's hand impairment at initial presentation and track their progress through rehabilitation.

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