Myles, Louise, Massy-Westropp, Nicola, and Barnett, Fiona (2024) ***Exploring anthropometric and functional factors that influence working adult's handgrip strength in north Australia.*** **Work, 79 (3) pp. 1027-1037.**

Exploring anthropometric and functional factors that influence working adult's handgrip strength in north Australia

Exploring anthropometric and functional factors that influence working adult's handgrip strength in north Australia

Abstract

Background

Handgrip strength (HGS) is a reliable assessment of hand function. Interpretation of HGS is commonly done using normative data. Normative HGS data HGS considers the influence of age and gender without adjustment for anthropometric measurements or functional factors known to influence HGS.

Objective

To determine the potential relationship of select anthropometric measurements (height, weight, hand length and width, forearm length and circumference) and functional factors (hand dominance, work and lifestyle category) to HGS.

Methods

This study included a sample of 119 males and 96 female workers from North Queensland. HGS and six anthropometric measurements were obtained using calibrated instruments and reliable measurement protocols. Age and gender along with three functional factors were documented by self-report.

Results

Right and left mean HGS was greater for individuals who performed heavy/very heavy work (58.1±10.1 kg and 54.1± 10.9 kg respectively) compared to light (38.5±12.3 kg and 35.5±11.8 kg) or medium work (44.1±10.8 kg and 40.0±12.9 kg). Mean HGS was greater for individuals who performed heavy/very heavy activity (right 48.5±13.6 kg and left 44.5±13.7 kg) compared to light activity (right 36.3 ± 11.2 kg and left 33.9 ± 11.3 kg) within their lifestyle. HGS positively correlated with gender ($p=0.0001$), work ($p=0.001$) and anthropometric measurements of forearm circumference ($p=0.001$), hand length ($p=0.006$) and hand width ($p=0.052$).

Conclusions

Easy to measure anthropometric measurements of forearm circumference, hand length and width are the strongest predictors of HGS in addition to an individual's physical activity at work and in their lifestyle. Consideration of these factors could lead to improved evaluation of HGS scores.

Key words

- Hand Grip Strength
- JAMAR dynamometer
- Normative data
- Hand anthropometry

1. Introduction

Hand strength is required to perform most functional activities of daily life including work demands and lifestyle activities**.** Evaluation of an individual's hand function routinely includes the assessment of handgrip strength (HGS). HGS is a performance-based measure which assesses at the body function and structures level and forms part of a comprehensive evaluation of hand function. Occupational therapists utilise HGS testing to measure work capacity, the functional impact of upper limb injuries and diseases and as a method of measuring and evaluating rehabilitation progression. HGS testing is a simple measure to quantify and evaluate hand function across a range of occupational therapy practice settings including hand therapy and work rehabilitation [1-4].

HGS is also used as a health indicator related to cardiometabolic diseases, bone health, physical dysfunction, frailty and all-cause mortality [5, 6]. Subsequently the wide application and the predictive capabilities of HGS mean HGS assessment is relevant to not only occupational therapists but a wide range of health professionals. The benefits of using HGS testing as a measure of hand function are its simple procedure, reliability and the availability of normative data for comparison [7, 8].

Evaluation of HGS scores commonly includes comparison to normative data which outlines an individual's ability in comparison to the general population [9, 10] . Normative data for HGS is tabulated into right and left hand scores with gender and age as the only distinguishing parameters. The influence of age and gender on HGS is well established with previous studies identifying men are stronger than women and age is directly correlated to HGS with strength increasing from early adulthood until a peak is reached in the middle of the third decade with a decline in strength in older adulthood [11-14].

Recent studies however have looked beyond these accepted influencing factors of age and gender, to explore the influence of anthropometric measurements and/or functional factors on adult HGS [11, 15, 16]. Research findings have identified the significant impact and predictive capabilities of various anthropometric measurements (height, weight, Body Mass Index (BMI), hand and forearm length, forearm circumference) and functional factors (hand dominance, work demands and lifestyle factors) on HGS [2, 17-21]. Despite the current research available exploring the influence of various anthropometric measurements and functional factors on HGS, limited normative data tables have been developed which address specific sub-populations such as occupations requiring increased physical upper limb strength or specific clinical diagnoses [10]. Researchers have described the inclusion of anthropometric measurements and functional factors when assessing HGS as providing increased contextualization for HGS assessment [20-24]. When assessing HGS it may also be important to consider the functional factors of hand dominance, work demands and lifestyle factors. The intensity and physical demands of both work tasks and activities within leisure time vary considerably and thus their influence on HGS should be considered [25]. The consideration of functional factors and anthropometric measurements may offer increased contextualization of HGS scores and aid in clinical decision making when evaluating HGS when suitable normative data for comparison is not available and when determining work capacity. Additionally, clinical experience and practice context are known to impact how HGS is assessed and the evaluation of HGS scores [26]. When assessing HGS, clinical experience was found to influence variations to the standard ASHT testing protocol. More experienced clinicians utilised their professional experience and knowledge of HGS to adapt the testing protocol as needed [26]. Comparison to normative data is not the only way to evaluate HGS scores. Alternative methods to evaluate HGS scores include comparison of left to right hands or affected to unaffected sides. These methods of evaluation were found to be more common in clinical settings such as private hand therapy clinics or hospitals where communication of an individuals' performance to external audiences is not required [26].

When comparing HGS to normative data, the data set utilised must reflect the population being assessed. Normative data is most relevant when developed using a population closely aligned to the individual being assessed [27]. Numerous peer reviewed studies have provided population specific normative data for Great Britain [28], Germany [4], Korea [29] and Taiwan [30].

Recent international studies have examined the influence of demographic factors, anthropometric measurements and functional factors on HGS in combination. However, to date there is only one Australian population study to have examined the influences of height, weight and BMI on HGS [3]. No Australian studies to date have considered the predictive power of both anthropometric measurements and functional factors on HGS. Using the findings of an earlier literature review and focus group study with occupational therapists who assess HGS regularly [26], specific anthropometric measurements and functional factors were selected to investigate in relation to HGS. Therefore, the aim of this study is to determine which of these select anthropometric measurements and functional factors most strongly predict HGS.

2. Methods

2.1 Participants

Approval for this research study was obtained from the James Cook University Human Research Ethics Committee (ethical approval H8519). This study had a cross-sectional design and included the recruitment of a convenience sample from the general population residing in North Queensland (NQ), Australia. The geographic region of NQ encompasses five major regional centres: Burdekin, Charters Towers, Hinchinbrook, Palm Island and Townsville with a population 240 000 people and [31]. Within NQ, the top five industries by employment are health care and social assistance, public administration and training, retail trade, education and training, accommodation and food services [32]. Collection of HGS data from working adults within NQ allowed for a diverse snapshot of the Northern Australian population whilst maintaining an achievable sample size. The inclusion criteria were adults aged between 18 to 67 years, living in the North Queensland community who were healthy and free from any medical conditions which may affect hand strength. Prior to inclusion within the study, participants were asked to verbally acknowledge that they had no previous or current injuries or medical diagnosis which may impact hand function. The specific age range for the inclusion criteria was to ensure that participants were adults of working age as work was selected as one of the influencing factors to be examined within this study. Participants who reported symptoms of hand dysfunction or pain within the preceding 12 months or were aged outside of the inclusion criteria age range were excluded. A pilot of the data collection process (n=7) was carried out prior to the recruitment of participants. The pilot study and subsequent main study data collection were conducted by the primary author who is an experienced occupational therapist with over 20 years' experience working with HGS. The use of a single assessor throughout the study was employed to ensure test-re-test reliability.

Participants were invited to participate in the research via online social media advertisements, university staff emails and online student forums. Additional recruitment through word of mouth was also employed. Data was collected from September to November 2021. Research locations included community and workplace settings within the NQ community which allowed for suitable privacy and space to set up the required testing and measurement equipment. The duration of testing was 10-15 minutes including the questionnaire and measurement procedures. A variety of workplace settings including heavy industry such as mining and construction, health services and administration-based organizations were included in the data collection process to capture the diversity of the working community within the NQ population. Participants were provided with an information sheet detailing the research aim and procedures prior to participants providing their written informed consent.

Data was collected from 215 healthy adults (males = 119, females = 96), aged between 18-66 years who resided within North Queensland, Australia.

2.2 Measurement procedures

2.1.1 Questionnaire

Participants were asked if they currently or had previously experienced any pain, discomfort, injury or chronic condition affecting either of their upper limbs within the preceding 12 months. Participants who answered yes, were not included in any further assessment. Participants who met the inclusion criteria self-completed a questionnaire detailing name, age, gender, hand dominance and title of their occupation (Appendix One). If unsure, hand dominance was determined by asking participants "Which hand do you write with?" [33]. Participants listed their work occupation and were then required to self-select a category describing physical demands of the main tasks or duties that they usually perform in that occupation as part of the participant questionnaire. The questionnaire also contained a follow up question asking participants if they had participated in any physical activity, exercise, recreation or sport during the past week. If the participants responded positively, they were then asked to select a category describing the physical demands of the physical activity performed outside of their work duties. The definition of these categories were adapted from the definitions of sedentary work, light work, medium work, heavy work and very heavy work outlined in The Revised Handbook for Analyzing Jobs [34]. Definitions of the work and physical activity categories are described in Table 1.

Table 1

Classification of an individual's work occupation using a standardised system such as the Australian and New Zealand Standard Classification of Occupations (ANZSCO) was not considered appropriate as this system classifies and defines occupations based on the level of skill required to perform the occupation, not the physical demands involved [35]. Instead, identification of the physical demands required to perform the main duties of an individual's work occupation provides key descriptions of physical effort exerted by the individual to perform the work tasks. For both questions that related to the physical demands of the work tasks and any physical activity outside of work, the same categories and descriptors were used. Participants selected one response from the categories of light, medium or heavy/very heavy. Participants could ask for clarity or further explanation regarding any of the questions within the questionnaire.

2.1.2 Measurement of anthropometric measurements

Height and weight were measured to the nearest 0.5 cm and 0.1 kg using a mobile stadiometer (Seca 213 Portable Measuring Rod, Seca Corporation, Hanover MD) and Tanita BC541 electronic scale (Tanita Corp., Tokyo, Japan), respectively. Hand length, width and forearm length and circumference were measured using a soft anthropometric tape measure and utilizing a standardized procedure. Each anthropometric measurement was documented for both the left and right upper limbs of each participant. Hand length was measured from tip of the middle digit to the ulna styloid process [36] . Hand width was measured at the level of the metacarpophalangeal joints of the index and fifth digits with the fingers adducted. Forearm length was measured from the tip of the olecranon process to the styloid process of the ulna. Forearm circumference was measured at 5 cm distal to the elbow crease [19]. The hand and forearm measurements were conducted while the participant was seated, and the limb was held in a supinated position. New equipment was purchased for this study to ensure calibration during the data collection period.

2.1.3 Handgrip strength testing

HGS testing was conducted using a calibrated Jamar digital hand dynamometer (Sammons Preston, Bolingbrook, IL, USA). Testing was conducted using the American Society of Hand Therapists (ASHT) standardized testing position and instructions. Participants were seated upright with both the hips and knees in 90° flexion with feet flat on the floor; testing arm at side, not touching the body; elbow flexed at 90°, forearm in neutral, wrist slightly extended between 0° and 30° and ulnar deviation between 0° and 15°; With the non-testing arm relaxed at side [37]. A demonstration was performed by the assessor in addition to verbal instructions for HGS testing. Using the dynamometer on the second handle position, three alternating trials for each hand were performed and documented allowing for a 10 second rest break between each trial [38]. As outlined within the ASHT testing protocol, the mean of three trials was recorded for both the right and left hands.

2.1.4 Statistical methods

SPSS 27 (IBM Corporation, New York, NY, United States) was used for statistical analysis of the data. A sample size of 200 was determined by a statistician based on a statistical test and power calculation at 80%. Due to potential attrition, data was collected from 215 participants. Prior to data analysis all variables were examined for normality with visual inspection of the histogram, P-Plots and scatterplots for right and left HGS found to have normal distribution. Testing for skewness, kurtosis, linearity and homoscedasticity was also performed to review the normality of the data. The mean and standard deviation (SD) of HGS and selected anthropometric measurements, and 95% confidence interval (CIs) were calculated. Paired sample *t*-tests were used to compare average HGS for the right and left hands. A one-way ANOVA test was used to compare HGS of the dominant and non-dominant hands. Simultaneous multiple regression was used to describe the relationship between the select demographic factors, functional factors and anthropometric measurements and average HGS of both hands. The value of significance alpha was considered at the level of 0.05.

Table 2

Table 3

3. Results

One hundred and nineteen men and 96 women participated in this study with two participants excluded as they were aged outside of the inclusion criteria or reported hand dysfunction. Descriptive statistics of participant characteristics and anthropometric measurements divided by gender are presented in Table 2. All anthropometric measurements were larger for men compared to women. Limited variability in height was observed for men and women.

Table 3 details HGS according to work category. Approximately 63% of participants performed light physical demands within their work tasks, 22% performed medium physical demands and 15% performed heavy/very heavy demands.. Within work categories, right and left HGS was stronger for workers who performed heavy/very heavy work compared to light or medium work.

Light physical activity outside of work duties was the most common category identified by 30% of participant closely followed by heavy/ very heavy physical activity which was selected by 29% of participants. Right and left HGS for participants who completed heavy/ very heavy activity within their lifestyle was significantly greater than right and left HGS of participants who performed light activity within their lifestyle. Participants who had not performed any physical activity, exercise, recreation or sport during the past week averaged greater HGS than all participants other than the heavy/very heavy category.

Of the 88.8% of participants who identified as right hand dominant, they were found to have 9.35% stronger HGS in their dominant right hand. In contrast, left hand dominant participants were found to be only 0.25% stronger in their dominant left HGS.

Table 4

All independent variables were included in the simultaneous multiple linear regression model to examine the association with the dependent variable of HGS. The multiple regression analysis showed a significant positive association between HGS and gender (p=0.001), work category (p=0.001) and the anthropometric measures of forearm circumference (p=0.001), hand length (p=0.006) and hand width (p=0.052). Forearm length (p=0.64) and height were found to be approaching significance (p=0.115). Age was found to have a negative correlation to HGS (p=0.702).

Due to the significant multicollinearity according variance proportions between height (0.97), weight (0.94) and Body Mass Index (BMI) (0.94) a regression analysis for average HGS was completed with weight and BMI removed. This model was run due to the strong association between HGS and the anthropometric variables of hand length, hand width and forearm circumference which are associated with body size and subsequently are potentially associated with the height of the individual. This model found the only significant relationship with average HGS was with age (p=0.036).

4. Discussion

The use of HGS testing is well established as an efficient way to measure an individual's hand strength. Consideration of the influence of demographic factors, anthropometric measurements and functional factors on HGS assists in providing a better understanding of hand function when interpreting HGS scores. Inclusion of these additional contextual factors including anthropometric measurements and functional factors is especially useful when suitable normative data sets which represent the population being assessed are unavailable for comparison. Additionally, when determining an individuals' work capacity, the HGS required to perform the physical demands of an occupation varies. Therefore, consideration of lifestyle and work demands and anthropometric measurements in conjunction with HGS scores when evaluating HGS is hoped to increase a clinician's confidence when determining work capacity.

Studies have detailed the relationship between gender and HGS and it has been clearly established that on average, men have stronger HGS than women of the same age [4, 12, 14]. Similarly, studies have documented a decline in HGS as age increases [12, 14, 28]. The relationship between other anthropometric measurements (height, weight, hand size) has been explored with varying agreement as to which factors influence HGS. Additionally, recent research has examined the influence of not only demographic factors and anthropometric measurements, but also functional factors (work, lifestyle factors) on HGS [11, 15, 20, 39]. Limited studies however, have described the predictive power using a combination of demographic, anthropometric measurements and functional factors for specific populations. Consequently, this study aimed to determine the relationship between HGS and relevant demographic, functional factors and anthropometric measurements in combination for Australian adults and to identify which factors most strongly predict HGS. The anthropometric measurements and functional factors examined in this study were determined based on a review of the current literature and a qualitative study which explored the factors occupational therapy clinicians believed influence HGS [26]. For the current study, the factors identified as the strongest predictors for HGS were gender, work, forearm circumference and hand length and width.

4.1 Demographic factors

Consensus exists that men are stronger than women when comparing HGS with gender identified as the most significant predictor of HGS [15]. Research has found that men are significantly stronger than women of the same age [18, 29, 39, 40]. The current study agreed with the mean male right HGS score to be more than 40% stronger than the mean female right HGS score. This difference in HGS may be attributed to muscle mass with men known to have increased muscle mass compared to women [41]. It is hypothesized that this difference in HGS within genders is as a result of anthropometric measurements and hormonal differences between genders which enhance bone and muscle growth for men and have a correlation to height, weight and hand measurements and subsequently influence HGS between genders [2, 42]. Future research examining differences between gender, anthropometrics and HGS could assist in explaining this relationship further.

It is well documented that HGS declines due to the effect of ageing and subsequent loss of muscle mass [12, 14, 28, 43, 44]. The results of this study found that age and HGS had a strong negative correlation. A strong negative correlation was found between age and HGS [39, 45]. The reduction of HGS with age is documented as part of the normal aging process. This study had an inclusion criteria of Australian adults aged 18 to 66 to ensure a sample within the working age range. With the average age of sample population being 35.1 years, the inclusion of a sample skewed towards a younger population may explain the negative correlation between age and HGS within this study. Age was found to have a significant relationship to HGS in the regression model where weight and BMI were removed. This result indicates the predictive variables within the regression analysis are highly reliant on each other. Weight and BMI relate to age [46], and this may explain the change in significance between HGS and age following the removal of weight and BMI from the prediction model.

4.2 Anthropometric measurements

The strongest HGS predictive anthropometric measurements were forearm circumference, hand length and width. Previous studies also found forearm circumference had a strong correlation to HGS [18, 21, 22, 47]. The strong positive relationship between HGS and forearm circumference may be a reflection of an individual's muscle mass with the thickness of the anterior forearm muscles being in this location [44]. The increased muscle mass within the forearms is likely to have contributed to the observed relationship. Additionally, variations in muscle mass occur within different ethnicities highlighting the importance of interpreting HGS results with awareness of these contextual factors [48].

This study found the relationship between height and HGS to be approaching significance, however height alone was not predictive of HGS. HGS and hand length were strongly correlated and longer limb lengths such as hand length are commonly associated with increasing height [49]. The relationship between height, weight, Body Mass Index (BMI) and HGS has been explored in numerous studies across varied populations with inconsistent findings. A significant positive correlation was found between HGS and height and weight [11, 23, 45]. A previous study aimed to describe HGS normative data for an Australian adult population and investigated the relationship between the anthropometric measurements of height, weight and BMI [3]. This study found a weak positive relationship for participants with higher BMI for the youngest and oldest adults in the sample, however due to a limited number of participants with low BMI the relationship between HGS and BMI could not be fully investigated [3]. It was concluded that no significant relationship between HGS and BMI existed for this sample. Furthermore, HGS was found to significantly correlate to height and weight, but not BMI [23, 50]. These varied results describing the relationship between BMI and HGS may be attributed to the fact that BMI does not examine body fat percentage and participants with higher BMI might have increased body fat or varied ratios of muscle mass which is not accounted for within the BMI equation [51]. Additionally, inclusion of participants with low BMI was found to be limited in the present study and previous research [3].

Hand length and hand width were found to have a strong positive correlation to HGS. The relationship between hand length and HGS has also been found to be significant [22, 23]. Hand width was positively correlated to HGS [11, 18, 21, 23, 45]. The strong association between hand length and width and HGS may be explained as a longer and wider hand allows for an increased mechanical advantage when gripping the dynamometer using the ASHT standardised testing procedure of the second handle position. Optimum grip span is known to correspond to maximum grip force generation [52]. Hand size therefore must be considered when developing work tools and when evaluating a worker's individual physical capability in relation to the physical demands of various occupations [20]. Furthermore, consideration of anthropometric measurements such as hand size and height in relation to HGS can help to determine the suitability of workers performing occupations with varying physical demands and the potential risk of associated injury [53]. Further investigation is required to determine the relationship between anthropometric measurements and HGS.

4.3 Functional factors

Although HGS data is separated into right and left hands, not all data sets account for hand dominance despite dominant HGS having been found to be greater than non-dominant HGS for both men and women, particularly in right hand dominant individuals [23, 29, 39]. This study found the difference between HGS in dominant and non-dominant hands was significant for right-handed participants with a 9.35% increase in hand strength in their dominant right hand. Conversely, left hand dominant participants were found to only have a 0.25% increase of hand strength in their dominant left hand. Therefore, hand dominance had a significant influence on HGS for right hand dominant participants only and this may explain why hand dominance did not predict average HGS overall. There was found to be no difference between the right and left HGS of left hand dominant participants. This may be attributed to lifestyle influences where tools and environments are built for right hand dominant populations and subsequently the right hand is used to perform tasks in preference to their dominant left hand [54]. Given normative data sets do not account for hand dominance, clinicians need to consider the influence of hand dominance and how this varies between right and left hand dominant individuals within their clinical reasoning. This is especially relevant if comparison to normative data is the only method of evaluating HGS.

Recent studies have examined the influence of work demands within an individual's employment on HGS in a variety of occupational settings [15, 21, 39, 55, 56]. Adults spend prolonged periods of time working and work tasks often involve significant hand function. Therefore, exploring the relationship between HGS and work is warranted. The HGS of participants was found to increase as the physical demands of their work increased. Right HGS of heavy/very heavy workers was found to be approximately 34% stronger than light workers. This strong positive correlation between occupation and HGS was in accordance with other studies [21, 23, 56]. However, one study found that occupational demands (sports, music and work) had no significant influence on HGS [15]. It must be considered that the use of hand strength for function should not be limited to work only and can include physical activity outside of employment.

Previous research has examined how lifestyle factors and physical activity performed outside of work can also influence HGS. Research has suggested that consideration of lifestyle factors and fitness is required [4]. The results of the current study showed that as physical activity levels increased, so too did HGS. However, right and left HGS for participants who had not engaged in physical activity of any kind in the seven days prior to HGS testing had greater HGS than participants who reported light and medium activity levels outside of their work. This may be explained by the observation that workers who actively perform heavy physical tasks at work are inactive during their leisure time outside of work [57, 58]. Additionally, workers who are engaged in work requiring less physical demands are more often engaged in vigorous leisure activities [25]. Further research into of the type, intensity and frequency of physical activity performed outside of work would provide insight into this phenomenon.

4.4 Implications for practice

The use of normative data alone as an evaluation method for HGS does not account for other contextual factors such as body size and physical activity both at work and outside of work demands. Additionally, comparison to normative data is not the only method to evaluate HGS. Clinicians use their professional reasoning and practice setting to determine the method of evaluating HGS. Health professionals working in clinical practice settings often rely on less formal methods of evaluating HGS than comparison to normative data. These other forms of evaluation include recording HGS scores over time to track rehabilitation progression and comparison of left to right or affected to un-affected limbs. Therefore, examination of an individuals' anthropometric measurements in combination with an understanding of their work demands and lifestyle factors is hoped to provide a more accurate expectation of HGS for an individual.

Based on the results of this study, it is recommended that an individual's work demands and lifestyle factors be considered when assessing and evaluating HGS especially in comparison to the available normative data. Normative data must represent the population being assessed. Therefore, if suitable normative data is not available for the population being assessed, consideration of an individuals' anthropometric measurements, work demands, and lifestyle factors may offer useful supplemental information to the normative data available.

The physical demands of an individuals' occupation vary dependent on the type of employment. Consideration of an individual's anthropometric measurements, lifestyle factors and current work demands when evaluating HGS will offer increased insight into an individuals' work capacity. Clinicians could consider the definitions of sedentary work, light work, medium work, heavy work and very heavy work outlined in The Revised Handbook for Analyzing Jobs to guide decision making regarding work capacity [34]. Subsequently, matching individuals with greater HGS to occupations which require increased HGS to perform the required work demands will be improved. In addition, the inclusion of simple, easy to measure anthropometric measurements of forearm circumference and hand length and width provide a highly accurate prediction of HGS to guide rehabilitation goals in practice settings where less formal methods of evaluation are favored over comparison to normative data. Use of these additional contextual factors offers a nuanced and considered evaluation of HGS and allows clinicians to use their professional reasoning to guide the evaluation of HGS which reference to normative data alone cannot provide.

4.5 Limitations and future research

While this study found strong predictors for HGS among anthropometric measurements and functional factors, there are limitations to consider. Limitations include that the data was collected from a sample localized within NQ, Australia. Therefore, this data may not be transferable to wider populations. Future research expanding the data collection to adults residing across Australia would provide an improved sample representing the Australia adult population more broadly. Additionally, specific details as to where each participant resided within this geographical area were not obtained which would have allowed for comparison across geographical locations and urban versus rural settings within the North Queensland region. Future research should document the residential location of participants to facilitate comparison between regions of Australia and provide insights into the variances in demographic factors, anthropometric measurements and occupational demands across regions of Australia.

When examining work categories and lifestyle factors, details were self-reported and relied on the participants understanding of the physical demand categories. Furthermore, the quantity of work hours performed was not examined with both part time and full time workers included in the study. However, a wide range across all work and lifestyle categories was obtained within the sample population.

5. Conclusion

Given the importance placed on HGS scores when evaluating hand function across all health disciplines, consideration of the evaluation method for HGS scores is crucial. The use of normative data for HGS evaluation allows for comparison of an individual to the general population with normative data displayed by age and gender. The reliability of using normative data to evaluate HGS score relies on the availability of normative data which represents the population being assessed. It is important to acknowledge that variances in anthropometrics do exist in different populations due to ethnicity. Therefore, if normative data tables are to remain categorised by age and gender alone, it is imperative that an individual’s HGS score is evaluated against the normative data collected from the population they are comparing to. Given HGS normative data may not be available for all population groups worldwide, consideration of the anthropometric measurements of forearm circumference, hand length and width along with the functional factors of work and lifestyle demands when evaluating HGS offers an improved understanding of HGS for these individuals. Further, the consideration of additional anthropometric measurements and functional factors when evaluating HGS will provide contextualization of the HGS results in relation to a person’s body size and daily occupations. HGS evaluation methods utilised in clinical practice go beyond comparison to HGS normative data. Consideration of these additional anthropometric measurements and functional factors enables clinicians to be guided by their professional reasoning when evaluating HGS and subsequently overall hand function.

Research ethics

Ethical approval (H8519) was granted by the James Cook University Human Research Ethics Committee.

Informed consent

Participants were provided with an information sheet detailing the research aim and procedures prior to participants providing their written informed consent.

Conflict of Interest

The authors declare that they have no conflict of interest.

Acknowledgements

Kenji Doma for assistance with statistical analysis.

Funding statement

Not applicable.

References

[1] Bohannon RW. Hand-grip dynamometry provides a valid indication of upper extremity strength impairment in home care patients. J Hand Ther. 1998; 11(4):258-60.
[2] Bhat AK, Jindal R, Acharya AM. The influence of ethnic differences based on upper limb anthropometry on grip and pinch strength. Journal of Clinical Orthopaedics and Trauma. 2021; 21:101504.
[3] Massy-Westropp NM, Gill TK, Taylor AW, Bohannon RW, Hill CL. Hand Grip Strength: Age and gender stratified normative data in a population-based study. BMC Res Notes. 2011; 4.
[4] Günther CM, Bürger A, Rickert M, Crispin A, Schulz CU. Grip Strength in Healthy Caucasian Adults: Reference Values. Journal of Hand Surgery. 2008; 33(4):558-65.
[5] Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, et al. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing. 2019; 48(1):16-31.
[6] Cruz-Jentoft AJ, Sayer AA. Sarcopenia. Lancet. 2019; 393(10191):2636-46.
[7] Bohannon RW. Adoption of Hand-Held Dynamometry. Percept Mot Skills. 2001; 92(1):150-.
[8] Wang Y-C, Bohannon RW, Li X, Sindhu B, Kapellusch J. Hand-Grip Strength: Normative Reference Values and Equations for Individuals 18 to 85 Years of Age Residing in the United States. J Orthop Sports Phys Ther. 2018; 48(9):685-93.
[9] Bohannon RW, Peolsson A, Massy-Westropp N, Desrosiers J, Bear-Lehman J. Reference values for adult grip strength measured with a Jamar dynamometer: a descriptive meta-analysis. Physiotherapy. 2006; 92(1):11-5.
[10] Larson CC, Ye Z. Development of an updated normative data table for hand grip and pinch strength: A pilot study. Comput Biol Med. 2017; 86:40-6.
[11] Angst F, Drerup S, Werle S, Herren DB, Simmen BR, Goldhahn J. Prediction of grip and key pinch strength in 978 healthy subjects. BMC Musculoskelet Disord. 2010; 11:94.
[12] Agnew PJ, Maas F. Hand function related to age and sex. Arch Phys Med Rehabil. 1982; 63(6):269-71.
[13] Dodds RM, Syddall HE, Cooper R, Kuh D, Cooper C, Avan Aihie S. Global variation in grip strength: A systematic review and meta-analysis of normative data. Age and Ageing. 2016; 45(2):209-16.
[14] Mathiowetz V, Kashman N, Volland G, Weber K, Dowe M, Rogers S. Grip and pinch strength: Normative data for adults. Arch Phys Med Rehabil. 1985; 66(2):69-74.
[15] Klum M, Wolf MB, Hahn P, Leclere FM, Bruckner T, Unglaub F. Predicting grip strength and key pinch using anthropometric data, DASH questionnaire and wrist range of motion. Arch Orthop Trauma Surg. 2012; 132(12):1807-11.
[16] Hossain MG, Zyroul R, Pereira BP, Kamarul T. Multiple regression analysis of factors influencing dominant hand grip strength in an adult Malaysian population. J. 2012; 37(1):65-70.
[17] De Andrade Fernandes A, Natali AJ, Vieira BC, Do Valle MAAN, Moreira DG, Massy-Westropp N, et al. The relationship between hand grip strength and anthropometric parameters in men. Arch Med Deporte. 2014; 31(161):160-4.
[18] Eidson CA, Jenkins GR, Hon KY, Abernathy AM, Brannon MB, Pung AR, et al. Investigation of the relationship between anthropometric measurements and maximal handgrip strength in young adults. Work. 2017; 57(1):3-8.
[19] Nicolay CW, Walker AL. Grip strength and endurance: Influences of anthropometric variation, hand dominance, and gender. Int J Ind Ergon. 2005; 35(7):605-18.
[20] Rostamzadeh S, Saremi M, Fereshteh T. Maximum handgrip strength as a function of type of work and hand-forearm dimensions. Work (Reading, Mass). 2020; 65(3):679-87.
[21] Saremi M, Rostamzadeh S. Hand dimensions and grip strength: A comparison of manual and non-manual workers. Advances in Intelligent Systems and Computing. 2019; p. 520-9.
[22] Mohammadian M, Choobineh A, Haghdoost AA, Hashemi Nejad N. Investigation of grip and pinch strengths in Iranian adults and their correlated anthropometric and demographic factors. Work. 2015; 53(2):429-37.

[23] Rostamzadeh S, Saremi M, Tabatabaei S. Normative hand grip strength and prediction models for Iranian office employees. Work. 2019; 62(2):233-41.
[24] Spruit MA, Sillen MJ, Groenen MT, Wouters EF, Franssen FM. New normative values for handgrip strength: results from the UK Biobank. J Am Med Dir Assoc. 2013; 14(10):775.e5-11.
[25] Leino-Arjas P, Solovieva S, Riihimäki H, Kirjonen J, Telama R. Leisure time physical activity and strenuousness of work as predictors of physical functioning: a 28 year follow up of a cohort of industrial employees. Occup Environ Med. 2004; 61(12):1032-8.
[26] Myles L, Barnett, F. & Massy-Westropp, N. Experiences of occupational therapy clinicians on the assessment and evaluation of adult handgrip strength. British Journal of Occupational Therapy. 2022: 03080226221135375.
[27] Innes E. Handgrip strength testing: a review of the literature. Aust Occup Ther J. 1999; 46(3):120-40.
[28] Dodds RM, Syddall HE, Cooper R, Benzeval M, Deary IJ, Dennison EM, et al. Grip Strength across the Life Course: Normative Data from Twelve British Studies. PLoS ONE. 2014; 9(12):e113637.
[29] Shim JH, Roh SY, Kim JS, Lee DC, Ki SH, Yang JW, et al. Normative measurements of grip and pinch strengths of 21st century Korean population. Arch Plast Surg. 2013; 40(1):52-6.
[30] Wu S-W, Wu S-F, Liang H-W, Wu Z-T, Huang S. Measuring factors affecting grip strength in a Taiwan Chinese population and a comparison with consolidated norms. Appl Ergon. 2009; 40(4):811-5.
[31] The State of Queensland (Department of Regional Development MaW. North Queensland. Queensland Government; 2021.
[32] The State of Queensland. North Queensland Regional Plan. In: Queensland Government Statician's Office, editor. Brisbane: Department of State Development, Manufacturing, Infrastructure and Planning; 2019.
[33] Oldfield RC. The assessment and analysis of handedness: the Edinburgh inventory. Neuropsychologia. 1971; 9(1):97-113.
[34] Administration USDoLEaT. The revised handbook for analyzing jobs. United States: Jist Works; 1991.
[35] Australian Bureau of Statistics. ANZSCO - Australian and New Zealand Standard Classification of Occupations. In: ABS, editor: ABS; 2022.
[36] Hans WJ. NASA Reference Publication 1024: Anthropometric Source Book. Vol. I: Anthropometry for Designers. Vol. II: A Handbook of Anthropometric Data. Vol. III: Annotated Bibliography of Anthropometry. E. Schweizerbart'sche Verlagsbuchhandlung; 1980. p. 111-2.
[37] MacDermid J, Solomon G, Valdes K, American Society of Hand Therapists. Clinical assessment recommendations. 3rd ed. Mount Laurel, N.J.: American Society of Hand Therapists; 2015.
[38] Trossman PB, Li P-W. The Effect of the Duration of Intertrial Rest Periods on Isometric Grip Strength Performance in Young Adults. OTJR: Occupation, Participation and Health. 1989; 9:362 - 78.
[39] Moy FM, Darus A, Hairi NN. Predictors of handgrip strength among adults of a rural community in Malaysia. Asia Pac J Public Health. 2015; 27(2):176-84.
[40] Spruit MA, Sillen MJH, Groenen MTJ, Wouters EFM, Franssen FME. New normative values for handgrip strength: Results from the uk biobank. J Am Med Dir Assoc. 2013; 14(10):775.e5-.e11.
[41] Gallagher D, Visser M, Meersman RED, Sepúlveda D, Baumgartner RN, Pierson RN, et al. Appendicular skeletal muscle mass: effects of age, gender, and ethnicity. J Appl Physiol. 1997; 83(1):229-39.
[42] Balogun JA, Adenlola SA, Akinloye AA. Grip Strength Normative Data For the Harpenden Dynamometer. J Orthop Sports Phys Ther. 1991; 14(4):155-60.
[43] Melton LJ, 3rd, Khosla S, Crowson CS, O'Connor MK, O'Fallon WM, Riggs BL. Epidemiology of sarcopenia. J Am Geriatr Soc. 2000; 48(6):625-30.
[44] Abe T, Thiebaud RS, Loenneke JP. Age-related change in handgrip strength in men and women: is muscle quality a contributing factor? Age (Dordr). 2016; 38(1):1-7.

[45] Hatem F, Katabie O, Eldesoky MT, Gayed M. Correlation between age, height and weightwith hand grip strength. Int J Pharm Res. 2016; 9(7):48-55.
[46] Harris TB. Weight and Body Mass Index in Old Age: Do They Still Matter? J Am Geriatr Soc. 2017; 65(9):1898-9.
[47] MacDermid JC, Fehr LB, Lindsay KC. The effect of physical factors on grip strength and dexterity. British Journal of Hand Therapy. 2002; 7(4):112-8.
[48] Leong DP, Teo KK, Rangarajan S, Kutty VR, Lanas F, Hui C, et al. Reference ranges of handgrip strength from 125,462 healthy adults in 21 countries: a prospective urban rural epidemiologic (PURE) study. J Cachexia Sarcopenia Muscle. 2016; 7(5):535-46.
[49] Zafar U, Shafiq Ur R, Hamid N, Ahsan J, Zafar N. Correlation between height and hand size, and predicting height on the basis of age, gender and hand size. Journal of Medical Sciences (Peshawar). 2017; 25:425-8.
[50] Anjum SN, Choudary P, Dimri R, Ankarath S. Comparative evaluation of grip and pinch strength in an Asian and European population. Hand Therapy. 2012; 17(1):11-4.
[51] Bandyopadhyay A. Body composition and hand grip strength in male brick-field workers. Malays J Med Sci. 2008; 15(1):31-6.
[52] Eksioglu M. Relative optimum grip span as a function of hand anthropometry. Int J Ind Ergon. 2004; 34(1):1-12.
[53] Bernardes SMF, Assunção A, Fujão C, Carnide F. Normative reference values of the handgrip strength for the Portuguese workers. PLoS ONE. 2020;15(8):e0236555.
[54] Armstrong CA, Oldham JA. A Comparison of dominant and non-dominant hand strengths. The Journal of Hand Surgery: British & European Volume. 1999; 24(4):421-5.
[55] Rostamzadeh S, Saremi M, Bradtmiller B. Age, gender and side-stratified grip strength norms and related socio-demographic factors for 20–80 years Iranian healthy population: Comparison with consolidated and international norms. Int J Ind Ergon. 2020; 80:103003.
[56] Lo VE, Chao SM, Tu HH. Normative Hand Strength of Healthcare Industry Workers in Central Taiwan. Int J Environ Res Public Health. 2020; 18(1).
[57] van Dommelen P, Coffeng JK, van der Ploeg HP, van der Beek AJ, Boot CRL, Hendriksen IJM. Objectively Measured Total and Occupational Sedentary Time in Three Work Settings. PLoS ONE. 2016; 11(3):e0149951.
[58] Coenen P, Huysmans MA, Holtermann A, Krause N, van Mechelen W, Straker LM, et al. Do highly physically active workers die early? A systematic review with meta-analysis of data from 193 696 participants. BJSM online. 2018; 52(20):1320.

Table 1: *Definitions of work and physical activity categories*

Category	Description
Light	For example lifting/carrying/pushing between 4.5kg – 9kg occasionally; and/or up to 4.5kg of force frequently
Medium	For example lifting/carrying/pushing 22kg occasionally; and/or up to 9kg frequently and/or 4.5kg of force constantly
Heavy / very heavy	For example lifting/carrying/pushing between 23kg to 45.5kg of force occasionally; and/or 22kg frequently and/or 9kg of force constantly

Table 2: Descriptive statistics of participant characteristics for men and women

Variable	Men		Women	
	Mean	Std. Deviation (range)	Mean	Std. Deviation (range)
Age (years)	35.6	12.6 (47)	34.6	11.8 (47)
Height (m)	1.8	0.6 (0.3)	1.7	0.1 (0.4)
Weight (kg)	93.6	18.2 (135.6)	71.5	12.9 (65.6)
Body Mass Index (kg/m^2)	28.8	5.6 (41.6)	25.3	4.4 (22.2)
Hand Length (cm)	20.0	0.9 (5.3)	18.1	1.1 (11)
Hand Width (cm)	9.2	1.0 (10.8)	7.9	0.5 (2.5)
Forearm Length (cm)	28.1	1.3 (6.5)	25.2	1.5 (9.5)
Forearm Circumference (cm)	29.8	2.4 (16.5)	24.9	2.4 (13.8)
Right HGS (kg)	52.4	10.5 (62.5)	30.6	5.7 (29.6)
Left HGS (kg)	48.6	10.6 (52.4)	27.8	5.5 (24.7)

Table 3: *Mean ± SD Right and left HGS (kg) according to work and physical activity*

Work Category	Participants	Men	Women	Right HGS	Left HGS
Light	135	58	77	38.5±12.8	35.5±11.8
Medium	48	31	17	44.1±12.8	40.0±12.9
Heavy/Very Heavy	32	30	2	58.1±10.1	54.1±10.9
Physical Activity Category					
Nil	44	34	10	46.7±14.9	42.7±14.4
Light	65	23	42	36.3±11.2	33.9±11.3
Medium	43	17	26	39.4±12.2	36.3±12.1
Heavy/Very Heavy	63	45	18	48.5±13.6	44.5±13.7

Table 4: Simultaneous Multiple Linear Regression model of Average Handgrip Strength

Independent Variable	B	*SE*	95% Confidence Interval		*p*	*β*
			LL	*UL*		
Age	0.016	0.042	*-0.067*	*0.099*	0.702	0.015
Gender	-7.668	1.795	-11.208	-4.128	<.001	-0.282
Hand Dominance	-1.005	1.545	-4.050	2.041	0.516	-0.023
Work Category	3.294	0.742	1.830	4.757	<.001	0.180
Lifestyle Category	0.710	0.439	-0.155	1.574	0.107	0.058
Height (m)	-52.655	33.218	-118.154	12.844	0.115	-0.341
Weight (kg)	0.435	0.340	-0.235	1.106	0.202	0.625
Body Mass Index	-1.820	1.055	-3.900	0.260	0.086	-0.722
Hand Length	1.670	0.605	0.477	2.862	0.006	0.168
Hand Width	1.238	0.633	-0.011	2.487	0.052	0.097
Forearm Length	0.851	0.456	-0.049	1.751	0.064	0.125
Forearm circumference	1.602	0.336	0.939	2.265	<0.001	0.402