Handgrip Strength of Australian Adults

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5	Myles, L., Barnett, F., & Massy-Westropp, N. *Exploring select factors that influence north Australian adult handgrip strength.* [Manuscript submitted for publication]. James Cook University.	Myles designed the study under the supervision of Barnett and Massy-Westropp. Myles collected the data. Myles completed the analysis, which was checked by Barnett and Massy-Westropp. Myles wrote the first draft of the manuscript, including all figures and tables. Revision and editorial input provided by Barnett and Massy-Westropp.	Name: Assoc Prof. Fiona Barnett Signature: Name: Dr Nicola Massy-Westropp Signature:
6	Myles, L., Massy-Westropp, N., & Barnett, F. (2023). The how and why of handgrip strength assessment. *British Journal of Occupational Therapy*. Advance online publication. https://doi.10.1177/03080226231208409	Myles designed the study under the supervision of Barnett and Massy-Westropp. Myles collected the data. Myles completed the analysis, which was checked by Barnett and Massy-Westropp. Myles wrote the first draft of the manuscript, including all figures and tables. Revision and editorial input provided by Barnett and Massy-Westropp.	Name: Assoc Prof. Fiona Barnett Signature: Name: Dr Nicola Massy-Westropp Signature:

Abstract

Hands are required to perform most functional activities of daily life. Evaluation of hand function routinely involves the assessment of handgrip strength (HGS) using an isometric dynamometer. HGS is used to compare an individual's strength to normative data. Due to its simple process of measurement and cost effectiveness HGS is also used widely in health contexts as an indicator of overall health status. The recognition that a standardised testing protocol is required during HGS assessment led to the development of a published guideline by the American Society of Hand Therapists (ASHT) which includes specific recommendations aimed at improving inter-rater and test re-test reliability. Despite the availability of a standardised testing protocol, a paucity of information is available describing how and why occupational therapists and other health professionals conduct HGS assessment in practice. Furthermore, various biological (age, gender, body size) and functional factors (work demands, lifestyle factors) are considered to influence HGS and are relevant to the evaluation of HGS. Influencing biological factors commonly accounted for include age and gender.

The aim of this research is to identify what factors influence Australian adult HGS. Specifically, this research aims to:

1. Identify the influence of various biological and functional factors on adult HGS
2. Explore the experiences of occupational therapy clinicians working across a range of practice settings in Queensland who work with HGS normative data, including what factors they believe influence Australian adult HGS
3. Determine which biological and functional factors most strongly predict HGS within an Australian adult population
4. Explore how and why Australian adult HGS is assessed and evaluated by clinicians across Australia

This research study used a mixed methods approach and contained four phases: 1) a systematic literature review (chapter 3) examining which biological and functional factors influence

HGS potential; 2) experiences related to assessing and evaluating HGS; 3) determining which biological and functional factors most strongly predict HGS potential, and 4) exploring how and why Australian adult HGS is assessed and evaluated. The findings from all four study phases were used to provide recommendations regarding the HGS assessment and evaluation decision making process.

Study phase one (systematic literature review – Chapter 3) provided details regarding the influence of biological and functional factors on HGS potential (paper 2) and informed which biological and functional factors were collected in the quantitative study phase three (exploring which biological and functional factors influence Australian adult HGS). Additionally, the findings from the literature review in study phase one were incorporated into an interview question in study phase two (experiences of occupational therapists in Queensland, Australia) to explore occupational therapists' perspectives on how biological and functional factors may influence HGS. Study phase three (exploring which biological and functional factors influence Australian adult HGS) concluded the biological factors of forearm circumference, hand length and width in addition to an individual's functional factors (work demands and lifestyle factors) most strongly predicted HGS.

Study phase two (experiences of occupational therapists in Queensland, Australia – Chapter 4) involved interviews and focus groups conducted with occupational therapists located in the state of Queensland, Australia to identify the experiences of occupational therapists on the assessment and evaluation of adult HGS. Key findings included that occupational therapists use clinical reasoning and practice context to guide HGS assessment. Further, assessment and interpretation of HGS scores is influenced by clinical experiences and biological and functional factors. The findings from study phase two led to the development of an online questionnaire completed by occupational therapists and physiotherapists working Australia wide exploring the how and why of HGS assessment (study phase four). The key findings from study phase four detailed there is considerable variation in testing protocol for HGS and the reason for testing may influence how HGS is assessed and evaluated. The findings from all four study phases led to the development of a proposed decision-making flowchart to guide the HGS assessment and evaluation process in practice.

In conclusion, with so much importance placed on HGS as a standardised assessment tool, investigation into how and why this assessment is used in practice offers insights into the value and evaluation of HGS assessment findings. A one size fits all approach for HGS assessment and evaluation is simplistic. HGS assessment and evaluation is determined by complex factors including the reason for assessment, the practice context and the clinical reasoning of the assessor.

Evaluation of HGS typically includes comparison to normative data to situate the performance of an individual in comparison to the general population. If HGS scores are to be compared to normative data, the American Society of Hand Therapists (ASHT) testing protocol must be adhered to, and the selection of suitable normative data developed from a population which most closely represents the individual must be ensured to allow for accurate evaluation.

How assessment and evaluation of HGS is taught to occupational therapists and other health undergraduate students influences HGS assessment and evaluation in practice. Considerations include whether the ASHT standardised testing protocol is examined and the methods used to evaluate HGS scores including the interpretation of HGS scores using normative data for comparison. Developing students' ability to critically analyse the HGS scores and the use of normative data based on review of the literature available may lead to better use of evidence to inform interpretation of HGS results.

Given the importance placed on HGS scores when evaluating hand function across all health disciplines, consideration of biological and functional factors in addition to age and gender will provide contextualisation of the HGS results in relation to a person's body size and daily occupations.

List of Publications Included in the Thesis

Two publications have been published in a peer-reviewed journal. The published papers are attached in Appendix D and Appendix E:

Myles, L., Massy-Westropp, N., & Barnett, F. (2023) Experiences of occupational therapy clinicians on the assessment and evaluation of adult handgrip strength. *British Journal of Occupational Therapy. 86*(3), 188-196. https://doi:10.1177/03080226221135375

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Two publications have been submitted to peer-reviewed journals (*Work: A Journal of Prevention, Assessment & Rehabilitation* and *British Journal of Occupational Therapy)* and are currently under review:

Myles, L., Barnett, F., & Massy-Westropp, N. *Do functional and biological factors influence handgrip strength: A systematic review.* [Manuscript submitted for publication]. James Cook University.

Myles, L., Barnett, F., & Massy-Westropp, N. *Exploring select factors that influence North Australian adult handgrip strength.* [Manuscript submitted for publication]. James Cook University.

List of Conference Presentations Resulting from Thesis

Two presentations based on work from this thesis have occurred at Australian occupational therapy conferences. The published conference abstract for the first presentation is attached as Appendix F and the second presentation is attached in Appendix G:

Myles, L., Barnett, F., & Massy-Westropp, N. (2021). Assessment and evaluation of adult handgrip strength; experiences of occupational therapy clinicians in north Queensland. *Australian Occupational Therapy Journal, 68*(S1), 112. https://doi.org/10.1111/1440-1630.12738

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Abbreviations

ADL	Activities of Daily Living
AHTA	Australian Hand Therapy Association
ASHT	American Society of Hand Therapists
BMI	Body Mass Index
FCE	Functional Capacity Evaluation
HGS	Handgrip Strength
ICF	International Classification of Functioning, Disability and Health
NQ	North Queensland
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
ROM	Range of Motion
WFOT	World Federation of Occupational Therapists
WHO	World Health Organization

Chapter 1 Introduction

1.1 The Thesis

This chapter introduces the background and context of this research. Occupational therapy practice concerning hand function is contextualised by discussing the relationship between hand function and activities of daily living (ADL), the occupational therapy practice setting and the literature around upper limb assessments. As this thesis is based on publications, each paper contains its own introduction, methods, results, discussion and conclusion. This chapter aims to provide a broad introduction to the importance of hand function in daily life and how hand function is assessed and evaluated including the role of occupational therapy in assessing and evaluating hand function. Detailed background information pertaining to relevant literature is provided in the introduction sections of each paper specific to the study contained within the paper.

1.1.2 Occupational Therapy practice and assessment of hand function

The World Federation of Occupational Therapists (WFOT) define occupational therapy as:

> *A client-centred health profession concerned with promoting health and wellbeing through occupation. The primary goal of occupational therapy is to enable people to participate in the activities of everyday life. Occupational therapists achieve this outcome by working with people and communities to enhance their ability to engage in occupations they want to, need to, or are expected to do, or by modifying the occupation or the environment to better support their occupational engagement* (WFOT, 2023, para 1)

Occupations include any everyday activity that enables individuals to spend their time completing the things that are meaningful to them and can include occupations such as self-care, productivity and leisure.

WFOT defines occupational therapists as:

> *Autonomous health professionals that work with individuals, groups and communities in a variety of settings to promote participation in occupations that give value and meaning to life. Occupational therapists are educated, self-directed and use evidence and judgement to complete assessments, plan and implement occupational therapy interventions and evaluate outcomes of service. To work as an occupational therapist, individuals must complete an education programme in occupational therapy, and in most countries, meet regulatory standards for entry-to-practice and continuing competency* (WFOT, 2023 para 3).

The concept of enabling participation in everyday activities through the use of occupation is central to the purpose of occupational therapy. Hands are vital for a large variety of tasks performed during daily life (Dollar, 2014). The most frequently used part of the body to perform ADLs is the human hand (Reissner et al., 2019) as they are required to perform complex and detailed functions and tasks including manipulation of objects, grasping and releasing, lifting and carrying. A study by Keramiotou et al. (2021) identified impaired hand function from reduced grip and pinch strength results in occupational difficulties performing ADLs. Mathiowetz (1993) postulated that '*if hand function were defined as the group of component skills needed to perform functional tasks, then the elements might include hand strength, range of motion and sensation'* (pp. 228). Various methods have been developed to objectively evaluate hand function in relation to the performance of everyday activities, with handgrip strength (HGS) assessment considered a crucial assessment tool in these evaluations (Mitsionis et al., 2009)

1.1.3 Occupational therapy and hand therapists

The profession of occupational therapy emerged following World War I to address the need for meaningful occupation during the rehabilitation of soldiers injured in battle. The United States involvement in the war facilitated the observation by Australian medical practitioners of new, structured and coordinated models of rehabilitation centered around recovery and community integration (Cusick & Bye, 2021). The rehabilitation services included both physical and occupational rehabilitation and were deemed highly successful (Lowe, 1992). At the time, limited resources within Australia lead to the development of the physical therapy profession only (Lowe, 1992). However, occupational therapy had not missed its opportunity to establish itself as a viable profession. During World War II extensive employment opportunities for occupational therapists were created to address the adverse health issues impacting returning soldiers (Cusick & Bye, 2021). At the conclusion of the second World War occupational therapy positions in Australia were formalised by the medical and military leaders of Australia (Cusick & Bye, 2021). Occupational therapists were recognised for their contribution to enabling and promoting function for individuals who had been impacted by physical or mental disorders (Cusick & Bye, 2021).

The 1950s and 1960s provided growing employment opportunities for occupational therapists within Commonwealth rehabilitation services, state run hospitals and specialty service areas (Macintyre, 2015). As the scope of the profession grew so too did workforce demand. The increased demand for occupational therapists combined with employment conditions which required married or pregnant women to cease work led to the need to expand professional training (Cusick & Bye, 2021). Changes to the political landscape of Australia in the 1970s led to the creation of higher qualification levels and in turn to a shift towards bachelor degree level qualifications in occupational therapy which were considered essential (Cusick & Bye, 2021). This transition provided the catalyst for Australian occupational therapy to define its underlying assumptions, roles and scope of practice facilitating the growth of the philosophy and the evidence base underpinning the occupational therapy profession (Cusick & Bye, 2021; Molineux, 2004).

Historically, occupational therapy has been heavily influenced by the medical model of health. Subsequently, in the 1970s and 1980s occupational therapy assessment tools focused on measuring physical component-based variables, such as HGS and range of motion (ROM) (Mathiowetz, 1993; Michener et al., 2001). A biomedical approach to assessment focuses on deficits in body structures and functions and assumes that by addressing these deficits this will result in improvement of overall occupational performance (Hocking, 2001). The International Classification of Functioning, Disability and Health (ICF) defines body functions as '*the physiological functions of the body systems'* and body structures as '*anatomical parts of the body such as organs, limbs and their components'* (WHO, 2001). The popularity of physical component-based assessments in the 1960s and 1970s led to dissatisfaction among occupational therapists who believed these type of assessments lacked the occupational perspective unique to the profession (Molineux, 2004).

During the evolution of the profession in the 1970's and 1980's, occupational therapists and physiotherapists developed specialist skills and knowledge to treat and rehabilitate hand and upper limb conditions. These clinicians became known as hand therapists. To support the creation of this specialist field the formation of an Association of Occupational Therapists and Physiotherapists whose focus on the treatment of hand and upper limb injuries and conditions was first proposed in Australia in August 1982 (Australian Hand Therapy Association, 2023). Occupational therapists provide hand therapy services including assessment and intervention to individuals with upper limb dysfunctions using a combination of occupation and biomechanical approaches (Robinson et al., 2016).

A paradigm shift occurred towards the end of the 20th century away from the medical model towards the creation of practice-based theories of occupation and models of occupational theories from around the world (Molineux, 2004). With the introduction of the ICF an increased understanding of the impact of health conditions on function shifted the focus of assessment away from standardised health outcomes to include consideration of the individual's ability to perform their everyday occupations (de Klerk et al., 2015). Occupational therapists utilise two major categories for assessment described as top-down and bottom-up (Holm et al., 2003). Top-down approaches focus on assessment of an individual's occupational roles whereas bottom-up approaches focus on assessment of performance components (Holm et al., 2003). The medical model continues to influence the occupational therapy profession, particularly within the hand therapy practice context where the bottom-up approach examining performance components related to body structures and functions continues to dominate hand therapy research and practice (Fitzpatrick & Presnell, 2004; Robinson et al., 2016). Assessments which measure physical component-based variables continue to add value within the occupational therapy profession as they aid in identifying the cause of occupational performance deficits and subsequent intervention planning (Mathiowetz, 1993). Given the importance of HGS scores, accurate assessment and interpretation of HGS scores is crucial to ensure the best outcomes for occupational performance.

1.1.4 Occupational Therapy Practice and hand function

Models of practice used within the occupational therapy profession look to examine occupational performance as a result of the dynamic and continuous relationship between the person, their occupations and their environments (Townsend & Polatajko, 2013). The Person-Environment-Occupational Model (PEO) proposes that to achieve occupational performance consideration of the key domains of the ‘person’, their ‘environments’ and their ‘occupations’ is required with all three domains being dependent and affected by each other (Baptise, 2017). Circumstances that lead to an imbalance between these domains indicates the need for assessment and whether a subsequent intervention is warranted.

The occupational therapy process involves conducting initial and repeated assessments from which intervention planning and intervention programs are developed (WFOT, 2023, para 5) Assessment is a key element within the occupational therapy process and is crucial for evidence based practice (Law, 1987). Occupational therapists work in a variety of practice areas including community health, disability, neurology, occupational rehabilitation and various other settings (Occupational Therapy Australia, 2023). Regardless of the area of practice, hand function is relevant to all occupational therapist clinicians as function can be affected by physical or neurological injury and various health conditions which in turn impacts on engagement in everyday occupations.

Evaluation of hand function includes obtaining a history of the injury/condition via interview, direct observations of wounds, posture, scarring and specific performance-based testing including ROM, oedema, vascular, sensation, strength and coordination (Klein, 2020). Assessment tools used by occupational therapists to assess hand function at a body function and structures level aim to assess movement, strength and sensation. These assessment tools include goniometry (ROM), manual muscle testing and/or dynamometry (strength) and sensory tools which are classified as either functional or physiological (Clerke, 2006). Sensory tests include monofilament testing, tests of light touch, hot or cold perception thresholds and pressure sense (Hislop & Montgomery, 2002; Mathiowetz et al., 1984; Norkin & White, 2009; Novak, 2001).

Measurement of HGS via a dynamometer is common practice to evaluate hand function as it is an essential requirement for hand strength to perform most daily tasks. The use of HGS testing as an objective standardised assessment to measure hand function is widely accepted across various occupational therapy practice areas. The practice setting of occupational rehabilitation commonly utilise HGS testing as a component of a larger Functional Capacity Evaluation (FCE) to demonstrate function within the home and workplace (Kunelius et al., 2007). Gibson & Strong (2003) defined FCE as a measure of occupational performance based on activity and activity limitation which is used to inform recommendations for participation in work. The use of HGS testing to assess hand function is also paramount for hand therapists working within specialised occupational therapy hand clinics (Burley et al., 2018). The purpose of assessing HGS via dynamometry is to compare an individual's strength to normative data (Mathiowetz & Bass-Haugen, 2008).

With so much importance placed on HGS as a standardised assessment tool, investigation into how and why this assessment is used in practice may offer insights into the value of these assessment findings in practice. The paradigm shift within the occupational therapy profession resulted in a change in thinking away from physical component-based assessments as a priority over occupational performance. The exploration of how and why occupational therapists assess HGS may help to explain how occupational therapists account for other subjective factors when evaluating hand function.

1.1.5 HGS testing and evaluation

The ability to measure upper limb strength was first documented by De La Hire, a Frenchman who created the first scientific study of muscle strength in 1699 (Evans, 1981). Upper limb strength was assessed and evaluated by lifting loads where the weights were known (Evans, 1981). As interest grew from English and European explorers who wished to compare strength between different ethnic groups, transportation of the heavy loads required for this method of assessment were deemed impractical when traversing unknown lands (Pearn, 1978a; Pearn, 1978b). Subsequently, a portable dynamometer to measure upper limb strength was invented (Pearn, 1978a). John Theophilus Desaguilers designed the Graham-Desaguiler dynamometer, produced in 1763 (Pearn, 1978a). Desaguilers was the first to establish the importance of a standardised testing position which enabled quantitative evaluation of muscle strength testing (Pearn, 1978a).

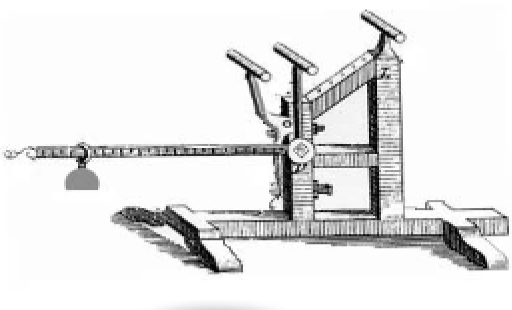


Figure 1 Graham-Desaguiler Isometric Dynamometer 1763 (Pearn, 1978a)

Desaguilers also established the concept of variation in strength of individuals regardless of similarities within body size and composition (Pearn, 1978a). The first documented study comparing various ethnic groups was conducted in Australia in 1800 by Francois Peron and Louis de Freycinet. This study compared the strength of five ethnic groups using the dynamometer (Pearn, 1978b). Several other dynamometers were created by various scientists over time with researchers and clinicians looking to improve portability and cost effectiveness within the dynamometer design (Pearn, 1978b).

When discussing HGS assessment, the type of muscle contraction assessed during dynamometry testing must be considered. Isometric dynamometers examine force generated by the muscle when there is no change in muscle length. Reporting of the force produced is generally documented as kilograms of force, or more specifically Newtons. The first Jamar dynamometer was created by Charles Bechtol in 1954 who described an isometric handgrip dynamometer where sylphons immersed in oil measured force applied to two parallel handles (Bechtol, 1954). H. C. Sanderson (of the Committee of Industrial Health and Rehabilitation of the California Medical Association) was quoted within a research paper by Kirkpatrick (1956) describing HGS as a measure of force, not pressure and consequently HGS could only be measured by isometric hand force dynamometers such as the Jamar. The Jamar hydraulic dynamometer is currently considered the gold standard for HGS measurement as it has the highest retest reliability and precision (Huang et al., 2022). Furthermore, Jamar dynamometers are cost effective and numerous normative data sets are readily available for evaluation methods by clinicians. More recently digital electronic hand-held Jamar dynamometers (Figure 2) were developed to allow for the measurement of HGS using a digital strength recording.

Figure 2 Jamar Digital Dynamometer

Developments within the dynamometer were mirrored by the developments of the HGS testing protocol. Several inventors of the various iterations of the dynamometer recognised the importance of standardising the testing position so that valid comparisons could be made for the same individual over time or when comparing between individuals. The first published guideline outlining standardised protocols for both the body and arm position during HGS testing was developed by the American Society of Hand Therapists (ASHT) in 1981 (Fess & Moran, 1981). Over time further recommendations by Mathiowetz et al. (1985) have been accepted and included into the current ASHT HGS testing protocol (MacDermid et al., 2015).

1.1.6 HGS testing protocol

The assessment of hand function using HGS testing is common practice within various occupational therapy settings (Reuter et al., 2011). The American Society of Hand Therapists (ASHT) developed a standardised HGS testing protocol to improve test-re-test reliability when measuring HGS (Lagerström & Nordgren, 1996). The ASHT standardised testing position and instructions involves having the individual seated in an upright posture 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. Using the second handle position of the dynamometer, three alternating trials on each hand are recorded with an average of the three trials used to compare to the norms (MacDermid et al., 2015). Despite the publication of the ASHT HGS testing protocol which provides clear guidelines describing how HGS testing should be performed, little is known about how HGS testing is conducted by occupational therapists and other health professionals in practice.

A consistent protocol for HGS testing is crucial to ensure best clinical practice amongst the profession of occupational therapy (Innes, 1999). Any variations to the testing protocol can impact upon the reliability of the HGS scores and subsequently the evaluation of these scores (Innes, 1999; Richards et al., 1996). Furthermore, Larson and Ye (2017) stated '*inaccurate assessment of HGS may impact both clinical and non-clinical outcomes'* (pp. 41). Despite the availability of the ASHT HGS testing protocol, variations to this testing procedure do occur in practice. Possible variations to the ASHT testing protocol could include the handle position, the position of the upper limb being tested, the number of trials completed, variation in rest time between trials and the type of contraction performed during the assessment.

1.1.7 The utility of HGS assessment

HGS has been used as an indicator of various adverse health events due to its low cost and simple process of measurement (Lu et al., 2022). Muscle weakness has been found to be a key indicator of poor health outcomes related to cardiometabolic disease, bone health, physical dysfunction and all-cause mortality and HGS is also used as a component to diagnose sarcopenia and frailty (Cruz-Jentoft et al., 2019; Cruz-Jentoft & Sayer, 2019). Due to the strong predictive capability of HGS related to disability and frailty, which are of concern to not only occupational therapists but many health professionals, there is support for the use of HGS as an indicator of patient status and progression (Reuter et al., 2011). The broad application of HGS to evaluate an individual's health status overall and as a predictor of health outcomes has become widely accepted within health services, however this is not the primary purpose of HGS testing within the field of occupational therapy. Rather, HGS testing is regarded as a useful assessment tool to assess upper limb function and to evaluate the impact of various upper limb impairment and conditions, to determine the amount of effort exerted and to evaluate the efficacy of treatment (Innes, 1999; Reuter et al., 2011). Health professionals including occupational therapists utilise HGS testing across a range of practice settings as a simple and reliable measure to quantify and evaluate hand function (Günther et al., 2008). Within the field of occupational therapy, importance is placed on HGS measurement as the results obtained may be used as an initial baseline from which to track rehabilitation progression, as a criterion to assess work capacity or to compare to normative data as a way of quantifying an individual's abilities relative to the general population (Innes, 1999; Reuter et al., 2011). Due to the significance and variety of applications for HGS testing as an assessment tool for health professionals across a variety of practice settings and for numerous purposes within the profession of occupation therapy, it is critical to establish how and why HGS is assessed and how HGS scores are evaluated to ensure best practice outcomes.

1.1.8 HGS evaluation methods

Understanding the complexity of how HGS is evaluated by clinicians is equally as important as understanding how HGS is assessed. HGS testing is a standardised assessment tool. An assessment tool is considered standardised following the establishment of validity, reliability, sensitivity and clinical utility (Corr & Siddons, 2005). de Klerk et al. (2015) stated '*standardised assessment provides quantitative information, useful for tracking the client's progress and demonstrating the outcome of therapy*' (pp. 43). To ensure accurate comparison to normative data, an individual's HGS must be assessed using the same consistent testing protocol as was used to develop the normative data set (Innes, 1999; Reuter et al., 2011; Richards et al., 1996; Wang et al., 2018). Occupational therapists look to provide evidence to demonstrate the effect of interventions and in turn support funding for services provided. The use of standardised assessments provide the ability to quantify intervention outcomes however this form of evaluation fails to consider the functional needs of the individual (Mathiowetz, 1993).

Once HGS scores have been obtained, the interpretation and use of this information is crucial to guide clinical decision making. The primary purpose of assessing HGS is to evaluate performance, most commonly by comparison of an individual’s strength to normative data (Mathiowetz & Bass-Haugen, 2008). The use of normative data allows for comparison of an individual’s strength in relation to the general population (Bhat et al.,2021; Bohannon et al., 2006; Larson & Ye, 2017). Normative data describes standard values for a specific population in regards to a specific characteristic such as HGS (Innes, 1999). The organisation of HGS normative data sets typically includes division by gender, age and right and left hand. Given the importance of normative data in the HGS evaluation process, the development of these normative data sets must be critiqued. One factor to consider when selecting appropriate HGS normative data for comparison with an individual include the sample size of the data set understanding that subcategories of age and gender reduce the number of subjects included in each stratum.

Following the ASHT introduction of a standardised testing protocol for HGS testing, Mathiowetz et al. (1985) pioneered the creation of HGS normative data for adults aged 20 to 75+ years using a dynamometer and the ASHT standardised testing protocol. This study was based on an American population using a convenience sample of 310 male and 318 female participants aged 20 to 94 years with fewer than 30 subjects on average in each stratum (Mathiowetz et al., 1985). Until the late 2010s limited studies had established more robust normative values for HGS within the United States leading to the Mathiowetz’s normative values being widely accepted within clinical practice (Wang et al., 2018). Furthermore, a research study which examined the maximal grip strength of 145 Australian adults concluded the United States norms were valid for an Australian population leading to the widespread adoption of Mathiowetz’s norms (Fairfax et al., 1997).

When formally comparing HGS scores to normative data consideration must be given to whether the data set utilised matches the population being assessed. Innes (1999) postulated that normative data is most appropriate when it is developed using a population closely aligned to the individual being assessed. Outside of the United States numerous peer-reviewed studies began to emerge and provided population-specific normative reference values for Great Britain (Dodds et al., 2014), Germany (Günther et al., 2008), Australia (Massy-Westropp et al., 2011), Korea (Shim et al., 2013) and Taiwan (Wu et al., 2009). The development of these normative data sets allowed clinicians to ensure that HGS evaluation using normative data was population specific. Population specific norms are crucial when evaluating HGS as the scores have been found to vary within differing ethnic groups, with research suggesting the variance may be attributed to anthropometric measurements such as height, weight, skeletal mass and limb length which are influenced by ethnicity (Bhat et al., 2021; De Andrade Fernandes et al., 2014; Leong et al., 2016). The influence of demographic factors of age and gender on HGS has been well established with studies identifying men being stronger than women and both genders experiencing an increase in HGS through early adulthood peaking in the third decade before declining with increased age (Agnew & Maas, 1982; Angst et al., 2010; Dodds et al., 2016; Mathiowetz et al., 1985).

Current studies have looked to examine other potential influencing factors on HGS. In addition to age and gender, other biological factors identified as influencing HGS include anthropometric characteristics. Anthropometric characteristics are defined as noninvasive quantitative measurements of the body (Casadei & Kiel, 2023). Anthropometric factors found to correlate with HGS include height, hand length, hand width/palm width and forearm circumference (Eidson et al., 2017; Hatem et al., 2016; Klum et al., 2012; Mohammadian et al., 2015; Moy et al., 2015; Rostamzadeh et al., 2020; Rostamzadeh et al., 2019; Saremi & Rostamzadeh, 2019). Saremi and Rostamzadeh (2019) hypothesized that the relationship between height and hand length is explained by the phenomenon that as height increases so too does hand length. This correlational relationship between hand length and height is further explained as hand length is used as a criterion to estimate height.

The relationship between HGS and functional factors have also been investigated in recent studies. Functional factors include hand dominance, occupation (job) and lifestyle factors. Despite HGS normative data being divided into right and left hands, data sets do not account for hand dominance. Research has identified that dominant HGS is greater than non-dominant HGS for both men and women, particularly for right hand dominant individuals (Moy et al., 2015; Rostamzadeh et al., 2019; Shim et al., 2013). A 10% rule has been discussed in previous research which describes right hand dominant individuals to be approximately 10% stronger in their dominant hand compared to their non-dominant hand, however the difference between dominant and non-dominant HGS is minimal for left hand dominant individuals (Incel et al., 2002; Petersen et al., 1989).

Adults spend significant periods of their day engaged in the productive occupation of work. Work tasks typically involve an extensive use of an individual’s hands to perform manual lifting, grasping, fine motor and dexterity actions regardless of the type of employment engaged in. Given the significant involvement of hand use during work, exploration of the relationship between work and HGS is warranted.

The influence of work (occupational demands) has been examined in recent studies across a variety of work settings (Klum et al., 2012; Lo et al., 2020; S. Rostamzadeh et al., 2019; Saremi & Rostamzadeh, 2019). When examining the influence of work on HGS, consideration of how occupations are classified is essential. The Australian and New Zealand Standard Classification of Occupations (ANZSCO) publication was developed by the Australian Bureau of Statistics (ABS), Stats NZ and the Australian Government Department of Education, Employment and Workplace Relations to provide a basis for standardising occupational data for Australian and New Zealand workers (ABS, 2022). ANZSCO is a skill-based classification system with distinctions between occupations based on the skill level required to perform different tasks within an occupation (ABS, 2022). The differentiation in skill levels is measured by formal education and training, previous job experience and the amount of on-the-job training required to perform the tasks within that occupation (ABS, 2022). Occupations are not classified by the physical demands required to perform the work tasks that constitute the occupation. ANZSCO has eight occupational categories which are Managers, Professionals, Technicians and Trades Workers, Community and Personal Service Workers, Clerical and Administrative Workers, Sales Workers, Machinery Operators and Drivers and Labourers (ABS, 2022). When examining the ANZSCO eight occupational categories there is no consideration of the physical demands required to perform the occupation described. Identification of the physical demands of the main tasks and duties performed as part of an individual's occupation would provide insight into the demands required for HGS. The adoption of categories associated with the physical demands of the person's occupation such as the definitions of sedentary, light, medium, heavy and very heavy work outlined in The Revised Handbook for Analyzing Jobs (United States Department of Labor Employment and Training Aministration, 1991) allows for a greater understanding of a person's occupation through the delineation of the physical effort required to perform a specific occupation and the associated HGS required.

Studies examining a combination of demographic, biological and functional factors to predict HGS are limited (Angst et al., 2010; Klum et al., 2012; Moy et al., 2015; Rostamzadeh et al., 2020). The only Australian study examining HGS and factors other than age and gender was by Massy-Westropp et al. (2011) who included the biological factors of height, weight and BMI.

Due to the paradigm shift within the occupational therapy profession towards the end of the 20th century, evaluation of hand function expanded beyond quantitative analysis using standardised assessments to include other forms of information gathering such as skilled observations and subjective data such as the individual's self-report of their ability to perform their everyday occupations (Hocking & Whalley Hammell, 2017). The inclusion of non-standardised skilled observations facilitates the use of professional knowledge and expertise when evaluating performance. Additionally, use of skilled observations when assessing HGS allows for inclusion of the individual's perspective (Hocking & Whalley Hammell, 2017). Research has found that the evaluation of HGS scores is completed in several ways, including non-standardised comparison to an individual's previous HGS scores to track rehabilitation progression, comparing affected to unaffected or right to left sides of the same individual and standardised methods of comparison with normative data (Innes, 1999; Reuter et al., 2011). These standardised and non-standardised forms of evaluation of HGS have value and utility within different practice settings. Although a standardised approach when evaluating HGS has its place, consideration of the reasoning behind why HGS is being assessed may be useful in informing the evaluation method used. Even if informal evaluation methods are utilised such as recording an individual's scores over time to track progression, consistency in the testing protocol is crucial to allow like for like for comparison of HGS scores over time. Therefore, regardless of the method of evaluation, the testing protocol used to obtain the HGS scores should be documented, especially if it varies from the standardised ASHT protocol to ensure reliability.

The practice setting can influence the type of HGS evaluation utilised. Practice settings such as occupational rehabilitation or community settings require formal reporting processes for funding applications. Additionally, requests are made by external parties to use normative data to provide a quantifiable comparison of an individual's hand function in relation to the general population to comment on work capacity. As such, occupational rehabilitation or community settings may be more likely to use normative data as part of their evaluation of hand function. Whereas practice settings where clients are engaged in rehabilitation activities to improve hand function following an injury or as a result of a medical condition are more likely to record HGS scores overtime or compare affected to unaffected sides. In turn, clinicians working in these practice settings are less likely to compare scores to normative data instead using these scores to track changes and progression over time for an individual. Subsequently, the intention behind how HGS score are evaluated can influence how the HGS testing is performed.

1.1.9 Significance

This mixed methods doctoral study explores the assessment and evaluation of Australian adults' HGS. Hand strength is required to perform most functional activities of daily life including work tasks and lifestyle activities. Evaluation of an individual's hand strength routinely involves the assessment of HGS (Mitsionis et al., 2009). HGS testing involves the measurement of the maximal force of the hand using the combined contraction of extrinsic and intrinsic muscles that flex the joints of the hand (Schlüssel et al., 2008, Larson & Ye, 2017). HGS is typically measured using a hydraulic dynamometer, with the Jamar hydraulic dynamometer considered the gold standard as it has the highest retest reliability and precision (Huang et al., 2022).

Age and gender have a significant influence on HGS with men being stronger than women and as age increases so too does HGS until declining throughout older adulthood (Agnew & Maas, 1982; Angst et al., 2010; Dodds et al., 2016; Mathiowetz et al., 1985). Recent research has expanded beyond the accepted influence of age and gender to examine the potential influence of other biological (height, weight, Body Mass Index (BMI), hand and forearm length, forearm circumference) and functional (hand dominance, occupation) factors in relation to adult HGS, but as yet not on an Australian population (Angst et al., 2010; Hossain et al., 2012; Klum et al., 2012; Lo et al., 2020; Mohammadian et al., 2015). Numerous biological and functional factors have been described in relation to HGS within the literature. Therefore, this research was designed to identify which biological and functional factors are the most important predictors to consider in relation to HGS. Given the importance placed on HGS when evaluating hand function across all health disciplines, consideration of these biological and functional factors in addition to age and gender will provide contextualisation of HGS results in relation to a person's body size and daily occupations. As such, the aim of this thesis is to identify what factors influence Australian adult HGS. Specifically, this thesis aims to:

1. Identify the influence of various biological and functional factors on adult HGS.

2. Explore the experiences of occupational therapy clinicians working across a range of practice settings in Queensland who work with HGS normative data, including what factors they believe influence Australian adult HGS.
3. Determine which biological and functional factors most strongly predict HGS within an Australian adult population.
4. Explore how and why Australian adult HGS is assessed and evaluated by clinicians across Australia.

Clinical reasoning of the assessor has also been found to influence the interpretation and evaluation of HGS scores. HGS may be assessed and evaluated for reporting purposes, to determine suitability for employment, as a baseline to track progression or as a quantifiable way to evaluate rehabilitation. The examination of how and why HGS is assessed by clinicians and how the results of HGS testing are evaluated is crucial to provide context and meaning to the application of this routine hand strength assessment tool and to ensure best practice outcomes.

Chapter 2 Methodological Approach

2.1 Chapter Overview

Chapter 2 situates the researcher within the thesis, including background experiences that informed the research and provides a rationale for the use of a mixed methods approach to explore HGS of Australian adults. This chapter also presents details regarding the establishment of trustworthiness and ethical approval related to the studies. Further information concerning the methods utilised (data collection and analysis) for each phase of the thesis are contained within Chapter 3, Chapter 4, Chapter 5 and Chapter 6, as these chapters are based on research papers. While methods specific to each of the studies are discussed in each relevant chapter, details of the overall thesis methodology and the rationale for the chosen methodology are included in this chapter.

2.2 Situating the Researcher

My professional background is as a qualified occupational therapist predominantly working in the practice setting of occupational rehabilitation. This practice setting involves providing assessment and interventions related to both injury prevention and injury management in the workplace for individuals with physical and/or psychological conditions. My current role as a lecturer in occupational therapy involves teaching undergraduate students about performance-based assessments including HGS.

The initial plan underpinning this research was to design normative data tables for an Australian adult population with sub-categories for various biological and functional factors that influence HGS. Within my clinical role I regularly utilised HGS assessment as an objective assessment tool to quantify an individual's hand strength and hand function specifically in relation to the performance of physical work demands as a part of an FCE. I observed that although HGS assessment was typically carried out using a standardised protocol, the interpretation and evaluation of HGS scores varied. Within the occupational rehabilitation practice setting, HGS scores were routinely evaluated in comparison to HGS normative data, but clinical reasoning was also utilised to interpret the HGS assessment findings. Reports detailing HGS findings often discussed not only the individual's performance in relation to the normative data, but also included clinical observations of functional use of hand strength during simulated work tasks such as lifting. This therefore made me question the relevance of the normative data in the interpretation of HGS scores and whether other factors such as clinical reasoning were more important in the evaluation of HGS. Anecdotally, I had participated in discussions with peers regarding an observed phenomenon that individuals who performed heavy physical work or were taller and had larger hands often scored higher than the expected norms whereas individuals with a smaller physical build or who performed more sedentary or light work duties were more commonly scoring below the expected norms for HGS. It seemed a logical conclusion that the more you used your hands for strength-based tasks the stronger your HGS would be. Likewise, if you were of a larger body size, there was potential to produce more powerful strength with your hands. Despite these assumptions around what factors may influence HGS, reference to normative data was the only formal way in which HGS scores were evaluated within my occupational rehabilitation practice setting as an occupational therapist. My professional experience suggested comparison to HGS normative data was not always the best form of hand strength evaluation and piqued my interest in exploring what factors influence HGS in an Australian adult population. Prior to commencement of this doctoral study, I had completed my post graduate honours degree completing a pilot study examining what factors influence HGS using a quantitative study design. The intention of this doctoral research was to expand on the findings of the post graduate honours research and consider the implications of any influencing factors on HGS in practice.

A preliminary review of the literature described numerous biological and functional factors thought to influence HGS which posed the question as to which factors were the most significant to include within the study. Therefore, this research evolved to determine which biological and functional factors most strongly predict HGS and thus could be included as sub-categories in future normative data tables.

2.3 Research Methodology

Research which adopts a mixed methodology is becoming increasingly common in recent times (Bryman, 2006). Mixed methods research design within the health sciences is seen to provide the opportunity to address complex, multi-layered issues to improve an understanding of meaning and values within a single research question (Wasti et al., 2022, Tariq & Woodman, 2013). The goal of a mixed methods research design is to provide a comprehensive and richer description that allows for a more complete understanding of the topic (Liamputtong, 2022). The aim of using a mixed methods research design within this thesis was to ensure rigorous integration of data and to facilitate a depth of knowing to the complexity of this research enquiry. Additionally, when considering the evaluation of research, a mixed methods approach provides a detailed description of the rigour of the research (Bryman, 2006).

A mixed methods approach was adopted for this thesis to allow for a combination of both quantitative and qualitative research to address the research questions (Creswell & Plano Clark, 2018). Specifically, an exploratory sequential mixed methods research design was chosen for this research to facilitate an approach of combining qualitative and quantitative data in a sequence of phases. The exploratory sequential design has several strengths including the use of separate phases which allow the design to be straightforward to describe, implement and report (Creswell & Plano Clark, 2018). The design for this thesis occurred in four phases (Figure 3), beginning with an analysis of the quantitative data in study phase one – literature review. Study phase two collected qualitative data detailing the experiences of occupational therapists in Queensland, Australia via interviews and focus groups. The qualitative and quantitative information from study phases one and two were then integrated within the development phase to design and pilot the quantitative HGS data collection process prior to the main data collection (study phase three – exploring which biological and functional factors influence Australian adult HGS). In the third study phase, quantitative data on HGS was collected and analysed (Creswell & Plano Clark, 2018). The quantitative information from study phase one (systematic literature review) and the qualitative findings from study phase two (focus groups/interviews) were used to design the online survey distributed to clinicians assessing HGS within Australia (study phase four).

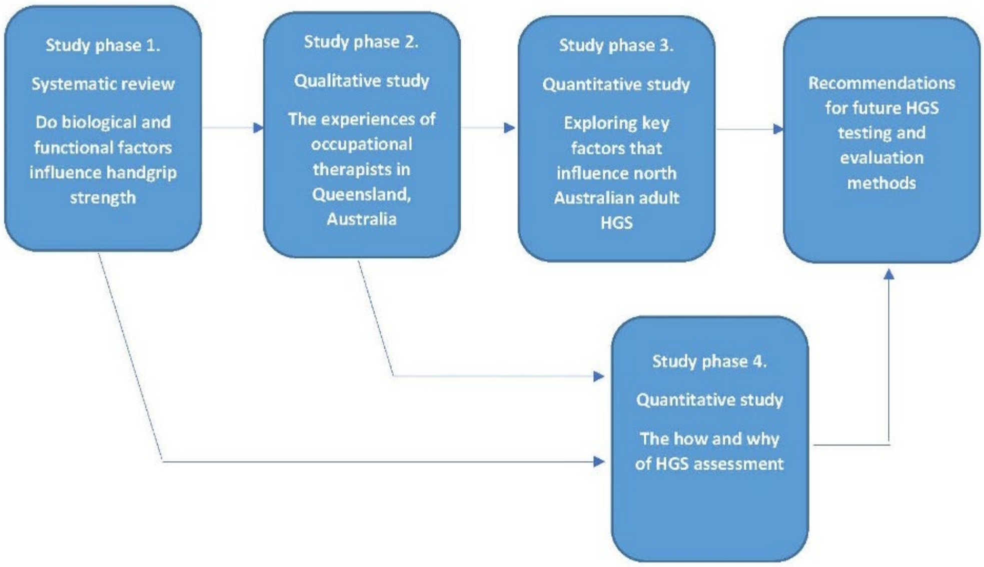


Figure 3 Exploratory Sequential Mixed-Methods Design for this thesis

This choice of an exploratory sequential study design was deemed suitable to answer the research questions. Past research has focused on quantitative study designs to explore the influence of various biological and functional factors on HGS and has not considered the qualitative experiences of clinicians who assess and evaluate HGS. Therefore, the use of a mixed methods research study design facilitates the examination of both the quantitative and qualitative data and the insights that emerge from integrating this data collection.

The qualitative data collected during study phase two (experiences of occupational therapists in Queensland, Australia) was underpinned by a constructivism approach with the assumption that knowledge is socially constructed by people, in this case occupational therapists who assess and evaluate HGS (Liamputtong, 2022). Additionally, quantitative data examined within study phase three (exploring which biological and functional factors influence Australian adult HGS) utilised a philosophical system of positivism by striving for knowledge generated by objective measures and scientifically verifying data using mathematical proof (Liamputtong, 2022). The use of both a positivist paradigm and a constructivist paradigm within the doctoral research led to a pragmatic approach overall with the belief that knowledge is generated through diverse sources using various research methods (Liamputtong, 2022). Pragmatism as a worldview focuses on the consequences of the research using multiple methods of data collection to address the research study aims (Creswell & Plano Clark, 2018).

2.4 Overview of study phases

Research within health sciences is described as a '*planned and systematic activity'* (Schmidt, 2019, p. 14) to create new knowledge. Therefore, planning of the research process is a crucial first step in any research study. Research is a cyclical process which contains multiple stages as detailed in Figure 4 (Liamputtong, 2022). This thesis followed the research process as outlined by Liamputtong (2022). As this thesis involved several study phases, repetition of steps five to 10 of the cyclic stages of a research project occurred for each of the four individual studies (Liamputtong, 2022). The cyclic stages of this research project will now be examined in relation to the four study phases.

Figure 4 The Cyclic Stages of a Research Project (Liamputtong, 2022)

2.5 Identifying the research problem

Research questions are usually developed from research problems such as the discovery of a gap in knowledge or an area of concern that requires answers (Liamputtong, 2022). The research problem for this thesis was formulated from the researcher's professional experience. The population intervention, comparison and outcome (PICO) framework as detailed in Table 1 assisted in guiding the development of the research problem.

Table 1 PICO for the Research Problem

P (Population)	Adult working population (over 18 years)
I (Intervention)	HGS assessment
C (Comparison)	Biological and functional factors

O (Outcome)	Identify the influence of biological and functional factors on HGS

2.6 Developing the research question

The research question of what factors influence Australian adult HGS was defined to guide the decision making for the research design, sample population, data collection and analysis for each study phase of the research (Farrugia et al., 2010). To answer the research question, the following aims were developed:

1. Identify the influence of various biological and functional factors on adult HGS.
2. Explore the experiences of occupational therapy clinicians working across a range of practice settings in Queensland who work with HGS normative data, including what factors they believe influence Australian adult HGS.
3. Determine which biological and functional factors most strongly predict HGS within an Australian adult population.
4. Explore how and why Australian adult HGS is assessed and evaluated by clinicians across Australia.

These research aims were developed following a broad review of the existing literature around HGS and further developed as the project progressed to address identified gaps in knowledge.

2.7 Reviewing the literature and theoretical framework

A systematic literature review (study phase one) was completed as an essential first step within the research. A review of the literature aimed to examine pre-existing literature and aid in refining the research. Research questions are developed when gaps in the literature are discovered (Schmidt, 2019). A review of the literature allowed for a compilation of knowledge on the research topic and the identification of any limitations in understanding the subject. Further, the literature review facilitated a critique of the existing knowledge related to the topic being examined thus providing a background to the research and justification for the development of specific research questions (Liamputtong, 2022). Literature reviews are essential to academic research. Xiao and Watson (2019, p. 93) stipulate literature reviews should be '*valid, reliable and repeatable*'. The use of a systematic literature review process requires planning and rigour and thus is considered the highest level of evidence in research design (Liamputtong, 2022).

A systematic review summarises, analyses and synthesizes a group of related literature (Xiao & Watson, 2019). Within health, systematic reviews are utilised to provide an objective summary of the literature for a variety of research projects (Liamputtong, 2022). The use of a systematic process minimises bias when reviewing literature by ensuring transparency, validity and objectivity (Liamputtong, 2022). Adherence to a protocol to describe the rationale, hypothesis, and planned method for the review increases the replicability of the review and adds to the rigor of the research design. The Preferred Reporting Items for Systematic review and Meta-Analysis (PRISMA) was implemented to guide this literature review (Moher et al., 2015).

2.8 Selecting research methodology

A qualitative descriptive research design was chosen to guide study phase two exploring the experiences of occupational therapists in Queensland, Australia who assess and evaluate HGS. The use of a qualitative descriptive research design is considered highly appropriate in health research as it provides factual straightforward descriptions of experiences and perceptions (Colorafi & Evans, 2016; Doyle et al., 2020). A qualitative descriptive design acknowledges the subjective nature and varied experiences of participants and aims to present the findings directly aligned to the research question (Bradshaw, Atkinson, & Doody, 2017). This type of research design is highly relevant in healthcare research, which is commonly concerned with experiences associated with healthcare intervention (Doyle et al., 2020).

Qualitative descriptive research generates data by describing the subjective perspectives and experiences of participants (Kim et al., 2017). The philosophical perspective aligned with this research approach is constructionism using interpretive and naturalistic methods (Lincoln et al., 2011). These philosophical perspectives consider reality to exist within multiple, dynamic contexts that are subjective (Lincoln et al., 2011). This approach allows researchers using a qualitative descriptive design to be flexible and dynamic when aiming to understand the unique human experience (Ormston et al., 2014). Furthermore, qualitative descriptive research also aligns with pragmatism as decision making within the research process is guided by the research context, aims and objectives to ensure the most appropriate methods are adopted to answer the research question (Yardley & Bishop, 2015). A qualitative descriptive methodology was selected as the most appropriate strategy as it allowed the findings from study phase two (experiences of occupational therapists in Queensland, Australia) to inform the quantitative data collection in study phase three (exploring which biological and functional factors influence Australian adult HGS).

Focus groups and one-on-one interviews were conducted for study phase two (experiences of occupational therapists in Queensland, Australia) to collect qualitative responses to describe the experiences of participants and are commonly used data collection approaches for a qualitative descriptive design (Kim et al., 2017). During focus groups and one-on-one interviews, participants are able to share their own views and experiences in addition to listening and reflecting on the experiences of others (Doyle et al., 2020). An interview guide detailing open-ended questions facilitated responses through the lens of the participants living in the reality (Liamputtong, 2020) in turn, allowing the researcher to develop an understanding of the phenomenon based on the information provided by participants (Bradshaw et al., 2017).

Thematic analysis was used as an independent approach to analyse the qualitative research findings in study phase two. Thematic analysis was utilised to identify patterns and themes in relation to the research questions based on the experiences and opinion of the participants (Braun & Clarke, 2013). Thematic analysis is considered highly suited to qualitative descriptive research as a reliable analysis method (Bradshaw et al., 2017; Vaismoradi et al., 2013). Common characteristics of qualitative descriptive analysis include transcribing and sorting the data, coding the initial data, adding comments and reflections, identifying patterns, themes and similar phrases to gradually create generalisations and consistencies across the data which are then linked to a formalised body of knowledge (Doyle et al., 2020). Inductive thematic analysis was used to identify and analyse themes which emerge across the data (Braun & Clarke, 2013). NVivo software was used to facilitate data analysis via the display of text from original transcripts, the ability to retrieve coded text and the development of codes (Liamputtong, 2020). Thematic analysis is considered a flexible research tool to provide detailed and complex accounts of the data (Braun & Clarke, 2013).

The philosophical background to thematic analysis can be conducted using both realist/essentialist and constructionist paradigms with either approach largely based on a factist perspective (Braun & Clarke, 2013; Doyle et al., 2020). A factist perspective involves the researcher exploring actual behaviours, attitudes and real motives of the participants (Ten Have, 2003). Focus groups and interviews were chosen as the approach to data collection to facilitate reciprocity with participants and the opportunity to explore diverse opinions (Liamputtong, 2022). The use of inductive thematic analysis allowed meaning to be developed based on the identified themes with no preexisting outcomes (Liamputtong, 2022).

Utilising the findings from study phase one (literature review) and study phase two (experiences of occupational therapists in Queensland, Australia) a cross-sectional design was utilised for study phases three (exploring which biological and functional factors influence Australian adult HGS) and four (the how and why of HGS assessment). A cross-sectional study design is a type of observational study which looks to provide a snapshot of the frequency and health characteristics of a population at a single point in time (Liamputtong, 2022; Setia, 2016; Wang & Cheng, 2020). Cross-sectional studies are used to describe features of a population from an available population related to the study question (Wang & Cheng, 2020). Typically, cross-sectional studies describe the distribution of variables within a specific population (Wang & Cheng, 2020). The cross-sectional design used for study phases three and four are considered quantitative research as it involves the collection of numerical data to test a theory (Claydon, 2015). Quantitative research is generally informed by a positivist paradigm with the underpinning assumptions of a single truth or reality with consideration of objectivity and deduction (Davies & Fisher, 2018; Sim & Wright, 2000). Knowledge generation within quantitative research is based on observed phenomenon independent of the researchers values or feelings (Handema et al., 2023). Quantitative studies are driven by the collection of numerical data for statistical analysis (Watson, 2015). Quantitative research uses a sample of a known population to describe the relationship between variables with the aim of making generalisations to the population of interest (Bloomfield & Fisher, 2019).

A cross-sectional study design was deemed appropriate for study phase three (exploring which biological and functional factors influence Australian adult HGS) which looked to determine which biological and functional factors (exposure measures) most strongly predict the outcome measure, being HGS within the NQ Australian adult population. To further specify, study phase three constitutes an analytical cross-sectional design as it aimed to quantify the relationship between the exposure and outcome variables with both the exposure and outcomes measured simultaneously (Ranganathan & Aggarwal, 2019; Wang & Cheng, 2020).

The cross-sectional survey design utilised within study phase four (the how and why of HGS assessment) is a type of descriptive quantitative research. This study expanded on study phase two (experiences of occupational therapists in Queensland, Australia) to include occupational therapists and physiotherapists practicing throughout Australia with the intent of improving the transferability of the findings to clinicians who evaluate HGS more broadly.

Cross-sectional surveys are frequently used in health fields to collect data on respondents' opinions as they are flexible and are relatively quick to conduct (Connelly, 2016). Cross-sectional surveys create a profile at one point in time which enables the exploration of association between variables (Liamputtong, 2022). Surveys are a type of quantitative descriptive research method which asks respondents a series of questions in a standardised way to facilitate quantification and statistical analysis (Liamputtong, 2022). This quantitative research approach was selected with the intention of generalising the findings to the wider population (Wright et al., 2016).

2.8.1 Participant recruitment

Participants for study phase three (exploring which biological and functional factors influence Australian adult HGS) were recruited using a convenience sampling method from the general adult population of the North Queensland (NQ) community in Australia. Participants were recruited in accordance with the study inclusion and exclusion criteria (Setia, 2016). This study aimed to include participants from a wide variety of employment types and industries to represent the main industries of employment within the NQ region. These industries are health care and social assistance, public administration and training, retail trade, education and training, accommodation and food services (The State of Queensland, 2021). Following inclusion within the study, the researcher measured the outcome and exposures variables of each participant at the same point in time (Setia, 2016). Data collected included a basic questionnaire detailing demographic information, recording of various biological measurements and functional factors and measurement of HGS following the ASHT testing protocol (MacDermid et al., 2015). All data were entered into SPSS to facilitate statistical data analysis of quantitative data (Watson, 2015).

Participants for study phase four (the how and why of HGS assessment) were recruited using purposive sampling via the distribution of an online survey to members of the Australian Hand Therapy Association (AHTA) via their mailing list. The online survey was created using Qualtrics and developed from the focus group interview guide from study phase two (experiences of occupational therapists in Queensland, Australia). The online survey expanded on study phase two (experiences of occupational therapists in Queensland, Australia) to include members of the AHTA which encompasses both occupational therapists and physiotherapists who assess and evaluate

HGS Australia wide. Quantitative data was collected via the online survey including basic demographic information, the HGS assessment and evaluation process and opinions regarding the influence of select biological and functional factors that influence HGS.

2.8.2 Data analysis

Data from study phase three (exploring which biological and functional factors influence Australian adult HGS) were analysed using a simultaneous multiple regression model. The application of multiple regression analysis was considered appropriate as it enabled the examination of the relationship between several predictor variables (biological and functional factors) in a simultaneous manner with the single continuous outcome measure of HGS (Slinker & Glantz, 2008). The intention of the statistical analysis is to use the sample to make inferences regarding the population as a whole (Watson, 2015). Thus, the simultaneous multiple regression model was used to examine the predictive relationship between select biological and functional factors and HGS.

Findings from study phase four (the how and why of HGS assessment) were analysed using descriptive statistical analysis and examined frequencies of responses. The findings provided descriptions of how and why HGS is assessed and evaluated by occupational therapy and physiotherapy clinicians across Australia. Within rehabilitation settings, HGS is commonly measured by occupational therapists and physiotherapist as a valid and reliable evalution of hand function (Mitsionis et al., 2009). Due to the inclusion of occupational therapists and physiotherapists Australia wide, this final study phase allowed for increased transferability of the study results.

2.9 Selecting research participants and addressing ethical issues

This thesis was conducted in Australia. Australia is comprised of six states – Queensland, New South Wales, South Australia, Tasmania, Victoria and Western Australia – and two territories the Australian Capital Territory and Northern Territory (Australian Government, n.d.). Focus groups and interviews were completed for study phase two (experiences of occupational therapists in Queensland, Australia) with occupational therapists within the state of Queensland. HGS data were collected for study phase three (exploring which biological and functional factors influence Australian adult HGS) from adult workers within the NQ region. The geographic region of NQ has a population of nearly 240 000 people and encompasses five major regional centres: Burdekin, Charters Towers, Hinchinbrook, Palm Island and Townsville (Queensland Government, 2021). 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 (The State of Queensland, 2019).

Recruitment of participants for study phase three (exploring which biological and functional factors influence Australian adult HGS) aimed to capture individuals residing throughout the NQ region who work in a variety of industries. Collection of HGS data from working adults within the NQ community allowed for a broad snapshot of the Northern Australian population whilst maintaining an achievable sample size. Further, the inclusion of participants working in the general NQ region aligned with study phase two which examined the experiences of occupational therapists working within Queensland who assess and evaluate HGS. To improve the generalisability of the thesis findings, data were collected via an online survey in study phase four from occupational therapy and physiotherapy clinicians who were members of the AHTA located in Queensland, New South Wales, South Australia, Victoria and Western Australia.

Research participants for study phase two (experiences of occupational therapists in Queensland, Australia) and study phase four (the how and why of HGS assessment) were identified using purposive sampling methods. Purposive sampling is used extensively in qualitative research to identify and select information-rich participants who are informed regarding the research topic (Palinkas et al., 2015). For study phase two (experiences of occupational therapists in Queensland, Australia) purposive sampling allowed for deliberate selection of participants who were occupational therapists in Queensland and highly experienced in the assessment of HGS (Liamputtong, 2020). Purposive sampling within study phase four (the how and why of HGS assessment) facilitated intentional recruitment of participants highly experienced in the phenomenon being studied (Liamputtong, 2022).

Research participants for study phase three (exploring which biological and functional factors influence Australian adult HGS) were identified using a convenience sampling method. A statistical test and power calculation conducted by a statistician at 80% determined that a sample size of 200 was required. Determination of an appropriate sample size provides confidence in the research regarding the ability to generalise the research findings (Liamputtong, 2022). Recruitment of 216 working adults from the general population residing within NQ, Australia was completed via convenience sampling. Convenience sampling enables researchers to identify individuals who are conveniently available and willing participants (Liamputtong, 2020). Additionally, snowball sampling whereby participants suggested other individuals who were interested in participating was also employed. Participants within this cross-sectional study were selected based on the inclusion and exclusion criteria designed for the study (Setia, 2016). The inclusion criteria were healthy adults, of working age with no previous or current injuries or medical diagnosis which may impact hand strength. 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.

Participants for study phase two (experiences of occupational therapists in Queensland, Australia) were identified using the researcher's professional networks and recruited through the distribution of an information sheet (Appendix G). Additionally, occupational therapy businesses who employed clinicians who assessed and evaluated HGS were contacted to distribute the information sheet to their staff. Following receipt of the information sheet, any respondent interested in participating in study phase two (experiences of occupational therapists in Queensland, Australia) was invited to join a focus group at which time they willingly agreed to participate in the study. Two participants who were unable to attend one of the scheduled focus groups due to availability, participated in one-on-one interviews. In accordance with the ethics approval granted by the James Cook University Human Research Ethics Committee (H7200) (Appendix A), following review of the information sheet all 19 participants were provided with and asked to sign a consent form which was completed prior to partaking in the study. No incentives were provided to entice participation in the study. All participants were informed regarding the secure storage of their information, along with the assurance of anonymity when reporting any findings from the interviews and focus groups. Confidentiality for the interview recordings and transcripts was adhered to using pseudonymisation to minimize the risk of personal data being shared inappropriately (Kalra et al., 2006).

Participants for study phase three (exploring which biological and functional factors influence Australian adult HGS) were also recruited using the researcher's professional networks and social media adverts followed by distribution of an information sheet (Appendix I). Employers within local NQ businesses also distributed the information sheet to their staff. After receiving the information sheet, any respondent who willingly agreed to participate in the study was provided with, requested to and signed the consent form in order to proceed with participation in the study. No incentives were provided to entice participation in the study, although the benefits of adding to the body of knowledge around HGS were discussed. All 216 participants were informed regarding the secure storage and confidentiality of their information. Confidentiality was ensured by the removal of participant names when entering data which were replaced with participant identification numbers (Liamputtong, 2022).

The inclusion criteria for study phase four (the how and why of HGS assessment) were Australian Health Practitioner Regulation Agency (AHPRA) registered occupational therapists and physiotherapists, who are members of the AHTA who assess and evaluate HGS as a standard part of their clinical practice in Australia. Due to the purposive sampling method limiting the potential sample population to members of the AHTA only, it was difficult to determine an exact sample size. As such, it was determined that if a large enough sample was not collected, the data would be analysed descriptively to still meet the project aims. Participants were directly recruited through the AHTA which is the national peak body for hand therapy in Australia. Members of the AHTA constitute occupational therapists and physiotherapists Australia wide who are highly experienced in the assessment and evaluation of HGS. An email containing the research study information sheet (Appendix K) and an email link to the online survey was distributed via the AHTA membership mailing list inviting members to complete the questionnaire. In accordance with the ethics approval granted by the James Cook University Human Research Ethics Committee (ethics approval H8854) (Appendix C), following review of the information sheet, any interested participants willingly agreed to participate in the study which was confirmed by selecting 'yes' to participate as the first survey question. No incentives were provided to entice participation in the study. The AHTA membership group comprises approximately 800 members. Forty nine members completed the online questionnaire. Anonymity of the participants was ensured using Qualtrics to host the online questionnaire. Participants were not required to provide their name or any information that could be used to identify them, thus minimising the risk of personal information being shared inappropriately (Kalra et al., 2006).

The foundational research ethics principles of autonomy, beneficence and justice were considered in the conduct of this research (Liamputtong, 2022). Research ethics are the moral principles used to guide the balance between the benefits and risks of a research project (Liamputtong, 2022). As such, researchers are responsible to ensure research participants' well-being is protected and they are treated with respect (Portney & Watkins, 2015). As health research requires voluntary contribution from participants, researchers must support the development of the researcher/participant relationship (Liamputtong, 2022). This research was conducted with consideration to the foundational principles of ethics being autonomy, beneficence and justice (Liamputtong, 2022).

Autonomy was respected by informing all participants within study phase two (experiences of occupational therapists in Queensland, Australia) of their right to withdraw from the study at any time prior to the transcription of the focus groups and interviews. Additionally, verbal consent was acknowledged at the beginning of all interviews. Beneficence refers to the researcher's responsibility to ensure the well-being of research participants (Liamputtong, 2022). Participants were informed that the purpose of the interviews was to explore the experiences of occupational therapists across a variety of practice contexts who assess and evaluate HGS and were encouraged to ask questions throughout. To address the risk of harm, it is crucial that participants in qualitative interviews are informed regarding the research study, the protection of their information, and the minimisation of exploitation (DiCicco-Bloom & Crabtree, 2006). Providing participants with an opportunity to share their experiences is a way of addressing justice as the interview contributes to new understanding of the experience by providing meaning (Townsend et al., 2010). Justice requires the equitable inclusion of participants specific to the study who are likely to benefit from the study results (Liamputtong, 2022). Therefore, the participants of this study who were occupational therapists who regularly work with HGS, are likely interested and value the study findings in relation to their clinical practice.

Autonomy was considered within study phase three (exploring which biological and functional factors influence Australian adult HGS) through the recruitment process by informing all participants of their right to withdraw from the study at any time prior to data analysis. Further, verbal consent was confirmed at the beginning of all data collection interactions. To respect the ethical principle of beneficence, participants were informed of the purpose of the data collection and encouraged to ask questions or seek clarification throughout the HGS testing process. Participants were informed that the findings from this study would contribute to new knowledge regarding the assessment and evaluation of HGS. Further, the potential benefits of an improved understanding of the phenomenon to guide HGS assessment and evaluation for the wider community including both consumers of health services and health professionals was also discussed which addressed the research ethical principle of justice.

The research ethical principle of autonomy was respected in study phase four (the how and why of HGS assessment) with informed consent required prior to engagement in the research questionnaire. Additionally, participants were informed that they were able to withdraw from the research study at any time without explanation or prejudice by simply closing their internet browser. It was further explained that unprocessed data would be removed from analysis. Beneficence was addressed in this research study by providing information to participants regarding the purpose and intention of the research study (Liamputtong, 2022). Participants were provided with the researchers contact details on the information sheet and encouraged to contact the researcher regarding any questions related to the study. Through the sharing of their opinions and experiences via the questionnaire, the ethical principle of justice for the participants was addressed. This process allowed participants to contribute to the body of knowledge related to the research study. Improved understanding related to HGS assessment and evaluation is of likely benefit to the participants (Liamputtong, 2022).

2.10 Collecting data

The focus groups and one-on-one semi-structured interviews contained in study phase two (experiences of occupational therapists in Queensland, Australia) involved in-depth discussions facilitated by the researcher which aimed to engage participants in discussions to elicit their perspectives and experiences working with HGS (Liamputtong, 2022). An initial pilot of the interview guide was conducted with one participant to enable a review of the semi-structured interview guide (Appendix H). From this pilot, the researcher was able to refine the order and phrasing of the questions with the aim of eliciting informative and comprehensive responses. Based on their availability, participants took part in either a focus group or one-on-one interview. Semi-structured interviews and the focus groups were conducted using an interview guide to frame the conversation.

Semi-structured interviews provide a balance of flexibility in guiding the conversation whilst ensuring all participants are asked similar questions (Liamputtong, 2022). Interview probes were also employed to encourage a natural flow to the conversation between the researcher and participants. Sampling continued until data saturation was reached; at which time no new themes were generated from the interview process (Liamputtong, 2020). Questions contained within the semi-structured interview guide (Appendix H) for this study were developed by the researcher based on the literature review and guided by the supervisory team. Furthermore, the interview guide was piloted and refined prior to the main qualitative data collection process to ensure questions were appropriately designed to answer the research question.

Focus groups and interviews were conducted either face to face or via telephone and were audio-recorded. Interview strategies included the use of open-ended questions, active listening and avoiding leading questions. These strategies were utilised to create a comfortable, non-judgmental environment. On completion of the focus group and interviews, participants were offered an opportunity to ask questions of the researcher. In accordance with the ethics approval granted by the James Cook University Human Research Ethics Committee (ethical approval 7200) (Appendix A), following review of the information sheet all 19 participants were provided with and asked to sign a consent form which was completed prior to partaking in the study.

Quantitative data were collected in study phase three (exploring which biological and functional factors influence Australian adult HGS) by a single assessor, the researcher, who as a qualified occupational therapist has more than 20 years' experience assessing and evaluating HGS. A pilot study was conducted to test the research protocols, data collection tools and recruitment strategies (Hassan et al., 2006). The pilot study which included seven participants allowed for refinement of the main data collection process. Findings from the pilot study indicated the questionnaire was easy to complete. Additionally, the pilot study enabled the researcher to practice the measurement of select biological factors including anthropometric measurements of the hand and forearm, height and weight to ensure consistency throughout the main data collection. Participants were invited to attend a suitable testing room which allowed for privacy during data collection, or the researcher arranged to attend local business where a suitable testing room to ensure privacy was available. Following a review of the information sheet, any participants who willingly agreed to participate in the study completed a demographic questionnaire detailing biological factors such as age, gender and functional factors such as hand dominance, work and lifestyle category (Appendix J). Following completion of the demographic questionnaire participants had an opportunity to ask questions and clarify responses with the researcher. The researcher then measured six biological factors (height, weight, hand length and width, forearm length and circumference) using reliable recommended measurement protocols (Nicolay & Walker, 2005). Finally, HGS was measured and recorded in accordance with the ASHT standardised testing protocol using a recently calibrated Jamar dynamometer (MacDermid et al., 2015). During data collection, participants were offered the opportunity to ask questions of the researcher.

An online purpose-designed questionnaire (Appendix L) was developed using Qualtrics to gather quantitative data in study phase four (the how and why of HGS assessment). The questionnaire was developed using the interview guide from study phase two (experiences of occupational therapists in Queensland, Australia). Use of the same questions from study phase two (experiences of occupational therapists in Queensland, Australia) within the online questionnaire was intentional to ensure consistency with the intention of improving the generalisability of the data collected. The questionnaire was anonymous with no personally identifying information collected. Following a review of the participant information sheet, participants provided their informed consent by selecting ‘yes’ to participate as the first survey question. Demographic questions included selecting their professional field (occupational therapy or physiotherapy), professional qualification, level of expertise working with HGS and geographical work location. The questionnaire grouped years of professional experience working with HGS into specific descriptors of year ranges and utilised the Australian Geography Standard descriptors to classify geographical work location (Australian Bureau of Statistics, 2021).

2.11 Analysing and interpreting the data

Upon completion of the focus groups and interviews within study phase two (experiences of occupational therapists in Queensland, Australia) the audio recordings were transcribed verbatim. An initial audio recording was transcribed by the researcher, which enabled self-reflection of the researchers interviewing style. An external transcription service was used to transcribe the remaining recordings following which the researcher reviewed the transcripts for accuracy with corrections made as required. NVivo software was used to facilitate data analysis via the display of text from original transcripts, the ability to retrieve coded text and the development of codes (Liamputtong, 2020). NVivo automated coding was not utilised. Thematic analysis was utilised for the open-ended questions to analyse and report on patterns by providing a detailed account of the data (Vaismoradi & Snelgrove, 2019). Thematic analysis allowed the researcher to identify and interpret common themes across the interviews and focus groups in addition to identifying common themes related to the interviews as a whole (Vaismoradi et al., 2013). Themes offered insight into important patterns within the data (Braun & Clarke, 2013). Creating themes involved grouping ideas and observations into categories based on significance, initially using codes (Liamputtong, 2022). Emerging themes were identified based on the interview transcripts. Regular re-examination of the audio recordings, transcripts and fieldnotes allowed for validation regarding the interpretation of the observations (Liamputtong, 2022). Adoption of this reflective practice was designed to minimise external bias and ensure rigour (Liamputtong et al., 2017).

Upon completion of the data collection process in study phase three (exploring which biological and functional factors influence Australian adult HGS), the participant data sheets were de-identified and assigned participant identification numbers to ensure confidentiality. Data was entered into an Excel spreadsheet and as data entry required transcription from hard copies, random cross checking between the hard copies and the Excel spreadsheet was completed by the researcher to ensure accuracy (Watson, 2015). The data was imported into SPSS 27 (IBM Corporation, New York, NY, United States) for statistical analysis. Prior to data analysis all variables were examined for normality via visual inspection and found to have normal distribution. Testing for skewness, kurtosis, linearity and homoscedasticity was also performed to review the normality of the data. The assumption of normality is critical to draw accurate and reliable conclusions (Elliott & Woodward, 2007). In consultation with a statistician, the statistical model of simultaneous multiple linear regression was then applied to examine the association between the independent variables and the dependent variable of HGS. The value of significance alpha was considered at the level of 0.05 (Watson, 2015). The use of multiple regression analysis enabled the examination of relationships between several predictor variables (biological and functional factors) in a simultaneous manner with HGS.

Following completion of the data collection process in study phase four (the how and why of HGS), 51 questionnaires were attempted, with two found to have insufficient data and not meet the completion requirements. As such, only the 49 complete questionnaires were considered adequate and included in the data analysis. SPSS 27 (IBM Corporation, New York, NY, United States) was used to analyse the quantitative data. Descriptive statistical analysis was utilised to explore demographic data of the participants including profession (occupational therapy or physiotherapy), years of experience working with HGS, educational level and geographical location.

2.12 Rigour

Qualitative research conforms to the idea that reality is socially constructed and as such reality cannot be measured directly (Cleland, 2017). Efforts to ensure high quality data within the qualitative research study phase two (experiences of occupational therapists in Queensland, Australia) focused on credibility, transferability, dependability and confirmability (Bradshaw et al., 2017). Credibility relates to the believability of the findings (Bryman, 2016). Credibility looks to critique what the participants say compared to how the researcher presents those viewpoints (Padgett, 2016). Transferability questions the generalisability of the study findings to a comparable situation (Bryman, 2016). Dependability examines the consistency and congruency of the research findings with consideration to the data collected (Liamputtong, 2022). Confirmability considers the potential influence of the researcher's own values on the interpretation of the research findings to ensure the data produced is true and free from bias (Bryman, 2016; Liamputtong, 2020). The use of these four criteria has been adopted by qualitative researchers as a method to judge the trustworthiness of their research (Bradshaw et al., 2017; Liamputtong, 2022). Table 2 outlines questions and actions to support rigour in this study.

Table 2 Actions to Support Rigour in Study Phase Two

Criteria	Question	Actions to support rigour
Credibility	Do the viewpoints fit the description and is the description credible?	Reflexivity, establish rapport, develop trusting relationship, prolonged engagement, member checking
Dependability	Can the findings be consistently repeated?	Audit trail describing study procedures including semi-structured interview guide
Confirmability	Are the findings solely based off the participants and free from bias?	Reflexivity, description of participant demographics, findings documented using direct quotes from participants
Transferability	Are the findings applicable to other settings?	Semi-structured interview guide, purposive sampling, providing sufficient study details, rich description

Credibility

Due to the researcher's own professional experience working with HGS, reflexivity was crucial to ensure the viewpoints of the participants were accurately represented. Reflexivity facilitated self-reflection by the researcher regarding their own prior-experiences, assumptions and beliefs and how these behaviours may influence the research (Bradshaw et al., 2017). The process of critical self-reflection by the researcher on their background enables credibility to their research (Liamputtong, 2020).

Consideration of the researcher's background was critical for not only the requirement for reflexivity but also aided in establishing rapport with participants. Rapport was built through shared experiences and shared work history which aided the development of a trustworthy relationship with participants. The establishment of rapport facilitated open discussion with participants. During the interviews and focus groups the researcher was mindful of her own assumptions associated with her clinical experiences and perspectives and thus conscious of the way in which the researcher asked questions to ensure the participants were not influenced to answer in a certain way. An example of this is question one of the interview guide which asked participants *"for what reasons do you assess clients' grip strength"* (Appendix H). Rather than assuming occupational therapists from certain practice contexts assessed HGS for certain reasons, the question was asked in an open manner to allow for unexpected responses. Prolonged engagement provided an opportunity for immersion into the research study which assisted in building trust with the participants. Member checking whereby participants reviewed the interview transcripts to ensure accuracy was also utilised to assess for credibility (Liamputtong, 2020).

Dependability

Audit trails were utilised to establish dependability. Audit trails are common practice within qualitative research studies to describe the research process and offer insight into the researchers' thoughts and decision making (Liamputtong, 2022). The audit trail consisted of research documentation, written communication, raw data and analysis. The study design was documented in consultation with the advisory team. Ethics approval was granted for this study.

Documentation collated as part of the audit trail included documents detailing the recruitment and interview process. All audio recordings, consent forms and interview transcripts were retained and stored in a secure, locked storage facility. Data analysis was conducted using

NVivo, as a data management tool. All data was saved on the James Cook University approved platform; OneDrive and two separate hard drives.

Confirmability

Reflexivity was implemented throughout data analysis to minimise researcher bias. Direct quotes from participants were used in the published research paper to limit misinterpretation from both the researcher and readers. To maintain confidentiality, the only demographic information recorded was participants' years of experience working with HGS, description of practice context and location and highest education level obtained. The researcher was conscious of ensuring anonymity of participants when choosing direct quotes for the study findings.

Transferability

Transferability was achieved via the adoption of a semi-structured interview guide throughout this study. The use of a semi-structured interview guide allows for the replication of the research as required. Furthermore, a rich description of the findings, whilst maintaining confidentiality, facilitates the replication of the study (Liamputtong, 2020). The published research paper is absent of any identifiable participant information. Purposive sampling was employed across study phase two (experiences of occupational therapists in Queensland, Australia) and four (the how and why of HGS assessment) to ensure the recruitment of occupational therapists and physiotherapists highly knowledgeable in the assessment and evaluation of HGS (Liamputtong, 2020).

Reliability and validity

Reliability and validity were also considered to ensure the rigour of study phases three (exploring which biological and functional factors influence Australian adult HGS) and four (the how and why of HGS assessment). Validity and reliability need to be considered when reviewing the quality of quantitative research (Wright et al., 2016). Within a quantitative study, validity refers to the extent to which a phenomena is accurately measured whereas reliability relates to the consistency of the measure (Heale & Twycross, 2015). Rigour within quantitative research centers around the examination of the quality of the research (Muijs, 2012). Validity is influenced by the sample selection, sample size, design of the research tools and appropriate statistical analysis of the data (Winter, 2000).

Within study phase three (exploring which biological and functional factors influence Australian adult HGS), the use of a statistical test and power calculation conducted by a statistician at 80% was utilised to determine an appropriate sample size. The questionnaire and measurement process were piloted with seven participants prior to the main data collection to review the suitability of the questionnaire to elicit relevant information and to allow for practice and ensure consistency when measuring the biological anthropometric measurements and during HGS testing. The statistical model of simultaneous multiple linear regression was deemed suitable for this quantitative study due to the ability to enter all independent variables into the model simultaneously with the aim of identifying which factors most strongly predict the dependable variable of HGS.

Sample size was also an important consideration within study phase four (the how and why of HGS assessment) to ensure appropriate representation. To ensure access to the population of interest, recruitment of participants was completed via the AHTA. The sample size was influenced by the purposive sampling method targeting members of the AHTA which limited the potential participants included in the study.

The questions contained within the online questionnaire were adopted from the earlier qualitative study phase two (experiences of occupational therapists in Queensland, Australia). Alignment of the questions to this previous study was used to address the reliability of the data between study phase two and study phase four. The adoption of the interview guide questions for the online questionnaire was intended to ensure consistency. The use of descriptive statistics was necessary to describe and analyse data including the examination of frequencies of responses.

2.13 Writing up and disseminating research findings

The findings from this doctoral research are of interest to health professionals who work with HGS and were therefore documented with consideration of the intended audience (Liamputtong, 2020). A research paper detailing the findings from study phase (systematic literature review – Chapter 3) has been submitted for publication within the *British Journal of Occupational Therapy*. This journal publishes research relevant to occupational therapy practice and as such as was considered a suitable journal to publish these results.

A research paper detailing study phase two has been published within the *British Journal of Occupational Therapy*. As this journal targets an international audience of occupational therapists, a detailed description of the research process specific to occupational therapists within Queensland, Australia was provided to ensure transferability of the findings for the readers to other appropriate settings (Liamputtong, 2020). Direct verbatim quotes were also used to detail rich descriptions of the results in an unbiased way which enhanced data triangulation (Liamputtong, 2020). Research findings were also presented to Australian occupational therapy clinicians at the 2021 Australian Occupational Therapy Conference via an oral presentation (Myles et al., 2021).

The development of a research paper outlining the findings of study phase three has been prepared and submitted to the research journal *Work: A Journal of Prevention Assessment & Rehabilitation*. This international journal covers the entire scope of the occupation of work. Given the findings of this research study identified work as one of the functional factors to most strongly predict HGS, the research paper was considered a suitable topic for publication in *Work: A Journal of Prevention Assessment & Rehabilitation*. Research findings were also presented to Australian occupational therapy clinicians at the 2023 Australian Occupational Therapy Conference via an ePoster (Myles et al., 2023).

A research paper describing the findings of study phase four has been published within the *British Journal of Occupational Therapy*. This international journal published the results of study phase two which examined the experiences of occupational therapists in Queensland, Australia. Given this study built on the results of study phase two, it is hoped this research paper will offer insights into how clinicians Australia wide assess and evaluate HGS.

2.14 Incorporating findings into evidence-based practice

Results of the phase two study were provided to research participants via oral feedback and referral to the published research paper as requested. Dissemination of research findings occurred via the published research paper and conference oral presentation.

Results of the study phase three will be disseminated via the research paper and conference ePoster. HGS is considered an important and quantifiable measure when evaluating hand function across all health disciplines. Therefore, integration of the study phase two and three findings into clinical practice is hoped to provide increased context to not only the assessment but also the evaluation of HGS by all professionals who work with HGS.

Results of the phase four study have been disseminated via the published research paper and via future conference opportunities. Given the importance placed on HGS scores within a variety of health-related fields it is hoped the findings of this study provide insights into how and why clinicians across Australia assess and evaluate HGS. Additionally, the results of all four phases of the research have been utilised in the development of a HGS assessment and evaluation decision-making flowchart (Figure 5) designed for application in practice which is provided in chapter 7.

Chapter 3 Literature Review

3.1 Chapter Overview

Chapter 3 is based on phase one of the doctoral study, a systematic literature review. The aim of the literature review was to identify which biological and functional factors influence adult HGS. A systematic review was performed on studies which examined HGS in relation to biological (age, gender, anthropometric characteristics, ethnicity) and functional factors (occupation, lifestyle, hand dominance) within a working aged population. The findings from the study along with the findings from study phase two (experiences of occupational therapists in Queensland, Australia) were used to determine which biological and functional factors were collected in the quantitative study phase three (exploring which biological and functional factors influence Australian adult HGS).

A paper has been submitted to the *British Journal of Occupational Therapy* which forms the basis of this chapter. As the findings from phase one are contained within a research paper, this paper contains its own introduction, methods, results, discussion and conclusion sections.

3.2 Literature Review: Do functional and biological factors influence handgrip strength: A systematic review

This section is based on a potential publication (Publication 1) in the *British Journal of Occupational Therapy.*

Myles, L., Barnett, F., & Massy-Westropp, N. *Do functional and biological factors influence handgrip strength: A systematic review.* [Manuscript submitted for publication]. James Cook University.

Potential publication one presents findings from the systematic literature review examining functional and biological factors which influence HGS. The findings from this paper conclude that select biological (height, weight, hand length, hand width/palm width, forearm circumference) and functional factors (hand dominance, occupation) should be considered along with the established categories of age and gender when evaluating an individual's HGS. Consideration of these predictive biological and functional factors in relation to HGS will improve confidence in decision making during the assessment and evaluation of hand function. This manuscript is included below.

Do functional and biological factors influence handgrip strength: A systematic review

3.3 Abstract

Introduction

The measurement of handgrip strength (HGS) is widely accepted for assessing and evaluating hand function. Age and gender are known factors that correlate directly with HGS. This review aimed to identify whether other biological and functional factors influence adult HGS and if so, which are the most important.

Method

A systematic review was originally conducted in 2018 and updated in October 2023. The following databases were systematically searched: Medline, CINAHL, Scopus and InformIT for studies which examined HGS in relation to biological and functional factors including anthropometric characteristics, occupation, hand dominance and ethnicity within a working-aged population.

Results

The search retrieved 19 studies which were critiqued using the McMasters Critical Appraisal Tool. This review concludes an individual's height, hand length, hand width/palm width, forearm circumference and hand dominance along with their occupation influence HGS in addition to the established categories of age and gender. It is recommended that future research examines how these factors influence HGS to allow for improved interpretation of HGS in comparison to normative data sets.

3.4 Introduction

Grip strength dynamometry is widely accepted as a standard method for assessing handgrip strength (HGS) and in turn upper extremity strength as HGS is widely used to describe overall hand function (Bhat et al., 2021; Bohannon, 2004; Günther et al., 2008). Hand function may be impacted following surgery, neurological conditions or injury (Mathiowetz et al., 1985). Measurement of HGS can evaluate the effectiveness of a rehabilitation intervention, determine a person's suitability to return to employment or can be used as an objective measure of true effort performance as a component of a functional assessment (Bohannon, 2003; Reuter et al., 2011). Research within the past 20 years has expanded the application of HGS assessment from merely a measure of hand function to consider HGS as an essential health indicator with close association to all-cause mortality (Strand et al., 2016). To date, no literature review has looked to examine a combination of both functional and biological factors on HGS utilising the complete American Society of Hand Therapists (ASHT) testing guidelines. With such significance placed on the interpretation of HGS scores, examining which biological and functional factors influence HGS is hoped to provide context and improved evaluation of HGS scores in relation to an individual's hand function.

It is widely acknowledged that age and gender are the main factors thought to influence HGS (Agnew & Maas, 1982; Dodds et al., 2016; Massy-Westropp et al., 2011; Mathiowetz et al., 1985). However, more recent studies have supported the consideration of not only the demographic factors of age and gender when comparing HGS to normative values but also functional and biological factors (Anjum et al., 2012; Bohannon et al., 2006; Klum et al., 2012; Leong et al., 2016; Mohammadian et al., 2015; Rostamzadeh et al., 2020). For the purpose of this review examples of functional factors include a person's occupation and hand dominance whereas biological factors include height, weight and various anthropometric values. It is believed that the consideration of other predictive factors would provide improved evaluation of an individual's HGS including comparison to normative data sets which are used to interpret HGS scores and to report on HGS findings. A study by De Andrade Fernandes et al. (2014) cautioned that the inclusion of additional biological and functional factors in an equation to predict HGS, particularly the inclusion of weight, height and Body Mass Index (BMI) may result in inaccurate assessment. This is because muscular strength may be affected by various other factors in addition to those mentioned. Although numerous studies have investigated various functional and biological factors in relation to HGS limited studies follow the complete standardised HGS testing protocol as outlined by the American Society of Hand Therapists (ASHT) (MacDermid et al., 2015). Furthermore, limited consensus has been reached regarding which biological and functional factors provide the strongest prediction of HGS.

Following the assessment of HGS, evaluation and interpretation of these scores occurs in various forms including reference to normative data. Clinical evaluation of HGS test scores does not always involve comparison to normative data sets. Often, the contralateral or uninjured upper limb is used for comparison and to gauge expected strength (Günther et al., 2008). However, utilising normative data sets to evaluate an individual's ability in comparison to the relative population is essential when making informed decisions (Innes, 1999). Additionally, in order to identify HGS impairments, normative data sets are required to allow for comparison to a normal population (Wang et al., 2018).

The findings of this review will assist in determining whether functional and biological factors should be considered when interpreting and evaluating a client's HGS scores in comparison to normative data sets. Specifically, the aim of this review was to identify whether various biological and functional factors influence HGS normative data and if so, which are most important.

3.5 Method

The following inclusion and exclusion criteria were developed to ensure the relevancy of the articles reviewed. The date range for inclusion was limited to 2010-2023 due to the volume of publications that matched the key word search as numerous studies have examined HGS and biological factors. The date range was also restricted to ensure the most recent research available was included. When considering the adult population to allow for the consideration of the influence of occupation, studies which exclusively examined older aged populations (beyond the working age), were excluded to narrow the focus towards working aged adults. Studies which examined a broad adult population incorporating older aged adults were included.

Key inclusion criteria included the use of a Jamar dynamometer for HGS testing and the application of the ASHT testing protocol within the study's methodology. Numerous studies have examined HGS and potential influencing factors however limited investigators adhered to all aspects of the testing protocol as outlined by the ASHT. Due to the wide range of HGS protocols identified in the research findings, inclusion of this methodological criteria significantly limited the number of studies included within the review and allowed for a reliable and consistent comparison across the included studies. The ASHT testing protocol requires participants to begin the assessment sitting upright with both the hips and knees in 90° flexion with feet flat on the floor, testing arm at sides, not touching the body, elbow flexed at 90°, forearm in neutral position, wrist slightly extended between 0° and 30° and ulnar deviation between 0° and 15°, and the non-testing arm relaxed at side. Three trials of each hand are taken by alternating between right and left hands and the average of the 3 trials is the recorded score (MacDermid et al., 2015).

Research studies which met the following inclusion criteria were included for review:

- Published within 2010 – 2023
- Published in the English language
- Adult population
- Working age population to allow for the consideration of the influence of occupation
- Healthy participants
- Jamar dynamometer for handgrip strength testing
- ASHT testing protocol (including 3 alternating trials on each hand, with the average score recorded)

- Focus on the influence of the identified biological and functional factors on HGS

Research articles were excluded from the review based on the following criteria:

- Non-English language studies
- Paediatric and older adult studies (beyond working age)
- Studies focusing on the impact of HGS on overall health/ fitness/ physical performance/ other health related assessments
- Secondary research (systematic reviews/ meta analyses)
- Use of non-Jamar dynamometer for HGS testing
- Studies which did not follow the ASHT testing protocol (including 3 alternating trials on each hand, with the average score recorded)

3.5.1 Information searches and sources

The literature search strategy was developed by one author (LM) and an independent research librarian. An updated literature search was conducted in October 2023 for research studies examining HGS and the identified functional and biological factors that affect HGS.

Free-text key words including exploring all terms under each subject heading and MeSH terms were used in combination (using Boolean operators) to systematically search the following databases: Medline, CINAHL, Scopus and InformIT. Specific key-words and phrases used included 'hand strength', 'grip strength', 'handgrip strength', 'normal range*', 'reference values', 'hand dominance', 'ambidexter*', 'anthropometr*', 'population', 'occupation', 'employment' 'vocation'. Examples of specific MeSH terms included '"hand strength AND reference values"'. A hand search using reference lists from the retrieved articles was also undertaken to elicit any additional articles that met the search criteria these articles were then reviewed in regard to the inclusion and exclusion criteria.

3.5.2 Data Collection and Integration Process

Each study retrieved from the four databases and the hand search of reference lists was evaluated by one reviewer for inclusion in the review at the title, abstract and full article stages with a second reviewer performing informal sample checks periodically. Full text articles were reviewed by two researchers (LM and FB) to confirm their suitability for inclusion in the review and ensure consistency and rigor. Data items were extracted using the following headings: Reference, sample size, study design, study purpose, variables measured, methodology and results (Table 1) and results of the collated data were integrated narratively.

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used to guide the selection process as presented in Figure 1. PRISMA flowchart of the literature search process (Page et al., 2021).

3.5.3 Critical Appraisal

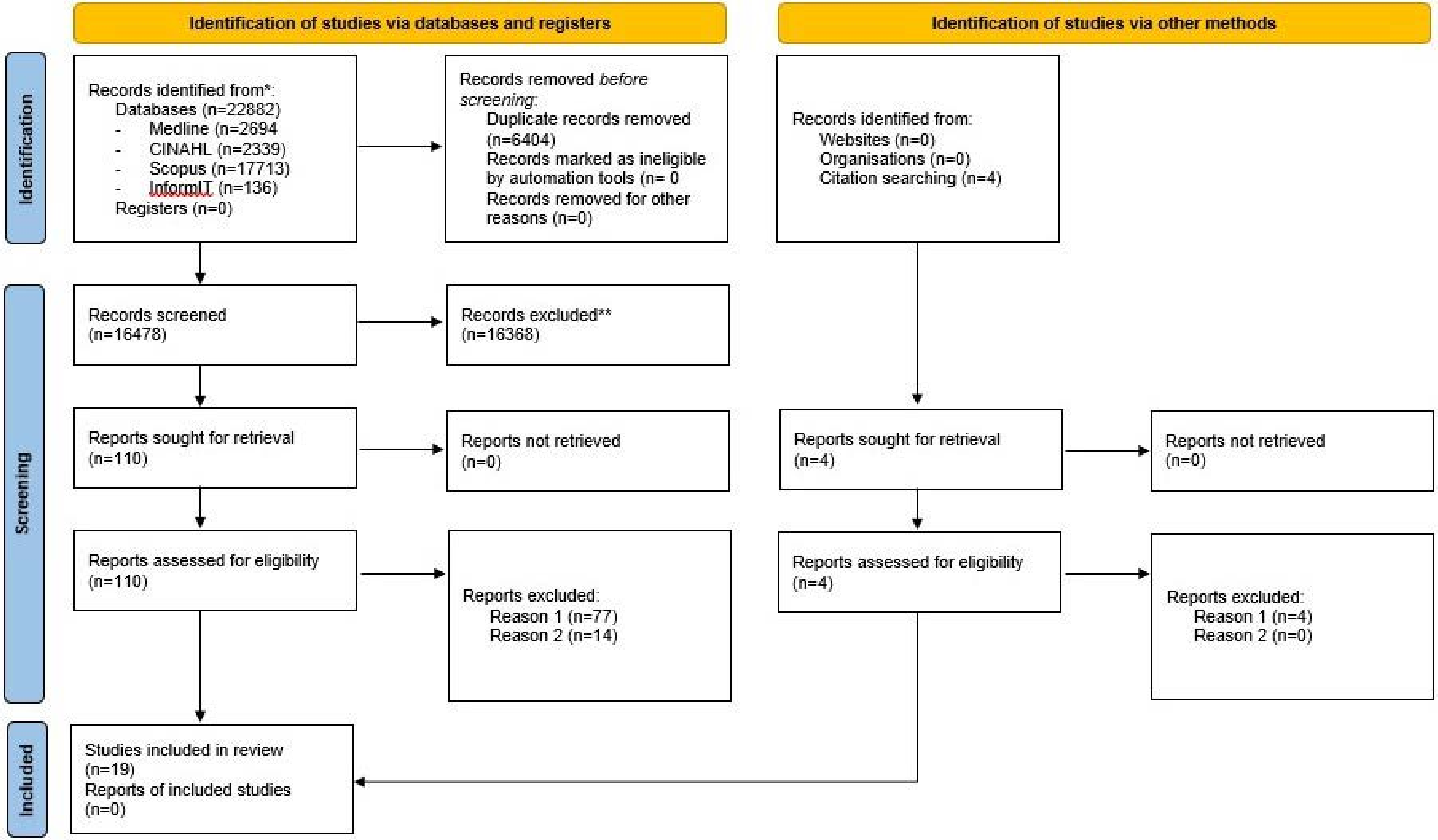
The McMaster Critical Review Form for Quantitative Studies (Letts et al., 2007) was utilised to conduct the critical appraisal and was applied to the full text articles of the included studies to determine research quality. The author (LM) independently read and scored the included articles on each question, by selecting 'yes', 'no' or 'not applicable/stated' if the item was not relevant to the study. The use of a scoring system allowed for comparison of the results across studies and the evaluation of methodological quality (Alexandratos et al., 2012). As the studies did not involve an intervention protocol the scoring system was adapted to remove the 3 points allocated within the intervention criteria thus the scores for quality were scaled to a total out of 11 points available. Review of the critical appraisal score was then confirmed by another author (FB). It is important to note that providing a single summary score or scale to identify the research quality can mask deficits in some criteria by scoring high in others (Crowe & Sheppard, 2011). However, the quality of all articles included in the review was considered and identified to be of low to high quality based on the McMaster Critical Appraisal Tool.

3.6 Results

3.6.1 Study Selection

The study selection process followed the PRISMA guidelines and is summarised in Figure 1. Sixteen thousand four hundred and seventy-eight articles were identified from the literature search. After title searching was conducted, 110 full texts articles were reviewed, and 19 articles met the inclusion criteria. Of these, 91 articles were excluded during the evaluation of the full article based on the previously identified inclusion criteria, specifically for variations from the standardised the testing protocol (reason one) and variances in the dynamometer utilised (reason two). The four articles identified during citation searching were also excluded due to variations from the standardised testing protocol. As a result, nineteen articles were included in the systematic review and recommendations were based on the results of these studies.

Figure 1 PRISMA Flowchart for identification and assessment of eligibility of studies for inclusion in systematic review



3.6.2 Study Characteristics

Data from all nineteen articles was extracted and critiqued using the McMaster Critical Review Form for Quantitative Studies (Letts et al., 2007) and is summarised in Table 1. Details of the Handgrip Strength Protocol and Variables Measured in the Included Studies. Ten studies (Angst et al., 2010; Langer et al., 2022; Massy-Westropp et al., 2011; Mohammadian et al., 2015; Rostamzadeh et al., 2020a; Rostamzadeh et al., 2020b; Rostamzadeh et al., 2019; Saremi & Rostamzadeh, 2019; Saremi et al., 2021; Spruit et al., 2013) were of high quality due to their sample sizes, the variables measured and the methodology employed. Seven studies (Bhat et al., 2021; De Andrade Fernandes et al., 2014; Hatem et al., 2016; Klum et al., 2012; Moy et al., 2015; Shim et al., 2013; Wang et al., 2018) were considered of medium quality and two (Anjum et al., 2012; Eidson et al., 2017) studies were identified as low quality based on the same analysis.

Table 1 Details of the Handgrip Strength Protocols and Variables Measured in the Included Studies

Reference	McMaster score	Sample	Design	Purpose	Variables measure	Methodology	Results
Angst et al., 2010	10	Convenience sample from the community between aged 18-96 years m=496 f=482	Cross-sectional – 1 point of data collection	To quantify the predictive power of easily assessable demographic and/or anatomical factors such as sex, age, occupational demands on the hand, body height, and body weight on grip and pinch strength. The second aim was to predict grip and pinch strength by a regression model of these factors.	• Age • Gender • Dominant hand was also determined by a standardised questionnaire • Height • Weight • Demands on the hand due to occupational activity (classified into six categories: beyond sedentary, sedentary, light, medium, heavy, very heavy) as set out in the directory of occupational titles.	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • Average of 3 measurements	• Height had the highest bivariate predictive power (0.680), followed by sex (0.635), age (0.460), weight (0.460) and occupation (0.377). • Sex was the strongest multivariate term • The overall predictive power of these cofactors combined was very high
Anjum et al., 2012	8	Convenience sample from hospital staff also individuals from social gatherings, religious congregations aged 20-70year 105 Asians (m=56 f= 49) and 103 Europeans (m=52 f=51).	Cross-sectional – 1 point of data collection	To assess normal grip and pinch strengths in Asian participants and to compare the corresponding values with the European population.	• Age • Gender • Hand dominance • Height • Weight	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • Average of 3 measurements	• Europeans showed higher HGS than Asians • Mean HGS was higher on the right side (dominant) than the left in Europeans • Grip strength significantly related to the weight (*P* value <0.01, 95% CI 0.35 to 0.64) and height (*P* value <0.01, 95% CI 0.65 to 0.82) in Europeans; but not to the body mass index (*P* value <0.53, 95% CI 0.13 to 0.25) in both Asian and European groups
Bhat et al., (2021)	9	Convenience sample of 210 (m=105, f=105) university students aged 18-35 years. 30 students from each of the 8 identified ethnic communities (African, Iranian, Chinese, Dutch, Polish, Indian, Malays).	Cross-sectional – 1 point of data collection	To evaluate whether hand dynamometry varies among young adults based on gender and various ethnicities, which correlates with their grip and pinch strength.	• Age • Gender • Hand dominance • Height • Weight • Arm length • Forearm length • Forearm circumference • Wrist circumference • Hand length • Hand circumference • Maximum fiver finger span • Digit length for all 5 digits	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • Average of 3 measurements	• Differences among various ethnic groups in regard to the anthropometric values and GS (p =0.000). • HGS was maximum in Dutch males and Malay females • Out of the 13 anthropometric measurements, 12 parameters correlated with grip strength except for arm circumference which showed no correlation (p - 0.295)

Reference	McMaster score	Sample	Design	Purpose	Variables measure	Methodology	Results
De Andrade Fernandes et al., 2013	9	Randomly selected sample throughout cities in Brazil m=1279 aged14-59 years.	Cross-sectional – 1 point of data collection	To verify the associations of the dominant hand values with weight, height and BMI. To gather data concerning normal HGS in men from the Zonada Mata region of the state of Minas Gerais, Brazil.	• Age • Gender • Dominant handed - defined as the hand favoured for performing daily activities, such as writing, eating and handling heavy objects • Height • Weight	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • Average of 3 measurements • 1 minute rest breaks between trials	• Weak positive association between height and grip strength of the dominant hand (Spearman's r=0.28, p<0.01) • Moderate positive association between the dominant HGS and body weight (Spearman's r=0.316, p<0.01) • Weak positive association between BMI and dominant HGS (Spearman's r=0.19, p<0.01)
Eidson et al., 2017	8	Convenience sample of 159 participants (m=36 f=114) from Birmingham, Alabama, US aged 19-34 years	Cross-sectional – 1 point of data collection	To investigate anthropometric measurements associated with maximal hand grip strength of healthy adults ages 19-34 years	• Age • Gender • Dominant hand – identified as which hand they write with • Height • Weight • Forearm length • Forearm circumference • Hand length • Hand width	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • Average of 3 measurements • 10 second rest breaks between trials	• Gender and hand width significantly associated with maximal HGS (*P* value <0.001 • Hand width or forearm circumference are the best hand anthropometric measures to estimate maximal HGS
Hatem et al., 2016	9	Convenience Random sample of 1029 participants (m=524 f=505) from urban, suburban and rural areas from a wide variety of settings 20-85 years	Cross-sectional – 1 point of data collection	To identify the relationship between Age, Anthropometric measurements as height and weight and Hand Grip Strength in both right and left hands.	• Age • Gender • Hand dominance • Height • Weight	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • Average of 3 measurements • 1 minute rest breaks between trials (alternating hands)	• Age inversely correlated with Grip strength for both right and left hands in both females and males (*P* value <0.0001) • Height and weight showed significant correlation with Grip strength for both right and left hands in both females and males (*P* value <0.0001), except that the weight did not correlate with female right hand grip strength

Reference	McMaster score	Sample	Design	Purpose	Variables measure	Methodology	Results
Klum et al., 2012	9	Convenience sample of 750 participants (m=387 f=363) aged 18-65 years	Cross-sectional – 1 point of data collection	To investigate the predictive power of the parameters age, gender, body height, body weight, BMI, occupational manual strain DASH score and ROM on grip strength A second goal was to develop models that enable the prediction of grip strength using multiple regression models.	• Age • Gender • Dominant hand • Occupational manual strain • Height • Weight • AROM wrist extension/flexion and ulnar/radial deviation • DASH questionnaire	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • Alternating hands between trials • Average of 3 measurements	• Gender was the most important parameter in predicting hand strength (*P* value <0.0001) • highly significant correlation between hand strength with body height, body weight and BMI (*P* value <0.0001) • highly significant negative influence of age (*P* value <0.0001) • The extension and flexion of the wrist correlated positively with grip strength (*P* value <0.0001) • Occupational manual strain had no significant influence on hand strength (*P* value 0.50)
Langer et al., (2022)	10	Convenience sample of 637 (m= 334 f= 293) community based adults aged 18-70+	Cross-sectional – 1 point of data collection	To establish normative data for grip strength for the adult population in Israel. The second objective was to compare the results of this study to international normative data.	• Age • Gender • Dominant hand • Type of work (high or low manual strain)	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • Alternating hands between trials • Average of 3 measurements	• HGS among men exceeded HGS in women • Progressive decline in HGS with increasing age • For both men and women, the dominant hand was stronger than the non-dominant • Results of a Welch's *t*-test showed a medium to large effect for type of work with high manual strain workers having stronger HGS
Massy-Westropp et al., 2011	10	Random sample of 2629 (m=1314 f=1315) aged 20 years and over living in Adelaide Australia	Cross- sectional. Stage one - stratified random sampling) Stage two attend - clinic for assessment	To describe normative data for handgrip strength in a community-based Australian population. To investigate the relationship between BMI and handgrip strength, and to compare with international handgrip strength norms.	• Age • Gender • Dominant hand • Height • Weight • BMI	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • Average of 3 measurements	• Analysis by Pearson r correlation, with a significance level of 0.05 • A very weak positive relationship between higher BMI and right HGS for the youngest and oldest adults • For young adults and those in their fourth, fifth and sixth decade, a higher BMI was inversely related to HGS

Reference	McMaster score	Sample	Design	Purpose	Variables measure	Methodology	Results
Mohammadian et al., 2016	10	Stratified random sampling method from the adult Iranian population aged 20-107 years m=526 f=482	Cross-sectional – 1 point of data collection	To investigate the correlation of anthropometric and demographic factors with hand strength as well as to develop regression models for grip and three types of pinch strengths including Tip, Key and Palmar in Iranian adult population.	• Age • Gender • Ethnicity • Dominant hand • Physical demands levels • Height • Weight • Hand length • Hand width • Mid-arm circumference • Forearm circumference • Hand span	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • Average of 3 measurements • 1 minute rest breaks between trials	• HGS of females significantly lower than those of the males (*P* value <0.0001) • inverse and significant correlation between age and HGS (*P* value <0.0001) • positive and significant correlation between HGS and anthropometric dimensions • Highest correlation of HGS with height, hand span, forearm circumference and hand length dimensions • no significant difference between physical demand levels and HGS for both genders
Moy et al., 2015	9	Multistage sampling of households within 5 randomly selected districts in rural Malaysia m=927 f=1142 aged 30 years and older	Cross-sectional – 1 point of data collection	To determine the predictors of handgrip strength among adults of a rural community in Malaysia	• Gender • Age • Dominant hand • Height • Weight • BMI	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • 3 measurements on each hand • 15 second rest break between trials • Highest of 3 measurements chosen for analysis	• Males had higher HGS compared with females (*P* value <0.001) • HGS declined as age increased for both genders (*P* value <0.05) • Those with medical conditions such as diabetes mellitus, hypertension and high cholesterol had significantly lower HGS (*P* value <0.01) • Positive and significant correlations between HGS and height (*P* value <0.001), weight (*P* value <0.001) and musculoskeletal score (*P* value <0.001) among males only • In the multivariate model for males, age, height, job groups and diabetes significantly predicted HGS • Dominant HGS significantly higher than non-dominant • Compared with the population in the West, participants had significantly lower HGS

Reference	McMaster score	Sample	Design	Purpose	Variables measure	Methodology	Results
Rostamzadeh et al., (2019)	10	Convenience sample of 418 (m=220, f=198) office employees aged from 20-60 years.	Cross-sectional – 1 point of data collection	To establish GS norms of Iranian office workers stratified by gender, age-group and hand dominancy. To review the correlation between GS and different demographic and anthropometric variables. To investigate the predictors of GS among the study population and to develop the appropriate predictive equations.	• Age • Gender • Dominant hand – identified as which hand they write with • Height • Weight • BMI • Hand length • Palm width • Palm length • Forearm length • Wrist circumference • Forearm circumference (all measured as per NASA anthropometric source book)	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • Average of 3 measurements • 1 minute rest breaks between trials	• There was a significant correlation between HGS and all measured variables, except BMI; suggesting that HGS increases as height, weight, hand length, palm width, palm length, forearm length, wrist circumferences and forearm circumferences of an office worker increase • HGS had the highest correlation ($p<0.01$) with palm width followed by palm length and hand length, respectively
Rostamzadeh et al., (2020a)	11	Stratified random sample from a public university in Iran 1740 male workers aged 20-64years. 2 occupational groups: light manual workers and office workers	Cross-sectional – 1 point of data collection	To compare maximum HGS between light manual workers and office employees and investigate if the expected differences are related to anthropometric dimensions of the workers' forearms and hands.	• Age • Gender • Dominant hand – identified as which hand they write with • Height • Weight • BMI • Hand length • Palm length • Handbreadth • Wrist circumference • Forearm length • Forearm circumference	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • Average of 3 measurements • 1 minute rest breaks between trials	• Maximum HGS of light manual workers was significantly higher then office workers for both hands • Dominant HGS was stronger on average than non-dominant for all workers • HGS increased until 35-39 years then gradually decreased for both work groups • Hand breadth and forearm circumference were significantly different between the 2 groups of workers with light manual workers having greater hand breadth and forearm circumference in both upper limbs • Weight, height and BMI highly correlated with HGS • Hand breadth and forearm circumference highest correlation with HGS for both groups of workers

Reference	McMaster score	Sample	Design	Purpose	Variables measure	Methodology	Results
Rostamzadeh et al., (2020b)	10	Quasi random sample from shopping centres and malls, service centres and public areas to ensure a wide variety of occupational, ethnic and socioeconomic backgrounds. 4282 Iranians (m=2167, f=2115). 2 occupational groups: manual workers (MW) and non-manual workers(NMW)	Cross-sectional – 1 point of data collection	To create normative data for GS in Iranian healthy population stratified by age, gender and hand side. To compare GS of Iranian population with consolidated and international norms. To investigate individual predictors of GS among studied demographic & anthropometric parameters To develop prediction equations for GS in Iran.	• Age • Gender • Dominant hand – identified as which hand they write with • Type of work; manual workers (MW) or non-manual workers (NMW) • Height • Weight • BMI • Hand length • Palm width • Palm length • Forearm length • Wrist circumference • Forearm circumference (all measured as per NASA anthropometric source book)	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • Average of 3 measurements • 1 minute rest breaks between trials	• Hand dominance had a significant effect on HGS ($p < 0.001$). Dominant hand stronger than non-dominant hand by about 10% and 11% for males and females, respectively. • MWs were stronger HGS compared to NMWs, on both sides ($p < 0.001$). Among NMWs, students had a weaker grip than non-students. • HGS increases with increasing weight, height, BMI, hand length, palm length, palm width, forearm length, wrist circumference and forearm circumference. • Palm width has the highest correlation with HGS in both genders ($p < 0.01$) for dominant and non-dominant hands
Saremi & Rostamzadeh (2019)	10	Stratified random sampling methods from difference organisations and companies. m=1740 aged from 20 to 64 years. 2 occupational groups: light manual (LMW) tasks (905) and office/clerical workers (835)	Cross-sectional – 1 point of data collection	To investigate whether light manual workers have higher GS compared to office/clerical employees as non-manual workers. To determine anthropometric differences between the two occupational groups. and To determine demographic and anthropometric factors related to GS in each occupational group.	• Age • Gender • Dominant hand – identified as which hand they write with • Work category • Height • Weight • BMI • Hand length • Palm width • Palm length • Forearm length • Wrist circumference • Forearm circumference (all measured as per NASA anthropometric source book)	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • 3 consecutive measurements on each hand • 1 minute rest break between trials	• HGS in LMW significantly higher than office/clerical employees • Palm width and forearm circumference significantly different between the two occupational groups • LMW had greater palm width and forearm circumference than office/clerical employees • All demographic and anthropometric factors significantly correlated with HGS • Palm width most significant correlation with HGS for LMW and office/clerical employees • Forearm circumference correlated to HGS for dominant and non-dominant of both occupational groups

Reference	McMaster score	Sample	Design	Purpose	Variables measure	Methodology	Results
Saremi et al., (2021)	11	Certified dentists who specialized in one of three specialities of maxillofacial surgery, endodontics or paediatric dentistry Purposive sample of 720 dental specialists M=330 f=390	Cross-sectional – 1 point of data collection	To investigate the relationship between dentists' hand functionality and dental speciality, socio-demographic factors and hand-forearm anthropometrics dimensions	• Age • Gender • Dominant hand – identified by classifying the non-dominant hand as the hand which holds the mirror during treatment • Dental speciality • Height • Weight • BMI • Hand length • Palm length • Palm width • Wrist circumference • Forearm circumference • Forearm length • Clinical experience	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • 3 consecutive measurements on each hand • 1 minute rest break between trials	• Average anthropometric measures higher in males than females • Height and weight significantly correlated to HGS • Hand length and forearm strongly correlated with HGS • Palm dimensions (length and width) correlated with HGS • Wrist and forearm circumferences moderately correlated with HGS • Significant effect for gender and age with HGS higher in males than females for all ages • Male and female maxillofacial surgeons had higher mean HGS and forearm circumference than the other specialists • Clinical experience negatively correlated to HGS for all specialties, suggesting HGS decreased with increasing seniority in dental work
Shim et al., 2013	9	Convenience sample of patients visiting health institution m=137 f=199 aged 13-77 years	Cross-sectional – 1 point of data collection	To establish the normal values of grip and pinch strength among the healthy Korean population and to identify any dependent variables affecting grip and pinch strength.	• Age • Gender • Dominant hand • Height • Weight • Hand width • Hand length • Forearm length • Forearm circumference	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • 3 consecutive measurements on each hand • 1 minute rest break between trials	• All mean strength measurements significantly greater in males than in females (*P* value <0.01) • HGS increased into young adulthood and then declined among the geriatric population • Hand dominance had no significant correlation with measured variables, however dominant hand had greater HGS • All metrics but the forearm lengths found to correlate with male HGS (r=0.4-0.5) • No significant correlations found between HGS and all metrics for females

Reference	McMaster score	Sample	Design	Purpose	Variables measure	Methodology	Results
Spruit et al., 2013	10	m=224,852 F=224,830 white ethnic background aged 39 - 73 years as part of the United Kingdom biobank prospective epidemiological study	Cross-sectional – 1 point of data collection	To develop normative values for right and left handgrip strength after stratification for confounders like gender, age, and height. To develop new normative values for handgrip strength, after stratification for sex, age, and height using individuals from the large UK Biobank dataset without chronic conditions.	• Age • Gender • Height	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • 3 consecutive measurements on each hand	• Men were stronger than women (*P* value <0.001) • A weak inverse correlation was found between HGS and age (*P* value <0.01) • A strong positive correlation was found between HGS and height (*P* value <0.01) • Men, younger individual, and taller individuals had higher HGS compared with women, older individuals and shorter individuals
Wang et al., 2018	9	Community dwelling and non-institutionalised United States residents aged 18 – 85 years as part of the normative phase of the NIH Toolbox project m= 449 f= 783	Prospective cohort study	To provide population-based grip strength reference values and equations for United States residents 18-85 years. Normative data will enable comparison of grip strength values in individuals with or without impairments to the reference values and allow clinicians to provide feedback during the rehabilitation process	• Age • Gender • Dominant hand • Height • Weight • BMI • Ethnicity (including language spoken) • Education	• Jamar Dynamometer (2nd handle position) • American Society of Hand Therapists testing procedure • Single maximal trial of 3-4 seconds	• HGS differed significantly by sex (men stronger than women), hand dominance (dominant side stronger) and age (younger adults stronger than older adults) (*P* value <0.001) • Stronger correlation between HGS and height (r=0.61) than the correlation between grip strength and BMI ((*P* value <0.045) • 3 variables identified (weight, height and aged cubed) for inclusion in reference equations • Participants with a high school diploma or higher degree were stronger than participants who did not finish secondary education

Sample sizes ranged from smaller convenience samples of 150 participants (Eidson et al., 2017) to larger cohort studies with of 449000 participants (Spruit et al., 2013). Ten studies had sample populations over 1000 participants (De Andrade Fernandes et al., 2014; Hatem et al., 2016; Massy-Westropp et al., 2011; Mohammadian et al., 2015; Moy et al., 2015; Rostamzadeh et al., 2020a; Rostamzadeh et al., 2020b; Saremi & Rostamzadeh, 2019; Spruit et al., 2013; Wang et al., 2018). The large sample sizes of these studies provides greater confidence when translating the research findings back to the general population (Banerjee & Chaudhury, 2010).

Seventeen studies used a cross-sectional study design with one point of data collection. The only exceptions to this study design were Wang et al. (2018) who employed a prospective cohort study design drawing data from The United States National Institutes of Health (NIH) Toolbox and Massy-Westropp et al. (2011) who used a cross-sectional study design with two points of data collection being phone interviews and face-to-face HGS assessment. Studies examined Asian populations living in the United Kingdom (Anjum et al., 2012), and Western population studies from Switzerland (Angst et al., 2010), Germany (Klum et al., 2012), Israel (Langer et al., 2022), the United Kingdom (Spruit et al., 2013), Australia (Massy-Westropp et al., 2011) and the United States (Eidson et al., 2017; Wang et al., 2018). Studies were also conducted in Brazil (De Andrade Fernandes et al., 2014), Iran (Mohammadian et al., 2015; Rostamzadeh et al., 2020a; Rostamzadeh et al., 2020b; Rostamzadeh et al., 2019; Saremi & Rostamzadeh, ; Saremi et al., 2021), Korea (Shim et al., 2013), Malaysia (Moy et al., 2015) and Egypt (Hatem et al., 2016). The study by Bhat et al. (2021) sought to evaluate HGS and hand anthropometry for young adults based on gender and eight varied ethnicities.

When examining the factors that may influence HGS, six common factors were identified: gender, age, hand dominance, ethnicity, occupation and anthropometric characteristics. All studies examined HGS in relation to age and gender. The inclusion of occupation/occupational strain or physical demand levels was only discussed in seven studies with the majority of studies finding a positive correlation between occupation / physical demand and HGS (Angst et al., 2010; Moy et al., 2015; Rostamzadeh et al., 2020a; Rostamzadeh et al., 2019; Saremi & Rostamzadeh, 2019). Angst et al. (2010) concluded that the occupational demand on the hand may have caused bias in relation to the HGS scores. In contrast. Klum et al. (2012) found no significant correlation between occupational manual strain and HGS.

Five studies (Bhat et al., 2021; Langer et al., 2022; Mohammadian et al., 2015; Moy et al., 2015; Rostamzadeh et al., 2020a) investigated the influence of ethnicity on HGS by comparing the HGS results of specific ethnic groups to other population sets. These studies all concluded that populations from developed countries or norms derived from predominantly Caucasian populations had increased HGS results compared with South Asian and African populations. This phenomenon may be attributed to nutritional differences amongst ethnic groups as malnutrition has been identified as a strong predictor for HGS regardless of disease (Norman et al., 2010). Furthermore, ethnic disparities across African, Asian and Caucasian populations have been identified as nutritional risks (Sadarangani et al., 2019).

The anthropometric characteristics of height, weight and the resultant BMI were explored in relation to HGS in numerous studies with conflicting results. Height rather than BMI was shown to have the strongest positive correlation with HGS (Angst et al., 2010; Hatem et al., 2016; Mohammadian et al., 2015; Moy et al., 2015; Saremi et al., 2021; Spruit et al., 2013; Wang et al., 2018). Various other anthropometric characteristics including hand length, forearm length, hand width/palm width and forearm circumference were also analyzed in comparison with HGS. Of these other anthropometric characteristics examined, hand length and hand width/palm width were found to have the strongest positive correlation with HGS (Mohammadian et al., 2015; Rostamzadeh et al., 2020a; Rostamzadeh et al., 2020b; Rostamzadeh et al., 2019; Saremi & Rostamzadeh, 2019).

3.7 Discussion

The aim of this review was to identify the influence of various biological and functional factors on adult HGS. The major influencing factors identified were age and gender. This finding is consistent with previous research which has concluded that there is a well-established relationship between gender and HGS, and age and HGS (Agnew & Maas, 1982; Dodds et al., 2016; Eidson et al., 2017; Mathiowetz et al., 1985).

Currently, most HGS normative data sets are classified by age and gender only. It is well documented that grip strength declines with increasing age (Agnew & Maas, 1982; Mathiowetz et al., 1985). De Andrade Fernandes et al. (2014) found a curvilinear relationship with HGS peaking during the third decade, followed by a decrease as age progresses. Hatem et al. (2016), Moy et al. (2015), Mohammadian et al. (2015), Saremi et al. (2021) and Shim et al. (2013) determined that a significant inverse correlation exists between age and HGS for both genders of the working population. This decline in HGS may be considered part of the normal aging process that sees a decline in muscle mass and a likely consequent reduction in muscular strength forces during HGS testing.

It is also widely accepted that HGS among men is higher than the HGS of women. Several studies in this review supported this viewpoint. Results from the studies by, Langer et al. (2022) Moy et al. (2015), Shim et al. (2013) and Spruit et al. (2013) concluded that all strength measurements were significantly greater in men than in women. Men are known to have higher percentages of muscle mass compared to women, which may explain why the variation in HGS exists between genders. Klum et al. (2012) concluded that gender was the most important factor when predicting HGS. Recent studies have identified other biological and functional factors which should be considered in addition to age and gender in order to improve the interpretation and evaluation of an individual’s HGS (Anjum et al., 2012; Dodds et al., 2016; Klum et al., 2012; Leong et al., 2016;

Mohammadian et al., 2015; Rostamzadeh et al., 2020; Rostamzadeh et al., 2019; Saremi & Rostamzadeh, 2019; Saremi et al., 2021).

3.7.1 Biological Factors

Biological factors found to be relevant to HGS include anthropometric measures such as height, weight, BMI, various hand and forearm measurements and ethnicity. The anthropometric factors found to have the strongest correlation with HGS were height, hand length and hand width/palm width (Angst et al., 2010; Eidson et al., 2017; Hatem et al., 2016; Klum et al., 2012; Mohammadian et al., 2015; Moy et al., 2015; Rostamzadeh et al., 2020; Rostamzadeh et al., 2019; Saremi & Rostamzadeh, 2019; Saremi et al., 2021; Spruit et al., 2013; Wang et al., 2018). Height alone was determined to have the most significant correlation with HGS in the findings from Mohammadian et al. (2015), Angst et al. (2010), Moy et al. (2015), Spruit et al. (2013) and Wang et al. (2018). The correlation between height and HGS within these studies is important to consider given the quality of these studies. These studies were scored as high and medium quality during the critiquing process due to their sample sizes, variables measured and the methodology utilised. Previous research (Agnihotri et al., 2008) concluded that a person's hand length is a prime criterion to estimate height and this in combination with hand width may provide a participant with a mechanical advantage when squeezing the dynamometer during HGS testing, particularly when using the standardised second handle position. The findings from this review support these previous findings.

Height and weight were identified as having a signification correlation to HGS in the studies undertaken by Angst et al. (2010), Anjum et al. (2012), Hatem et al. (2016) and S. Rostamzadeh et al. (2019). Interestingly, Body Mass Index (BMI), which is the relationship between height and weight was not found to have a relationship with HGS in the studies by Anjum et al. (2012) and S. Rostamzadeh et al. (2019). The current review found that BMI did not correlate to HGS for Asian, Middle Eastern and European populations (Anjum et al., 2012; Rostamzadeh et al., 2019) or those with higher BMI's (Massy-Westropp et al., 2011) where the relationship was reduced or even reversed. In the study by Massy-Westropp et al. (2011) only 27 participants were assessed to have a low BMI which limited the ability to investigate the relationship between HGS and low BMI. When evaluating BMI it is commonly accepted that BMI correlates strongly with weight but is independent of height (Sperrin et al., 2016). Therefore, anthropometric characteristics of height and hand length and hand width/palm width are not dependent on body weight, and this may explain why BMI does not always have a positive correlation to HGS.

Of the hand measurements taken and compared to HGS, hand width/palm width and forearm circumference provided the strongest relationship. The only other anthropometric measurement seen to correlate positively with HGS was hand length. This relationship may link to the strong correlations seen between height and HGS. As previously discussed, increased height generally results in increased limb lengths for an individual. Saremi and Rostamzadeh (2019) hypothesized that individuals with larger hands may have increased HGS due to their greater muscle mass. Similarly findings from Bhat et al. (2021) suggested that men had larger anthropometric measurements (around 10-15% greater) compared to women which may also assist in explaining the strong correlation between HGS and gender.

Body composition such as height, weight, limb length and skeletal muscle mass may vary among population groups of different ethnic backgrounds (De Andrade Fernandes et al., 2014). Anjum et al. (2012) concluded that Asian populations were found to have lower HGS compared to European populations. Bhat et al. (2021) concluded that average HGS varies among differing ethnic groups and this variance may correlate to anthropometric measurements such as height and hand size which are influenced by ethnicity. This supports the need to ensure population specific normative values are being utilised for comparison amongst population groups. Wang et al. (2018) discussed that although there are numerous peer reviewed studies that provide HGS normative values for populations outside of the United States, with most based on small convenience samples. Future research should be aimed at developing population specific norms.

3.7.2 Functional Factors

The relationship between HGS and hand dominance has shown that typically the dominant hand is stronger, however this correlation is weaker for left hand dominant participants (Bohannon, 2003). This was supported by Moy et al. (2015), S. Rostamzadeh et al. (2019) and Shim et al. (2013) who found dominant HGS to be significantly greater than non-dominant HGS regardless of gender. Hand dominance was recorded in a number of studies, however due to low rates of left hand dominant participants normative values were not categorized into dominant and non-dominant groups. When considering hand dominance and various population groups, De Andrade Fernandes et al. (2014) determined the strength difference between hands was found to be consistent, regardless of ethnicity. As there is a documented difference between dominant and non-dominant HGS, using categories identifying right or left hand dominance would aid in improved interpretation of the HGS normative data.

The studies by Angst et al. (2010), Klum et al. (2012) and Mohammadian et al. (2015) found occupation/ varying physical demand levels did not have a high predictive power for HGS. These studies were carried out with vastly different population samples of European and Iranian workers whose occupation and the physical work demands required are likely to vary significantly. The study by Moy et al. (2015) based on a Malaysian population found males who performed heavy manual work had higher HGS compared to those who performed light work, however the type of occupation did not predict HGS for females. Moy et al. (2015) hypothesized that this inconsistency for occupation to predict HGS for both genders may be due to the decreased diversity in occupations for females and the small proportion of females who were currently employed or had ever worked. Body size and composition contributes to an individual's physical capabilities and as such may have an indirect correlation to job performance (Roberts et al., 2016). The occupations performed by females are generally less physically demanding than males who have increased musculature compared to females. Several studies on the Iranian population all found significant correlation between HGS and occupation (Rostamzadeh et al., 2020a; Rostamzadeh et al., 2020b; Rostamzadeh et al., 2019; Saremi & Rostamzadeh, 2019; Saremi et al., 2021). These studies either only focused on one type of occupation such as office based workers (Rostamzadeh at al., 2019) and dentists (Saremi et al., 2021) or divided workers into two categories; manual workers and non-manual workers (Rostamzadeh et al., 2020a; Rostamzadeh et al., 2020b; Saremi & Rostamzadeh, 2019). Having broad occupational categories which were distinct from one another may have aided in demonstrating the correlation between HGS and occupation.

Unskilled manual occupations are often performed by workers from lower socio-economic backgrounds. Leong et al. (2016) discussed variations in muscle strength are linked to differences in socio-economic status and education levels. Possible variations in muscle strength and HGS may be due to dietary differences between the various populations due to the differences in socio-economic status (Leong et al., 2016). Wang et al. (2018) also concluded that participants with higher education levels were not stronger than participants who did not finish secondary education. Large variations of physical demand levels are required to perform the diversity of occupations within different cultures. Cultural differences also influence the types of occupations performed, socio-economic status and education of individuals. Therefore, further investigation into the significance of occupation in relation to HGS is required.

3.8 Conclusion

Various biological and functional factors have been examined in relation to adult's HGS with the aim of developing an improved understanding of how to interpret and compare HGS results with normative data sets. When analysing HGS, it is suggested that clinicians consider more factors than age and gender for improved evaluation and interpretation of a person's HGS. This review has identified height as the most significant factor in correlation to HGS along with the additional anthropometric factors of hand length and hand width/palm width. These anthropometric factors also link to ethnicity as populations from different geographical locations can have varying body sizes. When developing new normative data sets for HGS, anthropometric characteristics such as height, weight, hand length and hand width/palm width, hand dominance and occupation should be considered along with the established categories of age and gender to allow for improved evaluation of an individual's HGS. Further consideration of these predictive biological and functional factors in relation to HGS will allow clinicians to have greater confidence in decision making when guiding rehabilitation and measurement of hand function. It is also critical to ensure comparison is made between the same populations when comparing individuals to HGS normative data sets. Future research should ensure the study design considers the use of a standardised methodology when assessing HGS to ensure valid and reliable results.

3.9 Key Findings

- Height followed by hand width/palm width most strongly correlated to HGS
- It is critical to ensure comparison is made between the same populations when comparing individuals to HGS normative data sets

3.10 What the study has added

This study identified significant variation in testing methodologies across studies examining HGS in conjunction with biological and functional factors. When analysing HGS, it is suggested factors beyond age and gender are considered to improve HGS evaluation.

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Chapter 4 Phase Two – The Experiences of Occupational Therapists in Queensland, Australia

4.1 Chapter Overview

Chapter 4 is based on phase two of the doctoral study, where occupational therapy clinicians within Queensland, Australia were interviewed to explore their experiences working with HGS including how and why they assess HGS and which factors they believe influence HGS. The findings from this phase were also used to determine which biological and functional factors were collected in the quantitative study phase three (exploring which biological and functional factors influence Australian adult HGS). Additionally, the findings from this phase were also used to develop the online survey questions used in study phase four (the how and why of HGS assessment).

One paper was published from this phase, which forms the basis of this chapter. As the findings from phase two are contained within a research paper, this paper contains its own introduction, methods, results, discussion and conclusion sections.

4.2 Experiences of occupational therapy clinicians on the assessment and evaluation of adult handgrip strength

This section is based on a publication (Publication two) in the *British Journal of Occupational Therapy*:

> Myles, L., Massy-Westropp, N., & Barnett, F. (2023) Experiences of occupational therapy clinicians on the assessment and evaluation of adult handgrip strength. *British Journal of Occupational Therapy. 86*(3),188-196. https://doi:10.1177/03080226221135375

Publication two presents findings from the focus groups and semi-structured interviews with occupational therapy clinicians within Queensland examining their experiences when assessing and evaluating HGS. Occupational therapists were found to use clinical reasoning and practice context to guide HGS assessment. The findings from this paper assist in understanding the occupational therapists experience of assessing and evaluating HGS, including which biological and functional factors they believe influence HGS. Occupational therapists from various practice settings use clinical reasoning and practice context to guide HGS assessment and evaluation in place of explicit instructions or standardised protocols. This publication is included below.

Research Article

Royal College of Occupational Therapists

Experiences of occupational therapy clinicians on the assessment and evaluation of adult handgrip strength

British Journal of Occupational Therapy
1–9

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Abstract

Introduction: Handgrip strength (HGS) is commonly measured to assess hand function, however, little is known about how and why occupational therapists assess and interpret HGS. This study aimed to explore the experiences of occupational therapists who work with HGS. Additionally, the study explored what biological and functional factors occupational therapists believe influence adult HGS.

Method: A qualitative study design utilising purposive sampling identified occupational therapy clinicians within Queensland, Australia who assess HGS. Data were collected from 19 participants using a semi-structured interview process. The interviews were transcribed verbatim and analysed using thematic analysis.

Results: Variations of the American Society of Hand Therapists HGS testing procedure were used by the participants based on experience. When evaluating HGS, comparison to normative data was not always completed or seen to be valuable. Biological and functional factors such as height, hand length, occupation and lifestyle factors were considered to influence HGS.

Conclusion: The results of this study provide insight into the various ways occupational therapists assess and evaluate HGS according to experience and practice context. These variations in assessment and evaluation of HGS along with the influence of an individual's biological and functional factors need to be considered when interpreting HGS results.

Keywords

Hand strength, hand function, grip strength, biological factors

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Introduction

Measurement of handgrip strength (HGS) using a dynamometer is a common assessment tool in many occupational therapy practice settings (Reuter et al., 2011). HGS is a simple, quantifiable measure to aid in the assessment and evaluation of hand function (Günther et al., 2008). HGS may be measured as an initial baseline from which to track rehabilitation progression, as a tool to assess work capacity and to compare to normative data (Innes, 1999; Reuter et al., 2011). The comparison of HGS scores to normative data allows hand function and rehabilitation progress to be quantified. Reference values are significant for HGS as they describe the status of the hand and overall upper limb strength in comparison to the population values (Bhat et al., 2021; Bohannon et al., 2006). To allow for an accurate comparison, reliable and valid testing protocols which are consistent with the protocols utilised within the normative data set are required (Reuter et al., 2011; Wang et al., 2018).

The interpretation of HGS normative data can be difficult due to the influence of various biological (age, gender, anthropometric characteristics) and functional (hand dominance, occupation, lifestyle) factors. It has been widely acknowledged that age and gender influence HGS with men found to be stronger than women and younger adults stronger than older adults (Agnew and Maas, 1982; Dodds et al., 2016; Günther et al., 2008; Massy-Westropp et al., 2011; Mathiowetz et al., 1985; Wang et al., 2018). Previous studies have also discussed the potential influence other biological and functional factors have on HGS including hand dominance (Bohannon et al., 2006; Günther et al., 2008; Wang et al., 2018), different types of occupation (Günther et al., 2008; Josty et al., 1997; Lo et al., 2021; Rostamzadeh et al., 2019, 2020b; Saremi and Rostamzadeh, 2019) and anthropometric characteristics (Angst et al.,

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2010; Eidson et al., 2017; Lo et al., 2021; Massy-Westropp et al., 2011; Mohammadian et al., 2015; Rostamzadeh et al., 2019, 2020a; Saremi and Rostamzadeh, 2019; Shim et al., 2013; Wang et al., 2018). The correlation between HGS and these additional functional and biological factors is found to be varied.

HGS assessment has a wide range of applications across the diverse practice contexts where occupational therapists work. Despite having clear guidelines from The American Society of Hand Therapists (ASHT) describing how HGS testing should be performed, little is known about how occupational therapists from a variety of practice settings apply their knowledge and experience to assess and evaluate HGS. A study by Roberts et al. (2011) concluded that the use of various testing protocols can lead to confusion among clinicians regarding best practice. Innes (1999) agreed by suggesting that a common approach to HGS testing is important not only for research purposes but also for application in clinical practice. An improved understanding of how occupational therapists conduct HGS testing and interpret the HGS results will assist in understanding how hand function is monitored and evaluated by the profession. The aim of this research was to explore the experiences of occupational therapy clinicians working across a range of practice contexts in Australia who assess adult HGS. The research questions were: What are the experiences of occupational therapists working with HGS normative data? and What are the factors that influence Australian adult HGS?

Methods

Design

An exploratory qualitative design utilising focus groups and semi-structured interviews was chosen for this study which sought to understand the experiences of the participants when assessing and evaluating HGS.

A thematic analysis was utilised to identify and explore the participant's experiences and opinions relating to the research questions (Braun and Clarke, 2013).The analysis of the participants' experiences led to the identification of common themes and sub-themes. Ethical approval (H7200) was granted by the James Cook University Human Research Ethics Committee.

Participants

Participants were recruited using purposive sampling methods. The inclusion criteria were registered occupational therapists; available for face-to-face interview or telephone interview who assess and evaluate HGS as a standard part of their clinical practice within Queensland, Australia. The exclusion criteria were any health professionals other than occupational therapists and occupational therapists who do not assess HGS. Health professionals other than occupational therapists who also assess HGS were not included in the study as the research aims were focused on the experiences of occupational therapists. The primary researcher sent information via email about the study to occupational therapists who met the inclusion criteria and they were invited to participate in focus groups or a semi-structured interview based on their availability.

Participants from a wide variety of practice settings who assess HGS were approached to participate in the study to ensure a strong representation of occupational therapists in the study. Rather than utilising individual invites, all occupational therapists working at workplaces which met the inclusion criteria were invited to participate in the study, however not all occupational therapists from each workplace approached were available to attend. Nineteen participants consented to take part in the study.

The setting for the focus groups and one-on-one interviews was determined based on the most convenient location for the participants. Two focus groups were held on the James Cook University campus within the Rehabilitation Sciences building with another two focus groups and one interview facilitated at local occupational therapy practices within the Townsville community. One remaining interview was conducted via phone.

Data collection

Participants were provided with an information sheet detailing the research aims and consent form. Participants took part in a single focus group or semi-structured interview depending upon their availability to participate. A semi-structured interview guide was developed based off a prior systematic review exploring the factors which influence Australian adult HGS. The interview guide detailed open-ended questions which were utilised to frame the discussion with clinicians and provided the opportunity for participants to explore their views and opinions around the research aims and questions (Braun and Clarke, 2013). Lead questions and prompts were also utilised to ascertain more detail (Liamputtong, 2020). A pilot of the interview guide was carried out prior to the recruitment of participants with an occupational therapists experienced with HGS to refine the development of the interview structure and questions included (Table 1).

Two individual interviews and four focus groups were conducted for 19 participants over a 6-month period in 2019. The sessions ranged from 60 to 90 minutes and were all conducted by the first author who has over 17 years of experience working with HGS. The interviews and focus groups were facilitated either over the phone ($n=1$) or face-to-face ($n=5$), where suitable. All interviews were audio-recorded, de-identified and then transcribed verbatim. Transcriptions from the interviews were provided to participants for review to ensure accuracy of the data, and no changes were

Table 1. Sample interview guide for participants.

Questions for participants	
1.	For what reasons do you assess clients' grip strength?
2.	What testing procedure do you utilise? *Possible prompts*: • Handle position? • Testing position (sitting/standing/arm position) • How many trials? • Rest breaks? Alternating sides right to left? • Scoring (average or maximal)? • Do you provide prompting/motivation/encouragement?
3.	Why do you choose this position? *Possible prompts*: • Do you always use the same position?
4.	How do you evaluate the client's results? *Possible prompts*: • Do you compare the client's results to normative data sets? • What normative data sets do you utilise to evaluate HGS? • Why do you choose to utilise that specific normative data set? • Do you think these data sets are adequate for your needs?
6.	What are the advantages/disadvantages to using your chosen data sets?
7.	How do the results of the HGS testing guide your practice/intervention? *Possible prompts*: • How do you interpret the results?
8.	What factors do you believe influence HGS? *Possible prompts*: • Do you believe hand dominance influences HGS? • Do you believe the person's job influences their HGS? • Do you believe psychosocial factors influence assessment of HGS?
9.	Is there anything else that we haven't discussed in this session that you would like to add about this topic?

HGS: handgrip strength.

identified. Data saturation was reached when participants were found to provide no new information with the data collected fitting within the emerging themes (Padgett, 2008).

Data analysis

Analysis of the data was conducted by the first author using inductive thematic analysis, as described by (Braun and Clarke, 2013). This form of analysis was adopted to identify and analyse themes identified across the data sample (Braun and Clarke, 2013). Following a familarisation with the data in general, frequently occurring key ideas were identified as initial codes. A more detailed review of the transcripts was then undertaken to search for broad initial themes (Braun and Clarke, 2013). Themes were identified by grouping like ideas and words from the participants' discussions (Liamputtong, 2020). Transcripts were imported into QSR International Nvivo12 software, which is appropriate for qualitative research analysis (Welsh, 2002). Re-examination of these initial themes by a second researcher, FB, who was independent of the focus groups/interviews, and the use of mind-mapping allowed for refinement and identification of key themes.

To ensure the trustworthiness and rigour of this qualitative research, the checklist for thematic analysis developed by Braun and Clarke (2013) was reviewed as a guide. This 15-point checklist examines thematic analysis and follows the process through the stages of transcription, coding and analysis and includes an overall review and the development of the written report. Prolonged engagement of the authors lead to emersion in the data to ensure coding all stages of the thematic analysis were inclusive and comprehensive. Additionally, transcripts of each session and audio records were utilised. Member checking was also completed to allow participants the opportunity to comment on the trustworthiness of the information collated (Braun and Clarke, 2013). To address researcher bias and ensure credibility of the findings, reflections and observations were noted by the first author following each interview to ensure accurate representation of the participants' experiences.

Findings

Nineteen occupational therapists participated in the research project (female $n = 18$, male $n = 1$). All participants worked within Queensland; however, they were trained at various universities in Australia and had worked across Australia and internationally. All participants regularly assessed and evaluated HGS within their role despite working across broad practice contexts. These contexts included specialised hand therapy within both public and private practice ($n = 6$),

Table 2. Participant demographic information.

Variable	Values	Frequency
Gender	Male	1
	Female	18
Highest degree achieved	Bachelor degree	12
	Post graduate certificate/honours degree	5
	Coursework masters	1
	PhD	1
Years of experience with HGS	0–2 years	3
	2–5 years	4
	5–10 years	5
	10–15 years	1
	15–20 years	4
	More than 20 years	2
Practice context	Private practice	16
	Government organisation	3
Location of practice	Townsville	17
	Regional North Queensland	2
Currently assess HGS	Yes	19
	No	0

HGS: handgrip strength.

occupational rehabilitation ($n=6$), inpatient rehabilitation ($n=1$) and private practice across the community rehabilitation setting ($n=6$). Professional experience assessing HGS ranged from less than 5 years ($n=7$), 5–10 years ($n=6$), 10–20 years ($n=4$) to more than 20 years ($n=2$) (Table 2).

Thematic data analysis revealed three overarching themes: the HGS testing protocol; interpretation and evaluation of HGS scores and the influence of biological and functional factors on HGS.

Theme 1: HGS testing protocol

The ASHT HGS testing protocol outlines that the client is: 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. Using the dynamometer on the second handle position, three alternating trials on each hand are recorded with an average of the three trials used to compare with the norms (MacDermid et al., 2015). Participants described various iterations of the ASHT testing protocol. When discussing why they utilised certain testing procedures, participants reported it was how they were instructed at university with P6 stating ‘that’s how I was taught 25 years ago’. P4 and P18 stated they know it is the standardised process, or ‘that’s the way that all the clinicians I’ve ever worked with . . . we’ve always done it’.

Handle position

One variation to the testing protocol was to change the handle position from the second handle position for comfort or dependent upon the hand size of the client. P18 stated ‘I guess the average person we would usually have it on the second rung . . . If they’ve got quite a large hand then possibly out a bit further and likewise if their small then having it on the um, smaller size’. Multiple participants reported if they do change the handle position, they would document this change to the procedure in their clinical notes. Other participants spoke of changing the handle position when using HGS as a test of sincerity within legal contexts.

Trials

Another variation included using the maximum score of the three trials instead of the mean score or only taking one trial of each hand. One participant reported that referrers will request the highest of the three trials. P4 stated ‘if they’ve done a really bad one, I’ll just ignore that and I’ll just take the maximum’.

Duration

The maximal contraction duration also varied with P18 stating ‘I would ask the person just squeeze as hard as they can . . . but squeezing as hard as they can and stopping as opposed to squeezing and continuous squeezing hard’. By contrast, P6 stated ‘sustained is much better’ while P9 agreed, ‘the longer that you ask them to do something gives you way more insights’.

Clinical expertise

Participants reported that they used clinical reasoning to guide their assessment protocol with P1 stating I ‘don’t follow the standard protocol, but it's a fairly anecdotal one. It's how I feel on the day. You might do three standard measures on each side, or sometimes I don't. Sometimes I just do one and it depends on that patient. If, when they go to squeeze, it hurts them – you know, you stop'. Another highly experienced clinician P19 reported 'in my early years, I always did three on each hand . . . and take the average' but now 'I also do the abbreviated version where it's just one on each side, and that's a clinical judgement, whether I do one on each side or three and take the average'.

Theme 2: Interpretation and evaluation of HGS scores

When evaluating HGS, comparison to normative data was not always completed or seen to be valuable while the normative data set used for interpretation of the HGS scores varied. Instead, clinicians reported they would compare affected to unaffected or right to left sides as a more accurate representation of an individual's ability with P8 stating 'I wouldn't even refer to norms. I'd just be comparing them against themselves'.

Practice context

Practice context influenced the use of normative data with P6 stating 'In medico-legal world, we definitely need to use normative data'. This same participant reported they prefer to use normative data to examine where a client sits in comparison to the normal population particularly if they are documenting the HGS results for reporting purposes and the audience is not clinicians, stating 'I like just to have a reference point . . . this is just numbers to the readers . . . I think we need to provide a context for what that means'. This was supported by P9 who noted 'when you do compare it to the norms and document that, I think it's also important to specify further'.

Normative data

Mixed responses were received when discussing the normative data sets utilised with many participants stating they did not know the name of the normative data set used within their workplace. Some participants reported using normative data linked to specific Functional Capacity Evaluation assessments while P6 stated 'The normative data we're using at the moment is Bohannon, which is a meta-analysis'. Reasoning behind why participants chose not to use normative data to evaluate HGS included the categorisation of the data sets with P11 stating 'there's men and women, and then there's the age . . . there's not age characteristics'. P8 stated 'the normative data is really good, but also, there's so many other factors you need to take into consideration'.

Theme 3: The influence of biological and functional factors on HGS

Biological factors

Biological factors such as height and hand size were seen by many participants to have an influence on HGS. P6 identified that normative data 'doesn't take into account the size of the person'. Hand size was identified by five individual participants (P6, P10, P11, P12 and P4) as an influencing factor on HGS with P11 stating 'I guess people who are really tall generally do have bigger hands anyway. So, they'll find it easier'. In regards to weight, P19 noted 'people that are lean seem to be stronger'.

Functional factors

Functional factors including a person's employment, their roles outside of work including hobbies and physical fitness and hand dominance were also identified as potential influencers. P4 stated that 'lifestyle impacts grip strength . . . a lot more than age and the norms group it in age'.

Several participants identified employment or job role as an influencing factor with P6 stating, 'knowing the type of job . . . that changes your expectations about the norms you're comparing back to'. For example, 'you know they are working on a computer, so their grip strength is adequate for that task'. This was supported by P8 who stated 'assessment for her grip strength on paper actually looks very good for a female, but her job which is very physical . . . it wasn't sufficient'.

The discussions around hand dominance and its influence on HGS were varied. Some participants reported they often see clients with stronger HGS in their non-dominant hand and suggested this may correlate to the person's employment if they performed manual work and had to use their hands bilaterally along with the impact of the individual's lifestyle. Another suggestion was that the type of work tasks they perform may influence which hand is stronger. P11 stated 'if you're going to do a task and it has a gross and more intrinsic part to it, you'll use your dominant hand for the intrinsic part, and your non-dominant one . . . holds things and requires strength'.

Discussion

This study explored the experiences of occupational therapists within Queensland, Australia who assess adult HGS. The specific research questions of 'What are the experiences of occupational therapists working with HGS normative data?' and 'What are the factors that influence Australian adult HGS?' were explored with a number of themes identified. Identified themes included the HGS testing protocol utilised, the interpretation and evaluation of HGS scores and the influence of biological and functional factors on HGS.

Theme 1: HGS testing protocol

When assessing and evaluating HGS the testing protocol utilised was a significant point of variance. This inconsistency in testing protocol may impact reliability. Reasons for variance in the testing protocol included the clinician's training and their clinical experience. Clinicians with more years of practice used their professional experience and prior interactions with HGS to inform the adopted testing protocol based on a case-by-case scenario. In contrast, less experienced clinicians were more likely to adopt and adhere to the testing protocol they were trained to use as a routine procedure with no variations.

The variations from the standardised testing protocol included only taking one measurement on each hand, recording the score of a sustained squeeze technique and only recording the maximal contraction of the three trials completed. These variations in testing procedure are likely to influence the overall HGS score of an individual. The variations also influence the evaluation and interpretation of HGS results regardless of whether the clinicians is comparing to normative data.

Theme 2: Interpretation and evaluation of HGS scores

The interpretation and evaluation of the HGS scores elicited mixed responses. Participant's experiences included comparison to normative data sets, comparison to unaffected upper limbs and comparison to previous scores for the same individual to track progress. It has been noted that 'the identification of grip-strength impairments requires normative reference values to which an individual's grip-strength measurements can be compared' (Wang et al., 2018: 685). Whereas Reikeras (1983) suggested that the uninjured hand serves as a control. Regardless of the type of comparison, for the comparison to be accurate, the testing protocol utilised must be consistent each time. Any variations to the testing protocol need to be identified and documented to allow for consistency in the testing procedure. If HGS was not obtained using the same standardised testing protocol as the normative data set identified for comparison, the interpretation of the HGS scores would be impacted. This is supported by (Innes, 1999: 122) who stated 'to compare results with normative data, then the same position used to develop the norms is required'.

Practice context also influenced the interpretation and evaluation of HGS scores by clinicians. Clinicians in practice settings including occupational rehabilitation or community settings require external parties to understand an individual's HGS scores. Consequently, these clinicians tended to rely on the use of normative data to situate scores and allow for comparison to the general population. This was less common in hospital and private hand therapy practice settings where evaluation of HGS was more commonly done through comparison to previous HGS scores and injured versus uninjured limbs. HGS scores within these practice settings are likely to be reviewed by other health professionals who are more familiar with these types of assessments. This may explain the variance in evaluation of HGS scores across practice settings. These insights also built on the concept that the evaluation of HGS is more than a comparison to normative data and requires context and clinical reasoning to interpret and evaluate the results.

Theme 3: The influence of biological and functional factors on HGS

It is widely accepted that the biological factors of age and gender directly influence HGS. While these influencing factors are well established, conjecture remains as to the influence of other biological factors such as height, weight, body shape and size along with functional factors including hand dominance, occupation and lifestyle factors. This linked with one of the study's key aims to examine the participants' beliefs regarding variables previously identified through a systematic review as potential influences on HGS.

When discussing potential influencing factors on HGS a wide range of biological and functional factors were reported. Clinical experience allowed participants to speak regarding assumptions related to biological factors such as a person's build or body type. Hand size, followed by height being the anthropometric characteristics they believed most closely correlated to HGS. The correlation between anthropometric characteristics and HGS has been examined in numerous studies. Height has been found to have the strongest correlation to HGS (Angst et al., 2010; Mohammadian et al., 2015; Moy et al., 2015; Spruit et al., 2013; Wang et al., 2018). Hand length has been identified as a prime criterion to estimate height (Agnihotri et al., 2008). Therefore, the larger their hand size, the taller someone is predicted to be. The standardised HGS testing protocol has the handle position set at number 2 with no variation allowed based on personal preference or hand size. Consequently, hand length may provide a mechanical advantage when squeezing the dynamometer. This was supported by Saremi and Rostamzadeh (2019) who stated individuals with larger hands were more likely to have stronger HGS due to their increased muscle mass. There were mixed findings regarding the correlation between HGS and weight or body mass index (BMI). It is known that BMI correlates strongly with weight but is independent of height (Sperrin et al., 2016). Therefore, height and hand size are both likely independent of BMI and this may explain why BMI is not a consistent predictor of HGS.

Currently, HGS normative data is only categorised using age and gender with no allowances for hand dominance. Currently there is debate as to whether hand dominance has a reliable correlation to HGS. Previous studies have suggested a 10% rule stating the dominant hand is 10% stronger (Petersen et al., 1989); however, this does not seem to apply for left dominant individuals (Bohannon, 2003). A study by De Andrade Fernandes et al. (2014) found not only was right HGS stronger than the left but also dominant HGS was stronger than non-dominant. Rostamzadeh et al. (2020b) also identified hand dominance as having a significant influence on HGS suggesting that as the dominant hand is used more frequently and with increased force which may increase HGS of the dominant hand. The study by Wang et al. (2018) identified HGS values were not statistically different by hand dominance. The findings from the later study aligned with the beliefs of the participants in this study who reported that an individual's dominant hand was not always their stronger hand. Instead, participants suggested that an individual's employment or activities performed within their lifestyle were more likely associated with HGS than hand dominance. An understanding of the impact of hand dominance may improve a clinician's interpretation and evaluation of HGS results in comparison to not only normative data sets but also when comparing affected versus unaffected limbs.

Functional factors such as employment and activities including sports and hobbies all influence HGS. Participants discussed how knowing an individual's employment influenced their expectations regarding HGS. Employees who performed work with high physical demands were anticipated to achieve higher HGS scores. This was confirmed in the studies by Lo at al. (2021) and Rostamzadeh et al. (2020b) who found HGS of manual workers was significantly stronger than that of non-manual workers or healthcare workers. The findings by Moy et al. (2015) identified men who performed heavy manual had higher HGS, but this trend did not apply to women. In contrast, the study by Mohammadian et al. (2015) found no significant difference between physical demand levels and HGS for both genders.

Some studies examined not only the influence of employment but also lifestyle factors and sports in relation to HGS. Günther et al. (2008) identified no significant variation in HGS for working men or women based on their employment and instead hypothesised that lifestyle factors and personal fitness may be more closely related to HGS. Participants from this study identified the influence of physical fitness and leisure pursuits on HGS not just the tasks they perform at work. Hobbies, sports or unpaid work which requires increased physical demands may lead to stronger HGS despite performing sedentary tasks when employed. The physical demands required within various forms of employment also vary from country to country based on cultural differences. Therefore, caution must be taken when examining the correlation between employment and HGS (Rostamzadeh et al., 2020a). An understanding of the impact of an individual's employment and lifestyle factors may improve a clinician's interpretation and evaluation of HGS results.

Implications for practice

Consideration must be given as to the uniformity of the testing protocol utilised when testing, interpreting and evaluating HGS. The use of a consistent testing protocol as guided by clinical reasoning and practice experience is required for all HGS tests regardless of the intention to compare to normative data. This consistency in testing protocol can only be achieved if the AHTA standardised protocol is adopted for any trials which are intended to be compared to normative data. If a modified testing protocol is utilised, it must be documented so it can be replicated for future assessment to ensure consistency. This will allow for a reliable comparison of an individual's score with themselves or their unaffected limb.

Normative data sets are required to provide an informed evaluation of HGS test findings to various professional audiences. The wide scope of occupational therapy practice contexts means having a standard reference point for comparison is valuable. Basic evaluation strategies such as comparing affected to unaffected sides or tracking the progression of trials over time may be applicable in certain practice contexts.

The inclusion of other functional and biological factors including height, hand length, occupation and lifestyle factors when assessing an individual will improve the clinician's ability to interpret and evaluate HGS results and consider the use of these scores to quantify hand function, track progression and assess for work capacity.

Limitations and future research

While this study offers insight into the ways in which occupational therapists assess and evaluate HGS, some limitations were evident. This study focused on clinicians working in Queensland, Australia and despite some clinician's providing services to regional areas of Queensland, all participants were based in Townsville, Queensland. Therefore, the experiences of occupational therapists working in other practice contexts may not have been captured. The conclusions drawn from this study are applicable to the specific context of the study.

Future research with occupational therapists and other health professionals working throughout Australia using a tailored online survey is underway to identify commonalities and variances in assessment and evaluation of HGS and clinician's perceptions on what functional and biological factors influence HGS. This larger study will allow for improved transferability of the findings to the broader profession.

Conclusion

This study provided insight into the various ways occupational therapists assess and evaluate HGS according to clinical experience and their practice context. How these variations are likely to influence the interpretation and evaluation of HGS results was also provided.

These variations in assessment and evaluation of HGS and the influence of biological and functional factors should be considered when interpreting HGS results to best evaluate an individual's hand function.

Key findings

- Occupational therapists use clinical reasoning and practice context to guide HGS testing protocol.
- Assessment and interpretation of HGS is impacted by clinical experience and biological and functional factors.

What the study has added

Occupational therapists from a range of practice settings use clinical reasoning and practice context as opposed to explicit instructions or a consistent protocol to guide HGS testing and interpretation of results.

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Research ethics

Ethical approval (H7200) was granted by the James Cook University Human Research Ethics Committee dated 27/11/2017.

Patient and public involvement in data

During the development, progress, and reporting of the submitted research, Patient and Public Involvement in the research was included in the conduct of the research.

Consent

Participants were provided with an information sheet detailing the research aims and consent form.

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All authors contributed to the study design of this project. LM completed the data collection process and wrote the first draft of the manuscript. The data analysis, interpretation of results and critical evaluation of the manuscript were completed by LM with guidance from the other authors. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

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Supplemental material

Supplemental material for this article is available online.

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Chapter 5 Phase Three – Exploring key factors that influence north Australian adult handgrip strength

5.1 Chapter Overview

Chapter 5 is based on phase three of the doctoral study exploring which factors influence NQ Australian adult HGS. This study collected quantitative data on select biological and functional factors and HGS. The findings from study phase one (systematic literature review) and study phase two (experiences of occupational therapists in Queensland, Australia) informed the selection of the biological and functional factors included within data collection for this study.

One paper was prepared and submitted for publication from this phase, which forms the basis of this chapter. As the findings from phase three are contained within a research paper, this paper contains its own introduction, methods, results, discussion and conclusion sections.

5.2 Exploring key factors that influence north Australian adult handgrip strength

This section is based on potential publication (Publication 3) submitted to *Work: A Journal of Prevention, Assessment & Rehabilitation*:

Myles, L., Barnett, F., & Massy-Westropp, N. *Exploring key factors that influence North Australian adult handgrip strength.* [Manuscript submitted for publication]. James Cook University.

Publication three details findings regarding the predictive capability of select biological and functional factors on HGS within the NQ adult population. The findings from this study concluded anthropometric measurements of forearm circumference and hand length and width provide a highly accurate prediction of HGS. Additionally, an individual's work demands, and lifestyle factors need to be considered when assessing and evaluating HGS. This manuscript is included below.

Exploring key factors that influence north Australian adult handgrip strength

5.3 Abstract

Background

Handgrip strength (HGS) is a reliable, easy to administer assessment of hand strength and thus hand function. Interpretation of HGS is commonly done using normative data tables. Normative data for HGS considers the influence of age and gender without adjustment for other biological or functional factors known to influence HGS.

Objective

To determine the potential relationship of select anthropometric measurements and functional factors to HGS.

Methods

This study included a sample of 119 males and 96 female workers from North Queensland. HGS and six anthropometric measurements (height, weight, hand length and width, forearm length and circumference) were obtained using calibrated instruments and reliable measurement protocols. Age and gender along with three functional factors (hand dominance, work and lifestyle category) were documented by self-report.

Results

Right and left 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). 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.

5.4 Key words

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

5.5 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 (Bhat et al., 2021; Bohannon, 1998; Günther et al., 2008; Massy-Westropp et al., 2011).

HGS is also used as a health indicator related to cardiometabolic diseases, bone health, physical dysfunction, frailty and all-cause mortality (Cruz-Jentoft et al., 2019; Cruz-Jentoft & Sayer, 2019). Subsequently the wide application and the predictive capabilities of HGS mean HGS assessment is relevant to not only occupational therapists but also 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 (Bohannon, 2001; Wang et al., 2018).

Evaluation of HGS scores commonly includes comparison to normative data which outlines an individual's ability in comparison to the general population (Bohannon et al., 2006; Larson & Ye, 2017). 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 (Agnew & Maas, 1982; Angst et al., 2010; Dodds et al., 2016; Mathiowetz et al., 1985).

Recent studies however have looked beyond these accepted influencing factors of age and gender, to explore the influence of other anthropometric measurements and/or functional factors on adult HGS (Angst et al., 2010; Hossain et al., 2012; Klum et al., 2012). 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 (hand dominance, occupation) factors on HGS (Bhat et al., 2021; De Andrade Fernandes et al., 2014; Eidson et al., 2017; Nicolay & Walker, 2005; Rostamzadeh et al., 2020b; Saremi & Rostamzadeh, 2019). 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 (Larson & Ye, 2017). Researchers have described the inclusion of anthropometric measurements and functional factors when assessing HGS as providing increased contextualization for HGS assessment (Mohammadian et al., 2015; Rostamzadeh et al., 2020a; Rostamzadeh et al., 2019; Saremi & Rostamzadeh, 2019; Spruit et al., 2013). When assessing HGS it may also be important to consider the functional factors of 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 (Leino-Arjas et al., 2004). The consideration of anthropometric measurements and biological factors 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 (Myles et al., 2023a). 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 (Myles et al., 2023a).

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 (Innes, 1999). Numerous peer reviewed studies have provided population specific normative data for Great Britain (Dodds et al., 2014), Germany (Günther et al., 2008), Korea (Shim et al., 2013) and Taiwan (Wu et al., 2009).

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 (Massy-Westropp et al., 2011). 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 (Myles et al., 2023a), 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.

5.6 Methods

5.6.1 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 (Queensland Government, 2021). 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 (The State of Queensland, 2019). 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 organisations 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.

5.6.2 Measurement procedures

5.6.2.1 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). Hand dominance was determined by asking participants “Which hand do you write with?” (Oldfield, 1971). 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 (United States Department of Labor Employment and Training Administration, 1991). Definitions of the work and physical activity categories are described in Table 1.

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

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 (Australian Bureau of Statistics, 2022). 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.

5.6.2.2 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 (Fallahi & Jadidian, 2011). 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 (Nicolay & Walker, 2005). 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.

5.6.2.3 Handgrip strength testing

HGS testing was conducted using a calibrated Jamar digital hand dynamometer (Sammons Preston, Bolingbrook, IL, USA). Testing was conducted using the 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 (MacDermid et al., 2015). 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 (Trossman & Li, 1989). As outlined within the ASHT testing protocol, the mean of three trials was recorded for both the right and left hands.

5.6.3 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 biological factors, 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 selected demographic, anthropometric measurements and biological factors and average HGS of both hands. The value of significance alpha was considered at the level of 0.05.

5.7 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 biological measurements were larger for men compared to women. Limited variability in height was observed for men and women.

Table 2 Descriptive Statistics of Participant Characteristics for Men and Women

Variable	Men		Women	
	Mean	Std. Deviation	Mean	Std. Deviation
Age (years)	35.6	12.6	34.6	11.8
Height (m)	1.8	0.1	1.7	0.1
Weight (kg)	93.6	18.2	71.5	12.9
Body Mass Index (kg/m^2)	28.8	5.6	25.3	4.4
Hand Length (cm)	20.0	0.9	18.1	1.1
Hand Width (cm)	9.2	1.0	7.9	0.5
Forearm Length (cm)	28.1	1.3	25.2	1.5
Forearm Circumference (cm)	29.8	2.4	24.9	2.4

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. Managers, professionals and administrative workers were found to be common job titles within the light category. Whereas service/sales workers and trades workers were common occupations within the medium and heavy/very heavy categories respectively. Within work categories, right and left HGS was stronger for workers who performed heavy/very heavy work compared to light or medium work.

Table 3 Mean SD Right and Left HGS (kg) According to Occupation

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

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 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

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=0.0001), 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).

5.8 Discussion

The use of HGS testing is well established as an efficient way to measure an individual's hand strength. The aim of this study was to determine the potential relationship of select anthropometric measurements and functional factors to HGS. 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 (Agnew & Maas, 1982; Günther et al., 2008; Mathiowetz et al., 1985). Similarly, studies have documented a decline in HGS as age increases (Agnew & Maas, 1982; Dodds et al., 2014; Mathiowetz et al., 1985). 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 (Angst et al., 2010; Klum et al., 2012; Moy et al., 2015; Rostamzadeh et al., 2020). Limited studies however, have described the predictive power using a combination of demographic factors, anthropometric measurements and functional factors for specific populations. Consequently, this study aimed to determine the relationship between HGS and relevant demographic factors, anthropometric measurements and functional factors 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 (Myles et al., 2023a). For the current study, the factors identified as the strongest predictors for HGS were gender, work, forearm circumference and hand length and width.

5.8.1 Demographic factors

Consensus exists that men are stronger than women when comparing HGS, with gender identified as the most significant predictor of HGS (Klum et al., 2012). Research has found that men are significantly stronger than women of the same age (Eidson et al., 2017; Moy et al., 2015; Shim et al., 2013; Spruit et al., 2013). The current study agreed with the mean male right HGS score found 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 (Gallagher et al., 1997). 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 (Balogun et al., 1991; Bhat et al., 2021). 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 (Abe et al., 2016; Agnew & Maas, 1982; Dodds et al., 2014; Mathiowetz et al., 1985; Melton et al., 2000). The results of this study found that age and HGS had a strong negative correlation. 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 (Harris, 2017), and this may explain the change in significance between HGS and age following the removal of weight and BMI from the prediction model.

5.8.2 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 (Eidson et al., 2017; MacDermid et al., 2002; Mohammadian et al., 2015; Saremi & Rostamzadeh, 2019). 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 (Abe et al., 2016). 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 (Leong et al., 2016).

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 (Zafar et al., 2017). 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 (Angst et al., 2010; Hatem et al., 2016; S. Rostamzadeh et al., 2019). 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 (Massy-Westropp et al., 2011). 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 (Massy-Westropp et al., 2011). It was concluded that no significant relationship between HGS and BMI existed for this sample. Furthermore, HGS was significantly correlated to height and weight, but not BMI (Anjum et al., 2012; S. Rostamzadeh et al., 2019). 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 (Bandyopadhyay, 2008). Additionally, inclusion of participants with low BMI was found to be limited in the present study along and previous research (Massy-Westropp et al., 2011).

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 in previous studies (Mohammadian et al., 2015; S. Rostamzadeh et al., 2019). Hand width was positively correlated to HGS in studies by Angst et al. (2010), Eidson et al. (2017), Hatem et al. (2016), Rostamzadeh et al. (2019) and Saremi and Rostamzadeh (2019). 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 (Eksioglu, 2004). 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 (Rostamzadeh et al., 2020). 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 (Bernardes et al., 2020). Further investigation is required to determine the relationship between anthropometric measurements and HGS.

5.8.3 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 (Moy et al., 2015; Rostamzadeh et al., 2019; Shim et al., 2013). 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 (Armstrong & Oldham, 1999). 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 (Klum et al., 2012; Lo et al., 2020; Moy et al., 2015; Rostamzadeh et al., 2020a; Saremi & Rostamzadeh, 2019). 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 by Lo et al. (2020), Rostamzadeh et al. (2019) and Saremi and Rostamzadeh (2019). However, the study by Klum et al. (2012) found that occupational demands (sports, music and work) had no significant influence on HGS. 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 (Günther et al., 2008). 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 (Coenen et al., 2018; van Dommelen et al., 2016). Additionally, workers who are engaged in work requiring less physical demands are more often engaged in vigorous leisure activities (Leino-Arjas et al., 2004). Further research into of the type, intensity and frequency of physical activity performed outside of work would provide insight into this phenomenon.

5.8.4 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 (United States Department of Labor Employment and Training Aministration, 1991). 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.

5.8.5 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 North Queensland, 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.

5.9 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.

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7. Conflict of Interest

The authors declare that they have no conflict of interest.

8. Funding statement

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9. Reference list

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Chapter 6 Phase Four – The how and why of Handgrip strength assessment

6.1 Chapter Overview

Chapter 6 is based on phase four of the doctoral study, an online survey of occupational therapists and physiotherapists Australia wide who are members of the AHTA and assess and evaluate HGS routinely. Participants completed an online questionnaire detailing how and why they assess HGS and which factors they believe influence HGS. This study provides descriptions of how and why clinicians throughout Australia assess and evaluate HGS.

One paper was published from this phase, which forms the basis of this chapter. As the findings from phase four are contained within a research paper, this paper contains its own introduction, methods, results, discussion and conclusion sections.

6.2 The how and why of Handgrip strength assessment

This section is based on a publication (Publication four) in the *British Journal of Occupational Therapy*:

Myles, L., Massy-Westropp, N., & Barnett, F. (2023). The how and why of handgrip strength assessment. *British Journal of Occupational Therapy.* Advance online publication. https://doi.10.1177/03080226231208409

Publication four details findings from the Online questionnaire distributed to members of the AHTA, both occupational therapists and physiotherapists to examine their experiences assessing and evaluating HGS. The findings from this study concluded the use of the ASHT standardised testing protocol is not consistent. Clinicians use contextual factors including the reason for assessment, their clinical experience and practice context to inform how they assess and evaluate HGS. This publication is included below.

Research Article

Royal College of Occupational Therapists

British Journal of Occupational Therapy
1–8

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The how and why of handgrip strength assessment

Louise Myles[1], Nicola Massy-Westropp[2], Fiona Barnett[3]

Abstract

Introduction: Occupational therapists and physiotherapists routinely assess Hand grip Strength (HGS) to evaluate hand function. This study explored the experiences of clinicians who regularly assess and evaluate HGS including the testing protocol utilised, evaluation methods and the influence of various biological and functional factors.

Method: This exploratory survey ($n = 49$) was distributed online to members of the Australian Hand Therapy Association. The questionnaire asked recipients to identify HGS testing protocols, evaluation methods, use of normative data, reasons for assessment and the influence of biological and functional factors on HGS. Demographic data was also collected.

Results: Sixty-four percent of respondents were occupational therapists and 59% had over 10 years' experience assessing HGS. The standardised American Society of Hand Therapists (ASHT) testing protocol was consistently adopted by only 67% of respondents . Variations in contraction time, scoring and evaluation methods were identified. Gender, age, employment and lifestyle were considered the functional and biological factors which influence HGS.

Conclusion: This study details how and why occupational therapists and physiotherapists in Australia assess and evaluate HGS. Use of the ASHT testing protocol is not universal. Clinicians rely on the reason for assessment, clinical experience and practice context to determine how they assess and evaluate HGS.

Keywords

Handgrip, assessment, testing protocol

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Introduction

Hand Grip strength (HGS) is a simple and objective measure which provides a quantifiable evaluation of hand and upper limb function (Bhat et al., 2021; Günther et al., 2008; Larson and Ye, 2017). Hand function is required to participate in everyday life to complete self-care, work and leisure activities. Due to its versatile application, HGS testing is used across a wide variety of practice settings by a range of health professionals including occupational therapists and physiotherapists (Reuter et al., 2011).

HGS can be utilised to assess work capacity, to measure outcomes following trauma or surgery and as a baseline measure to track rehabilitation progression (Matheson et al., 2002; Reuter et al., 2011). The testing protocol used to assess HGS can influence the scores obtained and subsequently how a clinician interprets an individual's hand strength and upper limb function (Innes, 1999; Richards et al., 1996). The adoption of a standardised HGS testing protocol developed by the American Society of Hand Therapists (ASHT) in 1981 was thought to allow for improved reliability when monitoring rehabilitation progress in a quantifiable manner (Fess and Moran, 1981).

HGS is also used to compare an individual's ability in relation to normative data from the general population (Bohannon et al., 2006; Larson and Ye, 2017). To allow accurate comparison to normative data, the HGS testing protocol must be consistent with the testing protocol used to develop the normative data (Innes, 1999). A study by Myles et al. (2022) found both HGS assessment and evaluation can vary according to clinical experience and practice context and requires other factors to be considered in combination with the standardised testing protocol.

The influence of biological (age, gender, anthropometric characteristics) and functional (hand dominance, occupation, lifestyle) factors on HGS has been explored across various populations (Bhat et al., 2021; Eidson et al., 2017; Nicolay and Walker, 2005; Rostamzadeh et al., 2019; Saremi and Rostamzadeh, 2019). Age and gender have been

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identified as the strongest factors to influence HGS with men being stronger than women and HGS increasing from early adulthood into the third decade before declining with age (Abe et al., 2016; Agnew and Maas, 1982; Dodds et al., 2014; Günther et al., 2008; Mathiowetz et al., 1985). Conjecture remains regarding the significance of the influence of other biological and functional factors such as work and lifestyle (Günther et al., 2008; Lo et al., 2020; Mohammadian et al., 2015; Rostamzadeh et al., 2020). However, given the significance placed on HGS as an evaluation of overall upper limb function, consideration of the influence of biological and functional factors provides increased context and confidence when interpreting HGS scores. Few studies have examined how and why clinicians assess and evaluate HGS. This study expanded on previous qualitative research to include physiotherapists along with occupational therapists working within Australia (Myles et al., 2022). The aim of this study was to explore how and why occupational therapists and physiotherapists assess and evaluate HGS. A further aim was to determine the factors that influence HGS based on their clinical experience.

Method

Design

An exploratory cross-sectional study design utilising an online questionnaire containing pre-determined quantitative questions along with select open-ended questions was employed for this study which sought to describe how and why Australian hand therapists assess and evaluate HGS. The online questionnaire was created using the interview guide of a previous focus group study (Supplemental Appendix 1; Myles et al., 2022). Ethical approval (number) was granted by (anonymous) in August 2022. This research built on a previous study examining the experiences of occupational therapists within Queensland, Australia to include both occupational therapists and physiotherapists Australia-wide with the hope of allowing for improved transferability of the findings to clinicians who evaluate HGS more broadly (Myles et al., 2022).

Participants

Participants were recruited using purposive sampling methods through the Australian Hand Therapy Association (AHTA). The inclusion criteria were Australian Health Practitioner Regulation Agency (AHPRA) registered occupational therapists and physiotherapists, who are members of the AHTA who assess and evaluate HGS as a standard part of their clinical practice in Australia. The exclusion criteria were any health professionals other than occupational therapists and physiotherapists who are not members of the AHTA and who do not assess HGS. The primary researcher sought prior approval for the research questionnaire from the AHTA which included a formal application to the research committee consisting of a copy of the ethics approval, a participant information sheet and the questionnaire questions including a link to the online questionnaire. An email inviting members of the AHTA to complete the questionnaire, including the questionnaire link was distributed via the AHTA's email distribution list. The questionnaire was available from October 2022 to November 2022. A reminder alert was sent via the AHTA newsletter 2 weeks before the questionnaire closed.

Data collection

An online purpose-designed questionnaire was developed using Qualtrics to gather data to answer the research questions of "How and why do Australian occupational therapists and physiotherapists assess and evaluate HGS?" and "What are the factors that influence Australian HGS" (Qualtrics (https://www.qualtrics.com)). The questionnaire was anonymous, and participants were provided with an information sheet regarding the study before providing informed consent selecting 'yes' to participate as the first survey question. Demographic questions were formulated to describe the participants, their professional field (occupational therapy or physiotherapy), level of expertise working with HGS and geographical work location. The questionnaire grouped years of professional experience working with HGS into specific descriptors of year ranges and utilised the Australian Geography Standard descriptors to classify geographical work location (Australian Bureau of Statistics, 2021). Additionally, descriptions regarding HGS testing protocols and how HGS scores are interpreted and evaluated were collected using multiple choice questions which allowed respondents to select all that apply. The multiple choice questions and responses and the short answer questions were developed using an earlier study which explored the experiences of occupational therapists within Queensland, Australia who assess adult HGS (Myles et al., 2022). These questions were designed to allow participants to elaborate on the reasons they assess HGS and how they evaluate HGS. A ranking question was utilised to obtain the participants' opinions regarding what biological and functional factors they believe influence HGS. The final survey included 13 questions excluding consent: five demographic questions, six multiple choice questions, one short response question and one ranking question.

Data analysis

SPSS 27 (IBM Corporation, New York, NY, USA) was used for statistical analysis of the data. Descriptive statistical analysis was utilised to explore demographic data of the participants including educational background (occupational therapy or physiotherapy), years of experience working with HGS, educational level and geographical location. Only questionnaires which had responded to all multiple choice,

Table 1. Participant demographic information.

Demographic characteristics	*n*
State	
New South Wales	14
Queensland	14
South Australia	2
Victoria	9
Western Australia	9
No response	1
Work location	
Major city	32
Inner regional	17
Outer regional	0
Years of experience	
1–2	3
3–5	6
5–10	11
10–20	17
More than 20	12

short answer and 90% demographic questions were considered adequate and included within the data analysis.

Findings

Forty-nine complete questionnaires were included within this study. An additional two questionnaires were found to not meet the completion requirements as limited data was recorded in these attempts and were subsequently not included in the study. Demographic data detailing professional field, education level, level of experience working with HGS and geographical location are presented in Table 1. Of the 49 respondents, 32 (65%) were from a major city with the remaining respondents practicing in inner regional locations across Queensland, New South Wales, Victoria, South Australia and Western Australia. Respondents identified as being highly experienced working with HGS with 29 respondents (59%) having more than 10 years' experience assessing HGS while 40 respondents (82%) had more than 5 years' experience.

Data collected regarding the HGS testing identified variations in the adoption of the ASHT standardised protocol. The ASHT standardised testing position and instructions involves having the participants seated in an upright posture with both their hips and knees in 90° flexion with feet flat on the floor; testing arm at the 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 the side (MacDermid et al., 2015). Thirty-three respondents indicated that they follow the complete ASHT testing protocol when assessing HGS, of which 71% were occupational therapists and 61% physiotherapists. Of the respondents who identified as a qualified or qualifying Accredited Hand Therapist, 68% utilised the ASHT testing protocol. Forty-six (94%) respondents indicated they complete testing in a seated position using the second handle position. Thirty-seven respondents indicated they alternate trials between hands. Fifty percent of respondents indicated they record the mean of the three trials for each hand with the remaining 50% of respondents recording the maximum HGS score. The HGS score was determined using a short maximal contraction by 50% of clinicians with the remaining respondents utilising a sustained duration contraction.

Seventy-six percent of respondents who have more than 10 years' experience evaluating HGS stated they utilise the ASHT testing protocol with 52% of these same respondents also indicating the use of normative data to interpret HGS scores. By contrast, only 55% of clinicians with less than 10 years' experience stated they utilise the ASHT testing protocol during HGS assessment and 45% of these less experienced clinicians refer to normative data to evaluate HGS.

The most frequent reasons for assessing HGS were ranked in the following order: to evaluate rehabilitation progression (baseline assessment) (98%), to work towards a client's goal (96%), for return to work and following injury/surgery (96%).

When evaluating HGS scores, 49% of respondents indicated that they utilise normative data for comparison, with the normative data set by Mathiowetz et al. (1985) as the most commonly referenced. Other means of evaluating HGS scores identified included comparing affected to unaffected or right to left sides (96%) and recording progression over time (96%). Qualification as an accredited hand therapist did not impact the use of normative data with approximately 50% of accredited (or in the process of becoming accredited) and non-accredited clinicians reporting the use of normative data to evaluate HGS scores.

The most influential biological factors identified in rank order by the respondents were: gender (19 respondents), age (13 respondents), hand dominance (three respondents), forearm circumference (one respondent), height and hand length. The most influential functional factors which influence HGS were ranked as employment (seven respondents) and then lifestyle (three respondents).

Discussion

The current study aimed to build on an earlier qualitative study which explored the experiences of occupational therapists within Queensland, Australia who evaluate adult HGS (Myles et al., 2022). The current study was expanded to explore how and why occupational therapists and physiotherapists who are members of the AHTA working within Australia assess and evaluate HGS. Members of the AHTA were included in the study as HGS testing is an inherent requirement of their job role within their practice context as hand therapists. The specific research questions of "how and why do occupational therapists and physiotherapists who are members of the AHTA working within Australia assess and evaluate HGS" and "what factors influence HGS" based on their clinical experience. These topics were explored using questions around the reasons why HGS is assessed, the HGS testing protocol utilised, how HGS scores are interpreted and evaluated along with the influence of biological and functional factors on HGS.

HGS testing protocol

Commonalities and variances were identified in the HGS testing protocol developed by MacDermid et al. (2015) and used as standardised by the ASHT. Variations to the testing protocol were outlined by the respondents. Seventy-one percent of occupational therapists and 61% of physiotherapists confirmed the use of the complete ASHT testing protocol when assessing HGS. The majority of respondents (94%) had the client complete the test in a seated position and used the second handle position of the dynamometer when performing HGS testing. Research states that the use of a standardised testing protocol results in improved test-re-test reliability (Lagerström and Nordgren, 1996). Additionally, variations from the standardised testing position can impact HGS scores (Innes, 1999; Richards et al., 1996). Roberts et al. (2011) found that considerable variation in equipment and methods used for assessing HGS can in turn impact the scores recorded. Without consistent testing protocols, small changes in body position can result in altered HGS scores (Richards et al., 1996). Myles et al. (2022) suggested educational training, clinical experience and prior experience with HGS inform the HGS testing protocol utilised. The current study found clinicians with more than 10 years' experience more commonly used the ASHT testing protocol for HGS assessment and referred to normative data for evaluation of HGS scores. The standardised ASHT testing protocol in 1981 was developed to provide uniformity and consistent guidelines and language between health professionals (Fess and Moran, 1981). The results of this study suggest clinicians with more experience find the improved test re-test reliability of using the ASHT testing protocol along with the ability to interpret the HGS score in comparison to normative data of great benefit. The assessment and evaluation of HGS is determined by complex factors including clinical training and professional experience and the development of a standardised testing protocol has not resulted in a universal testing procedure. The study by Woods and Lilly (2018) found that certified hand therapists who indicated use of the complete ASHT testing protocol were all occupational therapists, who were highly experienced with over 21 years' experience assessing HGS. It could be suggested that clinicians who have completed undergraduate training at different points in time may have received different instructions as to how to assess and evaluate HGS.

The most common variations to the testing protocol related to the type of contraction performed during the assessment and the score recorded. Fifty percent of respondents indicated that they ask the client to sustain the duration of the contraction instead of performing a short maximal contraction. This variation in testing protocol could significantly influence the scores obtained during the assessment as a sustained versus short maximal contraction may cause increased fatigue when performing three trials on each hand. Previous research found good reliability for momentary strength after 1 second, after 4 seconds and after 5 seconds, but not in the 10-second test (Kamimura and Ikuta, 2001). Therefore it is reasonable to question the suitability and purpose of performing a sustained maximal contraction particularly as sustained maximal contractions also increases blood pressure and heart rate which may be relevant considerations if completing multiple trials in short periods of time (Innes, 1999).

When noting the HGS score, 50% of respondents recorded the mean of three trials for each hand as opposed to the maximum trials for each hand. Previous research has identified the preferred methods to obtain maximum HGS is to use the mean of three trials as this was found to produce the highest reliability (Mathiowetz et al., 1984). Use of the mean score also allows for increased consistency when assessing maximal effort as opposed to a single trial (Trossman and Li, 1989). A study by Haidar et al. (2004) found approximately 25% of participants achieved a maximum HGS score on the second or third trial. Therefore, only conducting one HGS trial may not offer a thorough evaluation of an individual's HGS compared to the mean of three trials.

The reason for assessing HGS may influence the testing protocol used. If the purpose of HGS assessment is to compare with an individual's previous scores or to work towards a client's functional goal, the use of the ASHT standardised testing protocol may be less critical. However, it is crucial for any comparison of scores whether over time to track progression or when comparing affected to unaffected upper limbs that a consistent approach to the testing procedure is used not only for research purposes, but also for clinical practice (Sousa-Santos and Amaral, 2017).

A study by Woods and Lilly (2018) among Certified Hand Therapists found 93.8% of respondents used the standardised testing position for at least 75% of attempts when assessing HGS. This study found 68% of qualified or qualifying Accredited Hand Therapists utilised the ASHT testing protocol. Woods and Lilly (2018) speculated that as the ASHT guideline book is only available to current members, this is likely to have affected access to the guidelines as it is not a requirement for CHTs to be members of the ASHT. It could therefore be suggested that qualified CHT would have increased professional experience compared to uncredentialled CHT assessing HGS and easier access to the standardised testing protocol which may have influenced the high usage of the ASHT guidelines. The study by Woods and Lilly (2018) did not explore the reasons for assessing HGS or the practice setting. To the authors knowledge, there is currently limited research examining years of professional experience, the reason for assessing HGS and the use of standardised testing procedures. Differences in testing protocol may not only impact reliability of the HGS scores, but also the ability to compare the scores to normative values which have been developed using the ASHT testing protocol.

Interpretation and evaluation of HGS scores

The method for evaluating HGS can vary based on the practice setting and the clinical reasoning of the assessor who determines the most appropriate method of evaluation. Comparison to normative data allows for evaluation of an individual's performance in relation to the general population (Larson and Ye, 2017; Myles et al., 2022). Consideration of the reasons why a clinician assesses HGS may offer insight into how HGS is interpreted and evaluated including the use of normative data for comparison. Sixty-nine percent of respondents stated that they assess HGS for reporting purposes while only 33% stated they assess HGS as part of a pre-employment or functional capacity assessment for which reference to normative data is crucial. In contrast, the majority of respondents identified the reason for assessing HGS was to evaluate rehabilitation progression (baseline assessment) and/or work towards a client's goal or for return to work purposes. If the main reason for testing HGS does not require formalised evaluation such as comparison to normative values this evaluation process may be seen to be irrelevant or less valuable than other evaluation processes which are individualised to the client.

Practice context was not specified by the respondents. However, all respondents are members of the AHTA and likely to work in professional roles which are primarily focused on assessment and the treatment of the upper limb. Previous research found that clinicians working in hospital and private hand therapy practice settings were less likely to utilise normative data to evaluate HGS scores and more accustomed to comparing with an individual's previous HGS scores or comparing affected versus unaffected upper limbs (Myles et al., 2022). Only 49% of respondents use normative data to evaluate HGS scores with the most commonly referred normative data set being that of Mathiowetz et al. (1985). Other methods of evaluation included comparison of affected to unaffected or right to left upper limbs (96%), recording progression over time (96%) and client feedback (30%). This speaks to the concept that interpreting and evaluating HGS goes beyond comparison to normative data and can include comparative evaluation, numerical analysis and feedback from clients based on their goals. Professional experience, practice context and clinical reasoning may be used to inform not only the HGS testing protocol but also the interpretation of the scores on a case-by-case scenario (Myles et al., 2022).

The influence of biological and functional factors on HGS

There are several biological (age, gender, height, weight, Body Mass Index, hand and forearm length, forearm circumference) and functional (hand dominance, employment, lifestyle) factors which are known to influence HGS. Respondents were asked to rank in order which factors they believed have the strongest influence on HGS. The top responses in rank order were gender, age, employment, lifestyle, hand dominance, forearm circumference, height and hand length.

It is commonly acknowledged that age and gender are known to influence HGS (Agnew and Maas, 1982; Angst et al., 2010; Mathiowetz et al., 1985). The results of this study found that the clinician's ranking of gender was the most significant influencing factor on HGS which aligns with previous research. Studies by Eidson et al. (2017) and Moy et al. (2015) found men have higher HGS than women of the same age with gender considered to be a significant predictor of HGS. Biological differences between men and women such as an increase in muscle mass for men compared to women is likely to describe this variation between genders (Gallagher et al., 1997). This supports the continuation of segregation of normative data into gender.

Normative data is also categorised according to age. Age was selected by many respondents to have an impact on HGS. The impact of ageing sees a decline in HGS due to the loss of muscle mass (Abe et al., 2016; Agnew and Maas, 1982; Dodds et al., 2014; Mathiowetz et al., 1985). Previous studies have detailed this phenomenon of reducing HGS with increasing age as part of the normal ageing process (Agnew and Maas, 1982; Dodds et al., 2014; Günther et al., 2008; Mathiowetz et al., 1985; Moy et al., 2015).

Forearm circumference, height and hand length were selected as the most influential anthropometric characteristics on HGS. Several studies have documented forearm circumference as a strong influencing factor for HGS (Eidson et al., 2017; MacDermid et al., 2002; Mohammadian et al., 2015; Saremi and Rostamzadeh, 2019). This relationship is thought to be due to the thickness of anterior forearm muscles at this location which correlates to an individual's muscle mass (Abe et al., 2016).

Following forearm circumference, both hand length and height were ranked higher than other anthropometric factors influencing HGS by respondents. Hand length is considered a prime criterion to estimate height (Agnihotri et al., 2008). Respondents may have been drawing on their clinical reasoning with the consideration that taller individuals have larger hands which may be seen to provide a mechanical advantage when gripping the dynamometer during HGS testing. A study by Saremi and Rostamzadeh (2019) found individuals with larger hands had stronger HGS and hypothesised that this was due to increased muscle mass.

The functional factors of hand dominance, employment and lifestyle were seen to influence HGS. Normative data for HGS is categorised into right and left hands; however, hand dominance is not considered. Previous studies have found that dominant hand strength is greater than non-dominant hand strength for men and women, particularly for right hand dominant individuals (Moy et al., 2015; Rostamzadeh et al., 2019). Lifestyle factors such as the design of tools and the set-up of the environment are generally made for right-handed individuals. This may explain the lack of difference between hand strengths in left hand dominant individuals as they may have adapted to these factors and utilise their right hand in place of their left hand (Armstrong and Oldham, 1999).

Recent studies have begun to explore the influence of employment and lifestyle factors on HGS. A study by Myles et al. (2022) found that knowing the physical demands of an individual's employment influenced the expectations of their HGS scores. Manual workers have been found to have increased HGS compared to non-manual workers (Lo et al., 2020; Rostamzadeh et al., 2020). However, some studies found no difference in HGS related to employment (Günther et al., 2008; Mohammadian et al., 2015). Employment forms a significant part of an individual's daily life and thus, the impact of hand function and in turn evaluation of HGS may be important in determining suitability and sustainability to perform work demands.

Choice of lifestyle activities outside of employment was seen to influence HGS. This was supported by Myles et al. (2022) who found HGS was influenced by hobbies, sport or unpaid work which requires increased physical demands. As hand function is required to perform most daily activities whether employment-related or during leisure time it is important to consider the influence on HGS of how an individual spends their time and the demands of the activities they are engaged with.

Implications for practice

This study has provided descriptions of how and why clinicians across Australia assess and evaluate HGS.

Limitations and future research

While this study uncovered some interesting findings, it is subject to limitations. One limitation of the present study is that practice setting was not examined within the online questionnaire. The questionnaire was distributed through the AHTA who has a large membership group; however, clinicians who are members of the AHTA are generally working in practice settings specifically treating the hand and arm. Therefore, occupational therapists and physiotherapists working in alternative practice settings such as occupational rehabilitation are unlikely to be members of the AHTA and subsequently not included in the study. Therefore, it is difficult to generalise the reasons why HGS is assessed to all practice settings where HGS is measured.

Conclusion

Current research examining how and why clinicians assess and evaluate HGS is limited.

Clinicians within Australia do not consistently adopt the complete ASHT testing protocol when assessing HGS. The majority consistently perform the assessment in a seated position, using the second handle position of the dynamometer. The most significant aspects of variation are the length of the muscular contraction, either short or sustained and recording the score as either the mean of three trials or the maximum trial for each hand.

Evaluation of HGS also varies depending on the reason for assessment. Clinicians who are reviewing and tracking progression following trauma or injury may simply record the numerical scores over time to track progress or compare the affected upper limb to the unaffected. Evaluation using normative data to compare an individual to the general population was not routinely conducted as a form of evaluation. The reason for HGS testing was found to influence how clinicians assess and evaluate HGS.

Biological and functional factors were considered to impact HGS results. Future research should investigate the reasoning behind the adherence to the ASHT standardised testing protocols and evaluation methods by general clinicians working in a wide range of practice settings.

Key findings

- There is considerable variation in testing protocol for HGS
- The reason for testing may influence how HGS is assessed and evaluated
- Consistent testing protocols within patients is needed for evaluation

What the study has added

Clinicians use a variety of testing procedures and evaluation methods when assessing HGS based on the reason for testing and their clinical experience. Consistent assessment and evaluation protocols are crucial to ensure reliability within patients when testing HGS.

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Research ethics

Ethical approval (H8854) was granted by the James Cook University Human Research Ethics Committee dated 25/08/2022.

Consent

Participants were provided with an information sheet regarding the study before providing informed consent selecting ‘yes’ to participate as the first survey question.

Patient and public involvement in data

During the development, progress and reporting of the submitted research, Patient and Public Involvement in the research was: Included in the conduct of the research.

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All authors contributed to the study design of this project. LM completed the data collection process and wrote the first draft of the manuscript. The data analysis, interpretation of results and critical evaluation of the manuscript was completed by LM with guidance from the other authors. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

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Supplemental material

Supplemental material for this article is available online.

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Chapter 7 Discussion, Recommendations and Conclusion

7.1 Chapter Overview

This research provides unique insight into how and why HGS is assessed and evaluated including the influence of select biological and functional factors and offers recommendations to facilitate an improved understanding of HGS scores in clinical practice. This research consisted of multiple study phases. Study phase one explored the literature to identify the influence of select biological and functional factors on HGS with the aim of using this study's findings to inform both study phase two (experiences of occupational therapists in Queensland, Australia) and study phase three (exploring which biological and functional factors influence Australian adult HGS). Study phase four (the how and why of HGS assessment) aimed to expand the findings from study phase two to include clinicians who assess HGS Australia wide.

Chapter 7 provides an interpretation of the findings from all four studies and details the implications and recommendations for occupational therapists and health professionals who work with HGS. Additionally, this chapter discusses relevant implications for future research and the education of health students who assess and evaluate HGS. The study limitations and concluding comments are also presented.

7.2 Discussion

7.2.1 Significance

Hands are required to complete most functional tasks that form a part of everyday life including the specific hand skill of gripping (Dollar, 2014). HGS is measured as a routine assessment to evaluate and quantify hand function of individuals across a range of health professions including occupational therapy (Innes, 1999; Mitsionis et al., 2009; Reuter et al., 2011). As mentioned in Chapter one, assessment of hand function throughout history has evolved from earlier isometric hand tools to measure hand strength to the modern hand-held isometric dynamometer.

Within the early years of the occupational therapy profession assessments for hand function centered around component-based performance skills and were guided and informed by a biomedical model of health (Burley et al., 2018). These assessments aimed to assess at the level of body function and structures and examine elements such as hand strength, range of motion and sensation (Mathiowetz, 1993). The International Classification of Functioning, Disability and Health (ICF) defines body functions as '*the physiological functions of the body systems'* and body structures as '*anatomical parts of the body such as organs, limbs and their components'* (WHO, 2001). Chapter One described a paradigm shift at the end of the 20th century that saw the development of practice-based theories of occupation and the creation of models of occupational theories (Townsend & Polatajko, 2013). This shift facilitated a change in the focus of assessment away from the evaluation of physical component-based variables only to include considerations regarding the individual's ability to engage in their everyday occupations (de Klerk et al., 2015). Despite this shift, assessment of HGS continues to focus on an impairment based approach examining physical components related to body structures and functions (Fitzpatrick & Presnell, 2004).

This research looked to examine whether contextual factors other than physical performance components can offer insights into an individual's occupational performance and functional abilities when evaluating hand function by examining the influence of biological and functional factors on adult HGS. Furthermore, this research aimed to identify the experiences of occupational therapists and physiotherapists who assess and evaluate HGS including how and why Australian adult HGS is assessed and evaluated across Australia.

This research concluded that select biological (height, weight, hand length, hand width/palm width, forearm circumference) and functional factors (hand dominance, occupation) strongly predict HGS and should be considered in conjunction with age and gender to provide increased context and confidence in decision making when assessing and evaluating HGS (Myles et al., 2023a; Myles et al., 2023b). This research also concluded that variation in the testing protocol and evaluation methods for HGS is common (Myles et al., 2023a; Myles et al., 2023b). Occupational therapists use their clinical reasoning and professional experience to guide their decision-making process (Myles et al., 2023a). This research concludes that occupational therapists are uniquely positioned to synthesize knowledge of the biomechanical elements of hand function with an understanding of the dynamic relationship that is occupational performance (Robinson et al., 2016).

7.2.2 HGS testing

The development of the ASHT clinical assessment guidelines for the assessment of HGS in 1981 was aimed to provide consistency in the testing protocol and subsequently improve reliability when assessing HGS (Fess & Moran, 1981). A standardised testing position is essential to facilitate accurate and reliable comparison for the same individual or when evaluating between individuals including reference to normative data (Lagerström & Nordgren, 1996). Additionally, any form of variation from the standardised testing protocol can impact HGS scores (Innes, 1999; Richards et al., 1996). Despite the development of these clinical assessment guidelines, prior to this research little was known about how and why occupational therapists and other health professionals assess HGS. This research found the ASHT testing protocol was adhered to inconsistently by both occupational therapists and physiotherapists (Myles et al., 2023a; Myles et al., 2023b). Common variations to the testing protocol included the handle position of the dynamometer, the number of trials conducted on each hand, the duration of the muscular contraction and the score that was documented (Myles et al., 2023a; Myles et al., 2023b). Study phase two found that occupational therapists with increased years of experience working with HGS used their clinical reasoning and professional experience to inform the testing protocol adopted whereas less experienced occupational therapists were inclined to adhere to the testing protocol they were trained to perform without variation (Myles et al., 2023a). Although study phase two only reported on the experiences of occupational therapists practicing within Queensland, Australia, the online survey within study phase four examined HGS testing protocols for occupational therapists and physiotherapists Australia wide. The findings of study phase four identified that 71% of occupational therapists and 61% of physiotherapists adopted the ASHT testing protocol in full when assessing HGS (Myles et al., 2023b). Furthermore, study phase four concluded the ASHT testing protocol was more commonly adopted by clinicians with more than 10 years of experience (Myles et al., 2023b). This finding is supported by Woods and Lilly (2018) who found the complete ASHT testing protocol for HGS was more commonly adopted by certified hand therapists who were highly experienced with over 20 years' experience working with hands. Therefore, it is suggested that more experienced clinicians value the test re-test reliability provided by using the ASHT testing protocol (Myles et al., 2023b).

7.2.2.1 Handle position

The ASHT standardised testing protocol states that the dynamometer handle should be set at position two. Occupational therapists within study phase two reported making adjustments to the dynamometer handle position for comfort or to fit the hand size of the individual (Myles et al., 2023a). This component of the ASHT clinical assessment guideline was consistently adhered to by the majority of participants in study phase four, with 94% of participants stating they use the second handle position of the dynamometer when assessing HGS (Myles et al., 2023b). This finding is significant as individuals with greater hand lengths and hand widths may have a mechanical advantage when squeezing the dynamometer using the standardised second handle position. (Agnihotri et al., 2008).

7.2.2.2 Number of trials

This research identified differences in the number of trials performed to assess HGS. Occupational therapists in study phase two discussed only measuring one trial of the right and left hands or using the maximum score in place of the mean score of three trials (Myles et al., 2023a). This was confirmed by the results of study phase four which identified 50% of participants record the maximum trial for each hand in place of the mean of three trials (Myles et al., 2023b). This finding is significant as three trials are recommended within the ASHT testing protocol to address reliability within the testing process (Mathiowetz et al., 1984). If an individual was to perform well or poorly during a single trial this would be unknown as no additional attempts are provided to examine consistency of effort thus making the results invalid. Furthermore, previous research identified an individual's maximum HGS score was achieved on the second or third trial (Haidar et al., 2004). It must be considered whether this abbreviated assessment provides a thorough and reliable evaluation of HGS in comparison to recording the mean of three trials.

7.2.2.3 Type of muscular contraction

The assessment of HGS using a dynamometer is aimed at measuring isometric hand force. Study phase two found inconsistencies regarding the duration of muscular contraction when assessing HGS with some clinicians requesting the individual squeeze hard and then stop whilst another clinician reported a sustained muscular contraction provides increased insight into function (Myles et al., 2023a). This difference in muscular contraction was also found within study phase four with 50% of participants directing the individual to perform a sustained muscular contraction instead of a short maximal contraction (Myles et al., 2023b). The performance of three sustained muscular contractions in place of a short maximal contraction is likely to affect HGS scores overall due to the effect of fatigue. Previous research identified good reliability when sustaining the muscular contraction after 1 second, 4 seconds and 5 seconds but not during the 10-second test (Kamimura & Ikuta, 2001). Kamimura and Ikuta (2001) concluded that performing of a sustained muscular contraction when assessing HGS is questionable (Myles et al., 2023b). Given the significant variation across multiple components of the HGS testing protocol, the education and training provided on HGS assessment to occupational therapists and other health professionals who assess HGS must be considered.

7.2.3 Handgrip strength evaluation

7.2.3.1 Normative data

One of the main uses of HGS scores is to evaluate an individual's strength in comparison to the general population via normative data (Mathiowetz & Bass-Haugen, 2008). This research found that comparison to normative data is essential for occupational therapists working in the practice settings of occupational rehabilitation and community settings where HGS score are communicated to external parties (Myles et al., 2023a). Comparison to normative data within these occupational therapy practice settings provides context and assists in situating an individuals' HGS scores in relation to the general population (Myles et al., 2023a). Comparison to normative data within these practices settings also aids in decision making regarding the individual's ability to perform specific work demands, determining suitability for various forms of employment and assists in justifying funding requests. However, in the current research clinicians working in rehabilitation settings including hospitals and performing hand therapy were found to be less likely to refer to normative data when evaluating HGS scores and instead compare an individual to their previous HGS scores or compare affected to unaffected limbs for evaluation (Myles et al., 2023a). These informal methods of evaluating HGS scores are appropriate within these highly clinical practice settings where rehabilitation of hand function is the primary focus. Recording HGS scores to track progression over time or comparing affected to unaffected limbs still offers a means to evaluate changes to an individuals' HGS scores. These scores can be communicated to colleagues working within the same clinical setting during treatment and rehabilitation processes. Occupational therapists and physiotherapists working within these settings typically utilise HGS as part of their clinical assessment (Mitsionis et al., 2009). Subsequently, they are familiar with HGS scores and the relevance to overall hand function regardless of the comparison to normative data.

The most frequently referred to normative data worldwide for HGS was developed by Mathiowetz et al. (1985) using a convenience sample of an American population. Findings from this research means that the suitability of comparing the general population worldwide to these norms must be questioned. It is known that body composition and anthropometrics including height and limb length vary among different population groups (De Andrade Fernandes et al., 2014). This variance in anthropometric measures includes height and hand size (length and width) which have been identified as significantly correlating to HGS (Klum et al., 2012; Wang et al., 2018). To accurately and reliably evaluate an individual's HGS scores to normative data, the normative data used for comparison must be considered to ensure it closely aligns with the population being assessed (Innes, 1999).

7.2.3.2 Factors that influence HGS

Normative data for HGS is generally categorised by gender and age only. Therefore, evaluation of HGS scores in comparison to normative data provides limited consideration of other factors which have been found to influence HGS. Recent research has explored beyond the accepted factors of age and gender to consider other potential influencing factors with the aim of providing increased contextualisation when assessing and evaluating HGS. This research aimed to identify which biological and functional factors most strongly predict HGS.

Biological factors

Different populations contain different ethnic profiles and consequently variances in biological factors such as anthropometrics are observed. Variance in HGS scores have been found among differing ethnic groups with research suggesting these differences are associated with variances in anthropometric measures (Bhat et al., 2021; De Andrade Fernandes et al., 2014; Leong et al., 2016). Therefore, the development of population specific normative data is crucial to facilitate accurate comparison.

Anthropometric characteristics found to correlate with HGS in recent studies include height, hand length, hand width and forearm circumference (Klum et al., 2012; Mohammadian et al., 2015; Moy et al., 2015; S. Rostamzadeh et al., 2019; Saremi & Rostamzadeh, 2019). Height and hand length are hypothesized to have a correlational relationship described by explaining that as height increases hand length also increases (Saremi & Rostamzadeh, 2019). The relationship is further explained as hand length is used as a criterion to estimate height (Agnihotri et al., 2008). Study three examined HGS in relation to anthropometric characteristics concluding that hand length and width along with forearm circumference most strongly predict Australian adult HGS. The relationship between HGS and forearm circumference likely represents the individuals' muscle mass within the forearms as the anterior forearm muscles are located in this region (Abe et al., 2016). As previously mentioned, increased hand length and width may provide a mechanical advantage when grasping the dynamometer using the standardised second handle position (Agnihotri et al., 2008). These findings further assert the need to ensure HGS scores are compared to population specific normative data to provide accurate evaluation. Variations to anthropometrics occur across populations from different geographical locations (Bhat et al., 2021; De Andrade Fernandes et al., 2014; Leong et al., 2016). Furthermore, the type of work performed and the physical demands required also varies according to cultural and social differences across the world (Pieterse et al., 2002). Consideration of an individuals' body size when examining HGS in conjunction with their physical capabilities to perform specific work demands may aid in ensuring an individuals' suitability to perform specific work occupations.

Functional factors

Hands are used constantly for work and home tasks. Therefore, exploring the relationship between work and lifestyle factors and HGS is justified. Previous studies have looked to examine the influence of work using classifications based on work titles and skill classifications. These classification systems do not necessarily reflect the physical demands required to perform the duties within each work role. Study three adapted the US definitions of sedentary, light, medium, heavy and very heavy work as described in The Revised Handbook for Analyzing Jobs (United States Deptartment of Labor Employment and Training Aministration, 1991). Additionally, the physical demands criteria were also applied to lifestyle activities that the individual performs outside of work with the intention of providing a clearer link between the activities an individual performs using their hands and their HGS scores. The findings of study phase three concluded that HGS was positively correlated with work. Right and left HGS of individuals who performed heavy/very heavy work was significantly higher than those who performed light or medium work. Similarly, HGS for individuals who performed heavy/very heavy activity within their lifestyle was significantly greater than those who performed light activity. The influence of work and lifestyle factors need to be considered in relation to the evaluation of an individual's HGS.

Previous research has found that typically the dominant hand is stronger than the non-dominant hand, however this association is weaker for left hand dominant individuals (Bohannon, 2003). Within study phase three, left hand dominant individuals were found to have minimally increased HGS in their left hand compared to the right hand. This phenomenon may be explained by lifestyle requirements such as tools and environments which are typically built for right hand dominant individuals requiring left hand dominant individuals to adapt and use their right hand to perform tasks in preference to the left hand (Armstrong & Oldham, 1999). Currently normative data sets do not delineate HGS scores by hand dominance. If comparison to normative data is the only form of evaluation for HGS, clinicians need to consider the influence of hand dominance and the variation between left and right hand dominant individuals.

Reason for assessing

Occupational therapists described the importance of clinical reasoning, professional experience and practice context to guide the HGS assessment protocol and their chosen method of evaluating HGS scores (Myles et al., 2023a). As has been discussed, occupational therapists working in practice settings which require formalised reporting processes or justification for funding are more likely to compare to normative data when evaluating HGS scores (Myles et al., 2023a). Occupational therapists working in clinical settings such as hospitals and private hand therapy practices utilise less formal methods of evaluation such as comparing an individuals' HGS scores over time, affected versus unaffected or right versus left hands (Myles et al., 2023a).

HGS testing using a dynamometer is an assessment of hand function based on the assessment of grip strength which is a performance skill at the level of body structures and functions (Fitzpatrick & Presnell, 2004). The influence of an occupational perspective within the profession particularly over the last 20 years has impacted on the decision-making process for clinicians. The use of physical component-based assessments as the only way to evaluate hand function has been questioned. The shift within the profession to consider a more occupationally based assessment of hand function may have led to less standardised ways of assessing and in particular evaluating HGS scores (Burley et al., 2018). Physical component-based assessments alone do not highlight the unique occupational perspective that occupational therapists bring to their practice, nor do these assessments capture the dynamic relationship that is occupational performance, instead only examining factors related to the person. Therefore, clinical evaluation of hand function using physical component-based assessments alone does not necessarily capture an individual's ability to perform their everyday activities. This may help to explain why occupational therapists also rely on their clinical reasoning and professional experience assessing HGS to inform the choice of HGS testing protocol and the HGS evaluation method.

7.2.4 Utility of HGS assessment

Assessment of HGS has a wide application across numerous health fields with a variety of health professionals adopting HGS as an indicator for general health conditions and all-cause mortality (Strand et al., 2016). Consistency within the HGS testing protocol is also required across these health fields to ensure reliability when comparing across research studies and when comparing to normative data. Numerous studies identified variations within the testing protocol and testing equipment (Dodds et al., 2014; Leong et al., 2016). These variations included the use of various types of handheld dynamometers, testing in standing with the elbow positioned in extension, conducting only one trial per upper limb and if three trials were conducted and only recording the maximum effort for each hand. As has been previously discussed, these variations in testing position and assessment led to questions regarding the reliability of the study findings and limit the ability to compare study results across population groups. If the intention of these large cohort studies is to provide HGS data from which an individuals' overall health and well-being is determined, standardised and repeatable testing protocols such as the ASHT clinical assessment guidelines are required to ensure reliability.

Evaluation of the HGS scores requires population specific norms for accurate comparison. Additionally, the testing protocol used to develop these norms must be specified to ensure the replicability of the procedure if the norms are to be compared to. These factors must be considered to ensure consistency and reliability when using HGS as a key indicator in relation to these highly important health conditions.

7.3 Implications and Recommendation

In discussing the findings from this research, several recommendations have been formulated in relation to occupational therapy practice and research. This section begins by providing a summary of the recommendations for occupational therapy practice including recommendations for health professionals who assess and evaluate HGS across other contexts. Furthermore, implications and recommendations are also outlined for further research and student education.

7.3.1 Implications and Recommendations for Future Application of Occupational Therapy Practice

Recommendations for future occupational therapy practice related to the assessment and evaluation of HGS are presented within this section. Recommendations for assessment and evaluation of HGS for future occupational therapy practice include how HGS is assessed, or more specifically the testing protocol utilised for HGS assessment. Additionally, recommendations are presented regarding the evaluation of HGS including the influence of functional and biological factors on HGS. In summary, recommendations are detailed regarding a proposed decision-making process for the assessment and evaluation of HGS.

7.3.1.1 Testing protocol

The following recommendations are regarding how HGS is assessed including the testing protocol:

- The use of a consistent testing protocol is crucial to ensure for test re-test reliability regardless of whether the HGS score will be compared to normative data for evaluation.
- The use of the ASHT standardised testing protocol is required if the HGS scores are intended to be compared to normative data (or adherence to the testing protocol used to develop the specific normative data).
- Any variations to the testing protocol should be documented to allow for future HGS testing to be completed in the same manner and in turn allow for reliability when comparing scores.

7.3.1.2 Evaluation of handgrip scores

The evaluation of HGS scores includes various methods with the following recommendations outlined for future occupational therapy practice:

- Comparison to normative data within the practice settings of occupational rehabilitation and work within the community provides increased context to external audiences such as referrers and funding bodies. Additionally, comparison to normative data is recommended to identify an individual's performance in comparison to the general population.
- Clinician's working in clinical settings such as private hand therapy clinics or hospitals may choose to compare HGS scores to normative data or may select less formal forms of evaluation including comparison of right to left or affected to unaffected limbs or recording scores over time to track progression.
- The reason for assessing HGS may determine the choice of how HGS is assessed and how HGS scores are interpreted as occupational therapists rely on their professional experience and clinical reasoning to guide the evaluation of HGS scores.
- New graduate occupational therapists rely on their training during their entry-level occupational therapy programs to guide their decision-making processes. This highlights the need for student education on the assessment and evaluation of HGS within the entry-level

program. Further details are provided in section 7.3.3, the implications and recommendations for student education.

7.3.1.3 The influence of biological and functional factors on handgrip strength

This research found that in addition to the accepted factors of age and gender, other biological and functional factors influenced the HGS of Australian adults. It is recommended that the following predictive biological and functional factors are considered when evaluating HGS to provide increased contextualisation and improved confidence when guiding decision making for treatment and rehabilitation of the hand:

- Biological factors of height, forearm circumference, hand length and hand/palm width and;
- Functional factors of hand dominance and work.

These contextual factors such as an individual's work, physical stature and lifestyle factors have been found to impact on HGS. Subsequently, when assessing and evaluating HGS all health professionals regardless of discipline need to consider the influence of these biological and functional factors in addition to age and gender for increased contextualisation of the HGS results in relation to a person's body size and daily occupations.

By considering the influence of these select biological and functional factors, occupational therapists can use their occupational knowledge within the evaluation of HGS and combine this perspective with the biomedical element of the quantifiable HGS scores for an improved understanding of how an individual's HGS relates to their everyday tasks. If suitable normative data representing the population being assessed is unavailable for comparison, the consideration of these select biological and functional factors may offer increased contextualisation of HGS scores and aid in clinical decision making.

The physical demands of an individuals' occupation vary dependent on the type of employment. Consideration of an individual's biological factors, 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 (United States Department of Labor Employment and Training Aministration, 1991) to guide decision making regarding work capacity. Subsequently, matching individuals with greater HGS to occupations which require increased HGS to perform the required work demands and vice versa will be improved.

7.3.1.4 Decision making regarding handgrip strength assessment and evaluation

The assessment and evaluation of HGS is a complex process influenced by the clinicians' professional experience, training and practice context. A proposed decision-making flowchart (Figure 5) has been created to assist in guiding the assessment and evaluation of HGS for occupational therapists.

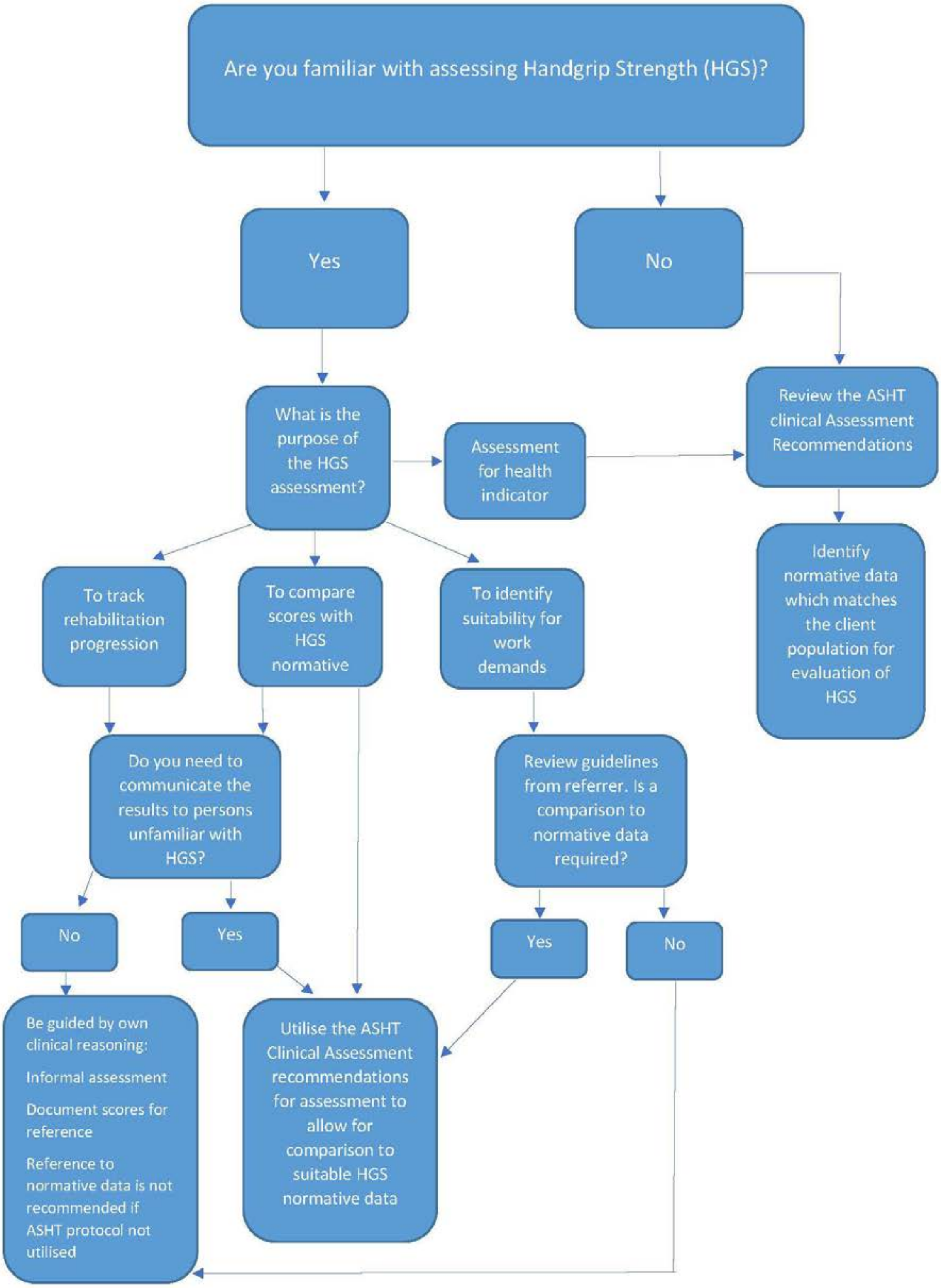

Figure 5 Handgrip Assessment and Evaluation Decision-Making Flowchart

This flowchart has been created to help guide the decision-making process when assessing and evaluating HGS. The flowchart is applicable for novice clinicians who are new to HGS assessment as well as experienced clinicians. The flowchart guides the user through a simple set of questions related to the purpose of assessing HGS and the intended audience for the HGS scores to determine both the assessment protocol and evaluation methods most appropriate. It is recommended this flowchart is introduced to occupational therapists during on-the-job training when instructing therapists on the assessment and evaluation of HGS. The useability and effectiveness of this proposed decision-making flowchart is not possible to gauge until extensive stakeholder input is obtained. It is also recommended to be trialed in practice and reviewed to determine its validity.

7.3.2 Implications and Recommendations for Research

Recommendations for research related to the assessment and evaluation of HGS will be provided within this section. Recommendations related to HGS research within the field of occupational therapy and health disciplines more broadly have been considered.

7.3.2.1 Development of future normative data sets

Population specific norms should be developed for various ethnicities and countries worldwide to replace the widely used HGS norms developed by Mathiowetz et al. (1985). The development of population specific normative data sets will ensure that individuals are being evaluated and compared to normative data collected from the population they are being compared to. Additionally, this research has found that body size (anthropometrics), occupation and lifestyle factors vary across populations dependent on ethnicity and the occupational demands within the country. As such, the consideration of select biological and functional factors within the development of new population specific normative data will provide contextualisation of HGS scores related to an individual's daily occupations and body size. It is important to acknowledge that variances in anthropometrics do exist in different populations and ethnic groups. Therefore, if HGS 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 belong to. As the Australian population becomes more culturally diverse through immigration, a more diverse blend of ethnicities is present within the population sample (Pham et al., 2021). Consequently, the representation of a typical Australian adult will change over time making the currency of normative data difficult to maintain. Supplementing available normative data with consideration of an individuals' body size along with their work and lifestyle demands will offer increased contextualisation when evaluating HGS scores.

Health research currently has a strong focus on using HGS scores to indicate overall health including mortality and morbidity of select populations with health issues. Given the importance placed on these HGS scores, all research studies examining HGS need consistent HGS testing methodologies to ensure the reliability and replicability of the results. Furthermore, when comparing an individual to the normative data, the assessment of HGS must be carried out using the same methodology adopted in the creation of the normative data set to ensure reliability.

7.3.2.2 Australia adult normative data

This research collected HGS data from adult participants located within the NQ region of Australia. Future research to expand the data collection to adults residing across Australia would provide an improved sample representing the Australia adult population more broadly. Additionally, comparison between regions of Australia could offer insights into the variances in the demographic, anthropometric characteristics and occupational demands across regions of Australia.

Future research must adhere to the HGS testing protocol as outlined by the ASHT to ensure consistency and rigour within the study methodology (MacDermid et al., 2015). Furthermore, the adoption of the ASHT testing methodology will enable direct comparison of any new research study with the results of this research.

It is recommended that any future research examining HGS of Australia adults include the documentation of the participants' residential town. By doing so, comparison between urban, regional and rural settings can be considered including the influence of location on the participants' type of work, lifestyle and anthropometric characteristics.

7.3.3 Implications and Recommendations for Student Education

The findings from this study are highly relevant to the education of entry-level occupational therapy students and potentially other entry-level health students who assess and evaluate HGS. Although this study focused on the assessment and evaluation of HGS by practicing clinicians, consideration of the current practice of educators of HGS in occupational therapy entry-level programs should be investigated. These findings can then be used in conjunction with the current study findings to inform recommendations for education on HGS assessment and evaluation.

Recommendations include educating entry-level occupational therapy students on the presence of the clinical assessment guidelines outlined by the ASHT when examining the practical element of HGS assessment and evaluation. During the evaluation of HGS scores, academic staff should facilitate a critical review of the normative data used for evaluation. This critical review may include asking the students to examine the study methods used to develop the normative data set, the currency of the research and the relevance of the population within the normative data study to the population being assessed. It is hoped that by asking students to consider the suitability of the normative data for comparison to the examined population it will generate the ability to think more critically when using assessment methods and challenge students to consider the value of comparing to normative data as a form of assessment evaluation. Engaging in this type of critical review of the normative data sets used for comparison with HGS scores should also enable discussion around other relevant forms of evaluation suited to HGS. Discussion could include the influence of practice settings and clinical experience on decision making when assessing and evaluating HGS. Additionally, building the capacity of the students to critically analyse HGS assessment and evaluation methods is a skill which could be translated across to other assessment processes across a range of occupational therapy practice settings.

The broad application of HGS assessment across all health disciplines means that the student education strategies discussed for occupational therapy students are also relevant to other entry-level health students. The handgrip assessment and evaluation decision making flowchart (Figure 5) is recommended to facilitate these critical analysis discussions within entry-level occupational therapy programs to provide a clear process to guide not only HGS assessment but also evaluation of HGS scores. Developing the student's ability to critically analyse the HGS scores and the use of normative data based on review of the literature available will lead to the ideal evidence-based practice.

7.4 Limitations

Whilst numerous measures were adopted to ensure consistency and rigour across the four study phases of this research, it is acknowledged that each study phase consisted of limitations.

7.4.1 Systematic review

Exclusion of multiple large scale and population specific studies occurred due to the inconsistent adoption of the complete ASHT testing protocol utilised when developing these normative data sets. These variations included use of non-Jamar dynamometers, changing the handle position of the dynamometer, only recording one trial of HGS, recording the maximum score in place of the mean score and performing the assessment in standing. Without a consistent approach to the HGS data collection methodology, comparison across research studies could not be reliably conducted. The date range for inclusion was limited to 2010-2023 due to the volume of publications that matched the key word search as numerous studies have examined HGS and biological factors.

7.4.2 Experiences of Queensland clinicians on the assessment and evaluation of HGS

A purposive sample of occupational therapists based in Townsville were recruited for study phase two. Despite some participants providing services to regional areas of Queensland, the findings are only applicable to the specific context of that study. As a result, study phase four was created which included both occupational therapists and physiotherapists working Australia wide with the intention of expanding the generalisability of the findings to a wider population. It is acknowledged that HGS is assessed by other health professionals including exercise physiologists and physicians. These professions were not included in the research as this project aimed to focus on the use of HGS in rehabilitation settings.

7.4.3 Exploring which biological and functional factors influence Australian adult handgrip strength

A convenience sample of working adults within the NQ region of Australia were recruited to participate in study phase three. Whilst participants were recruited from a wide range of rural and regional cities and towns within the NQ region, the geographical reach of this sampling method impacts on the generalisability of the results to the wider Australian population. Furthermore, participants were not asked to identify their town of residence so comparison between urban and rural regions of NQ was not possible.

The demographic questionnaire within study phase three asked participants to self-report their work and lifestyle category, by selecting from the options of light, medium or heavy/very heavy. The reliance on participants self-report may have reduced the reliability of this information.

7.4.4 How and why of HGS assessment

Within study phase four an online survey was distributed to members of the AHTA to identify their experiences assessing and evaluating HGS. Within the online survey, participants were not required to identify their practice context e.g. occupational rehabilitation, hand therapy, hospital, community or otherwise. Identification of practice context may have allowed examination and insights regarding differences in HGS assessment and evaluation across different practice contexts. These results could have then been compared to the findings of study phase two where practice context was identified for each participant.

7.5 Conclusion

This research has identified that a standard one size fits all approach to HGS assessment and evaluation is simplistic. Clinicians rely on other contextual factors such as the reason for assessment, the practice context and their clinical reasoning to guide both the assessment and evaluation of HGS. This is the first study, to the authors knowledge that has explored the predictive power of a combination of functional and biological factors in relation to Australian adult HGS. Furthermore, it is the first Australian study to explore how and why occupational therapists and physiotherapists assess and evaluate HGS.

This thesis contains four study phases. Study phase one identified which functional and biological factors most strongly predict HGS. Study phase one found when analysing HGS more factors than age and gender should be considered. This study concluded functional factors (hand dominance, occupation) along with biological factors (height, weight, hand length, hand width/palm width, forearm circumference) should also be considered to improve confidence in decision making related to HGS. The findings from the study phase one were used to inform study phase two. Study phase two concluded occupational therapists use variations to the HGS testing protocol and different forms of evaluating HGS as guided by their clinical experience, reason for assessment and practice context. The results of study phase four aligned with study phase two concluding that clinicians Australia wide do not consistently adhere to the complete ASHT testing protocol when assessing HGS. Additionally, both study phase two and phase four found that biological and functional factors were considered to impact on HGS. Study phase three concluded that the functional factors of occupation and lifestyle and the biological factors of height, weight, hand length, hand width/palm width, forearm circumference most strongly predicted HGS. Whilst the development of new normative data sets designed to include sub-categories for these select biological and function factors would provide improved comparison when evaluating HGS scores, the development of these new norms may be impractical due to the vast sample size required within each sub-category to meet a satisfactory estimation within the population. Instead, given the variance in body stature, type of work and lifestyle demands across populations, ensuring comparison of an individual to population specific norms would aid in improving the contextualisation of HGS scores for an individual.

Conceptualisation of a decision-making flowchart (Figure 5) for the assessment and evaluation of HGS has been developed based on the combined results of all four study phases of the thesis. The aim of the flowchart is to provide guidance for teaching HGS assessment within entry-level health programs in addition to guiding the actions of health professionals in practice when assessing and evaluating HGS. Extensive stakeholder input is required to determine the useability and effectiveness of this proposed decision-making flowchart. It is also recommended to be trialed in practice and reviewed to determine its validity.

Overall, this research identified several recommendations to improve the assessment and evaluation of HGS within the occupational therapy profession and the other health professions more broadly. Communication of these research findings to increase awareness of the implications to occupational therapy practice is recommended.

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Appendices

Appendix A: Ethics Approval for study phase two (experiences of occupational therapists in Queensland, Australia)

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Appendix B: Ethics Approval for study phase three (exploring which biological and functional factors influence Australian adult HGS)

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Appendix C: Ethics Approval for study phase four (the how and why of HGS assessment)

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Appendix D: Conference Abstract 1 – 'Assessment and evaluation of adult grip strength: experiences of occupational therapy clinicians in north Queensland'

Assessment and evaluation of adult grip strength; experiences of occupational therapy clinicians in north Queensland

Mrs Louise Myles [1] , A/Prof Fiona Barnett[1], Dr Nicola Massy-Westropp[2]

[1]James Cook University, Townsville, Australia; [2]University of South Australia, Adelaide, Australia

Introduction: The measurement of handgrip strength is widely accepted for assessing and evaluating hand function, however, little is known about how and why occupational therapists in North Queensland assess and evaluate handgrip strength.

Objective: The purpose of this study was to investigate the experiences of occupational therapists when working with grip strength. Additionally, the study explored what biological and functional factors occupational therapists believe influence adult grip strength and should be considered in the evaluation of grip strength in comparison to normative data.

Methods: Purposive sampling was conducted to identify occupational therapy clinicians within North Queensland who assess grip strength. Data were collected from 20 participants using a semi-structured interview process. Interviews were either one on one or conducted as part of a focus group. The interviews were transcribed verbatim and analysed using thematic analysis.

Results: Variations of the American Society of Hand Therapists grip strength testing procedure were used by the participants based on experience. When evaluating grip strength, comparison to normative data was not always completed or seen to be valuable and normative data used varied. Biological and functional factors such as height, weight and occupation were considered to influence individual grip strength.

Conclusion: The results of this study provide insight into the niche ways occupational therapists assess and evaluate grip strength according to experience and practice context. These variations in assessment and evaluation of grip strength along with the influence of an individual's biological and functional factors need to be considered when interpreting grip strength results

Appendix E: Conference Abstract 2 – 'What factors influence Australian adult grip strength'

What factors influence Australian adult grip strength?

Louise Myles, Fiona Barnett, Nicola Massy-Westropp

James Cook University, Townsville, Australia

Introduction: Grip strength is commonly assessed by occupational therapists and provides a simple quantitative measure of hand function. Reference values for grip strength are generally categorised by age and gender only with no other influencing factors accounted for.

Objectives: This study aimed (1) to collect grip strength data related to functional, biological and demographic factors for Australian adults and (2) to determine the relationship between these relevant factors and grip strength for Australian adults.

Methods: Participants completed a basic questionnaire on demographic information before undergoing measurement of biological factors such as height, weight, hand length, width and forearm length and circumference. Grip strength was assessed using a Jamar dynamometer and the grip strength testing procedure as outline by the American Society of Hand Therapists. Multiple regression analysis was conducted to determine which of the influencing factors most strongly predicts grip strength.

Results: Data were collected from 215 male (n = 119) and female (n = 96) Australian adults aged between 18 to 66 years. Preliminary findings indicate the accepted factors of age and gender are strongly predictive of grip strength. Forearm circumference was found to be the most predictive biological factor followed by hand length. Work was identified as the most predictive functional factor. It is recommended clinicians consider these other influencing factors when assessing and evaluating grip strength.

Conclusion: The identified influencing factors allow contextualization of an individual's usual occupations and correlating body measurements in relation to grip strength.

What factors influence Australian adult grip strength?

Louise Myles[1], A/Prof Fiona Barnett[1], Dr Nicola Massy-Westropp[2]
[1]James Cook University, [2]University of South Australia

Background

Handgrip strength (HGS) is simple and reliable assessment of hand strength utilised by health professionals including Occupational Therapists[1, 2, 3]

Interpretation of HGS may include reference to normative data which considers the influence of age and gender only[4]. Recent studies have explored other biological and/or functional factors on adult HGS[1, 5, 6, 7]

The aim of this study was to determine which demographic, biological and functional factors most strongly predict HGS for Australian adults

Method

Participants:
- 215 health adults (males n=119, females=96)
- Aged between 18-66 years residing in North Queensland
- Questionnaire (age, gender, hand dominance, work occupation & physical activity)
- Measurement of biological factors (height, weight, hand length, width and forearm length and circumference)
- HGS assessed using Jamar dynamometer following the American Society of Hand Therapists (ASHT) testing protocol[8]
- Multiple linear regression was used to describe relationship between demographic, functional and biological factors and average HGS of right and left hands

Table 1: Descriptive statistics of participant characteristics for men and women

Variable	Men		Women	
	Mean	Std. Deviation	Mean	Std. Deviation
Age	35.6	12.6	34.6	11.8
Height (m)	1.8	0.1	1.7	0.1
Weight (kg)	93.6	18.2	71.5	12.9
Body Mass Index	28.8	5.6	25.3	4.4
Hand Length	20.0	0.9	18.1	1.1
Hand Width	9.2	1.0	7.9	0.5
Forearm Length	28.1	1.3	25.2	1.5
Forearm Circumference	29.8	2.4	24.9	2.4

Table 2: Mean ± SD Right and left HGS (kg) according to occupation

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

Key Findings

- The factors identified as the strongest predictors for HGS in this study were **gender, work, forearm circumference** and **hand length**.
- HGS was found to increase as the **physical demands of work** increased
- As **physical activity levels** increased, so too did HGS

Conclusion

Given the importance of the HGS score when evaluating hand function, it is recommended that work demands and lifestyle factors be considered when assessing and evaluating HGS especially in comparison to available normative data.

The inclusion of the anthropometric measurements of forearm circumference and hand length and width provide a highly accurate prediction of HGS.

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Appendix F: Study phase two (experiences of occupational therapists in Queensland, Australia) information sheet

JAMES COOK UNIVERSITY
AUSTRALIA

INFORMATION SHEET

PROJECT TITLE: **Normative grip and pinch strength of Australian adults: A clinician's perspective**

You are invited to take part in a research project exploring the experiences of occupational therapists working with grip and pinch strength normative data including identifying which factors occupational therapists believe influence Australian adult grip and pinch strength. The study is being conducted by **Louise Myles** and will contribute to the **Doctor of Philosophy (Health)** at James Cook University.

If you agree to be involved in the study, you will be invited to participate in:

An interview in the form of a focus group or if you are unable to participate in a focus group in a one-on-one interview. The interview (focus group or one-on-one), with your consent, will be audio-taped, and should only take approximately 1 hour of your time. Specific locations for the focus group will be determined based on the number of participants at a location One-on-one interviews will be conducted via the telephone, face-to-face or electronically (e.g. Skype).

Taking part in this study is completely voluntary and you can stop taking part in the study at any time without explanation or prejudice.

If you know of others that might be interested in this study, can you please pass on this information sheet to them so they may contact me to volunteer for the study.

Your responses and contact details will be strictly confidential. The data from the study will be used in research publications and reports **including journals, theses, conference presentations, seminars etc.** You will not be identified in any way in these publications.

If you have any questions about the study, please **contact Louise Myles (Principal Investigator) or Fiona Barnett**

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Appendix G: Study phase two (experiences of occupational therapists in Queensland, Australia) interview guide

Sample interview guide for participants

Questions for participants	
1.	For what reasons do you assess clients grip strength?
2.	What testing procedure do you utilise? *Possible prompts:* • Handle position? • Testing position (sitting/standing/arm position) • How many trials? • Rest breaks? Alternating sides right to left? • Scoring (average or maximal)? • - Do you provide prompting/motivation/encouragement?
3.	Why do you choose this position? *Possible prompts:* • Do you always use the same position?
4.	How do you evaluate the client's results? *Possible prompts:* • Do you compare the client's results to normative data sets? • What normative data sets do you utilise to evaluate HGS? • Why do you choose to utilise that specific normative data set? • Do you think these data sets are adequate for your needs?
6.	What are the advantages/disadvantages to using your chosen data sets?
7.	How do the results of the HGS testing guide your practice/intervention? *Possible prompts:* • How do you interpret the results?
8.	What factors do you believe influence HGS? *Possible prompts:* • Do you believe hand dominance influences HGS? • Do you believe the person's job influences their HGS? • Do you believe psychosocial factors influence assessment of HGS?
9.	Is there anything else that we haven't discussed in this session that you would like to add about this topic?

Appendix H: Study phase three (exploring which biological and functional factors influence Australian adult HGS) information sheet

JAMES COOK UNIVERSITY
AUSTRALIA

INFORMATION SHEET

PROJECT TITLE: **Hand strength of Australian adults.**

You are invited to take part in a research project to identify hand strength of Australian adults. The study is being conducted by Louise Myles and will contribute to a Doctor of Philosophy at James Cook University.
If you agree to be involved in the study, you will be asked to complete a questionnaire, which asks you your age, gender, dominant hand and daily occupations. The questionnaire should only take 5 minutes to complete. You will be invited to have basic body measurements taken. These include height, weight and hand length, width and forearm length and circumference of both your left and right hand. Finally, you will be asked to participate in a series of tests of hand grip and thumb and forefinger (key) pinch strength using a Jamar hydraulic dynamometer and B&L pinch gauge.

You will be asked to grip the Jamar dynamometer and B&L (key) pinch gauge as hard as you can and three (3) measurements will be taken from both your left and right hands. Privacy will be adhered to at all times; only the researcher and yourself will be present during the questionnaire and the recording of measurements.



Taking part in this study is completely voluntary and you can stop taking part in the study at any time without explanation or prejudice.

If you know of others that might be interested in this study, can you please pass on this information sheet to them so they may contact me to volunteer for the study).

Your responses and personal information will be strictly anonymous. The data from the study will be used in research publications and reports including journal articles and theses. You will not be identified in any way in these publications.

If you have any questions about the study, please contact Louise Myles or A/Prof Fiona Barnett

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If you have any concerns regarding the ethical conduct of the study, please contact:
Human Ethics, Research Office
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APPENDIX 3

Appendix I: Study phase three (exploring which biological and functional factors influence Australian adult HGS) Demographic questionnaire

Demographic Questionnaire
Participant ID number:

About you

1. **How old are you?** ________ years

2. **Your gender?** (circle one answer)

   Female
   Male
   Other

3. **Dominant hand?** (circle one answer)

   Right
   Left

4. **Where were you born?** (circle one answer)

   Australia
   New Zealand
   United Kingdom
   Europe
   Asia
   North America
   Other (please specify) ________________

5. **What is your occupation?** (eg. Sales assistant, Accounts clerk, etc.)

____

6. **What category of work describes the main tasks or duties that you usually perform in that occupation?** (Tick one category)

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

7. **During the past week did you participate in any physical activity, exercise, recreation or sport?** (circle one answer)
   No → end of questionnaire
   Yes

8. **What category of work describes physical activity, exercise, recreation or sport you performed?** (Tick one category)

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

Thank you for your time.

Appendix J: Study phase four (the how and why of HGS assessment) information sheet

JAMES COOK UNIVERSITY AUSTRALIA

Information Sheet

INFORMATION SHEET

PROJECT TITLE: **Grip strength of Australian adults: A Clinicians Perspective**

You are invited to take part in a research project exploring the experiences of working with grip strength with the goal to develop a decision-making flowchart for grip strength testing. The study aims:

- To explore Australian versus North Queensland clinicians' experiences assessing and evaluating grip strength of Australian adults.

The study is being conducted by **Louise Myles** and will contribute to the **Doctor of Philosophy (Health)** at James Cook University. Funding is provided by JCU to support PhD research.

Once permission is granted by the Australian Hand Therapy Association (AHTA) association to distribute the online research survey all clinicians who are members of the AHTA will be invited to voluntarily participate in the online Qualtrics survey. The information sheet along with the link to the online survey will be emailed to all members of the AHTA via the AHTA eNews newsletter.

The survey will request your written consent and information regarding basic demographics – professional qualifications, years spent assessing grip strength; reasons for assessing grip strength; clients groups assessed for grip strength; use of grip strength normative data sets; factors which influence grip strength. It is expected that the survey will take approximately 10 to 15 minutes to complete.

Taking part in this study is completely voluntary and you can stop taking part in the study at any time without explanation or prejudice. At any time, participants can simply close the browser and their unprocessed data will be removed from analysis.

Your responses and contact details will be strictly anonymous as you will not provide your name or any information that could be used to identify you.

The data from the study will be used to develop a decision-making flowchart for grip strength testing. The data from this study will also be used in research publications and reports **including journals, theses, conference presentations, seminars etc.** Direct quotes may be included in these research outputs. You will not be identified in any way in these publications.

If you have any questions about the study, please **contact Louise Myles (Principal Investigator) or Fiona Barnett**

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Appendix K: Study phase four (the how and why of HGS assessment) questionnaire

Online questionnaire:

Questions for participants	
1.	Professional field: - Occupational Therapist - Physiotherapist
2.	Level of professional qualification: - Bachelor degree - Bachelor degree with honours - Masters - PhD
3.	Are you an Accredited Hand Therapist or in the process of becoming an Accredited Hand Therapist? - Yes - No
4.	How many years' experience do you have assessing handgrip strength: - Less than 1 year - 1-2 years - 3-5 years - 5-10 years - 10-20 years - More than 20 years
5.	Where are you currently practicing? (Name of town/city)
6.	For what reasons do you assess handgrip strength? (Select all that apply) - Do not assess grip strength - Pre-employment assessment / part of functional capacity assessments - Reporting purposes - To evaluate rehabilitation progression (baseline assessment) - To work towards a client's goal - Following injury / surgery - For return to work
7.	Who are the clients that you work with? (Select all that apply) - Workers (both injured and uninjured) - Clients with hand / upper limb injuries or conditions (including shoulder) / trauma clients / nerve injuries - Clients with functional upper limb and neurological related disorders
8.	Do you follow the American Society of Hand Therapists (ASHT) testing protocol when assessing grip strength? (client is seated, shoulder abducted, elbow flexed at 90, 2nd handle position, 3 alternating trials on both the left and right hand with the mean calculated) - Yes - No
9.	When assessing handgrip strength do you: (Select all that apply) - Complete testing in a seated position? - Complete testing in a standing position? - Use the second handle position? - Change the handle position as needed? - Record the mean of three trials for each hand? - Record the maximum trial for each hand?

	- Alternate trials between hands? - Ask the client to sustain the duration of contraction? - Ask the client to perform a short maximal contraction?
10.	Do you utilise normative data to evaluate handgrip strength scores? - Yes - No If yes, which normative data set do you refer to? (free text response)
11.	Alternatively /in addition to normative data, how do you evaluate handgrip strength scores? (Select all that apply) - Compare affected to unaffected or right to left sides - Record progression over time - Functional assessment - Based on client feedback
12.	Rank in order which factors have the strongest influence handgrip strength. - Age - Gender - Height - Weight - BMI - Hand length - Hand width - Forearm length - Forearm circumference - Hand dominance - Lifestyle - Employment - Other: (free text)