Relationship between hand anthropometry and hand strength and function in people with hand osteoarthritis

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Abstract:

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Hand Osteoarthritis (HOA) is the most common joint disease that affects the finger joints of older adults. Individuals with HOA have decreased handgrip strength and hand function. People with this condition have difficulties in grasping, gripping, twisting, and turning objects in daily living. As the disease advances structural changes such as loss of normal joint space, osteophyte formation, and bony nodules in people with HOA are common. Several investigators have examined the relationship between the hand or body anthropometrics and hand grip strength and hand function in healthy diverse populations; however, no previous studies have investigated this association in people with HOA.

The purpose of this thesis was to investigate the relationship between body and hand anthropometrics with hand strength and function in people with HOA, encompassing 2 papers. The first manuscript in this thesis was to describe the relationship between body and hand anthropometric variables with hand strength in people with HOA. In addition, it sought to establish the relative contribution among those variables for hand grip and pinch strengths in people with HOA. The second manuscript in this thesis was to describe the relationship between body and hand anthropometric variables with hand function in people with HOA. Further, it examines how anthropometric and demographic factors in combination explain hand function and health status in people with HOA. Finally, the thesis addresses the implications for the studies, limitations, and conclusions.

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CHAPTER ONE

Introduction and Literature review

Osteoarthritis (OA) is the most common type of arthritic joint diseases [1] usually affecting the joints of the hands.[2] It is estimated that 2.8 million Ontarians >15 years will be affected by arthritis or associated conditions by the year 2026.[3]

Hand OA is heterogeneous in nature[4] meaning it has diverse causes with multiple disorders not just a single disease. The severity and the course of the disease overtime differ between the individuals. In hand OA, several multiple hand joints are involved which affects hand grip strength and function significantly[5] in older adults. The pattern of joint involvement is primarily in a row from distal interphalangeal joints (DIPs), proximal interphalangeal joints (PIPs) and followed by metacarpophalangeal joints (MCPs). The association between hand strength and gender has been established[6] in the literature. Among all age groups men's grip strength is stronger than women.[7] Hand osteoarthritis is an age and sex dependent disorder commonly affecting females >50 years.[8] Vianna et al.[9] compared hand grip strength for males and females in healthy adults (18-90 years of age). This study showed that age explains 30% of the difference in hand grip strength in men and 28% in women. Although hand strength decreases after the age 60,[6] in males, hand grip strength starts to decrease more rapidly at the age of 30 years and in females at the age of 50 years.[9] However, in males this decline is steeper when comparing older age groups. Eventually in older adults (85+ years), the gender differences in grip strength will be insignificant.[7]

The most commonly used case definitions referring to OA disease are "Symptomatic OA", "Radiographic OA", and "Self-reported OA".[10] Symptomatic OA definition characterizes the presence of both radiographic evidence and joint symptoms (pain, stiffness, and loss of function) which relates to the pathology of the subjects.[11] The symptomatic type of OA of the hand was found in 26% of women and 13% of men over 70 years of age in a community sample.[12] Radiographic hand OA is defined as when two out of three groups of hand joints (1st Carpometacarpal (CMC)/Trapezio-Scaphoid, PIP, and DIP) are affected on a Kellgren Lawrence (KL) grading scale[15] of greater than or equal to 2.[13] Radiographic OA of the hand was found in 82% of women and 83% of men, respectively, with a mean age of 79 years for subjects sampled from a geriatric care facility.[14]

The severity and presence of OA is defined by KL grading system on a scale of 0 to 4.[15] The KL grading system is used for the hand, hip, and knee joints. Similarly, the Atlas For Radiographic Features of OA can be used to interpret individual radiographic characteristics such as osteophytes, decrease in joint space, and subchondral changes.[16] The American College of Rheumatology (ACR)[17] proposed clinical criteria for "Symptomatic hand OA" which facilitate in classifying OA disease is dependent on the patient's history, physical examination, and radiographic evidence. The minimum following characteristics exist in a patient classified as having hand OA; hand pain; stiffness, hard tissue enlargement of two or more of 10 selected joints (1st CMC, PIPs and DIPs of 2nd and 3rd finger joints of the both hands); less than three swollen MCPs and either; enlargement of two or more DIP or deformities of two or more joints of 10 selected joints.

In hand OA multiple joints are involved and hence the condition is termed as polyarthritic. Several subsets are established in hand OA, "Nodal OA" (NOA), "Generalized OA"[18], and "Thumb-base OA" with varying significance. [4] Nodal OA is characterized by the presence of multiple Heberden and Bouchard nodes at interphalangeal and TS joint mostly in females .[19] This subset of hand OA is usually assessed by physical examination, i.e., observation and palpation of the DIP and PIP joints by the physicians. The prevalence of NOA established using radiographic findings is up to 81% in an elderly population aged 71-100 years.[12,13]

"Thumb-base OA" is defined as arthritis of 1st CMC or base of the thumb which causes pain, functional disability, and difficulty in pinch tasks.[20] The radiographic prevalence of thumb base OA in persons $\geq$ 55 years is 35.8%[13] and symptomatic prevalence of 1st CMC OA in persons $\geq$ 71 years is 4.1%.[21]

Additionally, hand pain and disability, two common problems in the older adult (>65 years+) population,[22,23] may be related with arthritis. People with hand OA will have decreased hand grip strength,[5] decreased independence in performing their daily tasks,[17] and decreased productivity at work due to pain.[24] Even though most persons with hand OA are independent in performing their daily tasks, the amount of time to complete the task is greater than persons without hand OA.[25] Clinical assessment ideally involves both clinician-based assessments and structured assessment of the individual's perspective through the Patient-report outcome measures (PROMs).

In recent years, there has been an increasing interest in recognizing the importance of the International Classification of Functioning, Disability and Health (ICF),[26] a World Health Organization (WHO) framework for health and disability. It is a multipurpose classification system that provides a theoretical framework to document and systematize data of health and health related states. The ICF consists of two main parts: (1) functioning and disability and (2) contextual factors. The functioning and disability section of the ICF includes components such as body function, body structure, and activities and participation which are designated as disability. Contextual factors are subdivided into environmental and personal factors. The ICF has been designed as a tool for evaluating functioning in a social setting and ICF facilitates prediction of influence of physical impairments on function and its associated disability and health.[27] The contextual factors are subdivided into environmental and personal factors.

Patho-Biomechanics of Osteoarthritis

The single specific cause for OA has not been identified but the importance of biomechanical factors are well recognized within etiological factors.[28] In OA progression, involvement of the entire joint with loss of hyaline articular cartilage, development of outgrowth like structures (osteophytes), and bony sclerosis (increased thickness of the bony envelope) are the main characteristics of this disease.[1] The pathology of OA disease is complex, involving multiple associated factors and with progressive stages including: 1) genetic susceptibility[18], 2) low levels of inflammation including abnormal changes in the mechanical stress,[19] 3) entire changes in the gene expression of cartilage cells chondrocytes, and 4) when a specific expression gene is not regulated.[29] It has been suggested that the source of pain in OA is not likely from the articular cartilage[30] because it lacks nerve supply, lymphatics and blood vessels.[31] Tan et al.[32] published a study presenting distinguishable abnormalities of joint structure in acute and chronic hand OA conditions with the help of high-resolution magnetic resonance imaging (MRI). The abnormality of joint structures involves the loss of cartilage, edematous bone, thickening and enhancement of the synovium, osteophytosis, and the formation of Heberden's and Bouchard's node.[32] A number of studies are directed towards the significance of physical forces in the adverse events of this disease.[33-35] OA commonly occurs in the weight bearing joints such as the knees, hips, and ankles, however, it can affect any synovial joints of the body. Biomechanically, structures such as bone and cartilage receive and distribute forces during joint loading postures and during dynamic movements. Several studies of hand biomechanics have demonstrated that forces generated at the DIP joints during grip are substantially less than the forces at the PIPs, MCPs and CMC joints.[36]

Review of the Literature

Relationship between hand anthropometry, hand grip strength, and hand function

Hand grip strength is one of the significant components in the assessment of conditions such as rheumatoid arthritis, neuromuscular disease, preoperative and post operative status, and functional ability of older adults.[37] It is used as an indicator of overall physical strength and health,[38] and functionality of the hand and forearm musculature.[39] It is a common clinical assessment for various musculoskeletal,[40] neuromuscular[41], and cardiovascular disorders[44] performed by therapists and hand surgeons preoperative and postoperatively[42] in older populations.[43] Hand grip strength is assessed by different techniques and the equipment in the clinical setting range from dynamometry, manual muscle testing, and the use of a myometer and a modified sphygmomanometer.[37] The methodologies used in measuring hand grip strength and pinch strength varies across age and developmental stages. While measuring hand grip strength several parameters are considered such as age, sex, protocol of measurement, upper extremity, selection of instrument, number of trials, duration of the trial, and the condition of the individual to be evaluated.[60] A recent systematic review[61] confirms grip strength measurement has been well validated and is a useful indicator in evaluating middle-aged and older adults to predict functional outcomes.

The force output of different types of grip is influenced by the 1st web space (thumb and other fingers) and the action of thumb contra-opposition.[97] Different structures that contribute to this function are the first CMC joint, the first dorsal interosseous (FDI) muscle, the adductor pollicis muscle (AP), and the fascial clefts linking them. Hand grip strength measurement is affected by posture,[48, 46] age, sex, various angles of shoulder, elbow, forearm, and wrist; [47-49] hand span[50-51], and grip span.[46, 48, 50-53] Pinch grip strength measurement is affected by arm position (standing and sitting postures) ,[63] forearm position ,[66] wrist position,[64,65], sex, grasp type, pinch width,[65] and the type of tools used at the work place.[67] Range of motion can be impaired in hand OA as a consequence of osteophytes formation, cartilaginous lesions, and contractures of ligaments.[57] Furthermore, pain and disuse can contribute to the losses in strength and motion.

Pain and joint deformation are the major characteristics of OA that contribute to dysfunction.[5] According to the literature, there is a correlation between the severity of hand OA and function.[5,92,93,94] In the late stages of hand OA, the hand deformities increase. Kwok et al.[95] provides evidence for decreases in joint space width, pain, and loss of mobility in females with hand OA. There has been little attention directed towards the association between hand span and function. One might expect a relationship between hand span and the forces that are distributed throughout the joints during functional activities in people with or without hand OA. However, persons with hand OA might be more likely to experience pain with lower levels of joint forces. Further, as joint space narrows in hand OA, it is possible that this would affect hand span. Hand span can also be affected by skin contracture, which might occur in hand OA due to pain. One study that looked at hand span in long-term follow up of patients following CMC arthroplasty determined that hand span was significantly correlated (r= -.20 to -.27 and -.22 to -.36) with self-report functional measures.[98]

Anthropometric measurement is an essential and widely used element for screening and monitoring of disease processes across multiple conditions with physical manifestations.[68] Tools used for measuring anthropometric characteristics are simple to use, affordable, non-invasive, and require minimal training.[69] Anthropometry has been widely studied using vernier calipers,[70] electronic digital caliper,[71] Integrated Composite Anthropometers (ICA),[72] photographs,[73] and measuring tapes.[74, 79] The term "allometry" refers to "the study of comparative sizes"[75]. This definition is intended for researchers who are interested in relationships and comparisons between the sizes of two body regions (e.g., upper arm versus lower arm) or the size of the body region to a general measure (e.g., body height versus body weight); or how these comparisons relate to function (e.g., grip strength to overall body size). There has been little attention directed to the relationships between strength of the hand (grip and pinch) and hand anthropometry, however most studies in the field of Rehabilitation Science have only focused on health outcome measures which reflect the individual outcome during the disease process. The few studies investigating the relationship between basic anthropometric variables (body height, weight, and body mass index (BMI), hand anthropometric variables (hand span, finger spans, finger length, and hand circumference) and hand grip strength and pinch strength are described below.

Early examples of research into relationships between specific hand anthropometric variables and hand grip strength were carried out with children, adolescents, high school athletes, musicians, and healthy adults. For example, Hager-Ross and Rosblad[54] investigated relationships between hand grip strength with height, weight, and hand length. Pearson correlation coefficients between hand grip strength and height, body weight, and hand length were highly correlated at r = .90, .90, and .91

respectively, for boys ($p < .0001$ in all cases) and $r = .87$, .87, and .85 and respectively for girls ($p < .001$ in all cases). This study was conducted among Swedish children aged between 4 and 16 years.

Aghazadeh et al.[56] examined the effects of body height, weight, frame size (determined by an individual's wrist circumference in relation to his height), and fat-free cross sectional area (FFCSA) and hand grip strength. Pearson correlation coefficients between sex, height, weight, FFCSA and hand grip strength were highly correlated at $r = .77$, .61, .70, and .78 respectively. This study was conducted among student body at Louisiana state university, males aged 19 to 71 years and women aged 18-54 years. A stepwise regression analysis revealed that age, sex, and weight accounted for maximum variation r^2=.687, in predicting grip strength. However, the known anthropometric relationships involving students cannot be extrapolated to all other age groups or subset of conditions because of the dynamic growth and development processes in this population.

Ke Li et al.[59] examined the relationship between anthropometric data (height, weight, hand length, palm length, and circumference of the forearm, wrist, and hand) and maximal grip strength in 100 healthy participants ages 19 – 24 years. Maximal grip strength was measured using three dynamometers (Jamar®, Martin Vigorimeter and Myogrip) for both dominant and non-dominant hands whereas anthropometric data was measured using a standard measurement tape. They found high correlation between hand circumference and maximal grip strength across the Jamar ($r = 0.78$ and 0.78), Myogrip ($r = 0.82$ and 0.82), and Vigorimeter ($r = 0.66$ and 0.73) for dominant and non-dominant hands. A stepwise regression analysis was performed to determine the predictive models for maximal grip strength for each dynamometer. Hand circumference was the only anthropometric variable analytically selected for three dynamometers on both dominant and non-dominant hands whether taken independently or all together with resultant adjusted coefficient of determination $r^2 = 0.62$, 0.68, and 0.47 for Jamar®, Myogrip and Vigorimeter respectively).

A correlation study by MacDermid (2002)[91] examined the relationship of age, gender, height, weight, hand size, and hand dominance with grip strength and dexterity. Ninety healthy subject's hand anthropometric measurements were measured using the NK Hand Evaluation System (NKHES) with size measured by NK Micrometer, grip strength using NK Digit Grip computerized dynamometer, and dexterity using NK dexterity board. The results demonstrated low to high correlation between grip strength and height, hand span, hand width, and hand length (.38 - .82). In a multivariate analysis, gender was the most significant contributor explaining 52-76% of variation in grip strength for both dominant and non-dominant sides. Additional contributions to a lesser extent were found for hand span (65-67%) and hand dominance (62%).

Several research studies investigating changes in hand measurements have been carried out on musicians (e.g., pianists) to predict potential effects from repetitive work. For example, a recent comparative study by Sakai and Shimawaki[89] measured hand span, length of the thumb, middle, and little finger, abduction angles of the thumb and little finger of the right hand of 220 pianists with overuse disorder and 62 healthy pianists. They found significant differences in hand span, thumb length (short and long), little finger length, and middle finger length parameters but not in abduction angles among the groups. They found that pianists with smaller hand spans hyper-abducted and hyper-extended the thumb and little fingers to attain wider hand span than pianists with wider hand spans.

Hand span is important for five finger grip or overall hand grip strength whereas web span is important for different types of pinch grip strength. One important factor studied by researchers is the grip span influence on handgrip strength[77] and pinch grip strength. The terms hand span and optimal grip span are central in determining maximal hand grip strength.[77] There are relatively few research studies that investigated the setting (refers to optimal grip span) at which maximal hand grip strength be obtained from a standard dynamometer.[62, 76-79] For example, Ruiz-Ruiz et al.[77] investigated the position (grip span) at which maximum hand grip strength is obtained on standard hand-held dynamometers.

Participants assessed (n=70) were 40 females and 30 males of an average age of 40 years (range 20 – 80 years). They reported optimal grip span for both the genders suggesting that for males the optimal grip span can be positioned at 5.5 cm (for five finger grip) and for females when measuring handgrip strength, hand size should be measured because optimal grip span is influenced by hand size in females. An arithmetical equation was given to all female hands; grip span (y) = Hand size(x)/5 + 1.5 cm. This study found that a relationship exists between hand size and optimal grip span in females but not in males. They suggest the need for adjusting the setting of dynamometer positions (grip span) to the corresponding hand sizes.

To obtain the maximal grip strength the American Society of Hand Therapists (ASHT)[96] suggests using the 2nd handle position (out of 5) on the standard hand-held dynamometer. However, there are relatively few research studies investigating the optimal handle position of hand held dynamometers. Firrell and Crain[62] examined the correlation between the optimal setting of the dynamometer (for obtaining maximal grip strength) to the physical characteristics (age, weight, and hand dimensions) of 288 asymptomatic hands (dominant and non-dominant) of individuals aged between 4 – 78 years old at five different settings of computerized isometric dynamometer. This study examined grip strength from n=288 hands, 256 (89%) of them produced maximal grip strength at dynamometer setting size II. This study signifies that for obtaining maximal grip strength it is advised that all persons use dynamometer setting II (out of five dynamometer handle sizes) regardless of the age, body weight, and hand measurements. Though, dominant and non-dominant asymptomatic hands were measured in this study anthropometric differences were not reported. A number of studies have examined optimal grip spans and reported optimal grip spans at 5.5,[77] between 5.0 and 6.5 cm,[53] 2.5 cm,[80] 4.7 cm,[81]; and for the thumb-index finger grip the optimal grip spans are 5.0.[65.82]

Likewise the term lateral pinch grip span has been applied to situations when researchers aim to determine the optimal lateral pinch grip span to obtain lateral pinch grip strength. For example, Shivers et al.[84] quantified the relationship between lateral pinch grip span and lateral pinch grip strength. Participants were healthy men and women from different manual skill jobs ranging in age between 21 and 54 years. A commercial pinch grip dynamometer mounted into a wooden casing was used to measure the lateral pinch grip strength. They found significant increases in lateral pinch grip strength in those with greater lateral pinch grip spans. Taken together, these studies signify the importance of optimal grip spans to effectively measure maximal grip and pinch strength (large or small hands) and its relationship to hand dimension specifically hand span. Despite the importance of hand anthropometric measurement hand span, there remains a lack of research of its correlation with hand grip strength and pinch strength in hand OA population.

Hand OA affects not only grip strength but also hand function. Pain, tenderness, reduced grip strength, ROM, and joint stiffness has negative affects preventing the individual from performing specific activities (e.g. doing and undoing buttons, opening jars and bike riding) as well as engaging in social activities.[12,25,103] The presence of Heberden's nodes at the DIP and Bouchard nodes at the PIP joints also has adverse consequences on hand function.[102] To better understand the dynamics of the effect of hand OA deformities and function, it is necessary to examine the association between hand anthropometric measurements and hand function. Physical disabilities and social limitations are measured using health outcome measures such as the Patient Rated Wrist/Hand Evaluation (PRWHE),[99] Arthritis Impact Measurement Scale (AIMS 2)[100], and SF36.[101] In the present study these tools have been employed to determine the correlation between hand measurements and hand function.

Thesis rationale and objectives

Multiple studies have been published on the relationship between hand span and hand grip strength but most of these have been conducted using healthy subjects. The single study that examined patients with hand OA used a postsurgical population which would represent a late spectrum of disease and people where the anatomy had been surgically altered.[98] Furthermore, the analysis was a correlation table of multiple impairments as part of a validation study and not a major focus of the research. A gap in the literature is understanding the relationship between anthropometrics and hand strength in patients with hand OA that are typical of those living in the community. Therefore, the purposes of this thesis were:

1) To describe the relationship between anthropometric variables (height, weight, and BMI), specific hand anthropometric variables (hand span and web span), and hand grip and pinch strengths in people with hand OA.
2) To determine the significant predictors when anthropometric and demographic variables are mutually considered as predictors of hand grip and pinch strengths in people with hand OA.
3) To describe the relationship between body and hand anthropometrics (height, weight, BMI, and hand size measured as both hand span and web span), hand function, and health status in people with hand OA.
4) To determine the significant predictors when anthropometric and demographic variables are mutually considered as predictors of hand function and health status in people with hand OA.

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Chapter 2: Manuscript one

The relationship between the basic anthropometrics and hand anthropometric variables and hand strength (grip and pinch) in people with Osteoarthritis of the hand

Target Journal: *Hand Therapy (Journal of the British Association of Hand Therapists Ltd)*

CHAPTER TWO

The relationship between the basic anthropometrics and hand anthropometric variables and hand strength (grip and pinch) in people with Osteoarthritis of the hand

ABSTRACT

Study design: Cross-sectional study

Introduction: The relationship between hand anthropometry and hand strength in people with hand osteoarthritis (HOA) is not yet explored.

Purpose of the study: To examine the relationship between basic and hand anthropometric variables with hand grip and pinch strength in people with OA of the hand.

Methods: People over the age of 50 years (range 50-88 years, n=108, 87 females, 21 males) participated. The NK digits grip dynamometer was used to measure grip strength, and the NK pinch meter to measure three different types of pinch. A micrometer device in the NK Hand Assessment system was used to measure hand span and web span (i.e., 1st finger span; distance from the tip of the thumb to tip of the index finger).

Results: Weak statistically significant Pearson correlations were found between hand span, web span and grip strength in females (r = .36 and .33, p<.01). Moderate statistically significant correlations were found between hand span, grip strength, and tripod pinch strength (r = .50 and r = .49, p<.05) in males. Weak to moderate statistically significant correlations were found between web span, tripod pinch, and key pinch strength (r = .23-.45, p<.05) in males and females. Linear regression analysis revealed that hand span, sex, and age partially explain the variance in grip strength (r^2= .23, .31 and .37, respectively). Sex, web span, and age explained variance in narrow key pinch strength (r^2 = .19, .26 and .30, respectively). Web span, sex, and age minimally explain variance in tripod pinch strength (r^2 = .09, .13, and .21). Sex and web span explained variance in wide key pinch strength (r^2 = .17 and .21, respectively).

Conclusions: Age, sex, and hand size all contribute to hand grip and pinch strength in persons with HOA.

Introduction

Osteoarthritis (OA) is the most frequent joint disease, commonly affecting the hand joints[1] in particular the distal interphalangeal (DIP) joints, proximal interphalangeal (PIP) joints of the index and middle finger, and the first carpo-metacarpal (CMC) joints.[2] The American College of Rheumatology (ACR)[3] criteria facilitate classifying OA disease depending on the patient's history, physical examination, and radiographic evidence, whereas the Kellgren Lawrence (KL) grading scale is useful for grading the severity and presence of HOA.[4] A study in an older adult population estimated the prevalence of symptomatic HOA of 26% in women and 13% in men.[5] It is an age and sex dependent disorder commonly affecting females over the age of 50 years.[6] Some of the distinctive characteristics of HOA are pain, limited range of motion (ROM) especially in the 1st, 2nd, and 3rd fingers[7] leading to a decline in hand grip strength and pinch grip strength which will hinder daily activities.[6,8] Although hand strength decreases after the age of 60 years,[9] in males, hand grip strength starts to decrease more rapidly at the age of 30 and in females at the age of 50.[10] Therefore, hand grip strength decreases with dissimilarities between the sexes as we grow old. Other characteristics of HOA are bony enlargements of the finger joints (Bouchard's and Herberden's nodes) and hand deformities associated with structural abnormalities such as osteophytes.[11] Due to involvement of multiple hand joints in HOA, composite outcome measures such as hand grip strength (power grip) and pinch grip strength (precision grip) are valid measurement strategies.[102]

In clinical settings, the most commonly measured impairment is hand strength which indicates the overall physical strength, nutritional status and health of the individual.[12] Measurements of grip and pinch strength are important because they reflect the functional integrity of the hand.[13] The methodologies used in measuring hand grip strength and pinch strength vary for different population groups (children, adults, and seniors). While measuring hand grip strength several parameters are considered such as age, sex, protocol of measurement, upper extremity and body position, selection of instrument, number of trials, duration of the trial, and the condition of the individual to be evaluated.[14] A recent systematic review[15] confirms that grip strength measurement has been well validated and is a useful indicator in screening middle-aged and older adults for functional disability.

Hand grip strength measurements are influenced by various factors such as age, sex, various angles of the shoulder, elbow, forearm, and wrist joints[16-18], posture[17,19], hand span[20,21], and grip span[17,19, 20-23] whereas pinch grip strength measurement is affected by arm position (standing and sitting postures)[,24], forearm position[25], wrist position[26,27], gender, grasp type, pinch width[27], and the type of tools used at work.[28] In the early stages, some of the major characteristics of hand OA are pain, stiffness, decreased ROM and decreased hand strength leads to hand dysfunction.[29] In the final stages of HOA, the hand deformities such as Bouchard and Herberden's nodes increase. Further, this provides evidence for a decrease in joint space width, pain, and mobility in females with HOA.[30] According to the literature, there is a correlation between the severity of HOA and hand function.[29, 31-33]

Naturally, as we grow old, changes in anthropometric dimensions results in a decrease in hand grip strength and pinch grip strength. However, no reports were found in the literature on the question of the effects of basic anthropometrics or hand anthropometry to hand strength in people with HOA. One study that looked at hand span in long-term follow up of patients following CMC arthroplasty determined that hand span had low, but significant relationships (r= -.20 to -.27 and -.22 to -.36) with self-report functional measures.[93] Previous studies[21,35-37,40-42] have reported the association between basic anthropometric variables, hand anthropometric variables, and hand grip strength in healthy populations including children, teenagers, athletes, and adults and seniors.[38,39] However, very few studies[36,43] have investigated the association between hand anthropometry and pinch grip strength, particularly in different patient populations. A greater understanding of the relationship between hand size and hand strength might suggest whether future normative data or strength models in patient populations should consider controlling for hand size in addition to the more typical epidemiological demographics of age and sex. Current practice in describing normative data or clinical outcomes often considers age and sex, but rarely considers hand size.

The primary purpose of this study was to examine the bivariate relationship between body and hand anthropometric variables (height, weight, body mass index, or hand span and web span) and hand grip strength and pinch strength in people with HOA. The secondary purpose of this study is to establish the relative contribution among those variables for hand grip and pinch strengths in people with HOA.

Methods

Participants

A cross-sectional study, using secondary data, obtained from McMaster Hand and Upper Limb Laboratory (MacHANd Lab), School of Rehabilitation Science, McMaster University, Hamilton, Canada was conducted. The parent study protocol was approved by the Hamilton Health Sciences/McMaster Research Ethics Board. The participants were locally recruited by flyers, daily newspapers, notes at senior community centres, and by means of community contacts. Informed consent was obtained from all of the participants prior to testing. All participants were assessed for OA by either a physiotherapist or occupational therapist using the ACR criteria for OA of the dominant hand.

Inclusion criteria were:

Aged 50 years or older

OA involvement of the dominant hand

If the participant had not been previously identified as having OA by a health care professional (HCP) then participants were examined to identify whether HOA was present based on pain, stiffness, and swelling of two or more DIP joints, PIP joints, CMC joints, and deformities of one or more of these joints in the index and middle fingers.

Exclusion criteria

Type II diabetes mellitus

Fractures or other hand injuries (e.g., burns, lymphedema)

Finger amputation

Joint replacements in the fingers or wrist of dominant hand, and/or a diagnosis of any other rheumatic diseases

Measures

Grip strength measurements were recorded using a computerized Digits-Grip dynamometer from the NK Hand Assessment System (NKHAS) (NK Bio-technical Corporation, Minneapolis, USA). It is part of a computerized hand assessment system. The device contains four pressure sensors and is modifiable to five different handle sizes similar to a classic hydraulic dynamometer. The Digit-Grip dynamometer was set at the 2nd handle position for all participants. Neither visual feedback nor motivation by the assessor was provided during testing. The testing protocol described by the American Society of Hand Therapists (ASHT) [44] was used to standardize the grip strength measurements. Participants were instructed to be seated upright in a chair with their arms in an adducted position, with 90° degree elbow flexion and forearms in a posture of neutral rotation. Each grip strength measurement was repeated three times and the average of the three trials calculated. The Digits Grip device was recalibrated between each participant. Previous research findings into grip measurements have been reliable, consistent for the patient population or normal participants when tested.[35, 45]

Three distinct types of pinch measurements were measured using the computerized NKHAS pinch meter. These measures included a tripod pinch (also called 3-jaw chuck), wide key pinch and narrow key pinch. The tripod pinch grip engages three fingers including the thumb, index finger, and the middle finger. Key pinch grip involves the thumb positioned on the top of the radial aspect of the index finger, typically centred on the middle phalanx. The thumb and the index finger are distanced at 32 (millimeters) mm apart in the wide key pinch whereas the narrow key pinch grip was executed with the thumb and the index finger at a distance of 12 mm. Previous research findings into pinch measurements have been reliable when performed and compared to other pinch gauges using a standardized procedure.[46]

Hand span was measured using the micrometer tool and the NKHAS software. Hand span was measured as the maximal distance in mm between the tip of the thumb and the tip of the little finger.[34] Participants were instructed to "turn your palm up" and "stretch your hand out as much as possible". Visual demonstration was provided. The evaluator aligned the micrometer and activated the computerized recording via a foot pedal. Previous research using the micrometer tool found it to be a reliable measure when used to measure hand anthropometry (pulp to palm distance).[94]

Procedures for web span measurement used the same micrometer device and participant instructions. It was assessed by measuring the maximal distance in mm between the tip of the thumb and the tip of the index finger after the patient maximally spreads the index finger and thumb.

The strength of the Pearson correlation co-efficients between independent and dependent variables was interpreted using Evan's descriptive terms.[95]

Table1

Evan's guide for strength of correlations[95]

Strength	r
Very weak	0.00 - 0.19
Weak	0.20 - 0.39
Moderate	0.40 - 0.59
Strong	0.60 - 0.79
Very strong	0.80 - 1.00

r- Pearson product moment correlation

Statistical Analysis

SPSS© for Windows (IBM©, version 22) was used for data entry, data graphing and all statistical calculations. Data quality was insured by crosschecking original records with data entered into the SPSS© file in 74% of cases. The Shapiro-Wilk Test was used to assess the normality of the data. Data analysis was performed for males and females separately for strength parameters, given expected sex-based differences in strength. Means and standard deviations of anthropometric variables and hand strength variables were calculated to create the descriptive summary of participant characteristics. Pearson's correlation co-efficient '*r*' was determined to test the bivariate associations between the dependent variables of grip strength or pinch strength types and independent variables such as age, height, weight, BMI, hand span, and web span. A Pearson correlation '*r*' was considered to be statistically significant with *p*-value less than 0.05. Stepwise multiple linear regression methods were used to determine which anthropometric variables predicted grip strength and pinch strengths when considered as a multifactorial model. The co-efficient of determination (R^2) and *p*-value was used to identify the relative contribution of significant independent variables to the variation in the dependent variable.

Results

A total of 108 participants met the ACR criteria for OA of the hand: females (n=87) in the study were aged from 50 to 88 years and males (n= 21) were aged between 56 and 83 years. The average female participant was younger, shorter, weighed less, but had a higher BMI than their male counterparts. On average, the hand grip strength (t-test = -7.7, $p<.001$), tripod pinch strength (t-test= -1.1, $p<.001$), wide key pinch strength (t-test= -2.3, $p<.001$) and narrow key pinch strength (t-test= -2.2, $p<.001$) variable measurements were greater in males when compared to female counterparts. The mean hand span of females was significantly smaller (18.3 cms; SD=1.5) than the mean hand span for males at 19.8 cms;

SD=1.9 (t-test = -1.5, *p*<.001). The mean web span of the females was 13.9 cms (SD=1.6) and the mean web span for the males was 14.4 cm (SD=1.8). There was no significant sex-based difference in web span.

Association between basic and hand anthropometric variables and hand grip strength and pinch strength

The results of Pearson correlation analysis between independent and dependent variables are summarized in Table 3. Larger hand span was moderately (positively) correlated to stronger grip strength and tripod pinch strength (r = .50 and r = .49, p < .05) in males whereas larger hand span and web span was weakly correlated with higher grip strength in females (r = .36 and r = .33, p < .01). Larger web span demonstrated weak to moderate positive correlation with greater tripod pinch and narrow key pinch strength in males and females (r = .23-.45, p < .05 respectively). Among person-level anthropometric variables height had a weak, but statistically significant positive correlation with grip strength (r = .29, p<.01), narrow key pinch (r= .26, p<.05) and wide key pinch strength (r = .24, p < .01 respectively). When the sample was divided by sex it was shown that being female, of older age, or experiencing pain had a weak but statistically significant (negative) correlation with lower strength for grip strength, tripod pinch, narrow key pinch, and wide key pinch strength (r = - .32, r = -.35, r = -.30, and r = -.28; p < .01 respectively). No significant correlation was found between BMI and grip strength or any of the different types of pinch strength. The models explaining how independent demographic and anthropometric variables were related to strength (dependent) variables are summarized in Table 4. The best predictor was hand span which explained 23% of the variance of hand grip strength; web span explained 9% of the variance of tripod pinch strength. Similarly, sex explained 19% of the variance of narrow key pinch strength and 17% of the variance of wide key pinch strength.

Table 2.
Summary of participants characteristics

	Females (n=87)	Males (n=21)
	Mean (SD)	Mean (SD)
Age(years)	67.0 (8.7)	72.1 (9.1)
Height (cm)	162.3 (6.8)	175.5 (7.4)
Weight (kg)	71.2 (14.9)	78.7 (13.2)
BMI (kg/m^2)	26.9 (4.7)	25.5 (3.4)
Strength (Kgs)		
Grip strength***	12.4 (5.2)	20.1 (9.6)
Tripod pinch***	4.0 (1.6)	5.1 (1.8)
Wide key pinch***	5.4 (1.8)	7.7 (2.2)
Narrow key pinch***	4.8 (1.7)	7.1 (2.2)
Hand span (cms)***	18.3 (1.5)	19.8 (1.9)
Web span (cms)	13.9 (1.6)	14.4 (1.8)

*** Statistical significant difference. SD – Standard deviation. Cms- centimeters, kg- kilograms, n- number of participants. *Height n=86, Weight n=81, BMI n=81 only.

Table 3.
Pearson correlations between age, basic and hand anthropometric variables and grip strength and pinch strength in people with HOA.

		Age	Height	Weight	BMI	Hand span	Web span
Grip strength	Males	-0.29	0.07	-0.18	-0.24	0.50*	0.36
	Females	-0.32**	0.29**	0.03	-0.08	0.36**	0.33**
Tripod pinch strength	Males	-0.09	0.09	-0.11	-0.17	0.49*	0.45*
	Females	-0.35**	0.16	0.02	-0.03	0.15	0.25*
Narrow key pinch strength	Males	0.01	-0.22	-0.17	-0.03	0.38	0.44*
	Females	-0.30**	0.26*	0.28*	0.20	0.08	0.23*
Wide Key pinch strength	Males	0.10	-0.16	-0.13	-0.04	0.36	0.40
	Females	-0.28**	0.24*	0.21	0.12	0.12	0.13

BMI-Body mass index. Females (n=87), Males (n=21).*Correlation is significant at p<0.05 level, **Correlation is significant at p<0.01 level

Table 4
Multiple regression analysis representing the best predictors for hand grip strength and pinch strength types in people with HOA.

Model	r	r^2	β (95% CI)	Sig
Grip Strength				
Hand span	0.48	0.23	1.94 (1.25 - 2.63)	.000
Sex	0.56	0.31	5.18 (2.17 - 8.19)	.000
Age	0.61	0.37	-0.21 (-0.34 - -0.08)	.000
Tripod pinch strength				
Web span	0.30	0.09	0.31 (0.12- 0.51)	.002
Sex	0.37	0.13	0.91 (0.11- 1.72)	.001
Age	0.46	0.21	-0.05 (-.09- -0.02)	.000
Narrow Key pinch strength				
Sex	0.44	0.19	2.22 (1.33 - 3.12)	.000
Web span	0.51	0.26	0.32 (0.11- 0.52)	.000
Age	0.54	0.30	-0.04 (-0.08- -0.00)	.000
Wide key pinch strength				
Sex	0.42	0.17	2.17 (1.24 - 3.09)	.000
Web span	0.46	0.21	0.23 (0.01 - 0.45)	.000

r-Pearson product moment correlation, r^2-co-efficient of determination, β-Unstandardized co-efficient, CI- confidence interval, Sig- significance

Discussion

This study indicates that there is a weak to moderate relationship between anthropometrics and hand grip strength and pinch strength in people with HOA, where people with larger hands are able to produce larger grip and pinch strength forces. In general, hand anthropometrics were more correlated to strength than were body anthropometrics, indicating that mechanical factors related to hand size and local hand musculature were more relevant than generic indicators like height and weight. Although age and sex were predictors, when considered in multivariate analysis they were less influential than the hand anthropometric variables suggesting that part of the reasons for sex differences in strength are related to differences in body size. Since sex and age are typically considered when interpreting hand strength measures for both healthy volunteers and persons with HOA, this data suggests that greater specificity in estimating loss of strength might be possible if hand size were considered in normative data comparisons. Hand size measurements are simple to obtain quickly and with inexpensive instruments. Furthermore these measures could help hand therapists identify people likely to have difficulty with functional tasks either because of the size of their hands or the likelihood of having insufficient strength due to small hand size. It might help therapists identify appropriate strengthening goals, if the capacity for improvement based on hand size, was considered. Overall, our data suggest that formal consideration of hand size anthropometric measurement might improve clinical decision making for patients with HOA.

Few studies have considered hand anthropometrics as a contributor to hand strength and how these are affected by pathology. A study designed to evaluate the validity of self report functional measures in post-surgical patients who have undergone tendon interposition arthroplasty of the CMC joint of the thumb reported a weak negative statistically significant association between hand span and self report functional measures[93], such that people with impaired hand span measure had difficulties during functional tasks emphasizing the relationship between hand span and hand function. A recent comparative study by Sakai and Shimawaki[96] measured number of hand anthropometric parameters including hand span in pianists to explore the relationship between hand size, finger abduction angles, and the incidence of hand problems due to overuse. The results showed that the people with small hand size tended to overtly abduct and extend the thumb to gain larger hand span resulting in overuse syndrome. In addition, they required greater strength in the wrist flexor musculature to perform against the resistance of the instrument. It can thus be suggested that individuals with small hand spans are likely to be at risk, resulting in difficulty in performing functional tasks.

Other studies have evaluated the relationship between hand size and strength in healthy participants including different age groups such as children, [36] teens, [77] athletes, [37] adults, and seniors.[35] MacDermid et al.[35] investigated the effects of physical factors to grip strength and dexterity in healthy participants aged between 15 and 78 years. The results of this study showed that hand span and grip strength are strongly correlated (r = .65, p<.001) and height was more predictive of grip strength than hand span. Our study found that hand span was moderately correlated with grip strength in males but revealed a weak significant correlation in females. The most important clinically relevant finding was that females with HOA have smaller hands with decreased hand strength compared to males. Nevertheless, differences in the results between these studies can be explained by dissimilarities in sample size, age group, and stratification of sex. A possible explanation for dissimilarities of sample size in research studies between males and females may be due to the fact that prevalence and incidence of hand OA is higher in females. One multicenter OA study found that females tend to report more severe OA pain compared to males.[98] Females aged 50 to 60 years may be 3.5 times more likely to develop HOA compared to males of the same age group.[99] Hence, the findings of this study cannot be extrapolated to all age groups. Several reports have shown clear differences in disease susceptibility to many painful musculoskeletal conditions[100, 101] in males and females. Therefore, it is important to consider stratification of sex in HOA research to avoid possible sex or gender bias. Fiebert et al.[97] explored the relationship between hand size and grip strength at different handle positions using the Jamar hand-held dynamometer. Participants were physical therapy female students aged between 20 and 40 years. The results of Fiebert et al. found that a weak to moderate correlation between hand size and grip strength (*r* = .33-.50) at different handle positions (2, 3 and 4) of the dynamometer used. Hand size was measured from the tip of the middle finger to the radio carpal joint using a measuring tape with the fingers positioned wide open. In contrast, in our study, hand size or hand span was measured from the tip of the thumb to the tip of little finger with the fingers wide open. The results of Fiebert et al. found that height was strongly correlated with hand grip strength at all positions followed by hand size. Our study found weak significant correlation between the variables body height, hand span, and grip strength in older adult females with HOA; however, the findings of the current study do not support the previous research. This inconsistency may be due to the differences in the age groups in the studies. No studies were found in the literature estimating the relationship between the web span and grip strength in patient populations. Some studies have evaluated the relationship between web span and strength in healthy participants in children[36] and athletes.[42] Our study found that weak to moderate significant relationship between web span and grip strength was found in females but not in males. A possible explanation for this might be due to the sample size of females, large enough to make a small effect significant. Another possible explanation for this is the differences in the type of work among males and females. One possible explanation for why correlations would be lower in clinical populations than healthy populations is that factors related to the severity and stage of disease might be important determinants of strength in clinical populations but are not applicable to healthy controls.

Tripod pinch grip strength is one of the most common and strongest used grip types among activities of daily living.[52,87] Our study found a moderate significant relationship between hand span and tripod pinch grip strength in males but not females with hand OA. It is difficult to explain this result, but it might be related to the differences in the occupational activities in the work place between males and females, body size, and composition. Since males have a broader range of hand size and strength, it might have been easier to detect significant relationships. Our study found weak to moderate significant relationship between web span, tripod pinch grip strength and narrow key pinch strength in males and females. These results are consistent with those of Helliwell et al.[53] which reported that individuals depend mostly on tripod and lateral pinch in daily activities.[53] As expected, we found that males had larger hand grip strength and pinch grip strength values compared to females which signifies that males have more muscle mass and these results are in accord with those of previous studies.[16,48] The fact that increasing age was associated with lower grip and the majority of our pinch patterns is in accordance with previous research studies.[61-63]

Sex-based differences in strength were expected, however, the relationship between age and sex was not expected to be different between males and females. Conversely, we found that the decline in both grip and pinch strength with aging was significant for females, but not males. There are several potential reasons for this. The most likely explanation is that given the predominance of HOA and females included, our sample may have been underpowered for males, resulting in a more imprecise and underpowered association. It is also possible that hand arthritis affects males and females differently and the relationship between hand size and strength is different for males and females. For example, if women develop arthritis earlier than men, there may be an age-related moderating effect where more deterioration have happened in women, than men, as age increases. In general, the expected relationship between age and grip strength in healthy participants is curvilinear where initially increasing age is associated with stronger grip strength, followed by a flattened stage, and a gradual decline in strength that occurs in older adults.[48] Age-related changes in hand strength can also be due to increasing rates of pathology, loss of muscle mass[64,65], decrease in peripheral motor nerve conduction[66], and other factors that tend to change with age such as decreased physical activity, height, and weight loss.[67] The age where grip strength starts to decline is not totally clear. Carmeli et al.[50] claims that decline in hand strength and function occur after the age of 65 years.[50] This is supported by another study that reports grip and pinch strength measures decrease successively over the age of 65 years.[51] Height starts to decline in 4th and 5th decades of life, and typically women are more affected than men by osteoporosis.[73-75] Changes in body composition such as a loss of height (due to a decline in height of the vertebrae, transition into a kyphotic posture),[76] decrease in fat-free mass, and an increase in fat mass may be more prevalent in females. A prior study that examined the relationship between key pinch grip strength to basic anthropometrics in healthy Chinese adults found a significant positive relationship between weight and lateral key pinch strength.

Regardless of sex, hand grip strength and pinch grip strength appears to decline over the age of 50 years. As expected, our study found that age was not significantly correlated between age, hand grip strength and pinch strength. Our study findings are consistent with those of previous studies which showed negative relationships between age, hand grip strength, and pinch strength.[51, 54-60] However, this outcome is contrary to that of Mathiowetz et al.[48] who found significant relationship between age and grip strength. This rather contradictory result may be due to the large sample size (i.e., 328 females and 310 males) whereas our study included 87 females and 21 males. Another possible explanation for this might be that the age ranges of the subjects were distributed evenly. The findings of this study might have been similar if larger sample size with evenly distributed age ranges was included.

The American Society of Hand Therapy (ASHT)[44] advocates the 2nd handle position when using the Jamar hand-held dynamometer for maximum hand grip strength. Some of the previous studies reporting anthropometric relationships cited here, however, measured maximal hand grip strength with grip span position either at all 5 settings[79, 80], 2nd setting[81, 82] or have not reported a specific setting.[83, 84] There are advantages to using standardized positioning, however, previous research has established that hand size affects the grip strength in healthy participants, and this study confirms that a similar relationship occurs in people with HOA. This would suggest that if the goal is to measure maximal grip strength, the optimal position might be different for people with larger hands versus those with smaller hands. Whether future guidelines should define a specific hand size measurement by which the normative values would be tested at a different position is something that would require further study and debate.

Some of the limitations in this study are as follows; the cross-sectional study design does not allow us to make conclusions about the cause and effect relationship among dependent and independent variables. Although we expected sex-based differences and analysed our data separately for males and females when looking at bivariate relationships, we acknowledge that we had a female predominance sample. This likely reflects both a female predominance in HOA, and higher rate of female volunteerism. Consequently, our conclusions are less stable in our male data. In regression models we considered sex as a covariate, confirming that it was a significant predictor. Our study sample was recruited from the community in a single city and may not be generalizable to patients presenting in clinical practice from other regions.

In summary, this study indicates that hand anthropometrics, body anthropometrics, and sex contribute to hand strength in people with HOA. Consideration of hand size when making decisions about grip and pinch strength impairments and their relationship to functional activity may provide more accurate assessment and clinical decision making.

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CHAPTER THREE

The Relationship of the hand or body anthropometric measures with hand function and health status in people with hand osteoarthritis (HOA)

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CHAPTER THREE

The Relationship of the hand or body anthropometric measures with hand function and health status in people with hand osteoarthritis (HOA)

Abstract

The purpose of this study was to investigate the relationship between body/hand anthropometrics (height, weight, body mass index (BMI), and hand size measured as either hand span and web span) and hand function and health status in people with OA of the hand (age range 50-88 years, n=108, 87 females, 21 males). Hand span (the distance between the tip of the thumb and little finger) and web span (the distance between the tip of the thumb and index finger) were measured with a computerized micrometer from the NK Hand Assessment system (NKHAS). Hand function was measured with the Patient Rated Wrist/Hand Evaluation (PRWHE), and the Arthritis Impact Measurement Scale II (AIMS II). Health status was measured using the Short Form-36 (SF-36) Physical and Mental Component Scores (PCSS and MCSS). Pearson correlations and multiple regression were used to assess the relationships. In females, there was a weak association between higher BMI and greater difficulty with usual activities (from PRWHE) (r = .26, p<.05) and larger hand span and health status (r = .28, p<.05) SF-36 PCSS. In males, there was a moderate association between web span and SF-36 MCSS (r = .53, p<.05) and between age and SF-36 MCCS (r = .45, p<.05). When all demographic and anthropometric variables were considered as potential predictors of hand function in multivariate step-wise linear regression models, web span accounted for 4% of the variation in AIMS 2 Hand and Finger scores. Hand span accounted for 6% of SF-36 PCSS, weight explained an additional 4%, and age explained an additional of 4% for a total of 14%. These data suggest that younger age and larger web span are associated with better physical health. PRWHE scores were not predicted by demographics or anthropometrics in multivariate models.

Introduction

Hand osteoarthritis (HOA) is a common joint disease worldwide, resulting in weakened grip strength and significant functional disability.[1] It is a common disease that affects up to 40% of adults and may severely impact their health status and quality of life.[2] HOA has a great impact on daily functioning and health-related quality of life.[3, 4] Kwok et al.[5] reported a decrease in joint space width, pain, and loss of mobility in females with HOA. Clinical features such as pain and joint stiffness associated with reductions in grip strength, pinch grip strength, joint mobility, and hand function can cause substantial limitations in the ability to perform daily activities.[6] In advanced disease of HOA, altered limb alignment and hand deformities will usually increase.[7] Structural changes in the body and hand anthropometry have significant implications on hand function and health status. Previous studies have indicated that greater severity of HOA is associated with poor hand function.[1,8-10] The association between hand anthropometry and hand function and health status in people with HOA has not been investigated. In addition, literature regarding the association between hand anthropometric variables and self reported function is scarce. However, a study that evaluated hand span as a part of construct validation process that compared it to patient reported outcomes (PRO) found low but statistically significant relationships (r= -.20 to -.27 and -.22 to -.36) in patients evaluated in long-term follow up of a CMC arthroplasty.[11] Studies have reported that simple anthropometric variables can predict hand grip strength[12] in healthy individuals and in patients with rheumatoid arthritis[13], however, no studies have reported that simple anthropometric variables can predict hand function in people with HOA.

The primary purpose of this study was to investigate the relationship between body and hand anthropometric variables (height, weight, BMI and hand size measured as either hand span and web span), hand function, and health status in people with HOA. The secondary purpose was to consider how anthropometric and demographic factors in combination explain hand function and health status in people with HOA.

Methods and Materials

Sample and study design

This cross-sectional study was conducted at the McMaster Hand and Upper Limb Laboratory (MacHANd Lab), at McMaster University, Hamilton, Canada. The study protocol was approved by the Hamilton Health Sciences/McMaster Research Ethics Board and all the participants provided informed consent prior to testing. One hundred and eight participants with osteoarthritis (OA) of the hand were recruited from the community using flyers, a newspaper ad, notes at senior community centres, and by means of community contacts. All participants' dominant hand was assessed by either a physiotherapist or occupational therapist using the American College of Rheumatology (ACR) criteria for OA of the dominant hand to confirm their self-reported diagnosis of OA.

Inclusion criteria were being 50 years or older and having a confirmed diagnosis of hand OA. If the participant had not been previously identified as having OA by a HCP then participants were examined to identify whether hand OA was present using the ACR criteria.

Exclusion criteria included: a) Type II diabetes mellitus, b) fractures or other hand injuries (e.g., current or has past history of burns), c) finger amputation, d) joint replacements in the fingers or wrist of the dominant hand, and/or e) a diagnosis of any other rheumatic diseases.

Study Measures

Hand Anthropometrics

Hand span was measured using the micrometer tool from the NK Hand Assessment System (NKHAS). Hand span was measured as the maximal distance in millimeters (mm) between the tip of the thumb finger and the tip of the little finger. Patients were instructed to “turn your palm up” and “stretch your hand out as much as possible”. The evaluator aligned the micrometer and activated the computerized recording via a foot pedal. Previous research has established that the micrometer tool of the NKHAS system was a valid measure when used to measure hand anthropometry (pulp to palm distance).[14] (Appendix 1). Procedures for web span measurement used the same micrometer device and participant instructions, but measured the maximal distance in mm between the tip of the thumb and the tip of the index finger after the patient maximally spread the index and thumb.

Hand Function

Patient-rated Wrist Hand Evaluation (PRWHE)

The purpose of the PRWHE questionnaire is to assess pain and disability in wrist and hand conditions such as OA, wrist fractures, instabilities of carpal bones, tendon tears, arthroplasties,[15] distal radius fractures,[16] or scaphoid fractures.[17] The PRWHE is a self-reported 15-item, wrist/hands specific joint outcome measure that consists of two subscales: a) Pain subscale and b) Functional subscale and two optional aesthetic questions which are not counted in the 15-item questionnaire. The pain subscale consists of 5 items and the functional subscale consists of 10 items with a response scale ranging from 0 to 10 where 0 is no pain and 10 is the worst pain.[18] The functional subscale consists of 10 items each rated from 0 to 10. MacDermid et al.[11] validated the PRWHE in people with hand OA using a sample who were assessed in long-term follow up of inter-positional arthroplasty of the carpometacarpal joint of the thumb.

Arthritis Impact Measurement Scale 2 (AIMS 2)

This PRO is a modified version of Arthritic Impact Measurement Scale (AIMS) used to evaluate disability and health status in persons with rheumatoid arthritis.[19] In the current study, the hand and finger functional subscale was used. It consists of 5 items with scores ranging from 1 to 5, where 1=able to perform and 5=unable to perform. The total score is calculated by summing the item scores, subtracting 5 from the total score, and then dividing by 2. The total score value ranges from 0 to 10 with higher scores demonstrating greater disability. It has been validated[20] in patients with HOA.

Health Status (SF-36)

The SF-36 is a 36-item PRO that measures overall health status. It consists of 8 scales which includes both physical and mental health items. The scales are as follows: 1) Physical functioning (PF), 2) Role limitations due to physical health (RP), 3) Bodily pain (BP), 4) General health perceptions (GH), 5) Vitality (VT), 6) Social functioning (SF), 7) Role limitations due to emotional problems (RE), and 8) General mental health (MH). All scales and their items are recoded, computed, and transformed into a raw scale score for each scale to a 0-100 scale with high score indicating better health status. Further, using scoring algorithms we can construct Physical Component Summary Score (PCSS) and Mental Component Summary Score (MCSS) from the eight scales. In the current study, we used the PCSS and MCSS scores that were constructed from the eight scales.

Statistical Analysis

All data was entered into SPSS© (version 22) and cross checked for quality. The Shapiro-Wilk Test was used to assess the normality of the data. Data analysis was performed for males and females separately, since there are sex-based differences in body anthropometrics. Means and standard deviations of body and hand specific hand anthropometric variables and PRO measures were calculated. Pearson correlations were used to describe the bivariate relationship between anthropometric variables and the dependent hand function or health status PRO (PRWHE, AIMS 2, and SF-36). A Pearson correlation '*r*' was considered to be statistically significant (indicating a relationship greater than zero) when the '*p*' value was less than .05. To consider age and sex simultaneously with multiple, potentially correlated anthropometric variables, we used stepwise multiple linear regression to identify significant predictors of hand function and health status. The co-efficient of determination (R^2) and '*p*' value were used to determine the strength and significance of the predictors.

Results

A total of 108 participants met the ACR criteria for OA of the hand: females (n=87) in the study were aged 50 to 88 years and males (n= 21) were aged between 56 and 83 years. The average female participant was younger, shorter, weighed less, but had a higher BMI than their male counterparts. The mean SF-36 PCSS and MCSS scores of females was 38.1 (SD=9.2) and 54.2 (SD=9.4) and the mean SF-36 PCSS and MCSS scores of males was 37.4 (SD=8.3) and 49.0 (SD=13.8). The mean hand span of females was 18.3 cms (SD=1.5) and mean hand span of males was 19.8 cms (SD=1.9). There was no significant difference in web span between males and females. Demographic information including age, sex, height, weight, BMI, hand span, web span, total scores of PRWHE, AIMS 2, and aggregated SF-36 PCSS and MCSS scores are illustrated in Table 1.

Association between hand or body anthropometric variables and hand function

The relationship between anthropometric variables and PROs are summarized in Table 2.

In males, larger web span was moderately (positively) correlated with better SF-36 MCSS (r = .53, $p <$ .05). In females, there was a weak significant correlation between increasing hand span and better PCSS (r = .28; p < .05). In females, higher BMI was associated with greater difficulty with usual activities (r = .26, p<.05). In males, older age was moderately associated with better mental health (MCSS) (r = .45; p < .05). When all demographic and anthropometric variables were considered as potential predictors of hand function in multivariate step-wise linear regression models, web span accounted for 4% of the variation in AIMS-2 Hand and Finger scores. Hand span accounted for 6% of SF-36 PCSS, weight explained an additional 4%, and age explained an additional of 4% for a total of 14%. PRWHE scores were not predicted by demographics or anthropometrics in multivariate models.

TABLE 1
Summary of participants characteristics

	Females (n=87)	Males (n=21)	Total (n=108)
	Mean (SD)	Mean (SD)	Total (n=108)
Age(years)	67.0 (8.7)	72.1 (9.1)	68.0 (8.9)
Height (cm)(n=86)	162.3 (6.9)	175.5 (7.4)	164.9 (8.6)
Weight (kg) (n=81)	71.2 (15.0)	78.7 (13.2)	72.8 (14.9)
BMI (kgs) (n=81)	27.0 (4.7)	25.5 (3.4)	26.6 (4.5)
Hand span (cms)	18.3 (1.5)	19.8 (1.9)	18.6 (1.7)
Web span (cms)	14.0 (1.6)	14.4 (1.8)	14.0 (1.7)
PRWHE			
Pain	23.3 (12.3)	24.2 (13.7)	23.5 (12.5)
Specific activities	18.9 (14.7)	22.3 (16.9)	19.5 (15.1)
Usual activities	8.8 (9.5)	12.8 (11.1)	9.6 (9.9)
Total Score	37.2 (21.6)	41.8 (25.2)	38.1 (22.3)
AIMS2			
Hand and Finger Function	3.2 (2.1)	3.3 (2.6)	3.2 (2.2)
SF-36			
PCSS (n=75)	38.10 (9.21)	37.4 (8.3)	38.0 (9.0)
MCSS (n=75)	54.24 (9.48)	49.0 (13.83)	53.0 (10.7)

SD-standard deviation, kg-kilograms, cms-centimeters, n- number of participants, BMI- Body mass index, PRWHE- Patient rated wrist/hand evaluation, AIMS2 – Arthritis impact measurement scale, PCSS- Physical component score, MCSS- Mental component score.

Table 2
Pearson correlations between age, anthropometric variables, hand span, web span and PRWHE, AIMS 2 and SF36 outcome measures in people with hand OA

		Age	Height	Weight	BMI	Hand span	Web span
PRWHE	Males	-0.32	0.04	0.12	0.09	-0.28	0.03
Pain	Females	-0.02	-0.07	0.13	0.19	-0.05	-0.03
	Males	-0.20	-0.14	-0.04	0.00	-0.39	-0.37
Specific activities	Females	0.08	-0.06	0.13	0.19	-0.09	-0.00
	Males	-0.31	0.00	0.05	0.02	-0.41	-0.29
Usual activities	Females	0.05	-0.00	0.21	**0.26***	-0.07	-0.02
	Males	-0.30	0.01	0.06	0.04	-0.33	-0.16
PRWHE total score	Females	0.00	-0.10	0.10	0.18	-0.09	-0.04
AIMS 2	Males	-0.02	-0.18	-0.13	-0.05	-0.26	-0.36
Hand and Finger	Females	0.01	-0.02	0.11	0.15	-0.07	-0.06
SF-36	Males	0.08	-0.22	-0.29	-0.19	0.31	0.36
Physical component score (PCSS)	Females	-0.21	0.08	-0.17	-0.23	**0.28***	0.01
SF-36	Males	**0.45***	-0.05	-0.27	-0.26	0.32	**0.53***
Mental component score (MCSS)	Females	0.05	-0.03	0.11	0.14	0.07	-0.07

PRWHE- Patient rated wrist/hand evaluation, AIMS 2 – Arthritis impact measurement scale, BMI- Body mass index, CI- Confidence interval. Females (n=87), Males (n=21). *Correlation is significant at p<0.05 level, ** Correlation is significant at p<0.01 level

Table 3
Multiple regression analysis representing the best predictors for hand function in males and females of patients with hand OA.

Model	r	r^2	β (95% CI)	Sig
PRWHE				
Pain	Not a significant predictor			
Specific activities	Not a significant predictor			
Usual activities	Not a significant predictor			
Total score	Not a significant predictor			
AIMS 2 Hand and Finger				
Web span	0.20	0.04	-0.25 (-0.50-0.00)	0.04
SF 36 Physical Health				
Hand span	0.24	0.06	1.20 (0.19-2.21)	0.02
Weight	0.31	0.10	-0.12(-0.24- -0.00)	0.009
Age	0.37	0.14	-0.21(-0.41- -0.00)	0.004
SF 36 Mental Health	No significant predictors			

r-Pearson product moment correlation, r^2- co-efficient of determination, β- Unstandardized co-efficient, CI- Confidence Interval, Sig- Significance
Dependent variables: Patient-Rated Wrist Hand Evaluation (PRWHE), Arthritis Impact Measurement Scale (AIMS) 2 Hand and Finger subscale, Short Form 36
Independent variables: Hand span, web span, weight and age.

Discussion

This study indicates that there is a non-significant to weak relationship between selected body anthropometrics (BMI) or hand anthropometrics (hand span, web span) and hand function or health status in people with hand OA. Overall, when considering the number of comparisons and the results of the multivariate analysis, anthropometrics' provide very limited prediction of hand function and demonstrate a small association with physical health. The nature of the associations between hand anthropometrics and function were similar to those reported in validation of PROs in patients with HOA who were evaluated following surgery.[11] For females we can be quite confident that neither hand span nor web span were significantly related to scores on the PRWHE since the correlations consistently hovered near zero and the larger size of the female subsample provided greater precision. In males we can be less confident about the nature of the relationship. The correlations between hand span and subscales of the PRWHE ranged between .28 and .41, which could be potentially clinically significant. However, none of these correlations were statistically significant in the males because of the smaller sample size. For correlation coefficients, the primary determinants of significance are the size of the correlation coefficient and the size of the sample,[21] suggesting that with a larger sample this same correlation coefficient would have been statistically significant.

The current study found that in females, higher BMI was associated with greater difficulty during usual activities. This is concordant with a systematic review which found a moderate level of evidence of positive association between BMI and the development of HOA.[22] In their study, the definition of HOA was the involvement of at least one hand joint and the inclusion criterion was based on either self-reported HOA or clinical or radiographical diagnostic results. Several other studies which are not included in the systematic review, suggests a strong relationship between higher BMI and greater difficulty with usual activities or disability in the literature in older adults[23, 24] as well as in HOA patients.[25, 26] Alternatively, these correlations may reflect that these items are looking more broadly at roles and life participation rather than specific activities and the fact that obesity independently limits role participation.[34]

Few studies have investigated the correlation between hand anthropometrics and hand function and health status in people with hand OA. One study designed to evaluate the validity of self-report functional measures in post-surgical patients who have undergone tendon interposition arthroplasty of the CMC joint of the thumb reported a weak negative significant association between hand span and PROs[11], such that people with impaired hand span would have greater difficulties during functional tasks. Although the sample sizes for both studies were almost identical in numbers, the findings of the current study is contrary to that of MacDermid et al.[11] who reported weak negative significant association between hand span and PRWHE subscales. We noted a weak to moderate negative relationship in males between hand span and PRWHE subscales which was not significant. We also found that hand span and SF-36 PCSS were more related compared to PRWHE subscales. In other words, people with larger hand span are likely to have better physical health. Differences between the studies may relate to the fact that we used a sex disaggregated data analysis or that because our sample was community-based they represented a milder form of arthritis than the previously studied postsurgical population.

Although it was not our study question, we found that there was an association between older age and better mental health in the males within our study sample but this effect was not observed in women. Since cross-sectional studies are unable to determine cause and effect we can only hypothesize about why these relationships occur, and why they are different between males and females. We know that females have a higher burden of comorbid illness as they age and this may be a factor.[27] Females are also more likely to be caregivers than males which may affect their mental health. These results are consistent with a systematic review and meta-analysis study [28] by Matcham et al. which showed that females with rheumatoid arthritis had lower SF-36 MCSS compared to men. Another study reported that patients with HOA demonstrated poor mental health compared to rheumatoid arthritis patients.[3] Our study also found that people with larger web span are likely to have better SF-36 MCSS. There is no clear reason for this association, nor was mental health a focus of this study. Given the number of associations we tested, it is possible that some spurious associations were found. To mitigate this, we looked for trends where consistent findings were found across subscales. For example, the relationship between hand span and PRWHE was consistent across all subscales in males, which reduce the likelihood that it was a spurious association.

In a previous study we demonstrated that hand anthropometrics do help explain grip and pinch strength impairments.[34] Our findings in this study which are much more weakly related to function are consistent with our conceptualization of how disability evolves considering body structure and function impairments as contributing factors to activity limitations and participation restrictions, that are modified by personal and environmental factors.[29] That does not mean that body anthropometrics are not important to consider when therapists intervene since they will affect what types/size of assistive devices that might be needed, assessment of the severity of when comparing findings to normative data and targets for strength improvement with interventions.

In evaluating the validity and potential clinical relevance of our findings, some limitations should be considered. It was our intention to study community dwelling individuals since hand OA is highly prevalent,[30] not specific clinical subsamples as these have been studied in the past.[31,32] While our study adds to the literature because of this, we also acknowledge that we did not report or control for severity of HOA. Our design was a cross-sectional study design that does not allow us to make conclusions about the cause and effect relationship among outcome and predictor variables. Consistent with the epidemiology of HOA, our sample consisted primarily of females. Therefore we have less confidence in our results for males because a lower sample size reduced our precision. In multivariate models although, we included sex as a covariate, the preponderance of females may have overly influenced the analysis. We were not sufficiently powered to do a disaggregated multivariate analysis. There are many factors that might influence the relationship between anthropometrics and hand function that were not considered, such as occupational history, disease severity, recreational activities, and others [2].

In conclusion, this study set out to examine the relationship between body/hand anthropometrics and hand function and health status in people with hand OA. Different anthropometric measurements such as BMI and hand span showed significant weak association to PRWHE subscale usual activities and PCSS in females. Age and hand anthropometric variable web span showed moderate significant association with MCSS in males.

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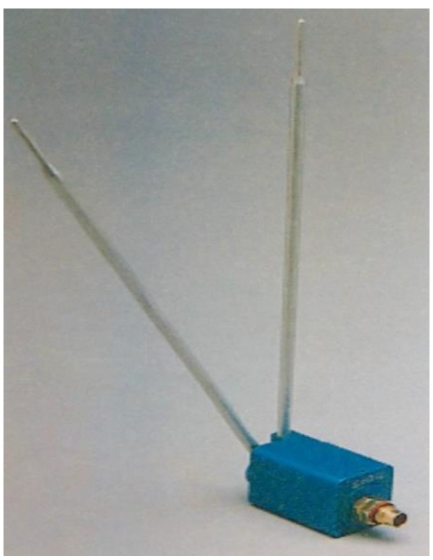
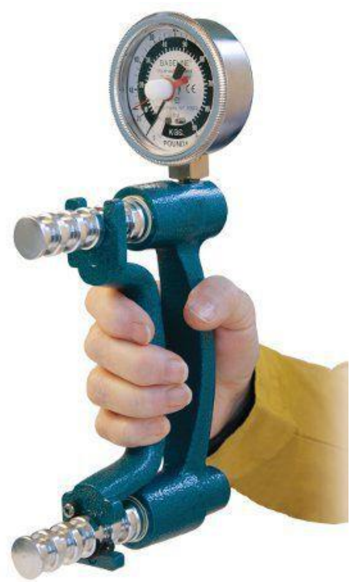
Appendix 1



Micrometer



NKHAS Digits grip dynamometer

CHAPTER 4

Thesis conclusion:

In reviewing the literature, no sufficient data was found on the relationship between hand anthropometry and hand strength and function in people with specific hand pathologies, including HOA. Previous studies have described the relationship that exists between hand anthropometry and hand strength and hand function in people with HOA after surgical reconstruction of the CMC joint. MacDermid et al.[5] found that hand span had low, but significant correlation with self-report function but this was reported in the context of instrument validation. Multiple studies conducted with healthy participants have explored the relationship between hand anthropometry and hand strength, [6-8] but little attention has been paid to examining the relationship in people with hand pathologies. The focus of this thesis was to examine the strength of relationships between hand anthropometry and hand strength and hand function in people with HOA.

Chapter two examined the relationship between body and hand anthropometric variables (height, weight, body mass index or hand span and web span) and hand grip strength and pinch strength in people with hand OA. Initial correlation analysis identified that there was a weak to moderate association between anthropometrics and hand grip strength and pinch strength in people with hand OA. Hand span and web span demonstrated a weak to moderate association with hand grip strength, tripod pinch, and narrow key pinch strength. There was a weak association between height, hand grip strength and pinch grip strength (narrow key and wide key pinch strength). Hand anthropometrics were more correlated to strength than the body anthropometrics. Regression analysis established the relative contribution among those variables for hand grip and pinch strength in people with hand OA. Hand span (23%), sex (31%) and age (37%) help to explain the variance in grip strength. Sex, web span and age explained variance in narrow key pinch strength. To a lesser extent web span, sex and age explained variance in tripod pinch strength. Sex and web span explained variance in wide key pinch strength.

Chapter 3 investigated the relationship between body and hand anthropometric variables (height, weight, body mass index and hand size measured as either hand span and web span) and hand function and health status in people with HOA. Initial correlation analysis identified that there was a weak association between the BMI and usual activities (from PRWHE) [9] and the larger the hand span the better the SF-36 PCSS in females. In addition, larger web span was moderately associated with SF-36 MCSS in males and an increase in age was associated with increased SF-36 MCCS. Regression analysis revealed how anthropometric and demographic factors in combination explain hand function and health status in people with HOA. Web span accounted for 4% of the variation in AIMS 2 Hand and Finger scores. Hand span accounted for 6% of SF-36 PCSS, weight explained an additional 4%, and age explained an additional of 4% for a total of 14%. PRWHE scores were not predicted by demographics or anthropometrics in multivariate models.

Implications of thesis study findings

The data from the hand anthropometric measurements could help hand therapists to determine the appropriateness of hand strength, better assess the need for improving it and finally, to evaluate whether the treatment plan has been successful. These measures could help hand therapists identify people likely to have difficulty with functional tasks either because of the size of their hands or the likelihood of having insufficient strength due to small hand. By considering the impact of hand size on normal scores, a therapist might better judge improvements during the development and revision of the treatment plan. Using hand size measurements health care professionals might be able to better judge whether hand strength had recovered sufficiently to normal.

Clinicians are likely to use this information to target people who might need informational resources about assistive devices or when evaluating whether functional impairments are consistent with the patient's presentation. Although such information would never be used in isolation nevertheless, it is one additional piece of information that clinicians could use in clinical decision-making.

Hand anthropometric data is critical to the design of tools for hands. In product development, (such as cell phones, mouse, assistive devices) hand tool designers might use this information to design hand-held adaptive devices to improve functional impairment, working conditions and performance. Consequently, the correct ergonomics will improve safety and health of the individual by reducing the stress on the joints.

Limitations

Our study sample primarily consisted of females (87 females and 21 males), partially due to the fact that there is a female preponderance in HOA. Additionally a larger number of females compared to the male counterparts volunteered in this study. As a result, our findings are less stable in our male data. According to Zhang et al,[1] in this age range (>70 years old), the female-male ratio in HOA sample was 2:1.[2] Therefore, since our sample was a sample of convenience and the ratio of female-male was 4:1, to some degree it reflects the normal distribution of HOA female to male ratio in the population. In a 2001 study, the prevalence of females in all age groups was higher than males.[3] Therefore, having primarily females in the study allowed for a meaningful correlation and regression output in differentiating the sex differences and also identified contributing predictors for hand grip strength and pinch strength.

The cross-sectional study design does not allow conclusions about the cause and effect relationship among dependent and independent variables. Those variables are correlated and correlation is not necessarily causation. Although there is a correlation between hand anthropometry and hand strength in addition to hand function this correlation is not by coincidence. Smaller hand span does not always cause a decrease in hand strength and function. This study has been conducted at a specific point in time and it was not a longitudinal study where the causal effect, if it existed, could have been observed over a period of time. Additionally, decrease in hand span does not acquire in all hand OA cases. There are many other factors that may contribute to the loss of hand strength. Aging is a covariate and one of the good examples of such factors.

Our study sample was recruited from the community in a single city and may not be generalizable to the full spectrum of people with osteoarthritis. The AIMS II hand and finger subscale was not intended to be used by itself. The arm function subscale has not been included in this study. In the arm function subscale of the AIMS II each question involves arm related tasks and are not specifically designed to reflect hand anthropometry. Inclusion of this subscale could have affected the results. The hand and finger subscale has been validated by MacIntyre in 2009.

People with smaller hands are likely to have poorer function. This information by itself does not necessarily provide guidance for improving function because you cannot change the size of the hands. On the other hand, in early stages of HOA, the symptoms can be managed with therapeutic exercises. In the late stages of HOA, the data from measurements can be used by the HCP to suggest assistive devices and environmental changes to accommodate the individual and provide quality of life.

As commonly stated, in self-reported surveys and questionnaires, self-reported function may not represent the actual function and in this case actual hand function. It is an ongoing limitation of studies using such self-reported tools.

Strengths

This study employed a relatively large sample size providing a stable estimate of the people with HOA in general population.

Another strength of this study was the use of standardized diagnostic and health outcome measures such as American College of Rheumatology (ACR) criteria and PRWE, AIMS, and SF-36. The NKHAS provides precise measurement since it is a computerized device that is calibrated at each use.

Although, this study used expensive NKHAS, a ruler which is inexpensive can be used in clinics.

Conclusion:

In summary, the study indicated that hand anthropometrics are simple, inexpensive clinical and research assessment measures that contribute to hand strength in people with HOA. In contrary, hand anthropometrics offers weak contribution to hand function and health status in people with HOA. Consideration of hand size when estimating whether measured grip and pinch strengths may be useful when anticipating which patients are likely to have strength related functional difficulties.

Future research would be worthwhile i) if the study sample size is large ii) with equally proportioned male and female samples iii) with an age-grouped distribution iv) other relevant variables such as grip span position for larger hands versus small hands needs to be explored. Future guidelines should define a specific hand size measurement by which the normative values would be tested at a different position is something that would require further study and debate.

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