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Pinch Span and Force: Normative Data, Requirements for Functional Tasks and Life Roles, and the Influence of Carpometacarpal Joint Osteoarthritis

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PINCH SPAN AND FORCE: NORMATIVE DATA, REQUIREMENTS FOR FUNCTIONAL TASKS AND LIFE ROLES, AND THE INFLUENCE OF CARPOMETACARPAL JOINT OSTEOARTHRITIS

by

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The three studies that form this dissertation build knowledge related to functional pinch. Study 1 provides normative data for the Baseline® 5-Position Hydraulic Pinch Meter, which may be used in clinical practice. The data collected in this study demonstrate the relationship between lateral pinch strength and age and reveal that strength decreases with age in both males and females. Through examination of the lateral pinch force produced at the 5 different pinch spans, it was found that the strongest lateral pinch strength was produced at 4-5 cm of pinch span. This information can be used by clinicians as they modify or adapt tasks for their clients for improved functional performance.

The literature indicates that 5-7 pounds of pinch force is required to complete most daily tasks (Terrono et al., 2011). Study 2 examines the use of pinch force to open 15 different food packages. It was found that males use greater than 7 pounds of force to open 5/15 items, and females use greater than 7 pounds of force to open 3/15 items. Given the decrease in lateral pinch strength that occurs with age, this information is important, as opening food packages is a basic task needed to maintain independent living.

The development of osteoarthritis in the carpometacarpal joint of the thumb has been reported in the literature as part of the aging process for many older adults. This pathology has also been associated with a decrease in hand strength. Study 3 seeks to examine the relationship

between radiographic findings and functional loss, hand strength, and pain. No statistically significant relationship has been found among these variables. However, semi-structured interviews have produced a list of many tasks that participants reported as being difficult or producing pain. Moreover, the qualitative data reveal that resiliency and persistence of the older adult participants contribute to their ability to complete daily functional tasks despite pain, difficulty, and increased time demands to do so.

Functional pinch is a complex concept important for hand function, which impacts many aspects of participation in activities of daily living and, in turn, impacts quality of life and completion of life roles. Because of this complexity and the difficulty in performing research with human subjects, pinch is challenging to research but absolutely essential for future understanding of the use of the hand for participation in functional tasks.

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CHAPTER 1

INTRODUCTION

Functional Pinch

The theme of the research that comprises this dissertation is pinch. Lateral pinch, or key pinch, is clinically described as lateral prehension or pulp-to-side pinch, which is when the thumb contacts the lateral side of the index finger (Magee, 2008). The ability to pinch is critical to hand function, as pinch strength has been correlated with independence of activities of daily living, such as performing hygiene tasks, bathing, and toileting (Bae et al., 2015). As individuals complete everyday tasks, the hand is used for pinching various objects of different sizes and shapes, which all require varied applications of force. For example, pinch is used to open and close medication bottles, food containers, and packages for grooming and personal hygiene. Pinch is used to squeeze containers, such as eyedrops and toothpaste, and pinch is also used for tasks, such as turning on and off items within the home. The literature demonstrates that pinch strength declines with age, making pinch tasks more difficult. The literature has also indicated that grip strength is correlated with frailty measures with aging (Sternang et al., 2015). Pinch could also be negatively correlated with frailty.

Individuals who have suffered an injury to the upper extremity report increased difficulty performing functional tasks that require pinch as a result of their pathology and residual limitations. Incidence of hand osteoarthritis (OA), when examining 1026 adults with a mean age of 58.9 (SD 9.9), was found in 44.2% of women and 37.7% of men and is, therefore, identified as a common problem impacting daily functional performance—most notably, a 13.7% decrease in lateral pinch strength (Haugen et al., 2011; McQuillan et al., 2016).

Pinch Assessment

Occupational therapists perform pinch strength assessment as one component of a comprehensive upper extremity evaluation, which includes shoulder, elbow, wrist, and hand. Assessment of pinch is performed to establish a baseline, to develop treatment goals, and then to monitor progress. One component of this dissertation is the examination of pinch strength using a newly developed pinch meter that assesses pinch at various pinch spans. Lateral pinch is typically assessed using the B&L Pinch Meter, which assesses pinch at a pinch span or pinch width of 2 cm. Pinch span can be described as the distance from the thumb to the lateral side of the index finger, and lateral pinch strength is the amount of force in kilograms (kg) created with lateral pinch needed to complete a task. The Baseline® 5-Position Hydraulic Pinch Meter allows pinch strength assessment at five different pinch spans but has not been tested to demonstrate interrater reliability. The meter is also lacking normative data using health subjects, which would be useful in clinical practice to clarify at which pinch span the greatest force is produced. Since many functional tasks require pinch force at various spans, knowing the optimal pinch span for lateral pinch could provide clinicians with valuable information when modifying tasks for clients or when building up handles or utensils. Previous literature about which pinch span produces the greatest force has provided conflicting results.

Impact of Arthritis on Pinch

This dissertation provides information to improve understanding of the relationship between osteoarthritis of the base of the thumb and pinch strength. Hand osteoarthritis is a very common problem impacting functional pinch, and its incidence increases with age (Haugen et al., 2011). Specifically, the thumb carpometacarpal (CMC) joint is often affected by osteoarthritis. Approximately 15% of the population older than 30 years of age suffer negative

effects, and in post-menopausal women, that number increases to 33% (Higginbotham et al., 2017). This is because one pound of force produced with pinch translates to 13 pounds of force at the CMC joint of the thumb resulting in wear on joint integrity (Berger & Meals, 2015).

Pereira et al. (2011) performed a systematic review of the prevalence of osteoarthritis and discovered that the greatest incidences of OA are found in joints of the hand. Despite this finding, Towheed (2005) reported an insufficient amount of research pertaining to the clinical impact of OA of the hand, while OA in the knee joint is the most researched. Zhang et al. (2002) links OA in the hand with functional impairment, pain, instability, deformity, and loss of range of motion. Villafane et al. (2012) assessed individuals with CMC OA of the thumb and found decreased strength with increased pain, depression, and anxiety. Relevant knowledge on how thumb CMC osteoarthritis impacts quality of life, role performance, and life satisfaction, as well as the negative impact on functionality, would aid occupational therapists in providing treatment from a more holistic perspective. Additionally, it would be important to have a greater understanding of the relationship between severities of arthritic changes as evidenced by x-ray and the functional limitations associated with thumb CMC OA and the impact on life satisfaction. It is quite possible that the two may not correlate.

Relationship of Pinch with Functional Demands

An additional component of this dissertation is to provide greater understanding of the pinch force required to complete functional tasks. Since arthritis can result in a decrease in pinch strength, as well as functional impairment, it is also important to know which activities an individual can perform given their current level of strength (Dedeoglu et al., 2013; Villafane et al., 2012). Even though pinch is assessed as part of a clinical evaluation of the upper quadrant, it is not clear how impairment of pinch strength impacts functional performance. To improve this

understanding, the literature would need to identify the pinch force required to complete several daily functional tasks. Smaby et al. (2004) examined pinch force needed to complete six tasks (inserting/removing a plug, using a key, using an ATM card, operating a zipper, stabbing food with a fork, and using a remote control) and found that a large range of force was required to complete these tasks (1.4N – 31.4N). Rice et al. (1998) used sensors to identify the force needed to spray an aerosol can of air freshener, open pill bottles, and push a spray bottle. They found weak correlations between grip and pinch strength and the force used to open containers successfully. These tasks comprise only a small portion of functional tasks completed requiring pinch force at various pinch spans and do not identify the pinch force required to open various types of food packages.

Terrono et al. (2011) reported that a person needs 20 pounds of grip strength and 5-7 pounds of pinch strength to complete most daily activities. There is limited evidence identifying the pinch force needed to complete various activities of daily living or to open various types of food packages. Food packages need to have a strong enough seal to prevent spoilage but not so strong as to prevent opening. Many older adults have difficulty opening food packages. However, even though older adults comprise the fastest growing segment of the U. S. population, the development of easy to open food packaging has been overlooked by the food industry (Costa & Jongen, 2010; Hensel, 2012). Sixty-one percent of participants over 60 years of age reported asking for assistance to open food packages, while 74% of those with weakness in their arms, wrists, or hand reported asking for assistance (Duizer et al., 2009). This is of even greater importance given that the number of persons aged 60 and over is approximately 810 million globally and is expected to increase to more than 2 billion by 2050 (United Nations, 2012).

Summary

The ability to use our thumb and perform pinch tasks is what separates humans from most other members of the animal kingdom. Pinch is commonly assessed by therapists during evaluations of the upper quadrant. However, it is not clearly understood how much pinch force is required to perform various functional tasks, such as opening food packages. It has been clearly identified in the literature that the diagnosis of osteoarthritis results in a decline in pinch strength and independence in the activities of daily living, as well as that loss in pinch strength is positively correlated with age. At a time in which the aging population is experiencing tremendous growth, the healthcare environment is examining methods to decrease healthcare costs. Aging is accompanied by falls, fractures, weight loss, and frailty (Tabue-Teguo et al., 2017). Bollwein et al. (2013) demonstrated that up to 90% of malnourished elderly people are more frequently frail and Verlaan et al. (2017) have indicated that malnutrition and frailty impact independent living. Additional examination of the relationship between pinch span and pinch force, the impact of osteoarthritis on pinch and its effect on quality of life and performance of life roles, and examination of the pinch force to open food packages at various pinch spans may contribute to the body of knowledge to impact nutritional frailty with aging.

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CHAPTER 2

NORMATIVE DATA FOR THE BASELINE® 5-POSITION HYDRAULIC PINCH METER AND THE RELATIONSHIP BETWEEN LATERAL PINCH STRENGTH AND PINCH SPAN

Introduction

Humans possess opposable thumbs, which separate us from most other members of the animal kingdom, and can oppose to a greater degree than other primates, such as apes and some monkeys. Humans have more muscles that go into the thumb as compared to other primates, which allows humans to have greater manipulative abilities to pinch items, operate tools, pick up small objects, and even eat with one hand.[1] As pinch is critical to hand function, assessment of pinch strength is one component of a comprehensive evaluation of the upper extremity, including shoulder, elbow, wrist, and hand. The typical pinch meter used in clinical practice is the B&L Pinch Meter (B&L Engineering, Santa Ana, California). This is a spring-loaded pinch meter used for assessing static pinch strength. Mathiowetz et al. (1985) published normative data using the B&L Pinch Meter for lateral pinch, three-point pinch, and two-point pinch with a sample size of 628 participants.[2] These norms, which are more than 30 years old, are used by both occupational therapists and physical therapists to compare patients' data based on sex and age. Therapists use this comparison to determine if a significant variance is present, which, in turn, guides the creation of patient goals, as well as the determination of progress made during the rehabilitation process. While there is a smaller study from 2013 by Phillips et al., which published normative data for grip and pinch using Michigan workers in an automotive and health care setting, the norms from Mathiowetz et al. remain the most commonly used norms for pinch strength in practice.[2,3]

Evaluation of pinch strength may be used as a factor in determining the success of a surgical approach or a therapeutic intervention and may also be used to predict the degree to which a patient will be able to perform activities of daily living, work tasks, and leisure pursuits. Normative data for pinch strength were published in 2016 by Fain and Weatherford, but those researchers examined only young adults between the ages of 20-34 in their sample of 237. These authors compared their findings to the norms from 1985 typically used in practice and found that all male groups demonstrated lower lateral pinch strength, and females demonstrated a slight increase in lateral pinch strength compared to previous norms.[4]

Lateral pinch, or key pinch, is clinically described as lateral prehension or pulp-to-side pinch during which the thumb contacts the lateral side of the index finger.[5] Lateral pinch strength is required to complete many functional tasks in daily life, such as turning a key, squeezing a tube of toothpaste, closing a Ziplock bag, and opening a bag of chips. Pinch strength is also required for many work and leisure tasks that can require different pinch spans. Objects that are pinched during functional tasks are of varied sizes and shapes, creating a greater or smaller distance/span or pinch width. Pinch span can be described as the distance from the thumb to the lateral side of the index finger, and lateral pinch strength is the amount of force in kilograms (kg) created with lateral pinch needed to complete a task.

Previous research has attempted to describe at which pinch width or span individuals are able to produce the greatest amount of pinch force. This literature is conflicting, however, as some authors reported that the greatest force is produced at the smallest pinch span, and some reported that it is produced at the larger pinch span. Researchers had to fabricate different types of apparatus to assess pinch strength at various pinch spans because a pinch meter at multiple spans was not yet available, which could account for the variance in findings. In 1996 Dempsey

and Ayoub fabricated a custom made pinch grip dynamometer and assessed various pinch spans using 16 subjects.[6] The authors concluded that lateral pinch strength increased as the pinch span increased from 1 to 5 cm, and then decreased at 7 cm of pinch span. Imrhan and Rahman developed a custom pinch meter apparatus in 1995, which was attached to a Chatillon digital push/pull force gauge and assessed pinch strength at 7 different pinch spans (2.0, 3.2, 4.4, 5.6, 6.8, 8.0, & 9.2 cm) with 17 right-handed male subjects. The strongest pinch force was produced at the smallest span of 2.0 cm, and the weakest pinch was demonstrated at the largest span of 9.2 cm with a decline between these two points. However, no statistically significant difference in pinch strength was found between the spans of 2.0 cm and 5.6 cm.[7] Shivers et al. assessed 40 subjects' lateral pinch strength at 11 levels of pinch span by fabricating a pinch apparatus with a wooden frame and attaching it to a B&L Pinch Meter by using a pulley system. Researchers found a consistent trend of increasing lateral pinch force with greater pinch span.[8] Shih and Ou assessed pinch strength at pinch spans of 2, 4, 6, and 8 cm and found that pinch force increased from 2 to 6 cm of pinch span and then decreased at 8 cm of pinch span.[9] Razza et al. assessed lateral pinch strength at 1 mm, 2 cm, and 4 cm of pinch span with 60 subjects and found that the greatest amount of force was produced at 2 cm of pinch span.[10] These findings were similar to those of Imrhan and Rahman and Dempsey and Ayoub.[6,7] Recently, Shurrab et al. assessed pinch strength at two positions of pinch spans (3.8 cm and 6.8 cm) with 46 healthy college students and found that, as pinch width increased, pinch force also increased in both males and females.[11]

The Baseline® 5-Position Hydraulic Pinch Meter was created by Fabrication Enterprises (FEI) and allows pinch strength to be assessed at the varied pinch spans of 2 cm, 3 cm, 4 cm, 5 cm, and 6 cm. The purpose of this study was to establish some metrics to determine whether this gauge can be considered for standardized assessment results. This study focused on interrater

reliability and examination of the pinch span where the greatest amount of lateral pinch force is possible for most people. It was hypothesized that the intraclass correlation (ICC) would be moderate to high, indicating acceptable agreement between raters. It was also hypothesized that the pinch force created with 5 different pinch spans would produce a bell-shaped curve—similar to what was produced with the Jamar Hand Dynamometer when used to test grip strength. The assumed benefit of the 5-position pinch meter is that not only would it allow identification of the maximum pinch force produced at varied pinch spans, but it might also be considered an evidence-based tool used to assess pinch strength in the clinical environment. To identify the value of this pinch meter in clinical practice, an additional purpose of this study was to determine if there was a statistically significant difference in pinch force produced at the 5 different positions of the pinch meter and to provide normative data for clinical use. Additionally, this study sought to determine if there was an interaction between pinch span strength, age, and sex.

Methods

The study received approval from the Human Subject Institutional Review Board (HSIRB) through Western Michigan University (WMU). There are no financial or personal relationships between the authors and Fabrication Enterprises Incorporated (FEI)—the manufacturer of the Baseline® 5-Position Hydraulic Pinch Meter. FEI did provide the researchers with three pinch meters for use with data collection, which were returned following completion of the study.

Reliability

Prior to the collection of normative data, interrater reliability testing was performed using ten volunteer second-year occupational therapy graduate students, who were recruited from the

Occupational Therapy Program at WMU. Eighteen teams of two were created, pairing the students into unique teams, with each student on at least two teams for comparison scoring. Data collection of interrater reliability occurred on the campus of Western Michigan University in downtown Grand Rapids, Michigan. Students were trained in the proper testing procedures to assess lateral pinch strength advocated by the American Society of Hand Therapists (ASHT), and they performed lateral pinch strength testing using the Baseline® 5-Position Hydraulic Pinch Meter. Other graduate occupational therapy students served as the subjects for this interrater reliability study. Raters were instructed to round up when reading the instrument to improve consistency in scoring. An overall intraclass correlation (ICC) was calculated.

Participants

Subjects for normative data collection for the Baseline® 5-Position Hydraulic Pinch Meter were recruited from various socioeconomic status levels across several locations in West Michigan, such as fitness centers, senior centers, restaurants, factories, and academic settings. Written consent was obtained from a member of the management team at each facility prior to data collection. Additional authorization was obtained through WMU's HSIRB for each additional location.

The sample was stratified into seven age groups by decades and by sex. A power analysis was performed using G Power, indicating that a sample size of 38 adults per age group per sex was appropriate to detect a moderate effect size (0.30) at 95% power with an alpha of 0.05. Males and females were divided into seven groups, each indicating a sample needed of 532.

A recruitment script was followed during all recruitment activities. Written consent was obtained from all participants following approved HSIRB procedures. Subjects were included in the study if they were at least 18 years of age and were developing typically and healthy.

Exclusionary criteria include any neurologic history (peripheral or central), any injury to the upper quadrant for which medical attention was sought within the last year, or any long-standing orthopedic issue that could impact pinch strength, such as a tear/injury to the ulnar collateral ligament of the thumb or congenital deformity.

Testing Procedures

Occupational therapy graduate students in their second year of study assisted the primary investigator with subject recruitment and data collection. Students were trained in recruitment, the written consent process, and testing procedures. Testing procedures recommended by the American Society of Hand Therapists were followed: subjects were seated, feet flat on the floor, elbow flexed at 90 degrees next to their side (glenohumeral joint adduction) with their thumb towards the ceiling (forearm in neutral), and wrist in slight extension. The arm was not supported by an armrest or by the examiner. Although Fabrication Enterprises Incorporated indicates that the Baseline® 5-Position Hydraulic Pinch Meter can be used to assess tip, palmar, and lateral (key) pinch, only lateral pinch was assessed during this research project. The weight of the pinch meter is approximately 3 pounds, and a majority of that weight is in the gauge portion of the meter. When holding the forearm in a neutral position for tip and palmar pinch, as recommended by ASHT, the gauge portion of the meter was then positioned against gravity placing stress to the hand during pinch. Therefore, only lateral pinch strength was assessed in both hands with three trials in each of the 5 positions measured at 2 cm, 3 cm, 4 cm, 5 cm, and 6 cm in pinch span with a rest period of 15 seconds between each trial. Testing alternated between the right and the left hand. This resulted in a total of 30 scores, and 15 for each hand. Scores for the three trials were then averaged for a mean score at each pinch span (10 mean scores, 5 per hand).

The position of the thumb metacarpal (MP) and interphalangeal (IP) joints in flexion, extension, or hyperextension were not controlled during lateral pinch testing. This testing protocol was used since a previous research study assessed 109 student subjects using lateral pinch to identify the various joint angles of the MP and IP joints during pinch, and found pinch pattern did not demonstrate any statistically significant differences in force with any of these positions.[12]

Occupational therapy second-year graduate students were used to assist with data collection for both the interrater reliability testing and the collection of normative data. Occupational therapy students were previously found to be reliable raters of pinch strength in a study conducted by Lindstrom-Hazel et al. (ICC between .949 and .990).[13] Schreuders et al. studied differences in grip and pinch measurements when performed by an experienced or an unexperienced examiner and found no differences in the raters' measurements.[14]

Data Analysis

All data was analyzed using IBM SPSS Statistics (version 24) by age and sex categories to develop normative standards. Sex and age were used as between-subjects independent variables. Lateral pinch strength at 5 different pinch spans bilaterally was included in the study as a within-subjects independent variable. The dependent variable used in the study was lateral pinch strength measured in kilograms of force. Box plots were examined to identify significant outliers and the Shapiro-Wilk test was used to assess if the dependent variable was normally distributed. Mauchly's test of sphericity was used to examine the variance of the differences between groups. Descriptive statistics were used to generate normative data and to identify at which pinch span level subjects demonstrated the greatest amount of pinch strength.

A one-way repeated measures analysis of variance (ANOVA) was utilized to determine whether there were any statistically significant differences between the means of the 5 different pinch span levels bilaterally. Effect size was calculated using partial eta squared. The Bonferroni post-hoc test was used for testing all pairwise comparisons of levels of the within-subjects factor.[15] A three-way mixed ANOVA was utilized to understand group differences/interaction between the within-subjects factor (pinch span levels where groups were formed by the combination of two between-subjects factors (age category and sex). Statistical significance was set at the customary level ($\alpha<.05$).

Results

Interrater Reliability

The Baseline® 5-Position Hydraulic Pinch Meter showed excellent interrater reliability (ICC = .981) among the 18 teams comprised of different combinations of the 10 raters.

Participants

A total sample of 605 healthy subjects of varying socioeconomic statuses were recruited from West Michigan, including 292 males and 313 females with an age range of 18 to 104 years old.

Descriptive Data

The mean scores and standard deviations for pinch/span level based on age and sex are presented in Table 1 for the right hand and in Table 2 for the left hand. Table 3 shows the mean range of pinch scores obtained at each pinch span/level to demonstrate the clinical relevance of the data. The pinch span/level where the greatest force was created was at the 3rd level (4 cm in pinch span) using the left hand for both males and females, at the 4th level (5 cm in pinch span)

for males using their right hand, and at the 3rd level (4 cm in pinch span) for females using their right hand (Table 2).

Table 1. Table of sample stratified by age categories measured in kilograms of force. The mean and SD, as well as the sample size for males and females bilaterally. (Right Hand)

Men		**Level 1**		**Level 2**		**Level 3**		**Level 4**		**Level 5**	
Age Group	**N**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
18-29	55	10.5	2.1	11.2	2.2	11.4	2.2	11.4	2.2	11.4	2.3
30-39	39	11.0	1.9	11.6	2.4	11.9	2.4	12.0	2.5	11.8	2.3
40-49	39	11.4	2.1	11.8	2.1	12.7	2.2	12.7	2.4	12.6	2.2
50-59	38	10.4	1.6	11.2	1.7	11.5	1.6	11.4	1.7	11.2	1.5
60-69	43	9.8	1.9	10.4	2.1	10.7	2.1	10.9	2.0	10.8	2.1
70-79	39	8.4	2.0	9.3	2.1	9.4	2.0	9.4	2.0	9.3	2.1
80+	39	6.7	1.5	7.2	1.7	7.3	1.6	7.3	1.8	7.2	1.7
Women		**Level 1**		**Level 2**		**Level 3**		**Level 4**		**Level 5**	
Age Group	**N**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
18-29	73	7.1	1.1	7.5	1.1	7.5	2.2	7.5	1.2	7.3	1.2
30-39	38	7.7	1.5	8.3	1.4	8.4	1.5	8.3	1.5	8.3	1.7
40-49	38	7.3	1.4	7.6	1.5	7.8	1.4	7.8	1.5	7.8	1.3
50-59	40	7.0	1.4	7.6	1.7	11.5	1.6	7.7	1.7	7.7	1.6
60-69	38	6.1	1.3	10.3	2.1	6.6	1.2	6.7	1.1	6.8	1.1
70-79	38	5.9	1.2	6.2	1.4	6.4	1.3	6.5	1.3	6.4	.91
80+	48	5.1	1.8	5.3	1.8	5.4	1.8	5.5	1.8	5.7	1.8

Table 2. Table of sample stratified by age categories measured in kilograms of force. The mean and SD, as well as the sample size for males and females bilaterally. (Left Hand)

Men		**Level 1**		**Level 2**		**Level 3**		**Level 4**		**Level 5**	
Age Group	**N**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
18-29	55	10.3	2.2	11.0	2.0	11.0	1.9	11.0	2.2	11.0	2.1
30-39	39	10.7	2.0	11.1	2.0	11.1	2.0	11.1	1.9	11.1	2.0
40-49	39	11.2	2.3	11.9	2.4	12.0	2.5	12.0	2.6	11.8	2.8
50-59	38	10.4	1.5	10.9	1.6	11.0	1.5	11.0	1.5	11.2	1.5
60-69	43	9.3	1.9	9.8	2.0	10.1	2.0	10.0	1.9	10.0	1.8
70-79	39	8.2	1.9	8.7	2.0	8.8	1.9	8.8	1.7	8.8	1.9
80+	39	6.2	1.7	6.5	1.8	6.4	1.9	6.6	1.8	6.6	1.9

Table 2. Continued											
Women		**Level 1**		**Level 2**		**Level 3**		**Level 4**		**Level 5**	
Age Group	**N**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
18-29	73	6.8	1.2	7.1	1.2	7.2	1.1	7.1	1.1	6.9	1.2
30-39	38	7.4	1.2	7.7	1.2	7.7	1.4	7.6	1.3	7.6	1.4
40-49	38	7.1	1.6	7.3	1.5	12.0	2.5	7.4	1.3	7.3	1.2
50-59	40	10.4	1.5	7.2	1.8	7.3	1.8	7.3	1.7	7.4	1.7
60-69	38	9.3	1.9	6.0	1.3	6.1	1.4	6.1	1.2	6.1	1.2
70-79	38	5.8	1.0	5.9	1.1	6.0	1.1	6.2	1.1	6.2	1.1
80+	48	4.7	2.5	4.9	1.5	5.1	1.6	5.1	1.8	5.2	1.8

Table 3. The lowest and highest mean lateral pinch strength score obtained from the various pinch spans/levels, and the span/level that produced the greatest amount of force.

Population	**Lowest Strength (measured in kilograms)**	**Highest Strength (measured in kilograms)**	**Pinch Span with Greatest Force**
Males R Hand	9.77	10.77	Level 4
Females R Hand	6.62	7.16	Level 3
Males L Hand	9.51	10.12	Level 3
Females L Hand	6.37	6.69	Level 3

Data Analysis

The assumption of normality was violated using the Shapiro-Wilk test. However, ANOVA is considered robust to deviations from normality. Following visual inspection of box plots, only two data points were noted to be extreme outliers out of 18,150 data points. Thus, outliers were not removed for data analysis. The assumption of sphericity was violated through examination using Mauchly's test of sphericity, indicating a heterogeneous sample. As a result, the Greenhouse-Geisser correction was used when interpreting results.

A one-way repeated measures ANOVA was conducted to determine whether there was a statistically significant difference in kilograms of force pinched at 5 different pinch spans with the left and the right hand. There was a statistically significant difference in pinch force created

when subjects pinched the Baseline® 5-Point Hydraulic Pinch Meter at 5 different pinch spans (Table 4). Post-hoc testing using a Bonferroni adjustment for simple contrasts shows significant differences in the right hand for both males and females between the 1st level on the pinch meter (pinch span of 2 cm) when compared with the 2nd, 3rd, 4th, and 5th levels and when the 2nd level on the pinch meter (pinch span of 3 cm) when compared to the 3rd and 4th levels. When using the left hand for both males and females, there was a significant difference only with the 1st level of the pinch meter when compared to the 2nd, 3rd, 4th, and 5th levels (See Figure 1). However, all other comparisons were not statistically significant.

Table 4. Results of ANOVA.

Population	df	F	Sig.	Partial Eta Squared
One-way mixed ANOVA				
Males R Hand	2.49, 725.21	87.68	p<.001	.23
Females R Hand	2.15, 670.21	47.49	p<.001	.13
Males L Hand	2.38, 692.99	37.08	p<.001	.11
Females L Hand	2.04, 636.56	20.74	p<.001	.06
Two-way mixed ANOVA (pinch spans/levels and sex)				
R Hand	2.37, 1400.65	12.76	p<.001	.021
L Hand	2.26, 1332.74	6.32	p<.001	.011
Three-way mixed ANOVA (pinch spans/levels and sex and age)				
R Hand	14.22,1400.65	.91	p=.552	.009
L Hand	13.53, 1332.74	.55	P=.899	.006

A three-way mixed ANOVA was used to examine a three-way interaction between age categories, pinch span/level, and sex, as previous literature demonstrates clear differences in strength between men and women. There were no significant three-way interactions between age category, pinch spans/levels, and sex. However, a statistically significant two-way interaction was identified between pinch spans/levels and sex (Table 4). This interaction is graphed in

Figures 5 and 6. The magnitude of pinch force produced at the 5 different pinch spans differs slightly based on sex. For the right hand, men demonstrated an increase in force from spans 1 to 2, which then leveled off across spans 3 to 5, while women demonstrated an increase in force from spans 1 to 3, which then decreased at spans 4 and 5. For the left hand, the men's force was relatively stable across all 5 spans, while women were more variable in the force they generated across the 5 spans.

Discussion

The overall aim of this cross-sectional study was to use descriptive data to develop norms for adults when using the Baseline® 5-Position Hydraulic Pinch Meter. A one-way repeated measures ANOVA was used to determine if there was a statistical significance between the 5 different pinch spans/levels, which could aid in deciding if the Baseline® 5-Position Hydraulic Pinch Meter may be warranted for clinical use. Even though a statistically significant difference was found between the 5 different pinch spans/levels, a small effect size was noted for both males and females bilaterally. Additionally, when looking at the clinical relevance of the difference in force produced between the various pinch spans/levels, males using their right hand demonstrated a mean difference in pinch strength of 1.00 kilograms of force and females .54 kilograms of force. When using the left hand, males produced a mean difference of .61 kilograms of force between the various pinch spans and females .03 kilograms of force (Table 3).

Our findings identified the greatest pinch force to be generated at 4-5 cm of pinch span, which was similar to the findings of Dempsy and Ayoub, who found the greatest pinch strength to be produced at 5 cm of pinch span.[6] However, our findings conflict with much of the previous literature, such as Imrhan and Rahma and Razza et al., who found the greatest pinch strength to be produced at 2 cm of pinch span.[7,10] Shih and Ou found the greatest pinch strength to be

produced at 6 cm of pinch span.[9] Heffernan and Freivalds found the greatest force to be produced at 1.27-3.81 cm of pinch span, and most recently, Shurrab et al. found the greatest amount of pinch force to be generated at 3.8 cm of pinch span.[11,16] These previous studies were all performed using some type of apparatus to measure pinch force that would be difficult to reproduce, and all were performed using much smaller sample sizes, which made it difficult to make comparisons between these previous studies and the present one. Identification of the pinch span, which demonstrates the greatest amount of pinch force, could be helpful to clinicians when modifying activities for clients, as well as when developing tools that require pinch. For example, the Baseline® 5-Position Hydraulic Pinch Meter could be beneficial to clinicians when identifying at which pinch span a specific patient demonstrates the strongest amount of pinch force, which, in turn, could give the clinician valuable information prior to modifying tasks or building up handles or utensils.

Mathiowetz et al. found lateral pinch strength scores to be stable for adults 20 to 59 years of age and then demonstrated a gradual decline from age 60 to age 79.[2] Our results demonstrate that females included in this sample produced the greatest amount of lateral pinch strength within 30-39 years of age and then demonstrated a slight decline. Males included in the present sample demonstrated their greatest amount of lateral pinch strength within 40-49 years of age and then had a decline, although with a greater slope (Figure 2). This information would provide greater clinical relevance if we knew the amount of lateral pinch strength required to complete many of our basic activities of daily living, allowing clinicians to predict which pinch tasks may be difficult with increasing age as strength declines.

Although both occupational and physical therapists assess pinch strength as part of a comprehensive evaluation of the upper quadrant, little research has been done to identify the

pinch force required to complete many functional tasks. The use of sensors to determine the pinch strength required to complete many activities of daily living at various pinch spans would be beneficial for clinicians to identify patients' return to function. It would also be beneficial to examine how pinch at various spans is impacted by pathology, such as osteoarthritis of the carpometacarpal joint of the thumb.

Study Strengths and Limitations

The Baseline® 5-Position Hydraulic Pinch Meter was found to demonstrate excellent interrater reliability. The large sample size is a strength of this study, as well as the clinical experience and credentials of the primary investigator. Additionally, the study methodology provides specific details regarding data collection, which allows for reproducibility.

However, there were several practical and methodological limitations of this study. First, given that subjects with a larger hand size may have been able to perform differently when pinching the meter as compared to subjects with a smaller hand size, researchers could have measured hand size and controlled for this variable in analysis. This could have been especially relevant when pinching the meter at the 4th and 5th levels of pinch span. Although the sample size of the study was significant, it was a convenience sample because all subjects were from West Michigan. When examining assumptions for the use of ANOVA, there were limitations of problems with normality; however, ANOVA is robust to violations of normality. Although the assumption of sphericity was violated, the Greenhouse-Geisser correction was used in response. Only minimal outliers were noted among the 18,150 data points. Given differences in occupations, functional requirements, and hand size, some variability in pinch scores would be expected.

An additional limitation with this study is that, although there was a small amount of difference in strength produced at each of the different levels of the 5-position meter, we don't know the impact of a .03 – 1.00 kilograms difference in strength on functional performance since this has not been demonstrated in the literature. We assess pinch strength in the clinical environment, but as treating therapists, we don't know how this translates to success with activities of daily living.

Conclusion

The clinical environment is becoming increasingly demanding for both assessments and interventions to be provided in a timely fashion to reduce cost. Assessing lateral pinch strength at 5 different pinch spans bilaterally is time consuming and not likely to be worth this increased time, given the limited difference produced between the various pinch spans. Although therapists include pinch assessment as part of a thorough assessment of the upper quadrant, obtaining more information regarding the strength required to complete many functional tasks will allow therapists to better predict a return to functional performance, identify relevant and achievable goals, and ensure a treatment plan that is occupationally based.

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Daniel O'Toole, Kathleen Parker, Chanel Raddatz, Kevin Reineck, Shibani Thaker, and Andrew Wiles.

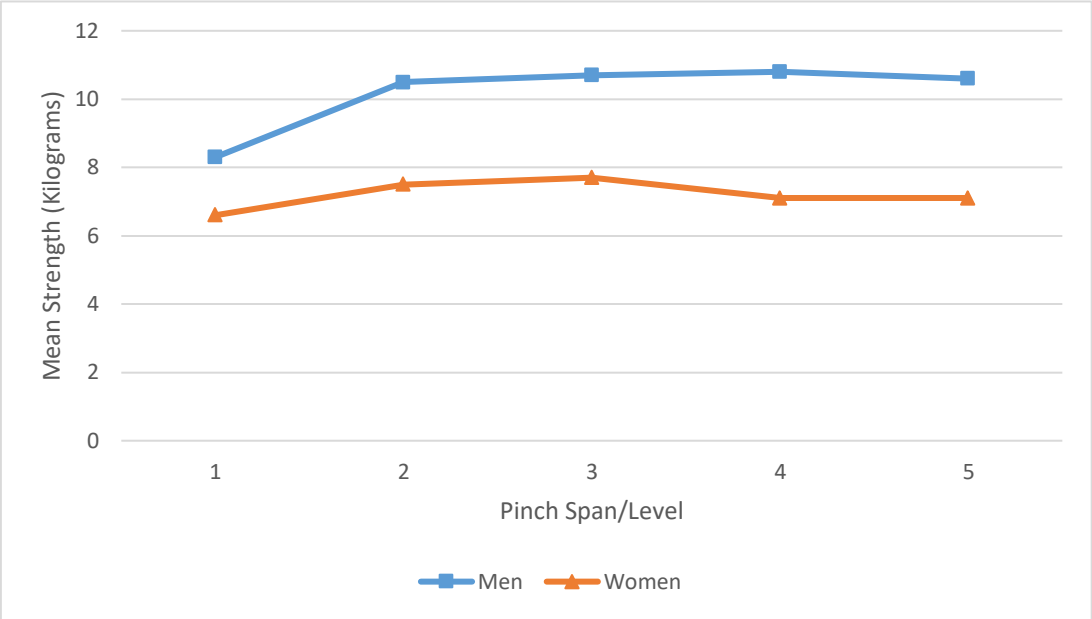


Figure 1. Mean lateral pinch strength using right hand for males and females at the 5 different pinch spans/levels.

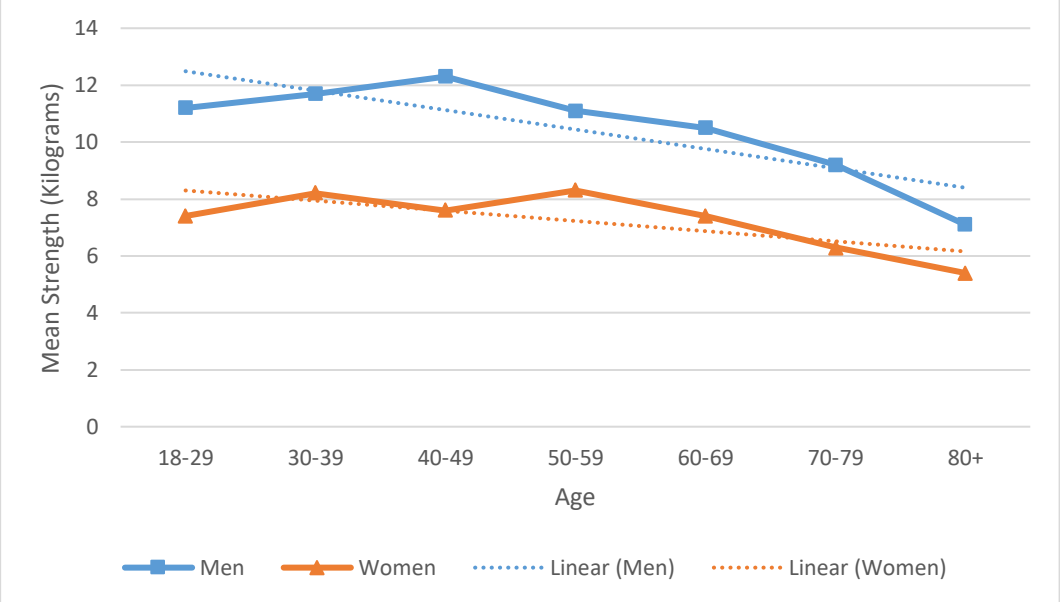


Figure 2. The relationship between lateral pinch strength and age for both males and females.

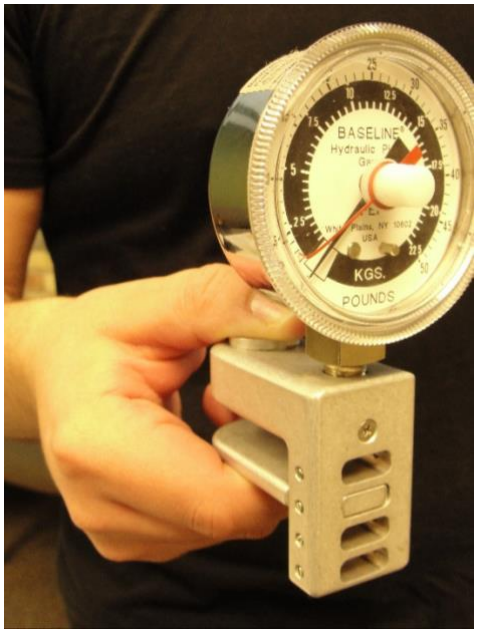
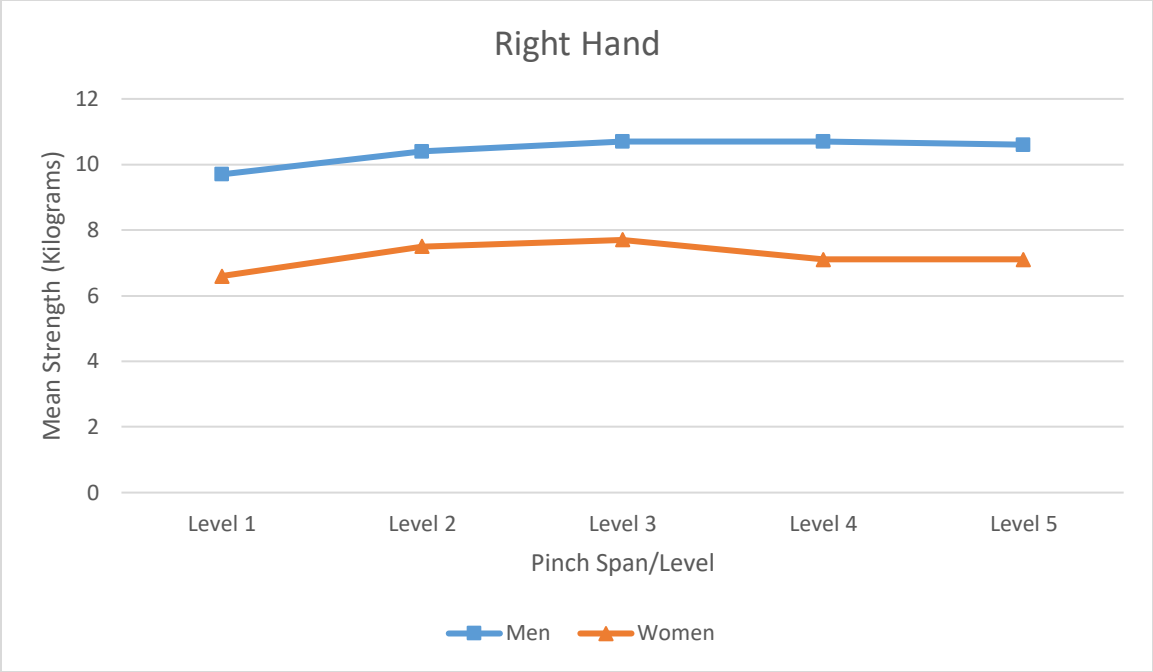
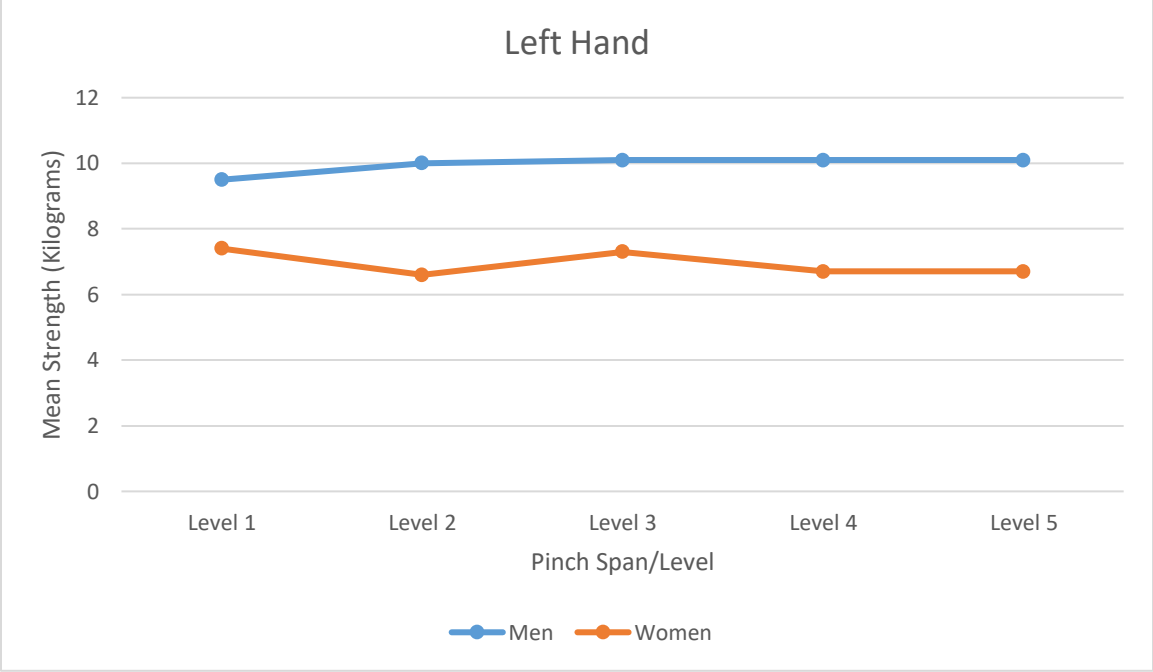


Figure 3. Photo of the Baseline® 5-Position Hydraulic Pinch Meter.

Figure 4. Photo of B&L Pinch Meter.





Figures 5 & 6. Results of two way interaction: The graphs above demonstrate only a weak interaction between sex and pinch span.

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CHAPTER 3

PINCH FORCE REQUIRED FOR ADULTS OVER 50 YEARS OF AGE TO OPEN SEVERAL TYPES OF FOOD CONTAINERS

Background

According to the United States Census Bureau, approximately 43 million people were age 65 or older in 2012, and by the year 2050, this number is anticipated to increase to 84 million (Ortman et al., 2014). Sixty-one percent of participants over 60 years of age and 74% of those with reports of weakness in their arms, wrists, or hands, reported asking for assistance to open food packages (Duizer et al., 2009). Even though older adults comprise the fastest growing segment of our population, the development of targeted food products for this age group has been overlooked by the food industry (Costa & Jongen, 2010; Hensel, 2012).

The function of muscles within the hand correlate with functional dependence in older adults (Incel et al., 2009). Terrono et al. (2011) reported that 20 pounds (9.07 kg) of grip strength and 5-7 pounds (2.27-3.18 kg) of pinch strength are needed to complete most daily activities. This is one reason that occupational and physical therapists assess pinch strength as a component of a comprehensive evaluation of the upper extremity, which includes the shoulder, elbow, wrist, and hand. Smaby et al. (2004) examined the pinch force needed to complete six tasks—inserting/removing a plug, using a key, using an ATM card, operating a zipper, stabbing food with a fork, and using a remote control—and found a large span of force was required to complete these tasks (1.4N – 31.4N). Rice et al. (1998) used sensors to identify the force needed to spray an aerosol can of air freshener, open pill bottles, and pull a spray bottle trigger. They found weak correlations between grip and pinch strength and the force used to open containers successfully. Liu et al. (2016) examined the relationship between hand function and grip strength and found conflicting information with no correlation between the two. However, it is unclear

how impairment of pinch impacts functional performance. Pinch force is used to complete many activities of daily life, such as bathing, dressing, cooking, and managing household tasks, required for independent living. Older adults who live alone have to use pinch force to open various types of food packages despite the limitations that may be present in pinch strength. There is limited evidence identifying the pinch force needed to complete various activities of daily living or to open many types of food packages.

This study addressed the following research questions:

1. How much pinch force is used to open 15 different common food containers/packages?
2. What is the range of pinch force used for individuals to open food packages?
3. Is there a difference in pinch strength used to open food packages based on sex?
4. Is there a relationship between the pinch span and the pinch force required to open the food package?

Methods

The study received approval from the Human Subjects Institutional Review Board of Western Michigan University. There were no financial or personal relationships between the authors and food corporations whose products were used for data collection.

Participants

Participants were recruited from several Western Michigan University campuses in southwest Michigan and were excluded if there was a self-reported history of orthopedic/neurological pathology to the upper quadrant in the last year or any other residual central nervous system dysfunction. Participants were also excluded if there was a presence of cognitive decline that would limit an individual's ability to follow directions to open food

packages. Written consent was obtained from all participants following approved HSIRB procedures.

Testing Procedures

This cross-sectional study used ELF System Sensors by Tekscan™ (See Figure 7) to measure the force used to open 15 different food packages (in pounds and kilograms of force). An engineer with 15 years of experience, who is a current doctoral student, was hired to develop the protocol for sensor use. Sensors were conditioned and calibrated prior to use and then re-conditioned and re-calibrated two times during data collection to ensure accuracy. Data collection occurred at three college campuses in southwest Michigan. The food items that were chosen were based on a review of the literature to identify the types of packages that older adults reported difficulty opening and were purchased at local grocery stores.

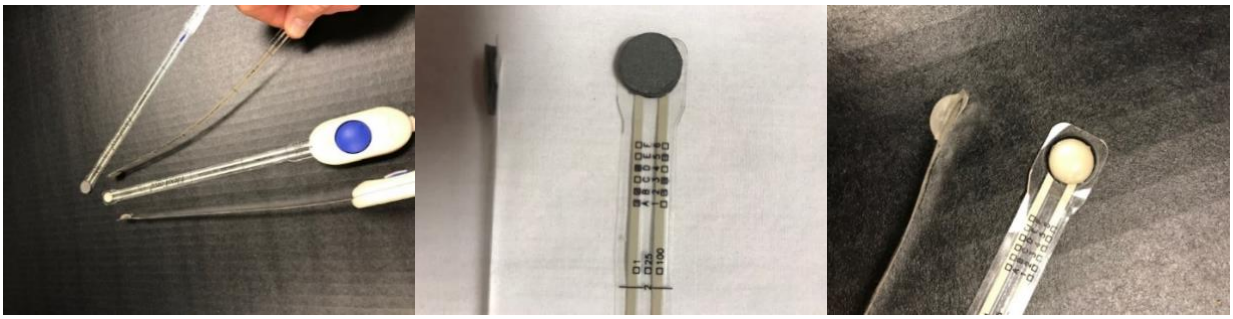

Figure 7. Tekscan™ sensors.

Food Packages Opened (See Figure 8 for hand position when opening.)

- Cereal bag inside box container – Frosted Mini-Wheats 450.8 g
- Nutrition drink – Ensure Individual Serving 226.8 g
- Lunch meat package with film lid – Oscar Mayer Uncured Natural Ham 226.8 g
- Coffee creamer – Coffee Mate French Vanilla 453.6 g

- Soda – Coke 567 g bottle
- Fruit Cup – Mott's Applesauce No Sugar Added) 110.6 g
- Yogurt – Chobani Greek Yogurt Black Cherry 150.3 g
- Cheese slices – Sargento Colby-Jack 212.63 g (zipping and pulling)
- Juice bottle – Minute Maid Apple Juice 283.5 g
- Chip bag – Lays Classic Potato Chips 226.8 g
- Flexible sealed bag – Blue Diamond Almonds 453.6 g
- Tear package of tuna – StarKist in Water 73.71 g
- Ready to serve container of soup – Campbell's Classic Tomato 314.7 g
- Pudding cup – Hunt's Snack Pack Chocolate Sugar Free 92.1 g

Grip, lateral, and 3-point pinch strength were assessed with each participant using procedures recommended by the American Society of Hand Therapists. These strength assessment procedures had the participant seated, the glenohumeral joint adducted, the elbow flexed to 90 degrees, and the forearm in neutral. The Jamar Hand Dynamometer and the B&L Pinch Meter were used to assess grip and pinch strength and were newly purchased to ensure calibration. Participants performed three repetitions (with a 30-second rest period between repetitions), and an average of the three was calculated.

All participants opened the same food packages but in a randomized order of presentation. Sensors were placed between the thumb and the food package based on typical finger placement for opening. Participants were asked how they would typically open each of the packages, as some participants used their dominant hand for opening, while others used their non-dominant hand. Participants were given a 30-second rest period after opening each of the food containers to avoid fatigue.

Figure 8. Food items opened.

Data Analysis

All data were analyzed using IBM SPSS Statistics (version 26). Shapiro-Wilk was used to examine normality of data, and box plots were visually inspected to identify outliers. Because of the presence of some outliers and violations of normality, both parametric and non-parametric methods of data analysis were used. Independent t-tests or Mann-Whitney U were used to determine if the force used to open packages differed by sex.

Results

Participants

A sample of convenience included 30 healthy adults over the age of 50 (15 women and 15 men) and between the ages of 50-83. The mean age for men was 63.53 +/- 2.184 and the mean age for women was 61.13 +/- 2.370. The age of both men and women were normally distributed as evidenced by Shapiro-Wilk p=0.41 men and p=0.32 women.

Descriptive Data

Table 5 identifies the sample hand strengths for grip, lateral pinch, and 3-point pinch bilaterally for both males and females. The mean scores and standard deviations for the force used to open the 15 different food packages for both males and females is presented in Table 6. The median force is reported for data, which was not normally distributed, or if outliers were present.

One subject—an 83 year old male—was unable to open the bottle of apple juice. After several attempts, efforts were discontinued due to a reddening of skin color and complaints of soreness. Otherwise, all other subjects were able to open each of the 15 different food packages.

Table 5. Hand strength of participants.

Hand Strength	**Average Force (kg)**	
	Males	**Females**
Right Hand Grip	39.34 +/- 2.29	27.80 +/- 1.48
Right Lateral Pinch	9.62 +/- .42	6.94 +/- .26
Right 3 Point Pinch	8.68 +/- .35	Median 6.65
Left Hand Grip	40.19 +/- 2.24	24.99 +/- 1.34
Left Lateral Pinch	9.54 +/- .41	6.64 +/- .23
Left 3 Point Pinch	8.26 +/- .43	6.46 +/- .32

Table 6. Mean/SD or median kilograms of force used to open food packages.

Food Item	Males			Females		
	Mean/Median	**SD**	**Range**	**Mean/Median**	**SD**	**Range**
Cereal	2.68	.26	.95 – 4.05	2.22	.28	.48 – 4.57
Ensure	5.71	.43	3.23 – 10.24	4.23	.44	1.52 – 7.46
Lunch Meat	1.70	.22	.52 – 3.51	Median 1.01		.30 – 3.30
Coffee Creamer	1.57	.14	.54 – 2.42	1.28	.15	.48 – 2.67
Soda Bottle	7.27	.57	3.98 – 12.54	4.80	.63	1.46 – 9.45
Fruit Cup	1.51	.17	.39 – 2.81	Median 1.25		.48 – 4.30
Yogurt Cup	1.70	.23	.52 – 3.32	Median 1.12		.30 – 4.55
Cheese Slices Zip	1.95	.22	.52 – 3.73	1.51	.24	.34 – 3.75
Cheese Slices Pull	4.02	.61	.69 – 9.85	2.39	.24	1.12 – 3.81
Juice	6.45	.74	.93 – 11.47	4.87	.51	2.01 – 9.44
Chips	3.47	.47	.73 – 7.37	2.67	.34	.82 – 5.33
Almonds	1.79	0.20	.73 – 2.91	Median .95		.46 – 3.49
Tuna	Median 1.51		.30 – 5.31	1.49	.30	.26 – 4.74
Soup	Median 1.21		.52 – 5.35	Median 1.32		.39 – 3.92
Pudding	2.20	0.39	.43 – 5.46	1.66	.22	.49 – 3.22

Comparing Mean/Median Scores

An independent t-test was used to determine if differences in the force used to open several types of food packages differed between men and women when there were no violations of normality and no evidence of outliers. Levene's test was used to determine homogeneity of variance. There was not a statistically significant difference in mean scores based on sex when

opening cereal, coffee creamer, apple juice, or pudding cups. The test of homogeneity of variance was violated when comparing mean scores to opening the pudding cups. See Table 7 for results.

Table 7. Results of independent t-test.

Food Item	Levene's Test	Degrees of Freedom	T Statistic	Mean Difference	Confidence Interval	Significance
Cereal	.890	28	1.195	1.00	-.718 – 2.727	.242
Creamer	.691	28	1.402	.632	-.291 – 1.555	.172
Juice	.252	28	1.777	3.479	-.539 – 7.497	.087
Pudding	.022	28	1.206	1.186	-.829 – 3.226	.241

A Mann-Whitney U test was run to determine if differences in the force used to open several types of food packages differed between men and women in the sample. Distribution of scores for both males and females were similar as assessed by visual inspection. Median force was statistically different between males and females when opening Ensure, lunch meat, soda, and almonds, and when pulling open cheese using an exact sampling distribution. See Table 8 for results.

Table 8. Results of Mann-Whitney U test.

Food Item	U	Z	Significance
Ensure	56.500	-2.324	.019*
Lunch Meat	61.500	-2.116	.033*
Soda	48.000	-2.675	.007*
Applesauce	93.000	-.809	.436
Yogurt	84.500	-1.162	.250
Cheese Zip	76.500	-1.493	.137
Cheese Pull	56.500	-2.323	.019*
Chips	82.500	-1.244	.217
Almonds	63.000	-2.053	.041*
Tuna	83.500	-1.203	.233
Soup	99.500	-.539	.595

*Statistical significance

Differences in Pinch Span

Many of the food items tested had a very narrow pinch span—meaning the distance between the thumb and lateral aspect of the index finger during pinch when opening the food package. This included applesauce and pudding cups, lunch meat, cheese package, tuna, soup, almonds, yogurt, chips, and cereal. Three items had a larger pinch span (soda 2.4 cm, Ensure 3.4 cm, and juice 3.5 cm). Hock and Lindstrom (2019) found the greatest amount of pinch force was produced at 4-5 cm of pinch span. The mean pinch force to open the soda was 6.03 kg, Ensure was 4.98 kg, and juice was 5.63 kg. There was homogeneity of variances, as assessed by Levene's test for equality of variances (p = .110). An analysis using ANOVA indicated that there were no statistically significant differences in pinch force used to open apple juice, Ensure, or soda with $F(2,86) = 1.598$, $p = .208$. Tukey post-hoc analysis revealed that, although there was a difference in force used with the three different food items, these differences were not statistically significant.

Conclusion

While Terrono et al. (2011) report that only 5-7 pounds (2.27-3.18 kg) of force is required to complete most daily tasks, the data from this study demonstrates that 5.72 kg of force for men and 4.23 kg of force for females were used to open bottles of Ensure. This is significant because this product is targeted for older adults who have demonstrated a decrease in hand strength (Hock & Lindstrom, In press). Additionally, males used 7.27 kg and females used 4.80 kg of force to open a bottle of soda, and males used 6.45 kg and females used 4.87 kg of force to open an individual bottle of apple juice. Additionally, the greatest variability in pinch force used was when opening the bottled items, such as soda, juice, and Ensure, as demonstrated by the greatest standard deviation in force. This variability in force used could have been due to the

slippage of sensors under the fingertips when opening, which could have decreased the force demonstrated for some subjects. Smaby et al. (2004) found a wide range of force was used to perform several tasks, and this data also demonstrates that a wide range of force was used to open several types of food packages—from 1.49 kg for females to open a tuna package up to 7.27 kg for males to open a bottle of soda.

Marks et al. (2012) surveyed individuals on perceived difficulty with opening food packages and participants reported a range of reactions from discomfort with opening or needing to use an assistive device to being unable to open the following food items: peelable packages, such as meat/cheese or yogurt, screw lids, beverage cans with pull rings, and plastic packages with pull strips. Several factors can impact the force required to open food packages, and authors identified that longer pull tabs allowed participants to apply greater force as compared to shorter pull tabs. Dittrich and Spanner-Ulmer (2010) found that small tear tabs are difficult to open. This current study found that participants used less force to open the soup pull tab (males 1.21 kilograms and females 1.32 kilograms), which was longer and textured, and used greater force to open the pudding cup (males 2.20 kilograms and females 1.66 kilograms), which was smaller and smooth in texture. Additionally, the applesauce cup and yogurt cup both had a foil pull tab, which were similar in size. Participants used similar force to open both the applesauce (males 1.51 kilograms and females 1.25 kilograms) and yogurt (males 1.70 kilograms and females 1.12 kilograms). Therefore, it would seem individuals would need less force to open pull tabs that were both longer and textured. Small changes in size and texture to opening tabs could have a large impact on this daily activity and be a means to address the many reports of older adults having difficulty with opening food packages.

There are many other factors that may also contribute to increased difficulty with opening food packages. The literature identifies hand strength declines and individuals requiring additional time to manipulate small objects as they age and a relationship with hand/muscle function and functional dependence (Incel et al., 2009). Additionally, further complications are introduced as the incidence of chronic disease pathologies of osteoarthritis, Parkinson's disease, and other orthopedic and neurological conditions increase with age. The incidence of carpal tunnel syndrome also increases with age, and older adults present with greater severity of the disease, leaving them with decreased sensation in the thumb, index, and long fingers, which were the primary digits used for opening food packages in this study (Gelfman et al., 2009). Additionally, Carmeli et al. (2003) report changes in the vascularity of the skin with aging, as well as sensory decline, which changes skin texture and hydration. McQuillan et al. (2016) identified a relationship between decreased pinch strength and early carpometacarpal arthritis even before significant radiographic presentation. These biological factors may all contribute to the difficulty that older adults have when opening food packages.

Older adults want to age in place, and one aspect to independent living is being able to open food items. When Ford et al. (2016) interviewed older adults to identify their views on the ease of opening food packages, participants reported negative experiences, annoyance, and frustration when doing so, therefore, documenting a resulting consumer vulnerability. Aging has been associated with falls, fractures, weight loss, and frailty (Tabue-Teguo et al., 2017). Verlaan et al. (2017) highlighted the decrease in the ability of older adults to age in place as malnutrition and frailty impact independent living capability. We should question if the challenges that older adults face when opening food packages contributes to weight loss, frailty, and malnutrition—all of which could impact independent living.

Discussion

Since most certified hand therapists are also occupational therapists, packaging engineers could work with occupational therapists who specialize in treating pathology to the upper quadrant (shoulder, elbow, wrist, and hand) as part of an interprofessional team when developing/researching accessible packaging options. Occupational therapists focus on activity analysis, which could assist in the development of food packages that are easier to open. The literature demonstrates that consumers base purchasing decisions of food items on functionality, legibility, manageability, and also openability (Goldman et al., 2014). Given the change in demographics of the population and the demonstrated difficulty in opening food packages with this group, it is important for the food industry to increase its attention to this need.

Limitations in this study were that the sample used was a sample of convenience. Additionally, participants' fingers would sometimes slip across the food package during data collection. This may have caused a decrease in concentration of pressure over the sensor, which may have been the reason as to why some data were not normally distributed, outliers were present with certain items, and some items demonstrated greater variability in force used for opening. Also, this could have decreased the average force used to open certain food items. If the test device would have adhered to the food package and was made of the same material as the item being opened, the results would have been better. This would mean that, if different packages were being tested, sensors would need to be varied to match the material of the food item.

Static pinch is assessed in the clinical environment. However, opening food packages is a dynamic task incorporating proximal strength of muscles that control the shoulder, elbow, forearm, and wrist. Pinch force used to open food packages was measured in this study, but the

strength of muscles of the shoulder, elbow, and wrist were not controlled. Again, this may have accounted for the variability of force used to open certain packages, especially bottled items.

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CHAPTER 4

THE IMPACT OF OSTEOARTHRITIS IN THE CMC JOINT OF THE THUMB ON PINCH FORCE, FUNCTIONAL PERFORMANCE, COMPLETION OF LIFE ROLES, AND LIFE SATISFACTION

Introduction

The baby boomers are aging. According to the United States Census Bureau, approximately 43 million people were age 65 or greater in 2012. By the year 2050, this number is anticipated to increase to 84 million (Ortman et al., 2014). This changing demographic is going to impact the number of adults suffering from symptoms related to osteoarthritis (OA) in the hand.

Osteoarthritis is the most common joint disorder occurring in the United States and is defined as having pain, aching, or stiffness in a joint and also demonstrates joint changes/deterioration through x-ray (Zhang & Jordan, 2010). The thumb carpometacarpal (CMC) joint is often affected by OA with incidences of 15% in adults older than 30 years of age, which increases to 33% in post-menopausal women (Higginbotham et al., 2017). Zhang et al. (2002) further links OA in the hand with functional impairment, pain, instability, deformity, and loss of range of motion. Hand OA currently impacts 44.2% of women and 37.7% of men and is, therefore, identified as a common problem impacting daily functional performance—most notably, a 13.7% decrease in lateral pinch strength (Haugen et al., 2011; McQuillan et al., 2016).

The incidence of thumb CMC OA can be associated with other hand pathology. Kim et al. (2013) examined the incidence of carpometacarpal joint osteoarthritis of the thumb in subjects undergoing a carpal tunnel release and found an incidence of 34% (n=216) in a total sample of 633 hands (Kim et al., 2013). This co-occurrence of carpal tunnel syndrome with thumb CMC OA contributes to the dysfunction associated with this pathology.

Pereira et al. (2011) performed a systematic review of the prevalence of OA and discovered the greatest incidences are found in joints in the hand; however, OA in the knee joint is the most researched. Mahendira and Towheed (2009) also reported that treatment of hand OA has received less attention as compared to treatment of OA of the hip or knee, while Towheed (2005) reported an insufficient amount of research pertaining to the clinical impact of osteoarthritis of the hand. Most importantly to this project, there is a lack of research on the impact of thumb CMC joint OA on the completion of life roles, life satisfaction, and limitations with functional tasks.

There is a lack of evidence to identify if a correlation exists between x-ray presentation and functional loss. The Eaton-Littler scale is described in the literature as a method to classify joint involvement in patients with CMC OA in the thumb. Gillis et al. (2011) reported that Eaton-Littler classifications of I are typically managed conservatively and classifications II-IV can be managed surgically. However, Berger et al. (2013) found the scale to demonstrate poor-fair interobserver reliability (0.11-0.56) and only fair-moderate intra-observer reliability (0.54-0.657) following systematic review. Despite these results, the Eaton-Littler classification is the most commonly used system to classify the severity of thumb CMC OA (Kennedy et al., 2016).

Current evidence has identified the typical conservative interventions for CMC joint instability associated with hand OA to include orthotics, pain management, exercises, and education in the principles of joint protection and activity modification (Neumann & Bielefeld, 2003). The purpose of joint protection and activity modification techniques are to decrease the force applied to the CMC joint of the thumb because one pound of force produced with tip pinch translates to 13 pounds of force at the CMC joint of the thumb (Berger & Meals, 2015). However, literature is lacking to identify how this pathology impacts individuals from a holistic

perspective. Again, Villafane et al. (2012) assessed individuals with thumb CMC OA and found decreased strength. They also measured pain, depression, and anxiety, but the researchers did not assess the impact of OA on other factors, such as the impact on life roles, quality of life or life satisfaction, or limitations with functional tasks.

Research hypotheses for this study included:

1. There will be an inverse relationship between AIMS-2 SF scores and pinch strength.
2. There will be no correlation between Eaton-Littler classification and AIMS-2 SF score.

Methods

This study received approval from the Human Subjects Institutional Review Board of Western Michigan University.

Participants

Participants were recruited from the patients of two hand surgeons in West Michigan. Participants were excluded if they had pathology to the central nervous system, such as Parkinson's disease, stroke, traumatic brain injury, Huntington's disease, or amyotrophic lateral sclerosis. Participants were also excluded if they had a cognitive limitation that would not allow them to be an effective historian or able to follow directions. Participants were excluded if they had an orthopedic injury to the upper quadrant in the last year for which they sought medical attention. Participants with carpal tunnel syndrome were included in the study given the high rate of co-occurrence with thumb CMC OA. Written consent was obtained from all participants following approved HSIRB procedures.

Participants included nine females and three males and were between the ages of 50 to 71 with a mean age of 63.83, SD 7.614. Participant demographics are included in Table 9. Most participants were married and living with their spouse (8/12), and 9/12 had at least some college

education. Five subjects were still working outside of the home, while seven were either disabled or retired. One outlier was noted when analyzing the age of the female participants, so the median age was reported in Table 9. Otherwise, both age and Arthritis Index Measures Scale Short Form (AIMS2-SF) values were normally distributed as evidenced by Shapiro-Wilk values >.05, and no other outliers were noted through visual inspection of box plots.

Table 9. Descriptive data of sample.

	Males	**Females**
Age	58.67 (8.083)	Median 67.56
AIMS2-SF	Males: 42.67 (0.074	Females: 44.11 (8.192)
Pain	4.67 (2.404)	5.33 (.782)
Eaton Classification	I: 0 II: 0 III: 0 IV: 3	I: 0 II: 6 III: 1 IV: 2
Employment Status	Full Time: 2 Part Time: 0 Unemployed: 0 Disabled: Retired: 1	Full Time: 2 Part Time: 1 Unemployed: 0 Disabled: 1 Retired: 5
Educational Level	Did Not Grad HS: 0 High School Grad: 1 1-4 Year College: 0 College Grad: 0 Graduate School: 2	Did Not Grad HS: 0 High School Grad: 2 1-4 Year College: 3 College Grad: 2 Graduate School: 2
Marital Status	Married: 2 Separated: 0 Divorced: 1 Widowed: 0 Never Married: 0	Married: 6 Separated: 0 Divorced: 0 Widowed: 0 Never Married: 3
Living Situation	Alone: 0 With Spouse: 2 With Family: 0 With Friend: 1	Alone: 2 With Spouse: 6 With Family: 1 With Friend: 0

Data Collection

Data was collected at the two hand surgeons' offices who referred participants to the study. This cross-sectional study used both qualitative and quantitative methods.

Quantitative

Descriptive data was used to describe the sample and included:

- Age
- Employment status (retired, full-/part-time, unemployed, disabled)
- Marital status (married, divorced, widowed, never married)
- Educational level (high school, some college, 4-year degree, graduate education)
- Living situation (alone, with family, etc.)
- Typical pain reports using Likert scale (0-10)

The Eaton-Littler classification system was used to identify the x-ray presentation of each participant. This information was provided by the referring physician following written consent from each participant. Classification levels I-IV, with joint involvement increasing from level I to level IV, were included in this sample in order to determine if radiographic findings align with functional limitations, pain, and hand strength.

The AIMS2-SF is a 26-item questionnaire that includes three questions on hand and finger function, three questions on pain related to arthritis, three questions on social activities, three questions regarding mood, two questions on arm function, two questions on self-care, two questions related to level of tension/frustration, two questions regarding work, and one question related to support from family and friends (Guillemin et al., 1997). Higher scores indicate a higher level of disability. The AIMS-2 SF demonstrates convergent validity using correlation coefficient to assess physical and symptom components with clinical variables (r=0.24-0.59) and an intraclass correlation coefficient >0.7 (Guillemin et al., 1997). Internal consistency was reported as good with a Cronbach's alpha coefficient range of 0.75-0.87 (Gignac et al., 2011). Categories of all days, most days, some days, few days and no days were converted to a 5-point

Likert scale, and some items were reverse coded prior to scoring per directions (Gignac et al., 2011). The AIMS2-SF was used to examine the relationship between its scores and hand strength, Eaton-Littler classification, pain, and age.

Grip, lateral, and 3-point pinch strength were assessed with each participant using procedures recommended by the American Society of Hand Therapists. These strength assessment procedures had the participant seated, the glenohumeral joint adducted, the elbow flexed to 90 degrees, and the forearm in neutral. The Jamar Hand Dynamometer was used to assess grip strength and the B&L Pinch Meter was used to assess pinch strength. Participants performed three repetitions (30-second rest period between repetitions), and an average of the three were calculated.

Qualitative

Individual semi-structured interviews were conducted by the doctoral student investigator and were 30-90 minutes in length based on the participants' willingness to respond to questions. Semi-structured interview questions asked during the face-to-face interviews are below. Additional questions were used as a follow-up in order to obtain greater descriptions and more rich detail.

1. Rate your pain level on the scale from 0 to 10 with 10 being "going to the hospital" type pain.

2. Describe the daily hassles that occur as a result of your thumb osteoarthritis.

3. What kind of daily activities do you have difficulty with as a result of your osteoarthritis?

4. Are there activities that you can no longer perform as a result of your thumb osteoarthritis?

5. Are you satisfied with the medical management of your thumb osteoarthritis?

6. Does your thumb osteoarthritis impact participation in social activities?

7. What life roles are impacted by the arthritis in your thumb? In what way?

8. How is your quality of life impacted by the arthritis in your thumb?

Epistemological philosophical assumptions were used to guide the researcher during data collection and analysis. This allowed the researcher to interpret the subjective information provided by participants, as this research relied on individual views and quotes provided by subjects to develop evidence. The Pragmatism Interpretive Framework guided this study since the research is focused on real world practice and can be used to find solutions to real world problems (Creswell & Poth, 2018). Multiple methods of data collection, including both qualitative and quantitative measures, were used to understand thumb CMC OA, further supporting the pragmatism framework (Creswell & Poth, 2018). Qualitative data was handwritten during the semi-structured interviews to allow the researcher to gain rapport with the participants. The handwritten notes were then transcribed by the researcher. Sessions were not recorded to increase the comfort of the participant given that data collection took place within a physician's office. A Phenomenological Approach guided the one-on-one semi-structured interviews to interpret individual descriptions of the essence of the OA of the thumb CMC joint (Creswell & Poth, 2018).

Rigor of study methods was ensured by using the Four-Dimensions Criteria (FDC). These criteria include credibility, confirmability, dependability, and transferability (Forero et al., 2018). Credibility was maintained as the doctoral student investigator has more than 20 years of experience working with adults with osteoarthritis in the hand and has earned the credentials of a certified hand therapist. Credibility was also maintained by securing field notes used during data collection, as well as all data collection paper forms, in a locked office. Confirmability was obtained through weekly debriefing calls between the doctoral student investigator and the

dissertation advisor, which allowed for confirmation from an additional researcher regarding study methods and data analysis. Dependability was ensured by maintaining a detailed record of the data collection process, including dates and notes regarding data collection and analysis. This allowed for repeatability of study methods. Transferability ensures that the results of this study could be generalized to individuals with osteoarthritis of the CMC joint of the thumb. This was demonstrated through the use of data saturation. Operational saturation was demonstrated following the lack of development of new codes/themes in data analysis, and theoretical saturation was achieved through the iterative process of coding data and developing key concepts and themes.

Data Analysis

Quantitative

All quantitative data were analyzed using IBM SPSS Statistics (version 26).

Qualitative

Following data collection with six subjects, information from the semi-structured interviews were reviewed, looking for emergent ideas and classifying material into a priori codes. The qualitative data analysis looked for recurring or repeating tasks that were either difficult for subjects to perform or tasks that caused pain. The analysis was an iterative process, which resulted in data being recoded following further review and identification of patterns and significant statements. Data were used to develop a textural description of what participants with thumb CMC OA experience (Creswell & Poth, 2018). Using Microsoft Word, statements were copied and pasted from the transcribed interviews into themes using the initial a priori codes. A priori codes are below and allowed for additional themes following a review of qualitative data:

- Pain

- Functional Loss
- Role Completion
- Frustration/Hassles
- QOL/Satisfaction
- Beliefs of Value of Medical Management
- Impact on Socialization

Three additional participants were then included within the study. The same process of data collection and analysis was performed. Data were collected until operational and theoretical saturation occurred.

Participants were offered free education on joint protection and energy conservation techniques that may decrease pain and improve functional performance. Additionally, participants were offered a custom orthosis at no cost, which may provide support to their arthritic thumb, decrease pain, and improve functional performance.

Results

Quantitative

Grip and pinch strength values are reported in Table 10 and were all normally distributed as evidenced by Shapiro-Wilk >.05. Outliers were noted with grip (4) and lateral pinch (1) scores of females using the left hand as evidenced by visual inspection of box plots. Therefore, median strength was reported for grip and lateral pinch of the female participants (See Table 10).

A Spearman's Correlation Coefficient was used to analyze the relationship between Eaton-Littler classification and hand strength. Data were stratified based on sex, given that previous literature demonstrated greater hand strength in males as compared to females. Male

data could not be included in the analysis due to the small sample size. Female hand strength was not found to be correlated with Eaton-Littler classification. See Table 11 for data.

Table 10. Mean and standard deviation of grip and pinch strength of sample.

	Right Hand (lbs)		**Left Hand (lbs)**	
	Males	**Females**	**Males**	**Females**
Grip	72.57 (11.98)	53.44 (18.02)	69.10 (10.69)	Median 53.67
Lateral Pinch	21.13(2.38)	14.22 (3.81)	20.10 (4.26)	Median 12.00
3 Point Pinch	17.33 (0.35)	12.30 (4.32)	17.20 (4.42)	11.30 (3.41)

Table 11. Spearman's correlation between Eaton-Littler classification and hand strength in female participants.

Correlation Hand Strength and Eaton-Littler Classification	**r_s**	**Significance**
R Grip	-.299	p=.435
L Grip	-.240	p=.534
R Lateral Pinch	-.025	p=.949
L Lateral Pinch	-.182	p=.758
R 3 Point Pinch	.120	p=.758
L 3 Point Pinch	.186	p=.632

Spearman's correlation coefficient was also used to analyze the relationship between AIMS2-SF scores and female hand strength. No significant correlation was noted, however, as evidenced by findings presented in Table 12.

Table 12. Spearman's correlation between AIMS2-SF and hand strength in female participants.

Correlation Hand Strength and AIMS2-SF	**r_s**	**Significance**
R Grip	-.067	p=.864
L Grip	-.479	p=.192
R Lateral Pinch	.197	p=.611
L Lateral Pinch	-.426	p=.253

Table 12. Continued		
R 3 Point Pinch	-.034	p=.932
L 3 Point Pinch	-.473	p=.199

During all analysis using the AIMS2-SF, the last two questions related to work were excluded. This is due to the fact that participants who worked would have a total maximum score of 130, and those who did not work would have a total maximum score of 120. AIMS2-SF scores and reports of pain values were all normally distributed as evidenced by Shapiro-Wilk >.05, and no outliers were noted. There was a very weak non-statistically significant correlation between x-ray presentation using the Eaton-Littler classification and the AIMS2-SF $r_s(10)$ = .062, p=.847. Additionally, there was a non-statistically significant correlation between reports of pain and Eaton-Littler classification $r_s(10)$=.241, p=.451. The relationship between AIMS2-SF scores and age was examined, and a non-statistically significant association was noted $r_s(10)$=.213, p=.505. There was also a non-statistically significant correlation between Eaton-Littler classification and pain reports r_s(10=.241, p=.451.

Qualitative

Participants reported a range in thumb pain from 2/10-8/10 with some participants reporting greater symptoms in their non-dominant hand, while others reported greater symptoms in their dominant hand. A few participants reported using various non-traditional methods to control their symptoms of pain, such as eating hot peppers and adding turmeric supplements. One participant described having thumb pain in his dominant hand many years ago, which has since subsided, but pain had increased in his non-dominant hand. These reports were interesting, given that both of his thumbs demonstrated an Eaton IV classification based on x-ray presentation, but one thumb was currently pain free.

All participants were easily able to identify several functional tasks that were difficult or painful to complete and reported pain during and following the performance of many tasks. Two of the 12 subjects even reached out to the investigator after the conclusion of the interview to report additional tasks causing difficulty. Female participants complained of difficulty performing tasks that are historically completed by this sex, such as washing dishes, ironing, sewing, performing household chores, opening jars and food containers, sealing Ziplock bags, holding a bowl while stirring or holding heavy pans, and using a rolling pin. Meanwhile, male participants complained of difficulty using a hammer, screw gun, or screwdriver, handling dry wall, and operating a chainsaw. Difficulty with functional tasks did not seem to follow any pattern based on Eaton-Littler classification, as the same tasks were reported as difficult in participants with an Eaton II or an Eaton IV. However, there was no method of being able to identify if those who were classified as an Eaton IV had the same functional limitations at earlier stages of the disease. Functional tasks that were commonly reported by many participants are included in Table 13. Participants frequently discussed living with CMC OA of the thumb and how they were frustrated with dropping/breaking items, having to use their other hand or two hands to complete tasks, and having to ask for help from others.

All a priori codes established were included in the qualitative interview data analysis. Participant involvement in social activities seemed to be the one area that was least impacted by osteoarthritis of the CMC joint. A theme of resiliency was added as a result of the review of the qualitative data. All participants described the need and the desire to continue with tasks that they wanted or required to achieve and, in fact, were many times unable to come up with tasks that they could no longer complete. Participants described tasks taking longer, causing pain, and requiring the need to develop or create adaptations to complete. Despite these difficulties,

participants all described the ability to "suck it up," "make do," and "complete all of my life roles." However, participants also reported feelings of hopelessness, sadness, and worry, given that this is a chronic condition that will get worse with age. Although participants seemed to be pleased with the medical options to address their thumb arthritis, they reported that they had instead hoped to have a diagnosis with a "quick fix" with either a shot or surgical procedure to eliminate their symptoms. No participants included in the study had elected to have surgical joint replacement procedures at the time of their physician appointment.

In addition to these feelings of hopelessness, participants expressed concerns about being able to complete tasks in the future as their symptoms worsened. Participants mentioned concerns of being able to participate in travel and leisure activities and maintaining their functional independence as they aged and their symptoms progressed. Themes that emerged from the qualitative data are included in Table 13. A more exhaustive list of representative comments are included in Appendix A.

Table 13. Themes and representative comments.

Themes	Participant Comments
Pain	"I have pain with just moving it." "When I pick up something it is like a knife going in my thumb."
Functional Loss	Commonly reported tasks that were difficult: - Lifting pans/dishes - Reading tasks (holding book/turning pages) - Donning jewelry/socks/fastening bra/buttoning - Driving - Opening jars/baggies/food containers/cutting meat - Squeezing shampoo, conditioner, lotion bottles - Writing - Toileting hygiene - Exercising (holding weights, bars, weight bearing)

Table 13. Continued	
Role Completion	"I volunteer making quilts and I have trouble cutting the material, sewing and ironing." "I used to do things for my granddaughter. She is 8 years old. Now she helps me." "I used to like to bake and cook dinner for my grandkids. Now I cannot do it the same." "It limits the things that I do with my grandkids. I cannot play rough with them, throw a baseball. I just don't do it."
Frustration/Hassles	"It is annoying because I have to get someone else to do things." "I broke a bowl and a glass in the kitchen. Slips right out of my hand on a bad day." "I don't like having limitations." "The things I like to do are less and less and that is disappointing."
Quality of Life/Satisfaction	"I feel like at the age of 60 I am already having pain that limits my use of my hand. How will it be when I am 70 as I know it will get worse? Makes me sad and worried." "I have not been feeling as independent." "I am functioning as a health mentor at work. It is a depressing thing to look at how arthritis effects my life."
Beliefs of Value of Medical Management	"Honestly I hoped something would be a quick fix. I thought I would just have a cyst or something that needed to be removed." "I used a splint, but did not feel like it helped." "Even though I got a shot, I feel like surgery is inevitable."
Impact on Socialization	"Does not impact my social activities."
Resiliency	"I just make myself do things even if it hurts and then I take extra Motrin after." "I can still do everything. I just have to alter or change how I do things. I have to hold things with two hands and pick up my grandchild differently." "I have stubbornness and I suck it up and complete all of my life roles." "There is nothing I can do about it. I don't get upset and instead just have to make do."

Discussion

It is clear from the review of qualitative data that the diagnosis of CMC OA in the thumb is accompanied by pain and many functional complaints. These complaints were significant enough for all participants in this study to seek medical attention because all participants were being seen by a hand surgeon for diagnosis. However, gaps remain in the literature determining if a relationship exists between x-ray classification, hand strength, and functional performance. This study was unable to adequately determine these relationships due to several limitations. First, the sample size was very small, as there were not enough male participants to adequately determine the relationship between hand strength and AIMS2-SF scores or hand strength and Eaton-Littler classification. Secondly, although the Eaton-Littler classification system is the most commonly used classification system for CMC OA, as previously indicated, it has been found to have poor-fair interobserver reliability and fair-moderate intra-observer reliability (Berger et al., 2013). Thirdly, the sample included in this study was not diverse as most were highly educated and had spousal or familial support, and none were unemployed. Additionally, it is likely that all participants were insured, since they all sought medical attention for their symptoms related to their thumb and were not being treated for another traumatic injury, such as a fracture or laceration needing urgent medical care. The sample also lacked diversity as all male subjects were rated as an Eaton IV classification, and the majority of females were either an Eaton II or Eaton IV classification. No participants in this study were classified as an Eaton I, which suggests that symptoms related to Eaton I classification may not be significant enough to seek medical attention.

Villafane et al. (2017) examined the differences in grip, tip, and tripod strength in 57 symptomatic females with thumb CMC OA and 53, matched by age, healthy female controls.

Researchers found a 61% reduction in grip strength, a 46.7% reduction in tip, and a 40% reduction in tripod pinch strength in the participants with thumb CMC OA (Villafane et al., 2017). Grip and pinch scores from this study were compared to normative data, collected by Phillips et al. (2013), from a sample of healthy Michigan workers with 49 subjects in the age range of 50-62. Male participants in this study demonstrated a 31-33% reduction in grip strength compared to norms reported by Phillips et al. (2013). However, females in this study demonstrated only a 1-3% reduction in grip strength compared to norms reported by Phillips et al. (2013). When comparing pinch strength in participants from this study to norms presented by Phillips et al. (2013), there was a 15-27% reduction in strength. Therefore, it is possible that this reduction in hand strength is the root of functional changes, frustration, and hopelessness in adults with thumb CMC OA.

Many occupational therapists will interact with adults with CMC OA in their practice. Becker et al. (2013) relate the diagnosis of trapeziometacarpal arthritis to being as inevitable as death and taxes. Following their review of 2321 subjects age 31 and older, they reported that the incidence of trapeziometacarpal arthritis increases to 85% between the ages of 71 and 80 in females and then up to 100% by age 91. The incidence in males was slightly lower but was still demonstrated as 93% in those who were 81 years of age or older (Becker et al., 2013). Therefore, it is critical for healthcare professionals to understand and empathize with all of the symptoms related to this diagnosis. Patients will not only demonstrate changes on X-ray and report complaints of pain with palpation, but will also have concerns about future functional independence and frustrations with the hassles of having difficulty or taking extra time to complete tasks or even having to give up loved activities.

Conclusion

The literature indicates that the onset of arthritis in many instances is a part of the aging process. Occupational therapists have to be prepared to ask the right questions regarding functional loss and adaptation, respect the loss of strength that co-occurs with osteoarthritis, and not just look at the range of motion loss and pain associated with this diagnosis. Occupational therapists play a key role in activity analysis and modification or adaptation of tasks. It is important to use these skills to not only decrease the stress to joints resulting in progression of joint deterioration, but also to adapt activity to increase independence with tasks, educate patients on how to recognize the need to make their own adaptations, reduce frustrations and the daily hassles in activities of daily living, and recognize feelings of sadness and hopelessness. Future research would be beneficial to more clearly examine adaptation of activity for individuals with thumb CMC OA to allow fulfillment of life roles and achievement of life satisfaction, given the clear demonstration of resiliency in this population. Additional research with larger sample sizes, including both males and females, that examines the reduction in hand strength with this diagnosis would also be beneficial.

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CHAPTER 5

CONCLUSION

This doctoral dissertation includes the results of three individual studies, which were performed to examine the concept of pinch as it relates to assessment, the performance of functional tasks, and the impact on quality of life when pathology is present—namely, thumb carpometacarpal (CMC) osteoarthritis (OA). Major conclusions that were uncovered through research and extensive review of the literature are described below.

Assessment of Pinch

Study 1 (Chapter 2) provided valuable information regarding the relationship between increased age and strength decline and also obtained normative data for the Baseline® 5-Position Hydraulic Pinch Meter. While this study identified that the greatest amount of lateral pinch force can be produced at 4-5 cm of pinch span, it was concluded that only a small effect size was noted when looking at differences in pinch force produced at the 5 different spans using the Baseline® 5-Position Hydraulic Pinch Meter. This information will allow clinicians to make educated decisions when purchasing pinch meters for their practices. Clinicians who select the Baseline® 5-Position Hydraulic Pinch Meter for use in the clinical environment can refer to the normative data created in this study to establish a baseline of pinch strength at the beginning of treatment and also to evaluate outcomes at discharge from therapy. The results of Study 1 are useful for clinicians to adapt or modify handles for improved performance of activities of daily living, as the research provides clarity on the optimal pinch span for production of the greatest pinch force.

The Use of Pinch for Functional Tasks

Study 2 (Chapter 3) identified the pinch force used to open several types of food packages. Terrono et al. (2011) reported that a person needs 5-7 pounds of pinch strength to complete most daily activities. Through the use of sensor technology, it was identified that a wide range of pinch force was used to open 15 different food containers. For example, males used an average of 16.03 pounds of force to open a bottle of soda but only 3.46 pounds of force to open a bottle of coffee creamer. Females used 10.74 pounds of force to open a bottle of apple juice but 3.28 pounds of force to open a pouch of tuna. In conclusion, greater than 7 pounds of pinch force was used by males to open 5/15 food items and females to open 3/15 food items that were tested.

Although the food items selected for this study are commonly used by older adults, there are many other types of food items that warrant testing to determine the force that is used for opening. This information is important because the need to open food containers is essential for independent living. Many older adults live alone in the United States. Census data from 2010 estimated that 11 million older adults who were not institutionalized live alone in the United States (Ortman et al., 2014). Difficulty or inability to open food packages could lead to nutritional frailty in this population, which may limit a person's ability to live alone, ultimately increasing cost for care and support.

The Impact of Thumb Carpometacarpal (CMC) Osteoarthritis (OA) on Pinch

Study 3 (Chapter 4) was a mixed-methods study that included two purposes: 1) to examine the lived experience of individuals who have been diagnosed with thumb CMC OA through a qualitative process and analysis and 2) to examine data for relationships between x-ray presentation and functional performance using the Arthritis Index Measures Scale Short Form

(AIMS2-SF) and correlations between pain ratings and age. Although no statistically significant relationships were identified using quantitative data, the results of qualitative data analysis identified various functional tasks that were frequently reported as difficult or painful. This qualitative data also provided a greater understanding of the daily hassles and concerns of these individuals with regard to their CMC OA. Resiliency was identified as a major theme in data analysis, as adults with thumb CMC joint OA adapt and modify tasks to complete requirements of their life roles despite pain and difficulty.

Although many times participants denied being unable to perform tasks, they still described an accompanied loss with this diagnosis. Individuals reported a loss of time, given that greater time was required to complete many things, or a loss of resources as they needed to purchase adaptive equipment to complete tasks. They also reported having others complete functional tasks just because it was quicker or easier or because they did not want to break things. These subtle changes are important for clinicians to recognize, as they may ultimately lead to a loss of confidence within their patients, which may, in turn, lead to future decreases in independence. It is important for clinicians to use this information to ask the right questions regarding functional performance of tasks and to also do a better job of not just recommending adaptive equipment options, but educating individuals on how to adapt tasks and to recognize future tasks that may require modification.

Discussion

While assessment of hand strength is necessary for the field of occupational therapy, it can also be useful in other healthcare fields, such as physical therapy, hand surgery, general orthopedics, physiatry, neurology, and general physicians. Assessment of pinch strength is used by occupational therapists to create a baseline for hand strength, which is used to develop goals,

identify limitations in hand strength, provide adaptive equipment for functional tasks, and track progress. Assessment of pinch strength is used by physicians in the differential diagnosis of nerve compression or pathology and also in the evaluation of loss of hand function following various orthopedic and neurologic conditions. Evaluation of hand strength is a factor used by general physicians to evaluate frailty or overall health measures with the aging population. Therefore, we must have reliable and valid testing instruments in order to accurately assess pinch force. The Baseline® 5-Position Hydraulic Pinch Meter is an additional tool that has demonstrated good interrater reliability and is available for use in clinical practice. Clinicians have the opportunity to make decisions about which tool they will use to evaluate their patients' hand strength. Clinicians should review the literature to identify the psychometrics of each instrument and other factors outlined by research, including the time to complete the assessment and the benefits of one instrument over others.

As clinicians we assess pinch but are lacking the research that identifies the amount of force used to complete different activities of daily living. Without this information, clinicians are unable to determine what tasks patients can and cannot perform based on their pinch force assessment. Study 2 (Chapter 3) identified the pinch force used to open several types of food packages; however, additional research must continue to determine the force used or required to complete many other daily tasks. This research must be interdisciplinary to engage with engineers to accurately measure force production and package scientists who create packages, along with hand therapists who focus on individuals and are experts in the anatomy and principles of kinesiology for activity analysis. When measuring the force to complete tasks, it would be beneficial to control for proximal strength to truly understand the force used by the hand. There are other variables to consider when measuring the force to open packages, such as

the position of the body and the size and material of the container. It is important to use human subjects to assess force to take into account the texture of skin, while also imbedding the sensors into the material of the functional task to avoid slippage. This research will guide therapists in determining which tasks may be difficult for their clients to perform, given an individual's strength assessment, while taking into account the complexity of hand function.

Using many small muscles in the hand to perform several types of pinch, the production of pinch force is multifaceted to complete activities of daily living. Pinch becomes even more complex with pathology. Osteoarthritis of the CMC joint in the thumb is a common diagnosis that can be considered part of the normal aging process. CMC osteoarthritis pathology results in a decrease in hand strength, while results from Study 1 (Chapter 2) demonstrated that pinch strength decreases with age in healthy subjects. Data obtained from Study 3 indicate that OA in the thumb is accompanied by complaints of pain and impacts an individual's ability to complete functional tasks. These complaints persist as people age, given that arthritis is a chronic condition. In response, individuals may develop resiliency to adapt so that they can continue to complete their life roles. We have to look at the limitations in hand function as a result of pathology in a holistic fashion and its relationship to other factors. For example, the strength of muscles proximal to the hand impact hand strength. The use of the hand to perform functional tasks is a dynamic activity, which not only includes the muscles of the hand, but also the muscles that control the joints of the wrist, forearm, elbow, and shoulder, all of which include many planes of movement. Another factor is that of motivation. An individual's decrease in independence, limited performance of life roles, chronic pain, or feelings of hopelessness may result in a decrease in motivation to perform tasks. If this occurs, the strength of the hand may be irrelevant for functional return of performing activities of daily living.

Future Research

The combined studies have implications for clinical practice and future research. While this dissertation provides normative data for the Baseline® 5-Position Hydraulic Pinch Meter, assessment of pinch at 5 different positions using the 5-position pinch meter will need additional time in the evaluation process, which is problematic in the current healthcare industry. This is especially important to consider given the small effect size noted when examining mean differences in force production between the 5 different pinch spans. Therefore, it necessary to create new normative data using the B&L Pinch Meter, which is a static pinch measurement of one position of pinch span and is commonly used in current clinical practice. The current norms provided with the purchase of a new B&L Pinch Meter are from Mathiowetz et al. (1985). Additional studies have been conducted since that one; however, they have employed small samples that lack diversity. There is a need for larger and more rigorous norm studies.

Much more research is needed on the force used or required to complete many aspects of activities of daily living. This dissertation studied only the force used (not required) to open 15 different types of food containers. Future research should include the force used to perform other types of functional tasks using larger, more diverse samples. Although it would be ideal if researchers could determine the amount of force *needed* to open the packages, the many variables involved with how the person is positioned in relationship to the package will make a difference. The American Society for Hand Therapists has specific positions identified to measure grip and pinch strength for valid comparisons. It is unrealistic to require people to use a specific position beyond placing their feet on the floor along with their shoulder adducted.

Given the chronic condition of OA in the thumb CMC joint, it would beneficial to complete longitudinal studies to provide data for practitioners to use on limitations at various

levels of involvement using larger, more diverse samples. Additional research would also be beneficial in examining the outcomes of task modification and the use of adaptive equipment to decrease stress to the thumb CMC joint.

Conclusion

In conclusion, this dissertation examined many factors associated with pinch strength. Pinch strength is a complex concept and important for hand function, which impacts many aspects of participation in activities of daily living. Mary Reilly describes the significance of hand function in her 1961 Eleanor Clarke Slagle lecture when she states, “That man, through the use of his hands as they are energized by mind and will, can influence the state of his own health (Reilly, 1962, pp. 88). Individuals use pinch force to complete leisure activities, which bring them joy, to prepare food and bring nutrition into their bodies, which brings them health, and to care for their essential needs, which brings independence. All of these factors promote quality of life. The use of our hands is a complicated issue to study but deserves more research attention.

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Appendix A

Themes and Representative Comments

Themes	Participant Comments
Pain	"It (pain) started in my left hand and then started in my right (dominant) hand and then the right steadily got worse." "I have pain with just moving it." "It always hurts for a while after I do things." "I went to the doctor 30 years ago when my thumb was really hurting. Now the pain is not as bad and I would just consider it a dull ache." "When I pick up something it is like a knife going in my thumb."
Functional Loss	Commonly reported tasks which were difficult: - Lifting pans - Handling dishes - Reading tasks (holding book/turning pages) - Buttoning - Jewelry - Donning socks - Driving - Opening jars - Squeezing shampoo, conditioner, lotion bottles - Writing - Sewing/knitting - Cutting meat with a knife - Toilet hygiene - Opening food containers - Exercise (holding weights, bars, weight bearing) - Ziplock™ bags - Fasten bra - Shoveling - Picking up/holding grandkids - Golfing
Role Completion	"I volunteer on a board and I can type the minutes, but I have pain after." "I volunteer making quilts and I have trouble cutting the material, sewing and ironing." "I used to do things for my granddaughter. She is 8 years old. Now she helps me."

	"I can't do as much with my grandkids." "I cannot sew like I used to. Now I just repair things when I sew and I cannot do the creative sewing like I used to." "I used to like to bake and cook dinner for my grandkids. Now I cannot do it the same." "It limits the things that I do with my grandkids. I cannot play rough with them, throw a baseball. I just don't do it." "I am worried about travel – hauling the suitcase and going through airport security."
Frustration/Hassles	"It is annoying because I have to get someone else to do things." "I really missed knitting as it was my relaxation in the evening. I was frustrated that I had to stop." "I broke a bowl and a glass in the kitchen. Slips right out of my hand on a bad day." "I don't like having limitations." "I would like to do things and get disappointed when I cannot." "The things I like to do are less and less and that is disappointing." "I get frustrated. It seems like it should be so minimal, but by the end of the day, I am physically exhausted because of dealing with pain all day."
Quality of Life/Satisfaction	"My quality of life is degraded a little bit." "I feel like at the age of 60 I am already having pain that limits my use of my hand. How will it be when I am 70 as I know it will get worse? Makes me sad and worried." "I have not been feeling as independent." "I am functioning as a health mentor at work. It is a depressing thing to look at how arthritis effects my life." "Everything is decreased with my quality of life."
Beliefs of Value of Medical Management	"Honestly I hoped something would be a quick fix. I thought I would just have a cyst or something that needed to be removed." "The medical management is not high enough for the symptoms to disappear. I had an injection, but it only helped for about a month."

	"Since I got a shot, I feel better." I used a splint, but did not feel like it helped." "Even though I got a shot, I feel like surgery is inevitable." "I am satisfied with the medical management for my arthritis."
Impact on Socialization	"Does not impact my social activities."
Resiliency	"I just make myself do things even if it hurts and then I take extra Motrin after." "I don't think my quality of life has changed because I still do the things I want. I just have to adjust how I do them." "I can do everything. It just takes me longer to do things." "I can still do everything. I just have to alter or change how I do things. I have to hold things with two hands and pick up my grandchild differently." "I have stubbornness and I suck it up and complete all of my life roles." "I am optimistic about things and find a way." "I make myself do things. It drives my husband crazy." "There is nothing I can do about it. I don't get upset and instead just have to make do."

Appendix B

WMU HSIRB Approval Letter—Study 1

WESTERN MICHIGAN UNIVERSITY

Human Subjects Institutional Review Board

Date: January 28, 2016

To: Nancy Hock, Principal Investigator
Debra Lindstrom, Co-Principal Investigator
Aubrey Aubrey, Student Investigator
Mary Lutzke, Student Investigator

From: Amy Naugle, Ph.D., Chair

Re: HSIRB Project Number 16-01-13

This letter will serve as confirmation that your research project titled "Psychometrics and Norm Study for Baseline® 5 Position Hydraulic Pinchmeter" has been **approved** under the **expedited** category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note: This research may **only** be conducted exactly in the form it was approved. You must seek specific board approval for any changes in this project (e.g., ***you must request a post approval change to enroll subjects beyond the number stated in your application under "Number of subjects you want to complete the study***)." Failure to obtain approval for changes will result in a protocol deviation. In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

Reapproval of the project is required if it extends beyond the termination date stated below.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: January 27, 2017

1903 W. Michigan Ave., Kalamazoo, MI 49008-5456
PHONE: (269) 387-8293 FAX: (269) 387-8276
CAMPUS SITE: 251 W. Walwood Hall

Appendix C

WMU HSIRB Approval Letter—Study 2

WESTERN MICHIGAN UNIVERSITY

Institutional Review Board
FWA00007042
IRB00000254

Date: September 19, 2019

To: Linda Shuster, Principal Investigator
Debra Lindstrom, Co-Principal Investigator
Nancy Hock, Student Investigator for dissertation

From: Amy Naugle, Ph.D., Chair

Re: IRB Project Number 19-09-12

This letter will serve as confirmation that your research project titled "" has been **approved** under the **expedited** category of review by the Western Michigan University Institutional Review Board (IRB). The conditions and duration of this approval are specified in the policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note: This research may **only** be conducted exactly in the form it was approved. You must seek specific board approval for any changes to this project (e.g., ***add an investigator, increase number of subjects beyond the number stated in your application, etc.***). Failure to obtain approval for changes will result in a protocol deviation.

In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the IRB for consultation.

The Board wishes you success in the pursuit of your research goals.

A status report is required on or prior to (no more than 30 days) September 18, 2020 and each year thereafter until closing of the study.

When this study closes, submit the required Final Report found at https://wmich.edu/research/forms.

Note: All research data must be kept in a secure location on the WMU campus for at least three (3) years after the study closes.

Office of the Vice President for Research
Research Compliance Office
1903 W. Michigan Ave., Kalamazoo, MI 49008-5456
PHONE: (269) 387-8293 FAX: (269) 387-8276
WEBSITE: wmich.edu/research/compliance/hsirb

CAMPUS SITE: Room 251 W. Walwood Hall

Appendix D

WMU HSIRB Approval Letter—Study 3

WESTERN MICHIGAN UNIVERSITY

Institutional Review Board
FWA00007042
IRB00000254

Date: August 22, 2019

To: Linda Shuster, Principal Investigator
Nancy Hock, Student Investigator for dissertation
Debra Lindstrom, Co-Principal Investigator

From: Amy Naugle, Ph.D., Chair

Re: IRB Project Number 19-07-11

This letter will serve as confirmation that your research project titled "The Impact of Osteoarthritis in the CMC Joint of the Thumb on Pinch Force, Functional Performance, Completion of Life Roles and Life Satisfaction" has been **approved** under the **expedited** category of review by the Western Michigan University Institutional Review Board (IRB). The conditions and duration of this approval are specified in the policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note: This research may **only** be conducted exactly in the form it was approved. You must seek specific board approval for any changes to this project (e.g., ***add an investigator, increase number of subjects beyond the number stated in your application, etc.***). Failure to obtain approval for changes will result in a protocol deviation.

In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the IRB for consultation.

The Board wishes you success in the pursuit of your research goals.

A status report is required on or prior to (no more than 30 days) August 21, 2020 and each year thereafter until closing of the study.

When this study closes, submit the required Final Report found at https://wmich.edu/research/forms.

Note: All research data must be kept in a secure location on the WMU campus for at least three (3) years after the study closes.

Office of the Vice President for Research
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