Protecting the Hand: Quantifying Pressures Involved in Daily Living Activities with Tools

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Protecting the hand: Quantifying pressures involved in daily living activities with tools

Kelly Cotter, Trisha Thompson, and Amanda Ward

Grand Valley State University

2012
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Definition of Terms

**Adaptive Equipment**: Tools designed to help people with disabilities be more independent (Heerkins, 2011).

**Area**: Any particular extent of space or surface; part (Merriam-Webster Dictionary, 2012).

**Autoimmune Disease**: Malfunctions of the immune system in which the body attacks its own tissues are now known to cause several enigmatic diseases, including Rheumatoid Arthritis (Rose, 1981).

**Force**: Method of measurement in Kilopascals (kPa). The equation is Force = Pressure \times Area (Novel Electronics Inc., 2011).

**Joint Protection**: Advice on and training in altering movement patterns of joints affected by inflammatory arthropathies, via the use assistive devices and/or task modification (Hammond & Lincoln, 1999).

**Novel Pliance-X Hand Sensor**: System includes a sensor mat, sensor cable, sync box, fiber optic cable with fiber optic/USB adapter, USB cable, belt, battery with cable and charger, a start and stop trigger, and a Bluetooth dongle. This equipment is used to collect and interpret force and pressure applied to the sensor mat (Novel Electronics Inc., 2011).

**Pressure**: Method of measurement in Newtons (N). The equation for pressure is Pressure = \frac{Force}{Area} (Novel Electronics Inc., 2011).

**Rheumatoid Arthritis (RA)**: A clinical syndrome with several inflammatory cycles, which lead towards a final common pathway in which persistent synovial inflammation and associated damage to articular cartilage and underlying bone are present (Scott, Wolfe, & Huizinga, 2010).
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**Osteoarthritis (OA):** A group of conditions associated with deteriorating articular cartilage as well as changes in the underlying bone (Roach & Tilley, 2008).
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Abstract

This study utilized individuals with no known hand joint pathologies and analyzed the pressure exerted on varying spoon handle diameters during a simulated self-feeding exercise. This was done in an effort to determine which spoon handle diameter required the least amount of pressure. Individuals with no known hand joint pathologies were selected in order to prevent any inaccuracy of results due to underlying co-morbidities. Methods: The Novel Pliance-X hand sensor was wrapped around 15 mm, 25 mm, and 40 mm spoon handles. The participants were asked to complete a self-feeding exercise. The self-feeding exercise was simulated by scooping quarters from a bowl, bringing the spoon to their chip, and returning the quarters to a bowl. Each participant in the study completed three trials for each of these spoon handles in a random order. After the simulated self-feeding exercise, the participants were asked to complete an exit form about preference, pain, and provide any additional comments. Results: From the quantitative data, the researchers were able to determine the force, maximum pressure, and mean pressure exerted on each spoon handle. It was determined that there was statistically significant difference on the force exerted on the 15 mm and 40 mm spoon handle. The 15 mm spoon handle required less force to hold than the 40 mm spoon handle. Qualitative results were gathered from the exit forms that were completed by each participant. Overall, the participants preferred the 15 mm spoon handle to the other spoons. Conclusion: The study did not demonstrate that increasing the handle size will decrease the force applied by the hand. Overall the participants preferred the 15 mm spoon handle due to comfort, ease, size/fit, and natural feel. Further research is needed to determine if training with adaptive equipment is necessary to increase familiarity with the tool and possibly decrease the forces applied by the hand.
Scope: The results from this study may demonstrate that to decrease the force applied by the hand to a spoon handle, more than just spoon handle size needs to be considered.
Chapter 1

Introduction

Background to Problem

Occupational therapy helps people across the lifespan participate in things they want or need to do through the therapeutic use of everyday activities ("About occupational therapy," 2011). With an expansive knowledge base of disease and dysfunction, an occupational therapist can adequately complete assessments, make recommendations for adaptive equipment, and help individuals reach their highest level of independence.

Occupational therapists utilize adaptive equipment with clients to improve the ability to complete self-care tasks, such as self-feeding (Gitlin & Burgh, 1994). Adaptive utensils that are modified to assist with self-feeding include forks, spoons, and knives. These may include utensils with built-up handles, weighted handles, and angled utensils. A mixed methods study completed on optimal cylindrical handle diameter concluded that participants rated a 35 mm handle for females and 40 mm handle for males, with the highest comfort rating (Kong & Lowe, 2005). This study also found that finger and phalange force was related to handle diameter. A negative correlation was found between finger force and handle diameter, as the handle diameter increased the finger force on the cylindrical handle decreased (Kong & Lowe). This study provides important information on optimal handle size, as well as the diameter required to exert the least amount of force on the handle, but it does not relate this information to specific pieces of adaptive equipment currently applied by occupational therapists (Kong & Lowe).

Adaptive equipment used by clients with hand weakness or arthritis makes self-feeding tasks easier. Adaptive equipment is not just for patient comfort but becomes necessary for joint protection in clients with arthritis or success with self-feeding in cases with hand weakness.
Therapists need quantitative information on adapted tools to make informed decisions as they select the best tool for their clients.

Individuals with osteoarthritis (OA) often experience pain with functional hand use. The World Health Organization (WHO) Scientific Group on Rheumatic Diseases estimates that 10% of the world's population who are 60 years or older have significant clinical problems that can be attributed to OA as cited by Pereira (2011). Adaptive equipment and adaptive techniques are often recommended to reduce the amount of force or stress to the joints through larger handles, tools that encourage joint alignment, and tools that promote leverage (Beasley, 2012). The occupational therapist's role with individuals who have OA is to improve the client's ability to perform daily tasks, help him or her adapt to disruptions in lifestyle, and prevent loss of function.

Findings of population-based studies show rheumatoid arthritis (RA) affects 0.5-1.0% of adults in developed countries. Rheumatoid arthritis is three times more frequent in women than men. Prevalence rises with age and is highest in women older than 65 years (Scott & Kingsley, 2008). People with RA can find it difficult to do daily chores such as dressing, cooking, cleaning and working. Occupational therapists can give advice on how to do every day activities with less pain and on how to use orthoses and assistive devices (Steultjens, et al., 2004). Occupational therapy's focus is to help facilitate increased performance in daily living activities, and overcoming barriers by maintaining or improving abilities or to compensate for decreased ability in the performance of occupations.

Joint protection techniques are used to reduce pain, inflammation, joint stress, and risks of deformity through using assistive devices and alternative movement patterns of affected joints to perform everyday activities (Hammond, Lincoln, & Sutcliffe, 1999). There are eight key principles of joint protection which include
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- maintenance of muscle strength and joint range of motion;
- avoidance of positions of deformity;
- use of the strongest joints available for the job;
- use of each joint in its most stable anatomical and functional plane;
- ensuring correct patterns of movement;
- holding joints or using muscles in one position for any undue length of time is contraindicated;
- the patient should never attempt an activity that cannot be stopped immediately if it proves beyond his or her power to complete it; and
- respect for pain (Cordery, 1965).

The three ways in which these principles are applied include a reduction of the force, elimination of the activity, and intermittent rest periods (Cordery). Using joint protection techniques can positively influence a client's independence in his or her environment and during his or her daily tasks which includes self-feeding tasks.

Preserving the client's ability to continue to self-feed through adaptive equipment may provide him or her an opportunity to maintain adequate nutrition. The American Dietetic Association (ADA) reports that under-nutrition adversely affects the quality and length of life, and therefore, has aroused the concern of geriatric health professionals as cited in Dorner (2010). In some cases, meal intake and nutritional status can be improved in clients with hand weakness through the use of adaptive feeding equipment (cups, utensils, and plates) that has been modified to allow for continued independence in self-feeding (Dorner). A study found that individuals with impaired hand strength, such as those with RA and OA, use more force and pressure to complete activities of daily living (ADLs) as compared with their healthy counterparts (Rahman,
Thomas, & Rice, 2002). Adaptive equipment with enlarged handles can decrease the force and pressure required to hold the equipment. An occupational therapist can decide which clients could benefit from adaptive feeding equipment and select the appropriate adaptive equipment based on the needs of that client and the activity.

**Problem Statement**

There is a lack of quantitative research on the use of adaptive self-feeding utensils for joint protection in clients with OA and RA. There is also a lack of quantitative research in regards to adaptive equipment that promotes self-feeding in order to support nutritional intake in clients with hand weakness, and optimizing functional independence. There are limited studies that focus on the minimum pressure or grip strength required to hold an adaptive feeding utensil with varying handle diameters.

**Purpose/Aims**

The purpose of this study was to determine a baseline for the minimum amount of pressure and force that is required to hold varying spoon handle diameters during a simulated feeding activity. Quantitative data determined the minimum hand pressure and force required to hold a self-feeding utensil. Qualitative data identified the participants comfort level while holding each spoon during data collection.

**Significance of Problem**

Currently, there is limited quantitative data to support the benefits of adaptive equipment to aid in joint protection in clients with arthritis, and in promoting self-feeding in order to support nutritional intake in clients with hand weakness, and in optimizing independence. Occupational therapists and insurance providers need data on adaptive equipment that has been quantitatively demonstrated to facilitate self-feeding. This data may assist the therapist in
selecting the appropriate tool to maximize function and provide evidence to possibly facilitate reimbursement from third party payers. This study will identify baseline information in healthy individuals without arthritis or weakness to determine the handle that requires the least amount of pressure and force for self-feeding.

**Research Question**

What is the minimal amount of pressure and force required to complete a simulated self-feeding activity with a standard spoon versus an adaptive spoon in women and men ages 20 years and above with no known muscle or joint pathologies?

**Key Concepts**

This study investigated several different spoon handle diameters and quantitatively determined the pressures and forces required to complete a simulated self-feeding activity with a standard spoon and an adaptive spoon. Qualitative data was collected from the participants related to comments made about comfort and ease of doing a specific simulated self-feeding task. The mixed methods design contributed to improving the validity, capitalized on the strengths of each approach, and offset their limitations (Spratt, Walker, & Robinson, 2004). It also provides a more complete answer to these research questions, going beyond the weaknesses of a single approach (Creswell, 2003).

The Novel Pliance hand sensor measurement systems used is a valid and reliable system (Lai & Li-Tsang, 2009). The Novel Pliance hand sensor has inter-rater reliability of 95% and a test-retest reliability of 98.8% (Lai & Li-Tsang). The system had less than a 1 mmHg error with testing (Lai & Li-Tsang). This will allow the study to be replicated for further research and review.
Summary

The purpose of this study was to determine a baseline for the minimum amount of pressure and force that is required to hold varying spoon handle diameters during a simulated feeding activity. Utilizing healthy individuals with no known muscle or joint pathologies will provide baseline data to establish the minimum amount of pressure and force required to hold a spoon and complete a feeding activity. This information may contribute to evidenced based practice in joint protection principles and self-feeding. Occupational therapists need quantitative information on adapted tools to make informed decisions as they select the best tool for their clients.
Chapter 2

Literature Review

Introduction

Chapter one provided an overview of the study. The purpose of this chapter is to review the literature on joint protection, adaptive equipment, tool design, grip and pinch strength, and nutrition relative to RA, OA, and hand weakness in an attempt to provide a background for this study. This chapter also gives an overview of the role of occupational therapy and the following theoretical frameworks, the biomechanical model and the Occupational Therapy Practice Framework, and how it applies to the study. This review of the literature attempts to provide support to this current study. The purpose of this study is an attempt to determine the optimal diameter of a self-feeding utensil (spoon) in order to protect the joints and facilitate self-feeding. This was assessed by quantitatively determining the minimum hand pressure and force required to self-feed with an adapted tool and qualitatively determining spoon preferences from the participants.

Rheumatoid Arthritis

Rheumatoid arthritis is a chronic, systemic, and progressive disease of the joints, surrounding tissues, and organs (Klareskog, Catrina, & Paget, 2009). Decreased hand function and pain are a few of the limiting factors of the disease progression (Bodur, Ylmaz, & Keskin, 2006). An estimated 21.6% of adults ages 18 and over have a doctor diagnosed form of RA (Helmick et al., 2008). Of this population, 60% were women. By the year 2030, the projected number of those with diagnosed RA will increase by 40%. Knowing the potential deformities involved in rheumatoid arthritis can assist occupational therapists in providing the most optimal care and tools to promote the highest level of function and independence. Hand dysfunction is a frequent cause of disability to those with RA (Badley, 1995). Studies have shown that joint...
mobility of fingers, grip strength, pain, and stiffness could only partially explain the deficits of grip function seen in RA (Dellhag, Hosseini, Bremell, & Ingvarsson, 2001).

Based on the study by Dellhag, et al. (2001), women with decreased hand function reported a feeling of clumsiness. Mechanical factors may contribute to hand dysfunction in these patients resulting in problems with smoothness, speed, and coordination, particularly during the early phases of the precision grip-lift sequence (Dellhag, et al.). In a study completed by Nordenskiold and Grimby (1993), women with RA (mean age of 55 years) with disease duration of 5-32 years (mean age of 12 years) had about 80% reduced grip force compared to healthy women. The study also argued that hand function may rely on a person’s ability to develop and use compensatory movement (McPhee, 1987). Documentation has shown that early diagnosis has aided in improvements in overall hand function (Bjork, Thyberg, Skogh, & Gerdle, 2007). Contradictory to this statement, both women and men continued to have affected hand function after 5 years post initial diagnosis as compared to healthy persons (Bjork, et al.). Limitations of this study included the lack of knowledge regarding the healthy referents’ general health and its influence on the Health Assessment Questionnaire (HAQ). It should also be noted that during the 12 month follow up, the women of the study had a significantly higher score in the area of limited hand function as compared to men (Bjork, et al.). Despite early diagnosis and early interventions, hand dysfunction is still present and persistent in individuals with RA.

**Osteoarthritis**

Osteoarthritis is the most common joint disorder in the United States and its prevalence increases with age (Ozkan, Keskin, Bodur, & Barca, 2007). The main symptom of OA is pain and joint deformities, and it frequently leads to physical disability and social limitations (Bagis, Sahin, Yapici, Bolgen, & Erdogan, 2003). Hand OA is very common among older adults, but
the link between OA and hand dysfunction remains unclear. Osteoarthritis has been documented clinically and radiologically in up to 90% of clients over the age of 65 (Baron, Dutil, Berkson, Lander, & Becker, 1987). Several studies have demonstrated that hand function is considerably affected by pain and tenderness rather than by the radiological grade of hand OA (Ozkan, et al. & Bagis, et al.). The radiological grade is determined by the narrowing joint space and the amount of cartilage lost (Kessler, Dieppe, Fuchs, Sturmer, & Gunther, 2000). In a study by Hill, Dziedzic, & Ong (2010), limitations due to hand OA curtailing functional ability, or causing pain, were experienced by many participants and often caused feelings of frustration. This particular study included participants with an age range of 51 to 84 years and estimated time with hand problems ranged from six months to 33 years. The large spectrum of experiences among the participants was a limiting factor of this study (Hill, et al.).

It has been reported in the literature that individuals with hand OA demonstrate reduced isometric grip forces, as compared to hands without arthritis (Thyberg, Hass, Nordenskiod, Gerdle, & Skogh, 2005). Individuals with hand OA tend to use an increased grip force to avoid slippage of an object during grasping and/or lifting (Guimaraes de Oliveira, Nunes, Aruin, & dos Santos, 2011). This study also reported that the grip force was higher during an activity in the group of individuals with hand OA than when compared with the control group. One limitation of Guimaraes de Oliveira, et al. was that only women were utilized in this study. Another shortcoming was the limited data on the level of deformity in the participant’s hands. Furthermore, the study also utilized a measurement system that measured the force of the thumb and the combination of all of the opposing fingers rather than assessing each individual finger (Guimaraes de Oliveira, et al). The factors mentioned above may lead to a high correlation with diminished performance of functional activities of daily living (ADL).
Joint Protection

Joint protection is a preventative intervention for people with arthritis (Hammond & Klompenhouwer, 2005) and aims to slow deterioration in hand function which can limit ADL (Hammond, Jefferson, Jones, Gallagher, & Jones, 2002). Joint protection can contain a range of strategies that includes exercise, orthoses, rest, energy conservation, and altering movement patterns of affected joints during everyday activities including use of assistive devices (Hammond, et al., 2002). One study reported that women with thumb based OA demonstrated improvements in grip force and performing ADL while decreasing pain and stiffness when the use of orthoses and exercise were added to a joint protection program (Boustedt, Nordenskiold, & Lundgren Nilsson, 2009). This study had a small sample size (n=35) so the authors recommended that further studies with a larger sample size be completed. Another study concerning the effects of exercise programs and joint protection for hand OA patients in outpatient care showed an improvement in grip force but no reduction of pain (Stamm, et al., 2002).

Hammond and Freeman (2001) completed a study on an educational-behavioral joint protection program for people with RA. Findings suggested that joint protection helped to slow the progression of RA over a period of one year and that there were improvements with hand pain, general pain, early morning stiffness, functional ability, and fewer self-reported disease flare-ups (Hammond & Freeman). A limitation of this study was that this design did not include a no-treatment control group (Hammond & Freeman). Another study showed that when using assistive devices in combination with joint protection techniques, the participants had a decrease in pain and an increase in their activity level in their daily life (Nordenskiold, 1994). However, it is unknown as to whether the participants would have used their assistive devices without
training and group joint protection education because there was not a no-treatment control group. Although adaptive equipment is widely used, there is moderate evidence as to its effectiveness for individuals with arthritis. A study by Nordenskiold (1994), which evaluated the use of assistive devices, found that after a 13 week course on joint protection, 91% of the devices were still being used at follow up and that 95% of the tools were in the kitchen area. As stated above, the limitations of this study were that all the participants were provided with the same intervention (Nordenskiold). In a systematic review that conducted an extensive literature search on the effect of assistive technology, only 13 studies were identified, 12 of which were excluded due to only one study meeting the inclusion criteria (Tuntland, et al., 2009). The one study utilized for this review found moderate evidence to support combining joint protection with adaptive device provision for increased hand function and pain reduction (Tuntland, et al.). Joint protection techniques utilized along with adaptive devices may help decrease pain, protect the joints, and reduce the risk of deformity in individuals with arthritis.

**Adaptive Equipment**

Varying terms can be used to describe assistive technology such as: aid, technical aid, assistive device, self-help device, adaptive device, assistive technology device, and adaptive equipment (Löfquist, Nygren, Szeman, & Iwarsson, 2005). For this study the term adaptive equipment, defined as tools designed to help people with disabilities be more independent, will be used (Heerkins, 2011). Three studies by Hammond (2004), van Kuyk-Minis (1998), and Wolfe (2000) highlighted that adaptive equipment helps an individual maintain independence and participation in meaningful activities.

Studies suggest that two thirds of individuals with arthritis use adaptive equipment daily (Hammond, 1998; Rogers & Holm, 1992). The individuals from the Hammond study may not
be representative of the general population as they are more motivated than other individuals because they have sought out the help. Assistive devices are recommended by clinicians to reduce pain and compensate for deficits and impairments. Adaptive equipment is one of the most commonly used non-pharmacological, non-surgical interventions for individuals with RA (Hammond; Veitiene, & Tamulaitiene, 2005). The most frequently used devices by individuals with RA are aids for personal care and protection, equipment for mobility, devices for housekeeping, and adaptations to the environment (Nordenskiold, 1994; Thyberg, et al., 2005). Few interventions for arthritis are as effective as a well-designed piece of adaptive equipment if the client is properly trained (Tuntland, et al., 2009). The limitation of the Tuntland study was the limited amount of research on the efficacy of adaptive equipment.

**Optimal Handle Size**

A study completed by Kong and Lowe (2005) found that participants rated 30 mm, 35 mm, and 40 mm handles as the most comfortable during grip force exertion. The highest comfort rating was a handle size of 35 mm for females and 40 mm for males. This study was limited by a small sample size (n=24) and a measurement system that alters grip distribution and on the tool handle (Kong & Lowe). Multiple studies have demonstrated that finger force decreased as the cylindrical handle diameter increased with maximal effort (An, Chao, Cooney, & Linscheid, 1979; An, Ueba, Chao, Cooney, & Linscheid, 1983; Fowler, Nicol, Condon, & Hadley, 2001; Kong & Lowe; Seo & Armstrong, 2008; Welcome, Rakheja, Dong, Wu, & Schopper, 2004). As a result of the previously cited studies, it is believed that as the adaptive spoon handle increases the finger force required to hold it will decrease. The study completed by Seo and Armstrong could not demonstrate decreasing force for handle diameters smaller than 38 mm. Contact area was only measured for handle diameters larger than 51 mm. One
limitation of the Welcome, et al. and the Fowler, et al. studies was the limited sample size of participants.

A study completed by Welcome, et al. (2004) found that contact force diminishes as the handle diameter increases. A smaller diameter (30 mm) yields the highest contact force which suggests a smaller handle diameter has considerably more pressure than the larger diameters (Welcome, et al.). A study completed by Pheasant & O'Neill (1975) found that the contact area of the skin to the handle demonstrates a reduced contact area for smaller handle diameters. Another study completed by Seo and Armstrong (2008) demonstrated the mean contact area to be greatest for a larger handle diameter (51 mm and 58 mm). The greater contact area available to hold on to, such as a larger handle diameter, may reduce the possibility of pain and discomfort (Franson-Hall & Kilbom, 1993).

While studies vary on the measurement of optimal handle size for maximum effort, the difference is minimal with multiple studies citing 38 mm and one citing 40 mm (Ayoub & Lo Presti, 1971; Edgren, Radmin, & Irwin, 2004; Garrett, 1971; Yakou, Yamamoto, Koyama, & Hyodo, 1997). The limitation of the Edgren, et al. study is the tool in which the measurements were taken. A dynamometer was used to approximate a cylindrical tool rather than using a hand sensor wrapped around an actual tool. Pheasant and O'Neill (1975) concluded the size of the handle being used during performance will affect the outcome of the activity. Therefore, the data obtained from this study may benefit occupational therapists by assisting them to choose an optimal handle diameter for an adaptive self-feeding utensil.

**Nutrition**

Health promotion has been described as the “process of enabling people to increase control over and to improve their health” (World Health Organization, 1986). Health promotion
is one of the five intervention approaches in the Occupational Therapy Practice Framework. Occupational therapy services can create changes in health goals that are recognized as being of public importance (Mallinson, Fischer, Rogers, Ehrlich-Jones, & Chang, 2009). A factor in promoting health in individuals with OA and RA is to promote nutritional intake. It has been shown that 7.3% of individuals over age 65 and 12.5% over age 75 require assistance with meal preparation (Miller, Falk-Kessler, & Bear-Lehman, 2002). Adaptive equipment may facilitate meal preparation and intake. The activities of meal preparation and food consumption are vital to health and wellness in individuals with OA and RA. Early recognition and treatment of nutritional problems can prevent debilitation (Malamud, 1986). As health professionals, occupational therapists should be aware of patients at nutritional risk. Recognizing how the limitations attributed to hand weakness and deformity will greatly improve the quality of care as occupational therapists.

Role of Occupational Therapy

**Independence.** Occupational therapy (OT) strives to reduce functional deficits and maintain abilities for an individual to perform at his or her maximum level of independence (Nordenskiöld, 1994). The occupational therapist bases treatment on a holistic view of the person and actively involves him or her in the treatment process (Nordenskiöld). Occupational therapy is provided to individuals after acute illness, accidents, and or significant functional impairments (Clark, et al., 1997). Occupational therapy interventions for arthritis include joint protection, training in ADL, and exercise (Stamm, et al., 2002). Occupational therapists utilize the biomechanical model during interventions to increase functional abilities for daily occupations (Cole & Tufano, 2008b).
Biomechanical Model. The theory of the biomechanical model is concerned with the ability to stabilize and move body parts in order to achieve the necessary motion for performing occupations (Kielhofner, 2009). This model has been identified as the most frequently used frame of reference in occupational therapy practice (Cole & Tufano, 2008b). Occupational therapists often use this model for individuals who lack range of motion (ROM), strength, and endurance in order to perform daily tasks (Cole, 2005). The OT may teach the individual energy conservation techniques, adaptations to compensate for lost physical body structure and function, and may incorporate adaptive equipment as needed. These techniques may help to prevent deformity, restore the ability for movement, and compensate for lost ROM, strength, and endurance (Cole & Tufano). Individuals with OA and RA commonly utilize these methods to maintain functional abilities.

This current research project focuses on the optimal handle diameter of a spoon that requires the minimum amount of pressure and force needed for self-feeding activities. The client populations that have been identified to benefit from this study are individuals with RA and OA of the hand and individuals with hand weakness. These individuals may display decreased ROM, increased pain and stiffness, and may fatigue easily when completing daily tasks with their hands (Radomski & Trombly Latham, 2008). With the baseline information for the normal hand obtained through the study, and considering the biomechanics of the hand, occupational therapists can help identify ways to allow individuals to participate in self-feeding while addressing limitations in ROM, strength, and endurance.

Occupational Therapy Practice Framework. The occupational therapy practice framework is used by occupational therapists to support health and participation in life through engagement in occupation (American Occupational Therapy Association, 2008). The practice
framework serves as a tool to guide OTs across all possible domains of practice and allows each therapist to choose the occupation-based models and frames of reference that best fit the client and the practice setting (Cole & Tufano, 2008a). This research study will focus on the domain of self-feeding and engagement in purposeful occupation.

Summary

After reviewing the literature it has been determined that information on the pressure required to hold a spoon is necessary due to the lack of research of pressure applied directly to the tool with various handle sizes during self-feeding. Occupational therapists have commonly used normative data on hand grip and pinch strengths as baseline measures to evaluate hand function (Mathiowetz, et al., 1985). Little information is available on the minimum amount of pressures required to hold a spoon and if the pressure is reduced with various handle diameters during a self-feeding activity. Healthy individuals were evaluated to obtain baseline information, eliminating the co-morbidities that are associated with hand conditions that may interfere with accurate data collection. It has been found that individuals with arthritis tend to grip objects more forcefully, and therefore, would skew the data of this study (Guimaraes de Oliveira, et al, 2011; Rahman, 2002). With careful evaluation, it has been decided that healthy individuals will be utilized for this preliminary study.

Chapter one provided an overview to the topic of the study. This chapter provided a review of the literature on joint protection, adaptive equipment, tool design, grip and pinch strength, and nutrition relative to RA and OA. Chapter three will identify the methods that were used in the study, discuss the rationale and purpose of the study, the location, the participants, instrumentation and materials used, the procedure, data analysis, and the possible limitations involved in the implementation of the study.
Chapter 3

Methodology

Introduction

Chapter one introduced the purpose of the study and the research question. The purpose of this study was to determine a baseline for the minimum amount of pressure and force that is required to hold varying spoon handle diameters during a simulated feeding activity. By quantitatively determining a baseline for the minimum hand pressure and force required by identifying the optimal handle diameter in healthy individuals, this may help facilitate self-feeding and meal preparation in clients with hand weakness and/or decreased pressure and force to protect the joints in cases of arthritis. Chapter two examined the literature related to the study in regards to:

- rheumatoid arthritis
- osteoarthritis
- joint protection
- adaptive equipment
- optimal handle size
- nutrition
- the role of occupational therapy
- biomechanical model
- occupational therapy practice framework

Chapter three will identify the study design and rationale, location and context of the study, participants, equipment and instruments, validity and reliability, and the procedure that was used.
Study Design and Rationale

This study utilized a mixed methods research design. Mixed methods research provides a more comprehensive understanding of the subject being studied (Golder, Light, & Stirk, 2007). A mixed methods approach can combine data and support findings, help eliminate or minimize alternatives, and strengthen conclusions by revealing contradictory aspects that may be overlooked (Locke, Spirduso, & Silverman, 2008). In a means to obtain statistical information for the pressure of each spoon handle diameter, a quantitative approach was utilized. This information was analyzed to help determine the optimal spoon handle diameter that requires the minimum amount of pressure and force to hold. Quantitative analysis was utilized along with the qualitative data for a concurrent triangulation strategy (Kielhofner, 2009).

The qualitative aspect was used to expand the understanding of subjective comfort level of the varying handle diameter based on self-report of the participants. An exit form (Appendix E) was developed to allow the participants to make further comments regarding the study procedures. The qualitative data was gathered using the exit form, the data was then analyzed using a coding process to determine common themes. One member of the research team recorded additional verbal comments by the participants.

Location and Context of the Study

This study took place at the Grand Valley Cook-Devos Center for Health Sciences in Grand Rapids, Michigan. This location was determined to be adequate for this study because of the central location of participants and access to the testing equipment. The testing took place in room 215 on the second floor of the building in the Biomechanics Laboratory.
Participants

Participants were in the age range of 20 years to 59 years, with no known hand and/or wrist joint pathologies. This age range was identified based on the demographics of the area being comprised predominantly of juniors, seniors, and graduate students. Both male and female participants were included. Those with known hand and/or wrist joint pathologies or under the age of 20 years were not included in the research study. Healthy individuals with no known hand and/or wrist joint pathologies have been chosen for this study in an attempt to determine normative baseline data on pressure required for self-feeding using varying spoon handle diameters. Participants were recruited for the study through mass electronic mailing to Grand Valley State University students. In addition to the mailing, 5 flyers were placed throughout the Cook-Devos Center for Health Sciences building to request voluntary participation in the research study (see Appendix A).

Equipment and Instruments

The Novel Pliance-X capacitive sensor used in this study is a dynamic pressure distribution measuring system designed for a variety of applications including medical, ergonomic, and biomechanical testing scenarios (Novel Electronics Inc., 2011). The Novel Pliance-X sensor was used in this study due to its ultra-thin (less than 1 mm thick) mat that allows for the flexibility needed to wrap around and adhere to spoon handles of varying diameters. Further instructions on the use of the Novel Pliance-X system device were obtained through the Pliance-X system manual and a GVSU faculty member trained in the use of the sensor.
The Novel Pliance-X system includes a sensor mat, sensor cable, sync box, fiber optic cable with fiber optic/USB adapter, USB cable, belt, battery with cable and charger, a start and stop trigger, and a Bluetooth dongle. This equipment is used to collect and interpret force and pressure applied to the sensor mat (Novel Electronics Inc., 2011). The sync box indicates transmission of data between the computer and the sensor, including errors during measurements, power failures, and proper calibration during zero measurement (Novel Electronics Inc.). The Bluetooth dongle transfers the data collection via wireless communication to the computer, reducing the possibility for physical limitations imposed by the system (Novel Electronics Inc.).

The Pliance Online Program collected and displayed the data gathered with the Novel Pliance-X sensor after calibration (Novel Electronics Inc., 2011). The program recorded the parameters of force (N), peak pressure (kPa), mean pressure (kPa), contact area (Cm²), pressure-time integral (kPa*s), and force-time integral (N*s) (Novel Electronics Inc.). This study analyzed the pressure required to pick up and hold a spoon with a standard diameter handle, and adaptive handles of 25 mm and 40 mm.

Validity/Reliability. This study investigated several different spoon handle diameters and quantitatively determined the pressures and forces required to hold a standard spoon and two adaptive spoons during a simulated self-feeding activity. The Novel Pliance-X hand sensor measurement systems used is a valid and reliable system (Lai & Li-Tsang, 2009). The Novel Pliance-X hand sensor has inter-rater reliability of 95% and a test-retest reliability of 98.8% (Lai & Li-Tsang). The system had less than a 1 mmHg error with testing (Lai & Li-Tsang). This allows the study to be replicated for further research and review.
Spoons. A study completed by Kong and Lowe (2005) found that participants rated 30 mm, 35 mm, and 40 mm handle diameters as the most comfortable during grip force exertion. The handles for this current research study were selected based on the research of Kong and Lowe that identified varying handle diameters and comfort levels. The spoons have varying handle diameters to find the optimal handle size for the least amount of force needed to hold the spoon handle and complete the simulated self-feeding activity. The handles for this study vary from a traditional handle diameter of 15 mm (See example Figure 1) to an increased diameter of 25 mm (See example Figure 2) and 40 mm (See example Figure 3).

Figure 1. Traditional spoon handle diameter. This figure illustrates the 15 mm spoon handle diameter.

Figure 2. Adaptive spoon handle diameter. This figure illustrates the 25 mm spoon handle diameter.
Figure 3. Adaptive spoon handle diameter. This figure illustrates the 40 mm spoon handle diameter.

Procedures

An adapted tool screening questionnaire was completed on each participant by telephone or e-mail (see Appendix B) and during this correspondence, a scheduled time for participation was established. On the day of the study, participants completed a demographic intake form to ensure no known joint pathologies existed and to document age (see Appendix C). Any volunteer with a history of arthritis or hand pain was excluded as the purpose of this study was to determine a baseline for the minimum amount of pressure and force that is required to hold varying spoon handle diameters during a simulated self-feeding activity.

The researchers explained the study, the potential risks involved, and provided the participant information form (see Appendix D). The researchers had the volunteer read over the participant information form and a copy was given to each volunteer. The study was submitted and approved through the Grand Valley State University Human Research Review Committee. The participant was assigned a letter for confidentiality on all documentation. Any and all research data linking the participants to this research study was stored in a locked cabinet in the occupational therapy department research files at the Cook-DeVos Center for Health Sciences. Data will be stored for at least three years and then destroyed. After participation in the research
study, participants were asked to complete an exit form based on their experience in the study (see Appendix E).

The group of participants followed procedures A through E during the data collection session for the spoon assessment: (the orders of the spoons were randomized per group).

A. Researchers demonstrated picking up a quarter from one bowl, bringing it to the mouth, and depositing the quarter in an empty bowl.

B. Each participant sat at a table and used either spoon A, B, or C to retrieve a quarter from the bowl of quarters and lifted the quarter to his or her mouth. This was repeated three times and an average of the three trials were taken.

C. After participants completed this task, the researchers removed the sensor from the spoon and then applied it to the next spoon to be tested.

D. Steps B and C were repeated for all spoons (spoons were tested in a random order).

E. After participants had used all three spoons, the researchers distributed an exit form (Appendix E) to each participant regarding which spoon was preferred and why.

The complete written procedure is as follows:

The sensor mat was laid flat on table C and unloaded for measurement by the Novel Pliance-X hand sensor measurement system. The sensor mat was wrapped individually around the spoon handle diameter and adhered with Micropore tape, as recommended by the manufacturer. Once the sensor mat was attached to the spoon handle, a baseline zero measurement was taken. This baseline was applied to all measurements for that spoon handle.

With the Pliance program running, the participants were asked to pick up the spoon, scoop a quarter located in a bowl, bring it to his or her mouth, deposit the quarter in the empty bowl, and then return the spoon to the table.
The sensor mat was removed, unloaded, and reattached with Micropore tape for the different spoon handle diameters and zero was established prior to each use. Each participant repeated this process on a 15 mm, 25 mm, and 40 mm handle diameter. Qualitative comments made by the participants were manually recorded throughout the study by the researchers. When the participants completed the series of handle grasps, they were asked to complete an exit form (Appendix E), were thanked for their time, and excused from the research study. This study had minimal risks, but a first aid kit was available in case of injury.

Data Analysis

The quantitative data was gathered using the Novel Pliance-X Sensor System. This program gives measurements for average force, maximum force, peak pressure, and average peak pressure for every millisecond throughout the scan (Novel Electronics Inc., 2011). A repeated measures analysis of variance was used to analyze the data to see the change in mean scores of the spoon handle diameters (Kogan, 1948). This test deciphered differences in related means to ultimately find the handle requiring the least pressure to hold. The spoon handle diameter is the independent variable and the pressure on the spoon handle diameter is the dependent variable.

The qualitative data was gathered using the exit form (Appendix E) that was provided to the participants upon completion of the research data. The data was be analyzed with a coding process which is the process of organizing the material into groups, like patient perspectives, before bringing meaning to those groups (Creswell, 2003). Once groups were established, common themes were identified for each group.

A concurrent triangulation design was utilized when gathering the quantitative and qualitative data. With the concurrent triangulation design, both the quantitative and qualitative
data are gathered at the same time (Kielhofner, 2009). Kielhofner stated that neither the quantitative or qualitative data are chosen as core or secondary data which allows the researchers to follow interesting developments as they occur.

Summary

This chapter presented an overview of the methods and the procedures were utilized in the research study. The mixed method concurrent triangulation strategy was discussed, as well as the rationale for choosing this study design. Chapter 3 also explained the participants, research location, and sampling methods, as well as the instrumentation, procedures of the research study, and the analysis of data. Chapters 4 and 5 will display the data results and the interpretation of these results. The researchers will use this information in an attempt to answer the research question: What is the minimal amount of pressure and force required to hold a standard spoon versus an adaptive spoon and complete a simulated self-feeding activity in women and men ages 20 years and above with no known muscle or joint pathologies?
Chapter 4

RESULTS

Introduction

Chapter one introduced the purpose of the study and the research question. The purpose of this study was to determine a baseline for the minimum amount of pressure and force that is required to hold varying spoon handle diameters during a simulated feeding activity. By quantitatively determining the minimum hand pressure and force required by identifying the optimal handle diameter in healthy individuals, this may help facilitate self-feeding and meal preparation in clients with RA, OA, hand weakness. Chapter two discussed the literature review pertaining to the topics of the study, such as rheumatoid arthritis, osteoarthritis, joint protection, and optimal handle size as it relates to the field of occupational therapy. Chapter three identified the study design and rationale, location and context of the study, participants, equipment and instruments, validity and reliability, and the procedure that will be used. Chapter four will present the qualitative and quantitative results.

Characteristics of Participants

There were 32 participants that took part in this research study. The participants ranged from 22 to 59 years of age with a mean age of 33.09 years of age. Twenty-one participants were male and 11 participants were female. Thirty-one participants were right hand dominant and one participant was left hand dominant. No participants were excluded from the study due to the prescreening process prior to the study.

Force and Pressure Results

The results for the 15 mm spoon handle are as follows: mean force (N) 4.8655, maximum pressure (kPa) 29.5486, and mean pressure (kPa) 1.1652. The results for the 25 mm spoon handle are as follows: mean force (N) 6.9516, maximum pressure (kPa) 29.7049, and mean
pressure (kPa) 1.6277. The results for the 40 mm spoon handle are force (N) 8.4447, maximum pressure (kPa) 34.8851, and mean pressure (kPa) 1.3781. The results indicate that as the size of the spoon handle increased, the mean force also increased. The output of force was greatest for males than females. One participant gave a pain rating of three out of five (five being high) with the 15 mm spoon. The remaining 31 participants all rated their pain a zero out of five on the functional pain scale (Gloth, Scheve, Stober, Chow, & Prosser, 2001).

**Quantitative Data Analysis**

The force of the hand-handle distribution was gathered through the Novel Pliance-X hand sensor. The hand sensor software collected data for each millisecond of the simulated self-feeding trial. The software collected numerical data for force, maximum pressure, and mean pressure. The equation for force is force = pressure × area, measured in Newtons (N), and the equation for pressure is pressure = force/area, measured in kilopascals (kPa).

The data was acquired from 32 subjects using three spoons with varying handle diameters and completed three trails for each spoon. An average of the three trials was computed using Excel spreadsheet for force, maximum pressure, and mean pressure. The averages were imported into SPSS software and statistically analyzed. The data illustrated an approximately normal distribution of residuals produced by the spoon handle trials. If the residuals are not normally distributed, then the dependent or independent variable may not follow the bell curve or important variables may be missing. A correction to this may produce residuals that are normally distributed.

**Force.** A repeated measures analysis of variance was computed for force, maximum pressure, and mean pressure. The null hypothesis for force is as follows: The spoon handle samples (15 mm, 25 mm, and 40 mm) will have mean forces that are equal. The alternative
hypothesis is: The means of force on the spoon handle are not all equal. The data was analyzed using a repeated measures analysis of variance (ANOVA) in SPSS. Mauchly’s Test of Sphericity was first examined to determine if the variations in the differences between all combinations of related groups are equal. Mauchly’s Test of Sphericity is a test for conditions to determine which F-test is correct. Violation of sphericity is when the variances of the differences between all combinations of related groups are not equal. A violation of sphericity for the repeated measures ANOVA can cause an increase in the type I error rate. Sphericity can be explained as the similarity of variances in repeated measures ANOVA (Sphericity, 2012). Mauchly’s Test for force showed an approximate Chi-Square of 1.712 and a p-value of .425. This significance level indicates that Mauchly's Test of Sphericity has not been violated, \( \chi^2(2) = 1.712, p = .425 \) as is shown in table 1.

<table>
<thead>
<tr>
<th>Measure: Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Subjects Effect</td>
</tr>
<tr>
<td>Handle Diameter</td>
</tr>
</tbody>
</table>

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: Handle Diameter

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
Sphericity has not been violated, therefore, sphericity assumed will be utilized with degrees of freedom of 2, an F-value of 6.528, and a p-value of .003. There was a statistically significant effect of handle size on force, as is shown in Table 2.

Table 2
*Tests of Within-Subjects Effects for Force*

<table>
<thead>
<tr>
<th>Measure: Force</th>
<th>Type III Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Handle Diameter</strong></td>
<td>Sphericity Assumed</td>
<td>206.8</td>
<td>2</td>
<td>103.42</td>
<td>6.528</td>
<td>.003</td>
</tr>
<tr>
<td></td>
<td>Greenhouse -Geisser</td>
<td>206.8</td>
<td>1.895</td>
<td>109.15</td>
<td>6.528</td>
<td>.003</td>
</tr>
<tr>
<td></td>
<td>Huynh-Feldt</td>
<td>206.8</td>
<td>2.000</td>
<td>103.42</td>
<td>6.528</td>
<td>.003</td>
</tr>
<tr>
<td></td>
<td>Lower-bound</td>
<td>206.8</td>
<td>1.000</td>
<td>206.84</td>
<td>6.528</td>
<td>.016</td>
</tr>
<tr>
<td><strong>Error(Handle Diameter)</strong></td>
<td>Sphericity Assumed</td>
<td>982.2</td>
<td>62</td>
<td>15.843</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Greenhouse -Geisser</td>
<td>982.2</td>
<td>58.742</td>
<td>16.722</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Huynh-Feldt</td>
<td>982.2</td>
<td>62.000</td>
<td>15.843</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower-bound</td>
<td>982.2</td>
<td>31.000</td>
<td>31.686</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
This p-value of .003 is significant, which allows the rejection of the null hypothesis in favor of the alternative hypothesis that the mean forces on the spoon handles are not all equal. The pairwise comparison illustrates a significant difference (p-value = .001) between the 15 mm spoon handle and the 40 mm spoon handle. The force on the 15 mm spoon handle was significantly less than the pressure on the 40 mm spoon handle. There was no statistical significance between the 15 mm and 25 mm (p-value = .171) or the 25 mm and the 40 mm (p-value = .494). Table 3 shows the results from this test. Figure 4 illustrates the differences in force on the spoon handle diameters.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Pairwise Comparisons for Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure: Force</td>
<td></td>
</tr>
<tr>
<td>(I) Handle Diameter</td>
<td>Mean Difference (I-J)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

Based on estimated marginal means

* The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.
Figure 4. Estimated Marginal Means of Force. Handle diameter 1 is the 15 mm handle, handle diameter 2 is the 25 mm handle, and handle diameter 3 is the 40 mm handle diameter. It is to be noted that as the handle size increased, the force on the handle also increased during the simulated self-feeding activity.

**Maximum pressure.** The null hypothesis for maximum pressure is as follows: The spoon handle samples (15 mm, 25 mm, and 40 mm) will have mean maximum pressures that are equal. The alternative hypothesis is: The mean maximum pressures on the spoon handle are not all equal. The data was analyzed using repeated measures ANOVA in SPSS. Mauchly’s Test of Sphericity for maximum pressure showed an approximate Chi-Square of 3.380 and significance
level \( (\alpha) \) of .185. This significance level indicates that Mauchly's Test of Sphericity has not been violated, \( \chi^2(2) = 3.380, p = .185 \) as is shown in Table 4.

<table>
<thead>
<tr>
<th>Table 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mauchly's Test of Sphericity(^a) for Maximum Pressure</td>
</tr>
<tr>
<td>Measure: Max Pressure</td>
</tr>
<tr>
<td>Within Subjects Effect</td>
</tr>
<tr>
<td>Handle Diameter</td>
</tr>
</tbody>
</table>

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

\( a. \) Design: Intercept

Within Subjects Design: Handle Diameter

\( b. \) May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Sphericity has not been violated, therefore, sphericity assumed will be utilized with degrees of freedom of 2, an F-value of 2.933, and a p-value of .061. There was not a statistically significant effect of handle size on maximum pressure, \( F(2, 62) = 2.933, p = .061 \), as is shown in Table 5.

This p-value indicates a failure to reject the null hypothesis that the maximum pressure is equal. This demonstrates that the mean differences in maximum pressure between the 15 mm, 25 mm, and 40 mm spoon handle diameters are not significant.
Table 5
Tests of Within-Subjects Effects for Maximum Pressure
Measure: Max Pressure

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handle Diameter</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sphericity Assumed</td>
<td>590.261</td>
<td>2</td>
<td>295.131</td>
<td>2.933</td>
<td>.061</td>
<td>.086</td>
</tr>
<tr>
<td>Greenhouse-Geisser</td>
<td>590.261</td>
<td>1.807</td>
<td>326.574</td>
<td>2.933</td>
<td>.067</td>
<td>.086</td>
</tr>
<tr>
<td>Huynh-Feldt</td>
<td>590.261</td>
<td>1.913</td>
<td>308.593</td>
<td>2.933</td>
<td>.063</td>
<td>.086</td>
</tr>
<tr>
<td>Lower-bound</td>
<td>590.261</td>
<td>1.000</td>
<td>590.261</td>
<td>2.933</td>
<td>.097</td>
<td>.086</td>
</tr>
<tr>
<td>Error (Handle Diameter)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sphericity Assumed</td>
<td>6239.326</td>
<td>62</td>
<td>100.634</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greenhouse-Geisser</td>
<td>6239.326</td>
<td>56.031</td>
<td>111.356</td>
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<td></td>
</tr>
<tr>
<td>Huynh-Feldt</td>
<td>6239.326</td>
<td>59.295</td>
<td>105.225</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower-bound</td>
<td>6239.326</td>
<td>31.000</td>
<td>201.269</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean pressure. The null hypothesis for mean pressure is as follows: The spoon handle samples (15 mm, 25 mm, and 40 mm) will have mean pressures that are equal. The alternative hypothesis is: The averages of mean pressures on the spoon handles are not all equal. The data was analyzed using repeated measures ANOVA in SPSS. Mauchly’s Test of Sphericity for mean pressure showed an approximate Chi-Square of 11.579 and a p-value of .003. This significance level indicates that Mauchly's Test of Sphericity has been violated, $\chi^2(2) = 11.579$, $p = .003$, as is shown in Table 6.
Table 6

Mauchly’s Test of Sphericity* for Mean Pressure

Measure: Mean Pressure

<table>
<thead>
<tr>
<th>Within Subjects Effect</th>
<th>Mauchly’s W</th>
<th>Approx. Chi-Square</th>
<th>df</th>
<th>Sig.</th>
<th>Epsilon&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Greenhouse-Geisser</th>
<th>Huynh-Feldt</th>
<th>Lower-bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handle Diameter</td>
<td>.680</td>
<td>11.579</td>
<td>2</td>
<td>.003</td>
<td>.757</td>
<td>.788</td>
<td>.500</td>
<td></td>
</tr>
</tbody>
</table>

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
   Within Subjects Design: Handle Diameter

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Since sphericity was violated, possibly causing a chance in an increase in a type I error, a correctional adjustment using the Greenhouse-Geisser was utilized. With the Greenhouse-Geisser correction, the mean pressure of the varying handle diameters did not display a statistically significant variance $F(1.515, 72.192) = 1.473, p = .239$, as is shown in Table 7. With the correction of the Greenhouse-Geisser, the p-value of .239 indicates a failure to reject the null-hypothesis. This demonstrates that the average difference in the mean pressure between 15 mm, 25 mm, and 40 mm spoon handle diameters are not significant.
Further statistical analysis taking into account age, gender, and hand dominance was created. During this more advanced statistical analysis, the data for mean and maximum pressure did not demonstrate a significant difference among the spoon handles in regards to age and gender, and hand dominance. There was however, a significant difference in the measurement of force. The output of force was greater for males than females. Age was not correlated in the core values.

**Qualitative Data Analysis**

Qualitative data was acquired during the research study by using the participant’s responses that they provided on the exit form (Appendix E), as well as field note comments that were recorded by the researchers. The data was analyzed with a coding process which is the
process of organizing the material into groups, like patient perspectives, before bringing meaning to those groups (Creswell, 2003). When analyzing the exit form and field note comments, four common themes were identified from the data in regards to preference of spoon: ease of use, comfort, size/fit, and natural feel/use. Upon reviewing the exit forms, four participants did not state a reason for spoon choice and participant O stated that “they prefer a tighter grip.”

Ease of use: Eleven of the participants chose their preference of spoon because it was easier to grip or hold when using it. Six of the participants preferred the 15 mm spoon handle. Participant W said “it was easiest to hold and scoop” and participant X said “it was easier to grip without using palm.” Four participants preferred the 25 mm spoon handle. Participant I felt “it was easier to hold on to with a good balance” and participant L stated “it was easier to grip with padding.” Only participant P preferred the 40 mm spoon handle based on ease of use and said that “it was easier to grip.”

Comfort: Six of the participants chose the spoon based on the comfort level when holding the spoon. Two of the participants preferred the 15 mm spoon handle. Participant E said “this spoon handle felt more comfortable” and participant AA stated that “it felt nice.” Two participants preferred the 25 mm spoon handle. Participant B commented that “it was comfortable” and participant EE felt it was “more comfortable with grip size.” Two participants preferred the 40 mm spoon handle. Participant H said “it was comfortable to hold” and participant K said “it was most comfortable to hold.”

Size/fit: Five of the participants preferred the spoon because of the size/fit of the spoon in the hand. Only participant U chose the 15 mm spoon and commented that “it is small, not heavy.” Two participants chose the 25 mm spoon. Participant V stated that “it fit in hand, weight” and participant FF said “it was soft/good grip size.” Two participants chose the 40 mm
spoon. Participant R commented on "the longer neck between handle and head of spoon" and participant DD said "it had a wider grip and it felt like I could pick up more quarters easier."

**Natural feel/use:** Lastly, five of the participants preferred the spoon based on the natural use of/familiarity of the handle. All five of these participants preferred the 15 mm spoon handle. Participant Q stated that "it more closely related to a spoon I typically use," participant Y said "it was the style of spoon I am use to using, and participant BB said "it is the most similar to spoons I am use to using, also easier to handle."

**Summary**

This chapter presented the statistical analysis of the quantitative and qualitative data. The data showed that there was a statistically significant difference in mean force between spoon handle diameters. There was statistically significant difference between the 15 mm spoon handle and the 40 mm spoon handle with the 15 mm handle requiring less mean force than the 40 mm handle. There was not statistically significant difference between spoon handle diameters for maximum pressure and mean pressure. The qualitative data showed that overall participants preferred the 15 mm spoon handle to the 25 mm and 40 mm spoon handles. These participants preferred the 15 mm spoon handle because of ease of use, comfort, size/fit, and natural feel/use than the other handles. Chapter 5 will discuss the interpretation of data, application to occupational therapy practice, limitations, and suggestions for further research.
Chapter 5

DISCUSSION AND CONCLUSIONS

Introduction

Chapter 1 introduced the topic of this research study including the significance, research question, and the key topics. Chapter 2 delved deeper into the background information with a literature review on OA, RA, joint protection, adaptive equipment, optimal handle size, and nutrition. Chapter 3 discussed methods for data collection and procedures. Chapter 4 discussed the participants and their demographics, as well as the results analyzing the quantitative and qualitative data gathered. Chapter 5 will discuss the interpretation of the statistical analysis and the qualitative data. It will also give the limitations of the study, the application to occupational therapy practice, as well as suggestions for further research.

Discussion of Findings

A statistical analysis was completed on maximum pressure, mean pressure, and force for all spoon handle diameters. The statistical analysis revealed that there was a statistically significant difference in force between the 15 mm spoon handle and the 40 mm spoon handle, with the 15 mm spoon handle having less mean force than the 40 mm spoon handle. This may have been due to the fact that the participants were not familiar with the 40 mm spoon handle as compared to the 15 mm spoon handle. Another assumption as to why the 15 mm spoon handle required less force than the 40 mm spoon handle was because force is pressure × area (Novel Electronics Inc., 2011). The greater surface area of the 40 mm spoon handle would have increased the force exerted. The results did not demonstrate a large enough difference to be significant between the 15 mm and the 25 mm spoon handle or the 25 mm and 40 mm spoon handle.
Application to Occupational Therapy Practice/Theory

This study did not demonstrate that increasing handle size will decrease force on the joints of the hand. This was also seen in a study completed by Seo & Armstrong (2008), in which a decrease in force on the handle was not seen below a 38 mm handle diameter. Previous studies that have been completed on optimal handle size focused on maximum effort and this study focused on minimal effort (An, Chao, Cooney, & Linscheid, 1979; An, Ueba, Chao, Cooney, & Linscheid, 1983; Fowler, Nicol, Condon, & Hadley, 2001; Kong & Lowe; Seo & Armstrong, 2008; Welcome, Rakheja, Dong, Wu, & Schopper, 2004). It should also be noted that the previous listed studies were completed on jobsite tools and not adaptive equipment.

Qualitative data indicated that overall, the participants preferred the 15 mm spoon handle. The reasons for this choice varied and included comfort, ease, size/feel, and natural feel. It was theorized that familiarity with the spoon may have swayed the participant’s preferences and the manner in which they held the spoon. Occupational therapy training may help promote proper mechanics of holding the spoon, joint protection principles, altering movement patterns, and fluency of utilizing the self-feeding utensil (Hammond, et al., 2002). The training and proper equipment may help maximize functional independence in the area of self-feeding by increasing comfort, ease of use, and natural feel/use. This may decrease the force the participants place upon the spoon handle. It was also indicated that training promotes an increase in the use of adaptive equipment with one research article showing after 13 weeks of training, 91% of equipment was still being used (Nordenskiöld, 1994).

A previous study in individuals with RA has shown that a decrease in hand function causes feelings of clumsiness, and problems with smoothness, speed, and coordination during grip exertion (Delhag, 2001). Thyberg, et al. (2005) found that individuals with OA demonstrated a decreased grip force as compared to those without arthritis. Individuals with
hand OA tend to use an increase in grip force to combat slippage during grasping or lifting tasks (Guimaraes de Oliveira, Nunes, & dos Santos, 2011). Based on these research studies, it was thought that a larger spoon handle would decrease the force in the joints of the hand. The results of this study did not support utilization of a larger handle during a self-feeding activity to decrease force on the joints of the hand but using participants with OA and RA may produce alternative results.

Limitations

The limitations of this study include: healthy participants, difficulty scooping quarters, the convenience sample, and limited left hand dominant participants. It was decided to utilize healthy individuals to establish a baseline and to avoid comorbidities of hand conditions interfering with test results. Quarters were chosen for scooping based on the fact that quarters have a standard weight but were awkward for the participants to scoop. Some of the participants scooped more than one quarter which may have skewed the data by increasing weight on the spoon. This study chose a sample of convenience based on the central location of the testing site. This sample group may not represent the true population. The left hand dominance sample size was too small to see statistical significance between pressures on the handles in the relation to hand dominance. In further research, hand measurements of the participants may enhance the understanding of hand size on pressure of handle utensils. By measuring the hand in regards to hand diameter, finger length, hand thickness, and overall hand length, the data could display significance in these factors of force, maximum pressure, and mean pressure.

Suggestions for Further Research/Modifications

The research conducted has led to suggestions and recommendations for future research and considerations. One recommendation for future considerations would be to use an
alternative material to scoop with the spoon. The participants felt that the quarters used were awkward and difficult to manipulate. This caused some participants to scoop more than one quarter at a time possibly affecting the pressure and the force. A more natural material, i.e: beans or rice, would be suggested but would be difficult to standardize. A brief period of training with each spoon handle may lead to an increase familiarity possibly decreasing the amount of pressure and force on the spoon handle during a self-feeding activity. To increase the familiarity, the researchers could have demonstrated the proper holding of the adaptive self-feeding utensil. A return demonstration by the participant would have indicated an understanding of how to hold the adaptive self-feeding utensil.

Conclusion and Summary

Further study is needed to determine if occupational therapists should be recommending enlarged handles on self-feeding utensils for individuals with hand conditions, especially if the handle lacks familiarity to the client. When using adaptive equipment, initially individuals tend to increase pressure and force on the handle due to the lack of familiarity with the equipment. One study showed that with acquired use and training, individuals loosen their grip the more they become accustomed to using the tool (Broker & Ramey, 2008). This research with healthy individuals does not demonstrate decreased pressure on the joints of the hand with increased handle size. Expanding the research to individuals with OA, RA, and hand weakness, and including a training period to increase familiarity, may produce different results due to the fact that these individuals tend to grip objects harder than healthy individuals. This population will more likely align with the demographic that utilizes adaptive self-feeding utensils.
References


*Clinical Rheumatology, 18*(4), 491–505.


*Rheumatology, 40*, 1044-1051.


*British Journal of Occupational Therapy, 68*(1), 25-33.


*Patient Education and Counseling, 37*(1), 19-32.


Hill, S., Dziedzic, K., & Ong, B. (2010). The functional and psychological impact of hand


of Hand Therapy, 13(2), 184–192.


Appendix A
Occupational Therapy Hand Sensor Study

Date: October 6, 2012

- Seeking participants ages 20 and above with no wrist and/or hand weakness or arthritis to test 3 different spoons.
- **When:** scheduled appointments approximately 1 hour
- **Where:** CHS 215

**Purpose:**

Help us determine which spoon requires the least amount of force and can best protect the joints of the hand

**Snacks provided to all participants!**
Appendix B
Adapted Tools
Screening Questionnaire

This will be sent by e-mail or by telephone to the potential participants to determine study eligibility

Date: ____________________________
Preferred first name: ____________________________

Study introduction:

Hello, my name is _______ and I am an occupational therapy student at Grand Valley State University. I am part of a research team that is conducting a study to determine which adapted tool requires the least amount of pressure and force to use. You have been contacted because you have responded to a flier regarding the study. If you agree to participate in this study, you will be asked to come to the Cook-DeVos Center for Health Sciences in Grand Rapids, MI. The researchers will contact you via e-mail to set up a one-hour appointment. During this hour, you will be asked to manipulate various adapted tools.

In order to determine whether you are eligible to participate in this study, it is necessary to ask you some screening questions about your health. If you decide to answer these questions, the answers you give will be kept completely confidential. Please respond to the following yes and no questions by bolding your answer.

Do you have a diagnosed disability involving your dominant arm or hand? Yes
No

Have you been diagnosed with arthritis? Yes
No

Are you a student, faculty, or staff member of the occupational therapy department? Yes
No

Comments: ____________________________________________________________
__________________________________________________________
__________________________________________________________

Thank you! Please return this screening questionnaire to HandSensorStudy@gmail.com if provided as an e-mail attachment.
If the patient has a diagnosed upper extremity disability, arthritis, or is affiliated with the occupational therapy department, the e-mail response will read:

Thank you for your time. Unfortunately, you are not eligible for this study. We appreciate your cooperation.

Thank you.

If the patient does not have a diagnosed upper extremity disability, arthritis, or is affiliated with the occupational therapy department, the e-mail response will read:

You are eligible to participate in this study. You will be required to come to the Cook-DeVos Center for Health Sciences at the scheduled appointment time which is ______ (date) and ______ (time). Would you still like to participate in this study?

Yes

No
Appendix C
Demographic Intake Form

Age: ____________  Study ID number ________________________

Gender:  Female  Male

Handedness:  Left  Right  Ambidextrous

Occupation: _______________________________________________________

History of hand injury or conditions:  Yes  No

If yes, please explain: ________________________________________________

_________________________________________________________________

_________________________________________________________________
Appendix D
Protecting the Hand: Quantifying pressures involved in daily living activities with tools

I am being asked to participate in a research study entitled "Protecting the Hand: Quantifying pressures involved in daily living activities with tools" conducted by Occupational Therapy student researchers Kelly Cotter, CTRS, B.S., Trisha Thompson, B.S., COTA, PTA, and Amanda Ward, B.S. from Grand Valley State University Occupational Therapy Weekend Hybrid Program supervised by Jeanine Beasley, EdD, OTR, CHT, FAOTA.

The purpose of this study is to identify the optimal diameter of an adaptive spoon in order to protect the joints in clients with osteoarthritis (OA) and rheumatoid arthritis (RA), and facilitate self-feeding in clients with hand weakness by quantitatively determining the minimum hand pressure and force required.

I understand that I will be excluded from the study if I currently have arthritis or other nerve and muscle weakness.

I agree to participate in this study that requires me to grasp three varying spoon handle diameters, scoop up a quarter from a bowl, and raise them to my chin. Each handle will be grasped three times for an average measure.

Although I may not receive any direct benefit from participating in this study, information from the study may provide insight as to the importance of identifying the optimal handle diameter in order to protect the joints of clients with OA and RA.

All information collected during this study will be done without revealing my identity and will be kept confidential. The results will be disseminated in aggregate form ONLY. Study participants will be provided results in aggregate form upon request. I also understand that all data collection records will be kept in a locked file cabinet at Grand Valley State University accessible only to the Principal Investigator. It will be destroyed after 3 years.

No risks or discomforts are expected to result from this study. I understand that I may withdraw from the study at any time without any penalty or consequence.

I understand that in the unlikely event that I am harmed while participating in this research emergency first aid will be provided and I will be referred to an appropriate medical care center. Any costs for additional medical care that may be required are my responsibility and that of your medical insurance company.
I agree that the study has been explained to me and I have been given an adequate opportunity to ask questions about it. I also agree that participation in this study is voluntary and that I may refuse to participate in or withdraw from the study at any time without penalty. If I decide to not participate in this study, my decision will not affect any future relations with Grand Valley State University.

I understand that if I have questions, I am free to contact the student researchers, Kelly Cotter, at cotterke@mail.gvsu.edu, Trisha Thompson at thompstr@mail.gvsu.edu, and Amanda Ward at warda@mail.gvsu.edu.

This research protocol has been approved by the Human Research Review Committee at Grand Valley State University. File No. 12-224-H
Appendix E
Participant number _______

Which of the three spoons did you prefer (Circle one)?

Why did you prefer this spoon over the others?

Please rate your pain while using the spoons:

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No pain</td>
</tr>
<tr>
<td>1</td>
<td>Tolerable (and does not prevent any activities)</td>
</tr>
<tr>
<td>2</td>
<td>Tolerable (but does prevent some activities)</td>
</tr>
<tr>
<td>3</td>
<td>Intolerable (but can use telephone, watch TV, or read)</td>
</tr>
<tr>
<td>4</td>
<td>Intolerable (but cannot use telephone, watch TV, or read)</td>
</tr>
<tr>
<td>5</td>
<td>Intolerable (and unable to verbally communicate because of pain)</td>
</tr>
</tbody>
</table>