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Comparison of an Ergonomically-Labeled Wedge Tool and a Standard Gardening Trowel:
A Randomized Counterbalanced Study of Wrist Range of Motion and Preference of Females with Arthritis

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This scholarly project reflects individualized, original research conducted in partial fulfillment of the requirements for the Occupational Therapy Doctorate Program, The University of Toledo.
Abstract

The purposes of this study were to investigate the differences in the degrees of movement in wrist ulnar and radial deviation, and palmar and dorsiflexion utilized while planting with a standard gardening trowel and an ergonomically-labeled wedge tool. The study also examined the perceived comfort of use, ease of use, and preference of tool comparing a standard gardening trowel and an ergonomically-labeled wedge tool. The sample consisted of 60 women over the age of 55 with arthritis in their dominant hand and/or wrist. Participants used the standard trowel and the wedge tool in a randomized, counterbalanced design, to dig four holes in the soil in a window box. Participants answered ordinal questions about frequency of gardening, ease of tool use, and comfort of tool use after using each tool. They also answered questions about the tool they preferred. The Biometrics Ltd. elgon was used to measure palmar flexion, dorsiflexion, ulnar deviation, and radial deviation of the wrist while participants dug holes (Biometrics Ltd., 2007). Pre-planned contrasts showed significant differences in the extremes of palmar flexion and dorsiflexion. No differences were found in extremes of radial and ulnar deviation. The wedge tool was better than the standard trowel at limiting extremes of palmar flexion, but the standard trowel was better at limiting dorsiflexion. The wedge tool promoted a more neutral average wrist position than the standard trowel. There was no difference in the average wrist position in radial and ulnar deviation. Participants used more total degrees of movement while using the wedge tool. Participants rated the standard trowel and the wedge tool equally for comfort and ease of use. These data should be considered when recommending tools for women with arthritis. Due to the mixed results in the wrist movements and perceptions of comfort and ease of use neither tool offers clear advantages over the other.
Comparison of an Ergonomically-Labeled Wedge Tool and a Standard Gardening Trowel: A Randomized Counterbalanced Study of Range of Motion and Preference of Females with Arthritis

The United States Department of Health and Human Services *Physical Activity Guidelines* for Americans (2008) recommends two and a half hours of “moderate-intensity physical activity” per week for healthy adults. Many individuals choose to incorporate physical activity into their leisure occupations. People with various degrees of physical ability partake in gardening as a leisure occupation. However, special populations such as people with arthritis may need modified gardening tools to help ease the pain and difficulties they may encounter while gardening. Ideally, garden tools that claim to have an “ergonomic” design should reduce the wrist range of motion required for use of the tool. This study will compare the wrist movements when using a standard trowel and the wedge (a tool that claims to have an ergonomic design) during a simulated gardening occupation. The literature review will provide background information about the benefits of gardening, the factors that can limit one’s ability to garden, the current standards for ergonomic tools, and studies that have examined differences between standard and ergonomic hand tools used for gardening.

**Gardening**

People in the United States are spending their free time participating in many different leisure occupations (United States Department of Health and Human Services, 2008). Gardening is popular among those leisure occupations. According to the National Gardening Association, 71% of households in the United States took part in at least one lawn or garden occupation in 2007 (Butterfield, 2009). The most prevalent gardening occupation was caring for the lawn,
followed by growing plants indoors, growing flowers outdoors, and doing landscaping projects (2009).

Gardening is a beneficial occupation for physical health. The U.S. Department of Health and Human Services suggests gardening as an acceptable way for people to fulfill their full or partial daily physical activity requirements (2008). Data from other studies confirm that gardening provides moderate-intensity effort, although individual intensity may vary (Gunn et al., 2005). A literature review of current epidemiological studies pertaining to postmenopausal women found that physical activity, including gardening can be beneficial for decreasing the likelihood of developing cardiovascular disease by 30-50% (Beitz & Doren, 2004).

A study conducted by Park and colleagues (2009) suggested that gardening meets the recommended U.S. Department of Health and Human Services criteria for daily physical activity. This study examined 53 community-dwelling older adults who were grouped by their level of participation in the occupation of gardening as defined by the U.S. Department of Health and Human Services. The groups consisted of 11 “active gardeners” who met their the United States Department of Health and Human Services daily physical activity demands through gardening, “gardeners” who did not meet the daily physical activity demands through gardening, and “nongardeners” who did not participate in the occupation of gardening at all. Each participant was measured for hand and pinch strength, bone mineral density, and overall psychological well-being (measured by the Short-Form 36 Health Survey). There were no statistically significant differences between the groups in bone mineral density or psychological well-being. However, the scores for these two domains in the population of “active gardeners” were better than the scores of other individuals in the general population that fit into this cohort. The researchers identified a positive correlation between the occupation of gardening and
increased pinch force and hand strength (Park, Shoemaker, & Haub, 2009). The findings suggest that the occupation of gardening can help individuals meet the goals of daily physical activity recommended by the United States Department of Health and Human Services.

Findings of other studies have suggested correlations between the occupation of gardening and psychological well-being. Researchers found that gardening promotes health and can encourage socialization within communities (Armstrong, 2000). This study evaluated 20 community gardening programs in upstate New York. Surveys of participants found that the most common reasons why people participate in the occupation of gardening are: to have access to fresh foods, to enjoy nature, and to reap the related health benefits.

A pilot study conducted by Heliker and colleagues (2000) suggested that gardening has positive impacts on well-being and that there are multiple common meanings associated with the occupation of gardening. The researchers examined 24 older adults in “culturally diverse settings.” The researchers used pre- and post-tests of a psychological well-being scale to evaluate the benefits of their gardening intervention. The intervention lasted for three months. The researchers found statistically significant improvements from baseline measures of psychological well-being associated with participation in the gardening program. The participants were given semi-structured interviews. These interviews elicited three common themes. The themes included: the legacy of gardening, gardening as spiritual healing, and remembering their favorite tree. The details associated with the study are vague. The lack of details pertaining to the gardening intervention and reliability and validity of the instrumentation are limitations of the study. However, a study performed by Clayton (2007) also found that people are motivated to garden because of their appreciation for nature, and they are also motivated by the feelings of pride that result from having created well groomed yards as end products of their energy.
Arthritis

Many people who have the desire to garden may be physically limited by disease processes and unable to garden with standard tools. Arthritis may be one of the diseases that limits one’s ability to garden. Arthritis is a condition that causes pain, stiffness, and swelling in the joints of the body (National Center for Chronic Disease Prevention and Health Promotion, 2008). Arthritis presents in over 100 different forms (2008). Arthritis affects approximately 46.4 million adults in the United States (Arthritis Foundation, 2010). The risk of developing arthritis increases with age and gender. Arthritis is more commonly diagnosed in females than in males (2010). Other risk factors for this disease include: obesity, repetitive use of joints, and repetitive trauma to the joints (2008). According to the National Center for Chronic Disease Prevention and Health Promotion (2008), arthritis is the most prevalent cause of disability in the United States. Approximately 19 million adults in the United States report that arthritis limits their daily occupations in some way (2008).

A survey conducted by the Arthritis Foundation (Gutfeld, 1993) found that 62 percent of people with arthritis enjoy the occupation of gardening more than other leisure occupations. The national medical advisor for the Arthritis Foundation, Teresa Brady, Ph.D., suggests that the individuals interviewed may enjoy gardening because of the sense of control it gives them that they otherwise lack in other occupations due to the limitations of their arthritis (Gutfeld, 1993). A qualitative study of people with rheumatoid arthritis suggests that the people in the study used compensatory strategies to perform daily occupations. These compensatory techniques include: dosing their activities, using new strategies, and stretching their limits (Lutze, & Archenholtz, 2007). Researchers have reported findings of social and psychological impacts of arthritis on the
people it affects (Gutfeld, 1993; Lutze, & Archenholtz, 2007; Plasqui, 2008; Reinseth, & Espnes, 2007; Stamm, Wright, Machold, & Sadlo, 2004). Many findings suggest that participation in physical occupations, including gardening increase the well-being of individuals who have arthritis (Lutze, & Archenholtz, 2007; Park et al., 2009; Plasqui, 2008; Reinseth, & Espnes, 2007; Söderback, Söderström, Schälander, 2004; Stamm et al., 2004).

As suggested by the literature, gardening can have many psychological benefits for people who have arthritis. Despite this fact we must not ignore the physical joint movement limitations that result from arthritis and its symptoms. The pain and stiffness associated with arthritis can potentially cause decreased grip strength in an individual’s grasp while participating in gardening occupations. Decreases in grip strength make it difficult to hold and manipulate a gardening tool without using unusual or awkward posturing. The continuous use of unnatural wrist posturing should be avoided because it may lead to musculoskeletal injuries (Aghazadeh, & Mital, 1987; UCLA Ergonomics, n.d.). Measures should be taken to prevent damage to the joints through the use of tools that keep the wrist in a neutral position (n.d.).

Ergonomic Design

The term ergonomic comes from Greek roots. It is translated to mean “the science of work” (Witchman, 1999). Ergonomic design is focused on providing environments and tools that are more efficient for use than standard environments or tools. Ergonomic design also promotes the prevention of musculoskeletal injuries, and it promotes the use of comfortable tools (1999). UCLA’s Ergonomics Department suggests that wrist movements should be limited to 15° in all planes of movement to prevent musculoskeletal injuries (UCLA, n.d.).

Occupational therapists have a role in environmental modification and the use of assistive tools to lessen the environmental strains on people. Occupational therapists have
expertise in recommending and designing assistive tools for daily occupations (AOTA, 2004). Occupational therapists work to prevent injuries as well as treat people who have sustained injuries. Inpatient or outpatient therapy may not always be enough to help people with physical limitations get back to work. Occupational therapists will also provide workplace interventions and modify tools or equipment needed to perform work tasks.

Environmental modification is not limited to the workplace. Occupational therapists help people with disabilities and limitations to participate in occupations around their homes. These occupations may include gardening. Occupational therapists may employ modifications and assistive tools to help people with disabilities compensate for physical limitations.

Companies are producing garden tools, that through labeling, claim to be ergonomically designed or have aspects of their construction identified as ergonomic in some way. Researchers need to test these claims to either support or refute them so occupational therapists know whether or not to recommend ergonomically-labeled tools as being advantageous over standard designs.

**Ergonomic Garden Tools**

Specific criteria for ergonomic designs of garden tools are not well documented in the literature. The Centers for Disease Control and Prevention (CDC, 2004) has published general recommendations for selecting proper tools. The CDC specifies that a tool meets the criteria to be classified as ergonomic “only when it fits the task you are performing, and it fits your hand without causing awkward postures, harmful contact pressures, or other safety risks” (CDC, 2004, p.1). The CDC (2004) also suggests using tools that have comfortable grips that will not slip out of the hand. The recommended diameter for a tool to fit comfortably in the hand should be between 1.25 inches and 2 inches for tasks that require a power grasp. This type of grasp may be applicable to some aspects of gardening. The wedge tool has a two inch bulb-shaped grip that
meets the CDC recommendations for this type of tool. However, it requires a spherical grasp instead of the recommended power grasp (see Figure 1).

Another factor to consider is the perceived comfort of the tool. The CDC (2004) suggests that the tool should be comfortable in the hand to promote safe use. A study of comfort factors found that functionality and physical adverse effects on the skin were consistently mentioned as factors in defining comfort across different types of hand tools (Kuijt-Evers, Vink, & de Looze, 2007).

The force generated by the fingers plays a role in gardening including holding onto a trowel to dig in compacted soil. The position of the wrist impacts the force that can be generated by the fingers (Zong-Ming, 2002). A study of 21 healthy adults examined the optimal wrist position to generate the most grip strength (O’Driscoll, et al., 1992). The findings in this study suggest that optimal grip strength occurs when the wrist is positioned in 35° of dorsiflexion and 7° of ulnar deviation (1992). A study of 9 health adults found that optimal finger and wrist forces are produced when the wrist is in 20° of wrist dorsiflexion and 5° of ulnar deviation (2002). Therefore, an ergonomic tool that positions the wrist between 20° and 35° of dorsiflexion and 5° to 7° of ulnar deviation would generate the most gripping force. The further one moves toward palmar flexion and radial deviation the less grasp power one generates.

Prior Studies

This study examined the use of gardening trowels and trowel substitutes. The study was based on a design similar to three prior studies that have examined the biomechanical properties of different ergonomically-labeled garden tools with female populations. These studies all consisted of simulated gardening occupations performed in labs. The first study compared the effects of standard and ergonomically-labeled gardening trowels on the wrist range of motion.
necessary to do a gardening occupation (Tebben & Thomas, 2004). The sample consisted of 64 female participants who were between the ages of 20 and 50 years of age with no disability or disease. The study design was a randomized repeated measure, counterbalanced design. The participants scooped potting soil into flowerpots using each of the trowels. The researchers did not find statistically significant differences between the required range of motion needed to use the standard and ergonomically-labeled trowels. The participants rated the two tools equally as comfortable to use. Therefore, the ergonomically-labeled trowel did not appear to offer advantages in terms of wrist positioning or perceived level of comfort over the standard design trowel.

The study conducted by Linton (2005) was a replication and extension of the study conducted by Tebben and Thomas (2004). Linton (2005) assessed a different ergonomically-labeled trowel using the same method as Tebben and Thomas (2004). Participants included 60 healthy females over the age of 55. The findings suggested that the ergonomically-labeled trowel was not significantly different in the use of palmar flexion, ulnar deviation, or radial deviation. However, the ergonomically-labeled trowel required less dorsiflexion during use than the standard trowel. The participants expressed that the standard trowel was significantly easier to use and more comfortable than the ergonomically-labeled trowel. Thus, Linton, by in large, replicated Tebben and Thomas’ results.

Mizen (2005) compared the required wrist range of motion, comfort of use, ease of use, and preference of participants for a standard bulb planter and an ergonomically-labeled bulb planter. Participants included 61 healthy females over the age of 50. The women were asked to use each tool to dig five holes in a flowerbox placed on an adjustable height table. The researchers did not find any statistically significant differences in the extremes of motion
between the standard bulb planter and the ergonomically-labeled bulb planter. The participants rated the ergonomically-labeled bulb planter more comfortable to use than the standard bulb planter. The current study utilized a modified version of the procedure used in the study conducted by Mizen (2005) due to similarities in the structure and function of the tools that were examined.

Based on the literature review it is apparent that many people in the United States choose gardening as a leisure occupation. According to the CDC, gardening provides a source of moderate exercise, which is associated with healthy living. Gardening can also be beneficial for psychological well-being and can be a source of social interaction. Although some people have the desire to participate significantly in gardening they may not fully be able to participate due to physical limitations caused by arthritis. Thus, there is a need to evaluate tools that would make it easier for people with arthritis to participate in gardening. Some ergonomically-labeled tools claim to help individuals to garden with comfort and ease. This population could benefit greatly from tools that could help ease their pain and allow them to continue to garden, but we need to evaluate tools before recommending them.

**The Present Study**

The purpose of the current study was to see if there was a difference between the wrist range of motion required to use a standard trowel and the wrist range of motion required to use an ergonomically-labeled trowel substitute. The primary research question asked if there was a difference between the (a) extremes of wrist movement; (b) average wrist positions; and (c) total range of wrist motion used with the standard trowel and the ergonomically-labeled wedge tool. Secondary research questions asked if there were differences in participants’ perceptions of comfort of use, ease of use, and preference (with and without knowledge of the price) for the
ergonomically-labeled wedge and the standard garden trowel.

Method

Participants

This study expanded upon the Mizen (2005) study by focusing on the older adult female population that has arthritis affecting the hands and wrists. To be eligible for the study the women had to meet specified criteria. The researchers minimized variability in hand size due to gender by including only females. The women had to identify that they had arthritis that affected the use of their hands. The participants also had to meet the age requirement of 55 years or older. Participants did not have any other conditions or diseases that limited cognition or their ability to understand instructions given in English.

Design

The current study used a randomized repeated measure, counterbalance design. This study was a portion of a larger study that examined the same dependent variables for two ergonomically-labeled tools. The participants used the wedge tool and another ergonomically-labeled trowel in addition to the standard trowel. This study focused on the ergonomically-labeled wedge tool as compared to the standard trowel. A custom computer program randomly assigned a tool sequence for each participant. The computer ensured that each of the tools had an equal opportunity of being the first condition. The nature of this design allowed the researchers to compare the participants to themselves and to assess for order effects. This eliminated the necessity to match participants on potentially confounding variables.

Instruments and Apparatus

The researchers used a 168cm x 118cm adjustable height table on which the window boxes were placed. Each participant used three window boxes and a demonstration window box
for the study. Each window box was 88.5 cm long and 18 cm wide. The depth of the potting soil in the window box was 11 cm. Between trials the density of the soil was controlled by placing fitted ply-wood covers on the soil with five pound weights on top of the of the ply-wood. Pots of flowers were available for the participants to plant if they chose to plant them. (See Figure 2).

The Biometrics Ltd. elgon was used to measure range of motion at the radiocarpal joint. The researchers used the SG65 elgon to measure flexion, extension, radial deviation, and ulnar deviation of the wrist (see Figure 3). The accuracy of the Biometrics Ltd. elgon was +/- 2 degrees measured over 90 degrees from a neutral position. The repeatability was greater than +/- 1 degree (Biometrics Ltd, 2007). The data collected by this instrument were recorded in a custom designed computer program.

The wedge tool is an ergonomically-labeled trowel substitute. It is a yellow, wedge-shaped garden tool made of composite plastic weighing 6.64 oz (see Figure 1). The wedge tool is 7 inches long with a 2 inch bulb-shaped knob for a handle. The wedge is a garden tool specifically designed for people who have wrist problems or conditions. The wedge tool is used to dig holes in loose soil by rocking the tool with a side-to-side and back-to-front motion. Wherry, the creator of the tool, claims that proper use of the wedge tool allows the wrist to remain in a neutral position (personal communication, 2009). The tool can be maneuvered in the palm of the hand with the fingers open. Its knob shaped handle meets the two inch criteria for the diameter of handle as suggested by the CDC grasp pattern (2004) (see Figure 4). The wedge tool is available online at http://www.wedgie.biz and in many garden centers in Chicago and across the Midwest for $16. This tool was compared to a standard trowel.

The standard trowel is 10.5 inches long with a 3 inch wide blade. It has a black plastic handle and metal blade. It weighs 5.44 oz (see Figure 5). The study also included another
ergonomically-labeled trowel known as the Natural Radius Grip (Niemeyer, 2010).

The researchers were interested in the participants’ perceptions of the ease of use and comfort of use of the tools in addition to their physical properties. Likert scales were used to assess how often the participants participated in gardening occupations, how easy each tool was to use, and how comfortable each tool was to use. Scales were also used to determine which tool each participant would prefer to use at home and which tool she would choose to purchase when the price of each tool is known. Refer to Appendices A-D for examples of data collection forms.

Procedure

The study was approved by the University of Toledo Institutional Review Board. The study was conducted at the University of Toledo Scott Park Campus. Participants were recruited from a local hospital, support groups, senior centers, gardening clubs, and branches of the Arthritis Foundation via flyers and verbal presentations. The researchers also recruited participants by handing out flyers to the participants at the completion of the data collection to give to anyone who they felt might be interested.

Potential participants contacted the researcher by phone. The researcher verified that the potential participant met the inclusion criteria. Then the researcher described the study and its purpose. The participants were informed about the methodological details of the study upon their arrival for data collection. They reviewed and signed the consent form after having it explained to them, and they were able to ask questions. The researchers then recorded the participant’s age, ethnicity, and hand dominance. The data were entered in the computer as well as on a data collection forms to verify that all data were recorded accurately. The data forms (see Appendix A) contained the participant’s assigned number (not the participant’s name), and they were stored in a locked file cabinet in the lab to protect the confidentiality of the participants. Next,
the participants were randomly assigned to one of the three orders of conditions.

The participant was instructed to remove any splints, wrist braces, or jewelry that she was wearing on her dominant hand or wrist. Possible confounding variables were minimized by eliminating the participant’s use of splints and wrist braces. Splints, jewelry, and watches worn on the dominant hand and wrist were removed because they could interfere with the elgon recording or restrict range of motion.

After jewelry and splints were removed the researcher placed the elgon on the participant and secured it with paper tape. The researchers asked the participant to flex her dominant elbow to 90° and adduct arm to her side with the forearm in full pronation. The researcher demonstrated this position. The distal endblock of the elgon was secured to the dorsal aspect of the participant’s hand over the third metacarpal once the researcher placed the participant’s hand in what she judged to be neutral alignment with the forearm. The proximal endblock of the elgon was secured to the dorsal aspect of the distal forearm near the wrist. The researcher secured loose leads to the participant on her shirt over the middle of the scapula (see Figure 3). The Biometric unit was attached to the participant’s belt loop or attached with an ace bandage on the back to avoid interference of leads. The researcher explained the purpose of the elgon while she placed it on the participant. The computer program was enabled once the elgon was properly attached to the participant.

The researchers instructed the participant to stand in front of the adjustable height table, turn, and stand parallel to the table. The researcher then adjusted the height of the table top to 16cm below the participant’s olecranon process while her elbow was flexed to 90° at her side. The participant turned to face the table and stood on a mark on the floor in front of the window box. The window box was centered directly in front of the participant 13 cm from the front edge
of the table. See Figure 2 for the setup arrangement.

Then the computer program randomly assigned the participant to one of the three possible orders of conditions. Once the condition was assigned the researcher asked the participant to place her elbow at 90° with the dorsal aspect of her forearm facing the ceiling. The researcher demonstrated and instructed the participant to place her wrist in neutral. Once the participant’s wrist was in neutral she was asked to remain in that position while the other researcher cued the computer to zero the elgon. Once the elgon was zeroed the researcher used a demonstration window box to demonstrate how to use the first tool. The participant then used the tool to dig one hole in the demonstration window box. Then the researcher asked the participant if she had any questions. The researcher addressed any questions and then proceeded to the first condition. The demonstration window box was replaced by the window box that was used by the participant in the first condition.

The participant was asked to dig four holes in the window box that were large enough to plant the flowers. The soil displaced by the standard trowel was placed in an empty flower pot placed directly behind the window box. The participant dug one practice hole. When the tool touched the dirt to begin the second hole the researcher activated the switch and recorded data. Data collection continued until the participant removed the tool from the soil at the conclusion of the fourth hole. At the end of each condition the researcher asked the participant to sit in a chair for a five minute rest period while the next condition is set up. The researcher asked how easy the tool was to use and how comfortable the tool was to use. Following the completion of the last condition the participant had the option to plant the flowers in the holes if she desired.

The protocol was slightly modified from that of the standard tool during the use of the wedge tool. The participant still dug four holes with the wedge, but this tool did not require
scooping. Thus, the participant did not displace dirt into a flower pot. The participant rocked the wedge tool in the soil to create each hole. The switch was activated to begin data collection when the wedge touched the soil on the second hole. Data collection continued until the wedge was removed from the soil at the completion of the fourth hole.

After the completion of the three conditions the researcher prompted the participant to assume the same position at 90° of elbow flexion that was used to zero the elgon. The researcher cued the computer to begin collecting data when the participant’s wrist was in neutral and stopped collecting data when the participant had displayed extreme range of motion for dorsiflexion, palmar flexion, radial deviation, and ulnar deviation. The researcher prompted each of these movements through demonstration. These measures were taken to provide a baseline for available range of motion. The maximum measures were recorded after the protocol was completed to ensure that the participant had sufficient use of the wrist to avoid measures that may be tainted by stiffness. Once the extremes of movement were recorded the researcher removed the elgon.

The researcher then asked the participant to answer the ordinal questions for ease of use, comfort of use, and choice of tool (with and without knowing the price) that can be referenced in Appendices B, C, and D. The researcher read each question to the participant and recorded her response. Following the responses to these questions the researcher thanked her for her time and participation. Each participant received a $25 Kroger gift card for her participation.

**Data Analysis**

The researcher first calculated descriptive statistics for age, hand dominance, and range of motion variables (including skewness). The study analyzed the measured degrees of movement in wrist ulnar and radial deviation, and palmar and dorsiflexion recorded by the elgon.
during the research to examine possible differences in wrist movement between use of the ergonomically-labeled tool and the standard tool. SPSS Version 17 was used to analyze the data (SPSS, Inc., 2009). The range of motion dependent variable calculations for each tool included:

1. the extreme degrees of movement in each direction averaged across participants (i.e., average of the maximum amount of dorsiflexion used by participants);
2. the average wrist position during tool use for each participant, averaged across all participants; and
3. the number of degrees of wrist range of motion in each plane (i.e., dorsiflexion/palmar flexion; radial deviation/ulnar deviation) used by each participant, averaged across all participants.

The researcher used pre-planned contrasts to compare the dependent variables for range of motion between the ergonomically-labeled wedge tool and the standard trowel. The data were analyzed for order effects and skewness. Pre-planned contrasts were performed to compare the wedge tool to the standard trowel. Due to the eight movement variables assessed, the .05 alpha was adjusted to ≤ .00625 (.05/8). Following the comparison the effect size (f) was calculated to report the magnitude of effect observed. Note that the effect sizes for the dependent variables were defined based on values recommended by Cohen (1988). Cohen (1988) defines an effect size as a small effect if f ≤ .1. A medium effect size is observed if f is between the values of .25 and .39, and a large effect size is defined as f ≥ .4 (1988).

Pearson Product Correlations were calculated for participant’s wrist range of motion ability and the range used with tools in dorsiflexion, palmar flexion, ulnar deviation, and radial deviation planes. Portney and Watkins (2009) define a good or excellent correlation as r > .75. A moderate to good correlation is defined as r is between .5 and .75, while a fair correlation is
defined as r is between .25 and .5. A poor correlation is defined as r < .25 (2009).

Results

The participants consisted of 62 women. The researcher removed two participants’ data due to a malfunction with the elgon at the end of their data collection. The 60 remaining participants’ ages ranged from 55 years old to 87 years old. The mean age of the participants was 69.7 years old. The standard deviation was 9.0. The participants consisted of 57 individuals who were right hand dominant and three individuals who were left hand dominant. The sample consisted of 91.7% Caucasian participants. Five percent of the participants identified themselves as African American, while 3.3% of the participants identified themselves as Latino or Hispanic.

No data were missing, and the data were not skewed. There were no order effects, so like conditions were combined for analyses. Pearson Product Correlations showed that there was a weak correlation (r=.30) between participants’ available radial and ulnar deviation and the amount of radial and ulnar deviation used. There was no correlation (r=.007) between the degrees of palmar flexion and dorsiflexion utilized while using the tools and the actual range the participants had available. The extremes of motion in the directions of palmar flexion, dorsiflexion, radial deviation, and ulnar deviation were identified for each participant using the wedge tool and the standard trowel. The extremes of these movements were averaged across the sample (see Table 1).

The pre-planned contrast for extremes of wrist palmar flexion showed that the wedge tool used significantly fewer degrees of palmar flexion than the standard tool. The effect size for this contrast was .31, which was medium in size (see Table 1). The pre-planned contrast for extremes of dorsiflexion showed that the wedge tool used significantly more degrees of dorsiflexion than the standard trowel. The effect size for this contrast was 2.07, which was large in size. The pre-
planned contrast for extremes of ulnar deviation showed that there was not a significant
difference between the degrees used for the wedge tool and standard trowel. The effect size for
this contrast was .25, which was medium in size. The pre-planned contrast for extremes of wrist
radial deviation showed that there was not a significant difference between the degrees used for
the wedge tool and the standard trowel. The effect size was .095, which was a small effect.

On average, the wedge tool positioned the wrist closer to neutral than did the standard
tool. The average wrist position for the wedge tool was in dorsiflexion while the standard tool’s
average wrist position was in palmar flexion. The effect size was .55, which was large in effect
(see Table 2). The pre-planned contrast for average wrist position in radial deviation and ulnar
deviation showed that there was not a significant difference between the wedge tool and the
standard trowel. The effect size was negligible.

The pre-planned contrast for total range of wrist movement in the dorsiflexion and
palmar flexion plane showed that the wedge tool used significantly more total degrees of
movement than the standard trowel. The effect size for this contrast was 1.41, which was large in
size (see Table 3). The pre-planned contrast for total wrist range of movement in the radial and
ulnar plane showed that the wedge tool used significantly more degrees of movement than the
standard trowel. The effect size for this contrast was .30, which was medium in size.

All participants responded to how frequently they participated in gardening occupations.
Five (8.3%) participants reported that they gardened infrequently. Seventeen participants
(28.3%) reported that they garden sometimes, while an additional 17 participants (28.3%)
reported that they garden often. Twenty-one participants (35%) reported that they garden very
often. All participants expressed their preference toward the tool they would choose to garden
with under the parameters of knowing and not knowing the prices of the tools. Thirteen
participants (21.7%) chose the wedge tool without knowing its cost. Twenty-four participants (40%) chose the standard trowel to garden with without knowing its cost. Nine (15%) participants chose the wedge tool after the price was revealed, while 29 participants (48.3%) chose the standard trowel after the price was revealed. There were no significant differences between the preference of tool when the cost was not revealed and when the cost was revealed ($z = .88, p = .38$). The reported percentages do not total 100% of the sample because the other portion of the participants chose the other ergonomically-labeled trowel that was a part of the larger study.

There was not a significant difference between the perceived ease of use of the wedge tool and the ease of use of the standard trowel ($z = .62, p = .54$). There was not a significant difference between the perceived comfort of use for the wedge tool and the standard trowel ($z = .49, p = .63$). The frequency of each rating is described in Table 4.

**Discussion**

This study explored the range of movement for wrist dorsiflexion, palmar flexion, radial deviation, and ulnar deviation while using the wedge tool and a standard gardening trowel. The purpose of this study was to examine differences in the extremes of wrist movement, average wrist positions, and total range of wrist movement while using these gardening tools. The extremes of wrist palmar flexion used by participants were $7^\circ$ less with the wedge tool than with the standard trowel. This implies that the wedge tool keeps the wrist closer to neutral than the standard trowel for palmar flexion movements. However, the mean of extreme of palmar flexion while using the wedge tool was still $34^\circ$ beyond neutral. The UCLA guidelines recommend that all repetitive movements should remain within $15^\circ$ of neutral in all directions to prevent musculoskeletal damage (UCLA, n.d.). The extreme of palmar flexion used with the wedge tool
exceeds this recommendation by 19°. Thus, while the wedge tool required significantly fewer degrees of palmar flexion than the standard trowel it is not ideal in that it still exceeded the recommended limits to range of motion for palmar flexion.

The wedge tool required the participants to use significantly more degrees of dorsiflexion than the standard trowel (see Table 1). The extreme of wrist dorsiflexion that participants used when using the wedge tool was nearly eight times the amount used when using the standard trowel. The extremes of the wedge tool exceeded the UCLA guidelines for dorsiflexion by 32° (UCLA, n.d.). Participants used an average of 6.3° of wrist dorsiflexion when using the standard trowel. This amount of dorsiflexion fits within the suggested UCLA guidelines for preventing musculoskeletal injuries (UCLA, n.d.). Thus, the standard trowel was better than the wedge tool in limiting extremes of wrist dorsiflexion and keeping the wrist in a more neutral position.

The excessive amount of dorsiflexion that participants used with the wedge tool may be attributed to the way that the participant initially held the wedge tool when she pushed it into the soil. Some participants used their palm pressed flat against the knob-like handle when forcing the wedge tool into the soil. This position forced their wrists into dorsiflexion. The excessive dorsiflexion may also be attributed to the location of the participant’s arthritis. Some participants had difficulty relaxing their fingers over the knob due to arthritis in the interphalangeal joints. As a result these participants relied more on their palms to push the tool through the soil, which may have contributed to the extreme position in dorsiflexion.

No significant differences were found between the extremes of wrist radial deviation used by participants when using the wedge tool and the standard trowel. Both the wedge tool and the standard trowel extremes of wrist radial deviation were within the UCLA safe zone.

No significant differences were found between the extremes of wrist ulnar deviation used
by participants when using the wedge tool and the standard trowel. The extremes of wrist ulnar deviation were similar between the wedge tool and the standard trowel. Neither of the tools kept the wrist in a neutral position. Extremes of ulnar deviation for both tools were at least two times the UCLA guideline.

Neither of the tools limited extremes of wrist movement in all planes. The wedge tool required participants to use fewer extreme degrees of palmar flexion than the standard trowel, but the wedge tool required participants to use significantly more degrees of wrist dorsiflexion than the standard trowel. There was no significant difference between the extremes of radial deviation and ulnar deviation used by participants when they used each of the tools. However, both tools kept the wrist from moving into extremes of radial deviation. Thus, it is difficult to conclusively recommend one tool as generally advantageous over the other in terms of limiting extremes of movement.

The second dependent variable in this study was an examination of the average wrist position used while digging. A significant difference was found in the average position of the wrist in the plane of palmar flexion and dorsiflexion between use of the wedge tool and the standard trowel (see Table 2). The average wrist position used by participants with the wedge tool was 8.6° of dorsiflexion. This is a neutral position as described by the UCLA guidelines (UCLA, n.d.). The average position for the standard trowel was 20.8° of palmar flexion. This is not within the UCLA safe zone (UCLA, n.d.). The wedge tool was better than the standard trowel at keeping the wrist in a more neutral position in the plane of palmar flexion and dorsiflexion.

No significant difference was found between the wedge tool and the standard trowel in the average wrist position used by participants in radial and ulnar deviation. The average position
utilized in the radial and ulnar deviation plane was nearly identical between the two tools (see Table 2). Both tools were within the UCLA specified safe zone of 15° (UCLA, n.d.). O’Driscoll and colleagues (1992) suggested that 35° of dorsiflexion and 7° of ulnar deviation is necessary to perform a powerful grasp, while Zong-Ming (2002) suggested that 20° of dorsiflexion and 5° of ulnar deviation was an optimal position. Neither the wedge tool nor the standard trowel resulted in average wrist positions that met these suggested criteria. Given the average positions for the tools, neither positioned the wrist to use the most powerful grasp. However, the standard trowel’s average wrist positioning in 20° of palmar flexion is especially concerning given the detrimental effect on grasping that palmar flexion positioning would produce. The ability to create a powerful grasp would be a concern for individuals who have decreased grip strength due to their arthritis.

The final range of motion dependent variable was an evaluation of the overall degrees of range of motion used during the gardening occupation. Participants used significantly more degrees of range of motion while using the wedge tool than while using the standard trowel (see Table 3). This was true for both of the observed planes of movement. The wedge tool required almost double the average range of movement in palmar flexion and dorsiflexion as the standard trowel. The differences in radial and ulnar deviation range of motion were not as drastic (6° fewer) for the standard trowel. The standard trowel may be advantageous over the wedge tool for women with arthritis who have a decreased range of motion due to the disease. It requires less overall total range of motion to use the standard trowel than the wedge tool.

The recommendations for ergonomic hand tools from the CDC (2004) suggest that tools should not cause awkward positioning. An ideal tool would maintain a neutral wrist position to limit injuries associated with repetitive use of the wrist or strain on the wrist. Neither of the tools
limited extremes of wrist movement in all planes. The wedge tool required participants to use fewer extreme degrees of palmar flexion than the standard trowel, but the wedge tool required participants to use significantly more degrees of wrist dorsiflexion than the standard trowel. There was no significant difference between the extremes of radial deviation and ulnar deviation used by participants when they used each of the tools. Both tools kept the wrist from moving into extremes of radial deviation. Thus, it is difficult to conclusively recommend one tool as generally advantageous over the other.

The findings of this study were similar to the findings of Tebben and Thomas (2004). Tebben and Thomas (2004) found that the ergonomically-labeled tool in their study required more extremes of motion than the standard trowel except in dorsiflexion. Conversely, the current study found the extremes of motion for the ergonomic wedge tool to be better than the standard tool for palmar flexion. There were no differences between the extremes of radial and ulnar deviation that participants used. Both of these studies have examined tools that required more than a neutral wrist position in some planes of movement to complete the gardening tasks. The tools studied in Tebben and Thomas (2004) used a much smaller range of motion than the tools in this study. This may be attributed to the differences in the style of tools that were studied and the different tasks the participants were required to perform in the experiments.

The results of Mizen (2005) were very similar to the findings in this study. Mizen (2005) compared the use of a typical bulb planter and an ergonomically-labeled bulb planter. Mizen found that participants used more extremes of wrist palmar flexion and dorsiflexion movement with the ergonomically-labeled bulb planter than with the standard bulb planter. The ergonomically-labeled wedge tool used more extreme wrist positions in dorsiflexion than the standard trowel. Similar to this study Mizen found no advantages of the ergonomic tool in ulnar
ERGONOMIC COMPARISON

and radial deviation movements over the standard tool (Mizen, 2005). The designs of the tools used in these two studies were comparable, and the tasks were also similar.

The analysis of the responses to the questions addressing ease of use, comfort of use, and preference of tool showed no statistically significant differences between the perceptions of ease of use and comfort of use for the tools. Over half of the participants found both the standard trowel and the wedge tool easy to use, and over 30% of the participants found both the wedge tool and the standard trowel very easy to use (see Table 4). Participants commented that the wedge tool was easy to use in the window box but “would not work in clay” in an outdoor garden. Participants commented that the wedge tool was “easy to use” and “it was quick at making holes.” Many individuals noted that they liked that they did not have to lift any soil when using the wedge tool. Participants often rated the standard trowel as easy to use stating that “it is what I’m used to.”

Over three-quarters of the participants rated the standard trowel as comfortable or very comfortable to use. The participants frequently commented “it fits my hand” or “it is what I am used to” when they rated the standard trowel as comfortable to use. The participants who rated the standard trowel as uncomfortable commented that “the handle did not fit well in my hand” or that the handle “hurt my palm” when using the standard trowel. Some others reported “I felt it (some strain) in my arm (forearm).” Just over two thirds of the participants rated the wedge tool as comfortable or very comfortable to use. These participants commented that they liked that they did not have to wrap their fingers around it. Others commented that they would like to use the wedge tool to “plant bulbs.” Two participants rated the wedge tool uncomfortable to use. The participants commented that the knob handle “hurt my palm” or that they experienced “discomfort” in their shoulder or upper arm. However, the majority of participants noted both
tools as comfortable and easy to use.

At the price of $16.00 the ergonomically-labeled wedge tool was more than double the price of the standard trowel ($6.99). Despite the differences in price, revealing the price to the participants did not have a great influence on their preferred choice of garden tool. The wedge tool was chosen as the preferred by 13 of the participants (21.7%) when they did not know its price. They commented that they liked the design and they liked how “quickly” they could use it to dig holes. Nine participants (15%) chose the wedge tool as their preference when they knew the price. They said that they “did not mind paying more for a tool if they knew they liked it and it worked.” Participants often commented that the perceived lack of versatility of the wedge tool played a role in their decision of which tool to choose. Twenty-four participants (40%) chose the standard trowel as their preference to garden without knowing the cost. Participants frequently explained “I already know that it works well”, “it is what I am used to”, or “it is what I have at home.” The same trends and comments were displayed when the prices of the tools were revealed. The standard trowel was chosen by 29 of the participants (48.3%) when its cost was revealed.

Mizen (2005), Tebben and Thomas (2004), and Linton (2005) have found that it can be very difficult to find a gardening tool that promotes a neutral wrist in all directions during its use. The wedge tool met the criteria defined by the CDC (2004) for handle diameter and weight, but it did not provide a more neutral wrist position than the standard trowel while planting. Some participants specifically commented that they did not prefer the wedge tool because the handle was difficult to hold despite the fact that the wedge tool was designed specifically for people who have arthritis. Participants may have found this handle difficult to grasp because of limitations in their ability to flex their fingers fully around the knob-like handle.
Implications for Occupational Therapy

Gardening is a popular leisure occupation that holds a great deal of personal meaning for people. It can be done and modified across the lifespan. Occupational therapists are knowledgeable in environmental modification and assistive equipment. Individuals with arthritis may not need modified or assistive tools to garden, but they may be seeking a tool that is more comfortable and accommodating to their condition. It is within the scope of occupational therapy to make recommendations of tools that might optimize the client’s ability to continue to enjoy the benefits of gardening. Occupational therapists should thoroughly examine the evidence about a tool’s benefits before making recommendations to clients with arthritis. Therapists should also keep in mind that each client has unique limitations and needs. The results of this study demonstrated that the differences between the extremes of movement used when planting with the standard trowel and the wedge tool did not favor the ergonomically-labeled tool except in limiting extremes of palmar flexion. The ergonomically-labeled wedge tool promoted a more neutral average wrist position than did the standard trowel in the plane of palmar flexion and dorsiflexion, but there was no difference in the average position promoted by the tools in the plane of ulnar and radial deviation. Finally, the ergonomically-labeled wedge tool used significantly more total degrees of range of motion in palmar flexion and dorsiflexion, as well as in radial and ulnar deviation, than did the standard trowel. Thus, occupational therapists should be careful when recommending the wedge tool for women with arthritis despite the labeled claims of ergonomic benefits. Occupational therapists need to consider range limitations of women with arthritis when recommending tools. Tools that use fewer degrees of motion in a plane that is limited by arthritis may be beneficial for individuals in order to help them to continue to garden despite their range limitations.
Limitations

The setting of this study was not naturalistic to the occupation of gardening. The researcher made attempts to make the setting as naturalistic as possible by using soil, window boxes, live plants, and making the room welcoming. The room was decorated with pictures of gardens, and the room also contained artificial plants and a watering can. This does not negate the unnatural feeling of the participants having elgons taped to their hand and arms and a transmitter attached to their waist.

The results of this study can only be generalized to 55-87 year-old women with arthritis in the hand or wrist using the wedge tool and the standard trowel examined in this study. The women in this study qualified for this study based on age and reported that they had arthritis in the hand or wrist.

Finally, the questions about the participants’ preference of tool were asked while the participants were presented three choices (the wedge tool, the standard trowel, and the other ergonomically-labeled trowel being studied concurrently). Forcing choice between just two tools at a time may have led to different results.

Future Research

Future research should examine the use of other tools with other populations. For example, a future study could examine tool use by men. The population could also be modified by including participants who have other conditions that may cause pain, fatigue, or weakness. These potential populations may include people with fibromyalgia, people with multiple sclerosis, or people who have their range of motion limited by scarring from burns.

Despite the limited population it is appropriate for occupational therapists to help people with disabling conditions continue valued occupations. Asking participant’s perceptions of a tool
is beneficial in understanding why the participant liked a tool or did not like it. Future studies should to be sure to ask each preference in separate pairs when sharing a sample. This will help avoid complicating statistical analyses.

Conclusion

This study examined the wrist range of motion used by a group of older women with arthritis of the wrist or hand while using a standard and an ergonomically-labeled wedge tool trowel substitute while doing a simulated gardening occupation. The ergonomically-labeled wedge tool was beneficial over the standard trowel in limiting extremes of palmar flexion. Participants performed similarly using the wedge tool the standard trowel in the plane of ulnar and radial deviation. The ergonomically-labeled wedge tool used significantly more total degrees of range of motion in palmar flexion and dorsiflexion and radial and ulnar deviation than the standard trowel. Participants had mixed perceptions of the wedge tool’s comfort and ease of use despite the possible benefit presented by this tool. Thus, people should be cognizant of personal preferences when they are choosing new gardening tools. Occupational therapists should be cautious about suggesting ergonomically-labeled tools based on ergonomic benefits described on labels. The best practice is for a client to experience using a variety of tools before purchasing one with observation of movement patterns by the occupational therapist. Modifying the occupational form of gardening occupations is well within the scope of practice of occupational therapists. However, occupational therapists should remember the unique preferences of the client when making such modifications.

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Niemeyer, S. (2010). *Ergonomic labeled trowel versus standard design: A randomized counterbalanced study of preferences and effects on wrist range of motion in women with arthritis.* Unpublished scholarly project. The University of Toledo, Toledo, OH.


Stamm, T., Wright, J., Machold, K., & Sadlo, G. (2004). Occupational balance of women with


Table 1

*Extremes of Wrist Movement in Degrees Using the Wedge Tool and Standard Trowel*

<table>
<thead>
<tr>
<th></th>
<th>Radial Deviation</th>
<th>Ulnar Deviation</th>
<th>Palmar Flexion</th>
<th>Dorsiflexion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wedge</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>9.6°</td>
<td>33.3°</td>
<td>34.0°</td>
<td>47.8°</td>
</tr>
<tr>
<td>SD</td>
<td>11.5°</td>
<td>7.8°</td>
<td>10.9°</td>
<td>10.4°</td>
</tr>
<tr>
<td>Minimum</td>
<td>14.0°</td>
<td>16.0°</td>
<td>11.0°</td>
<td>28.0°</td>
</tr>
<tr>
<td>Maximum</td>
<td>63.0°</td>
<td>51.0°</td>
<td>60.0°</td>
<td>73.0°</td>
</tr>
<tr>
<td>Range</td>
<td>77.0°</td>
<td>35.0°</td>
<td>49.0°</td>
<td>45.0°</td>
</tr>
<tr>
<td><strong>Standard Trowel</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>7.6°</td>
<td>29.3°</td>
<td>41.7°</td>
<td>6.3°</td>
</tr>
<tr>
<td>SD</td>
<td>8.8°</td>
<td>8.5°</td>
<td>13.8°</td>
<td>9.6°</td>
</tr>
<tr>
<td>Minimum</td>
<td>7.0°(^1)</td>
<td>4.0°</td>
<td>14.0°</td>
<td>25.0°(^2)</td>
</tr>
<tr>
<td>Maximum</td>
<td>32.0°</td>
<td>50.0°</td>
<td>76.0°</td>
<td>26.0°</td>
</tr>
<tr>
<td>Range</td>
<td>39.0°</td>
<td>46.0°</td>
<td>62.0°</td>
<td>51.0°</td>
</tr>
</tbody>
</table>

| Contrast Estimate    | 2                | 4               | 7.6            | 41.6         |
| Standard Error       | 1.7              | 1.5             | 2.3            | 1.9          |
| p-value              | 0.265            | 0.009           | 0.001          | < 0.001      |
| Effect Size (f)      | 0.095            | 0.25            | 0.31           | 2.07         |

\(^N=60\)
\(^1\) Ulnar Deviation
\(^2\) Palmar Flexion
### Table 2

**Average Wrist Position in Degrees While Using the Wedge Tool and Standard Trowel**

<table>
<thead>
<tr>
<th></th>
<th>Palmar Flexion/ Dorsiflexion</th>
<th>Radial/Ulnar Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wedge</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>8.6°</td>
<td>12.4°</td>
</tr>
<tr>
<td>SD</td>
<td>11.3°</td>
<td>8.1°</td>
</tr>
<tr>
<td>Minimum</td>
<td>13.0°</td>
<td>12.0°</td>
</tr>
<tr>
<td>Maximum</td>
<td>35.4°</td>
<td>32.1°</td>
</tr>
<tr>
<td>Range</td>
<td>48.4°</td>
<td>44.1°</td>
</tr>
<tr>
<td><strong>Standard Trowel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>20.8°</td>
<td>12.1°</td>
</tr>
<tr>
<td>SD</td>
<td>10.6°</td>
<td>8.6°</td>
</tr>
<tr>
<td>Minimum</td>
<td>54.5°</td>
<td>13.2°</td>
</tr>
<tr>
<td>Maximum</td>
<td>1.0°</td>
<td>27.7°</td>
</tr>
<tr>
<td>Range</td>
<td>55.5°</td>
<td>40.9°</td>
</tr>
</tbody>
</table>

- Contrast Estimate: 29.3 0.3
- Standard Error: 2.1 1.5
- p-value: < 0.001 0.836
- Effect Size (f): 0.55 0.02

N = 60

1. Palmar Flexion
2. Dorsiflexion
3. Ulnar Deviation
4. Radial Deviation
Table 3

*Total Wrist Range of Movement in Degrees While Using the Wedge Tool and Standard Trowel*

<table>
<thead>
<tr>
<th></th>
<th>Palmar Flexion/Dorsiflexion</th>
<th>Radial/Ulnar Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wedge</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>81.9°</td>
<td>42.9°</td>
</tr>
<tr>
<td>SD</td>
<td>11.8°</td>
<td>9.6°</td>
</tr>
<tr>
<td>Minimum</td>
<td>57°</td>
<td>23°</td>
</tr>
<tr>
<td>Maximum</td>
<td>117°</td>
<td>84°</td>
</tr>
<tr>
<td>Range</td>
<td>60°</td>
<td>61°</td>
</tr>
<tr>
<td><strong>Standard Trowel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>47.9°</td>
<td>36.9°</td>
</tr>
<tr>
<td>SD</td>
<td>12.3°</td>
<td>10.3°</td>
</tr>
<tr>
<td>Minimum</td>
<td>26°</td>
<td>18°</td>
</tr>
<tr>
<td>Maximum</td>
<td>90°</td>
<td>68°</td>
</tr>
<tr>
<td>Range</td>
<td>64°</td>
<td>50°</td>
</tr>
<tr>
<td>Contrast Estimate</td>
<td>33.9</td>
<td>6.0</td>
</tr>
<tr>
<td>Standard Error</td>
<td>2.2</td>
<td>1.7</td>
</tr>
<tr>
<td>p-value</td>
<td>&lt; 0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Effect Size (f)</td>
<td>1.41</td>
<td>0.3</td>
</tr>
</tbody>
</table>

N= 60
Table 4
*Ratings of Ease of Use and Comfort of Use for the Standard Trowel and the Wedge Tool*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency (%)</th>
<th>Very Difficult</th>
<th>Difficult</th>
<th>Easy</th>
<th>Very Easy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ease of Use</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>2 (3.3)</td>
<td>3 (5)</td>
<td>36 (60)</td>
<td>19 (31.7)</td>
<td></td>
</tr>
<tr>
<td>Wedge</td>
<td>1 (1.7)</td>
<td>9 (15)</td>
<td>32 (53.3)</td>
<td>18 (30)</td>
<td></td>
</tr>
<tr>
<td><strong>Comfort of Use</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>2 (3.3)</td>
<td>11 (18.3)</td>
<td>36 (60)</td>
<td>11 (18.3)</td>
<td></td>
</tr>
<tr>
<td>Wedge</td>
<td>2 (3.3)</td>
<td>16 (26.7)</td>
<td>29 (48.3)</td>
<td>13 (21.7)</td>
<td></td>
</tr>
</tbody>
</table>

N= 60
Figure 1. The ergonomically-labeled wedge tool.
Figure 2. The window box is centered on the table as noted by the tape. The plants are located to the participant’s left, and the ergonomically-labeled wedge tool is located to the participant’s right.
Figure 3. The elgon is placed on the dorsal aspect of the participant’s right arm while her elbow is flexed by her side. The endblocks (green) and the leads are secured with paper tape.
Figure 4. The participant is using the wedge tool by grasping the handle and rocking the tool in the soil to create holes. No soil is scooped from the window box.
Figure 5. The standard trowel.
Appendix A

IRB # ____________________

Age____________
Ethnicity_______________________
Hand Dominance ________________

Gardening Question: (circle a number 1-4)

Please rate how often you garden

1  2  3  4
(never) (sometimes) (often) (very often)

P.I. – Julie Jepsen Thomas
Appendix B

IRB # ____________________

1. How easy was the Green Handled tool to use?

   1  2  3  4

   (very difficult)   (very easy)

2. How easy the Black Handled tool was to use?

   1  2  3  4

   (very difficult)   (very easy)

3. How easy the Yellow Handled tool was to use

   1  2  3  4

   (very difficult)   (very easy)

4. How comfortable was the Green Handled tool to use?

   1  2  3  4

   (very uncomfortable)   (very comfortable)

5. How comfortable was the Black Handled tool to use?

   1  2  3  4

   (very uncomfortable)   (very comfortable)

6. How comfortable was the Yellow Handled tool to use?

   1  2  3  4

   (very uncomfortable)   (very comfortable)

Provide any information about the tools that you may have.

P.I. – Julie Jepsen Thomas
Appendix C

IRB # ____________________

If you were to choose a tool to garden with, which one would you use? Please circle answer.

Green Handled Tool  Black Handled Tool  Yellow Tool

Please state any reasons you have for your choice in trowel:

P.I. – Julie Jepsen Thomas
Knowing the cost of the following tools, which one would you choose to garden with?

Please circle answer.


Please state any reasons you have for your choice in trowel.

P.I. – Julie Jepsen Thomas