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Ergonomically Labeled Trowel Versus Standard Design: A Randomized Counterbalanced Study of Preferences and Effects on Wrist Range of Motion in Women with Arthritis

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Abstract

The purpose of this study was to investigate the difference in the extremes of wrist range of motion, average positioning of the wrist, and the total range of motion used while gardening with an ergonomically labeled trowel and a standard design trowel. A secondary purpose was whether the participants perceived differences between the trowels in comfort, ease of use, and preferred choice of trowel with and without knowing the price. A counterbalanced, repeated measure, randomized design was used. There were 62 women who were over the age of 55 and who had arthritis in the wrists who participated in this study. The wrist was measured in the directions of ulnar deviation, radial deviation, palmar flexion, and dorsiflexion by a Biometrics Limited elgon. Planned comparisons were used to compare the ergonomically labeled tool to the standard tool. The ergonomically labeled tool required significantly less palmar flexion while the standard tool required significantly less dorsiflexion and radial deviation. No differences were found between the two tools in the direction of ulnar deviation. Average wrist positioning during digging in soil was significantly better with the ergonomically labeled trowel in that it kept the wrist closer to a neutral position in both planes of movement. However, there was less total range of motion used with the standard trowel in both planes of movement. There were no differences in perceptions of ease of use, comfort, or preference between the two trowels. The mixed movement results indicate that the ergonomic tool is not clearly more beneficial in maintaining the wrist in the desired neutral position for women over 55 with arthritis. Occupational therapists should use caution when recommending tools that are labeled ergonomic to women who have arthritis.
Ergonomically Labeled Trowel Versus Standard Design: A Randomized Counterbalanced Study of Preferences and Effects on Wrist Range of Motion in Women with Arthritis

Gardening is one of the top leisure pursuits for Americans (Rothert, 1994). Millions of adults enjoy tending to plants and/or gardens every year, whether it is inside or outside. Gardening involves a lot of manual work that entails using hand tools. Hand tools, like trowels, pruners, etc., may cause pain if used repetitively. When using hand tools a person needs to make sure that the tool is comfortable to use and used correctly. Good ergonomic hand tools are ones that limit the extremes of motion at the wrist. When the wrist is repeatedly moved to the extremes of its range, it may begin to cause problems with the joints and supporting tissues. One group of people who may experience pain in the wrist is people with arthritis. Along with the pain, people with arthritis may experience stiffness and swelling in and around the joints. Limiting the extremes of range of motion can help eliminate some of the pain experienced. Arthritis is a disability that can limit one’s leisure occupations. The goal of this study was to investigate how well an ergonomically labeled tool can prevent extremes of motion in the wrist. The study compared an ergonomically labeled garden trowel to a standard trowel. Prior to describing the study, literature involving gardening, arthritis, ergonomics, ergonomic hand held tools, and ergonomic gardening will be discussed.

Gardening

Gardening is a favorite pastime for many people and provides more than just enjoyment. It can help to relieve stress, provide exercise, increase strength, and cognitively stimulate the mind (Rothert, 1994). Gardening is an occupation that can provide people with a sense of satisfaction. It can come from seeing new plants grow or tasting fresh vegetables from the garden. Gardening can be adapted for all people. With the right tools and set-up everyone has
the capacity to garden. “Adapted tools can increase a client’s confidence and sense of independence” (Hewson, 1994). Hewson also states that it is important to use the tools properly and avoid positions that will increase pain or soreness (1994).

There are many physical benefits from gardening. Gardening can increase a person’s range of motion and can involve a variety of muscle groups. Fine and gross motor skills are developed as the body is involved in movements that stretch and strengthen the muscles and joints (Adil, 1994). Coordination, stamina, and flexibility can be improved while gardening. Gardening also can help increase a person’s self-esteem. The physical exertion of gardening allows one to release tension and anxiety along with releasing feelings of anger or aggression (Adil, 1994). Gardening is a recommended pursuit for people with many different disabilities, including those with arthritis.

Arthritis

Arthritis is the nation’s most common cause of disability. It results in inflammation of joints (Orchanian, 2007). People of all ages can develop arthritis, but it is most common in people over the age of 65. In 2004, forty-three million Americans reported that a doctor told them that they had arthritis (Orchanian, 2007). Nearly 19 million adults in the United States report limitations in their occupations due to their arthritis (Center for Disease Control and Prevention, 2009). Women are affected three times more frequently than men.

There are more than 100 causes of joint inflammation (Carter, Van Andel, & Robb, 2003). One of the most common types of arthritis is rheumatoid arthritis. The hands are by far the most severely affected by rheumatoid arthritis and it often results in the subluxation of the joints. Dorsiflexion of the wrist is one of the first movements to be limited (Orchanian, 2007).
Arthritis is accompanied by stiffness, general aching, weakness, and fatigue that are experienced throughout the body. It can cause pain, swelling, redness, heat and decreased range of motion (Carter et al., 2003). The onset of symptoms may be sudden and vary in degree. One may have exacerbations and remissions. It is important to note that arthritis is variable from person to person.

The goals for persons with arthritis are to relieve pain and stiffness, reduce inflammation, preserve muscle strength and joint function, and maintain as much of a satisfying lifestyle as possible (Orchanian, 2007). People who have arthritis will benefit from a combination of rest to the joints and range of motion exercises (Carter et al., 2003). Gardening will help with strengthening, range of motion, and can help relieve the stiffness that is felt. The right tools can help people who have arthritis feel more independent.

**Ergonomics**

Ergonomics is the study of work. It is the art and science of reducing physical and psychological problems that might arise from the interaction between people, equipment, and the environment (Berg-Rice, 1999). It is also possible to use principles derived from ergonomics to reduce the physical problems that occur with leisure pursuits. The gardening workplace should be set-up to eliminate the need for extremes of reaching and to avoid extreme flexion of the wrist and elbow (Cooper Tools, 2000). The person should avoid repetitive motions for any tasks performed.

Occupational therapists can play a role in ergonomics. Therapists are educated to be aware of typical human abilities and a person’s physical, cognitive, and psychological limitations and capabilities. They have knowledge in anatomy and physiology, neuroanatomy, kinesiology, and the treatment of injuries, and apply this to work-related musculoskeletal ergonomics and
injury prevention (Berg-Rice, 1999). Occupational therapists help people obtain their highest functional performance in all areas of life, including work, recreational occupations, and life at home. Maximizing a person’s functional performance comes with knowledge of the person’s typical range of functioning (Berg-Rice, 1999).

Proper positioning is important in all occupations (UCLA Ergonomics, n.d.). A person should keep arms close to the body, the elbows flexed to 100 degrees, forearm neutral and the wrist straight. The safe zone for movement of the wrist is 15 degrees in all directions (UCLA Ergonomics, n.d.). They also recommend avoiding tools that have finger grooves, hard plastic handles, and sharp edges.

The Center for Disease Control (CDC) has published guidelines for hand tools. They recommend that the handle size should allow a person to grip the handle so that the forefinger and thumb overlap by 3/8 of an inch. The handle diameter should range from 1 3/8 inch for small hands to 2 1/8 inch for large hands (Center for Disease Control and Prevention, 2001). The tool handles should be covered with a material that is slip-resistant. The CDC states that a tool becomes ergonomic only when it fits the task you are performing. The best tool is one that is appropriate to the job you are doing, fits the work space available, reduces the force you need to apply, fits your hand, and can be used in a comfortable work position. Symptoms that indicate problems with tool use include tingling in the fingers, swelling in the joints, decreased ability to move, decreased grip strength, pain from movement, sore muscles, numbness, or a change in skin color on the hands or fingertips (National Institute for Occupational Safety and Health [NIOSH], 2004).

A person is at risk of injury if a forceful grip on tools is often used, if the wrist is moved to the extremes of motion, or if the wrist is moved rapidly or repetitively. One should be careful
when choosing an ergonomically labeled tool. Not all tools that are labeled ergonomic are carefully designed (NIOSH, 2007). Tool handles that have hard or sharp edges that press into the hand, wrist, or arm, can increase the risk of injury. Gripping tools can be physically demanding and is often repetitive work. Not using tools properly may injure the muscles, tendons, cartilage, nerves, and/or blood vessels of the hand, wrist, and elbow. If the injury is left untreated it can weaken the hand and make it very difficult to grasp items or use the hand (NIOSH, 2007).

Rothert (1994) states there are several things to remember when evaluating tools for gardening. Lightweight tools are usually easier to use. He recommends that one use a tool with a longer handle. Adding length to hand tools may make items more easily reached. A tool with a smaller blade and tool head should be used because it reduces the amount of force needed to perform the task. Proper selection of a tool is important (Rothert, 1994). It is important to remember to pick a tool that does not cause pain.

**Ergonomic Hand Held Tools**

Dartt and Rosecrance (2008) investigated the relationship between ergonomically designed aviation snips for sheet metal workers to aviation snips that were not ergonomically designed. The new ergonomic snip was used with twenty-five sheet metal workers and had a narrower handle span than the original snip design. All the participants used the ergonomically labeled snip for six weeks. At the end of the six week period a focus group was held and eighty percent of the participants preferred the narrow snip over the wider snip. The majority of participants also thought the narrower snip was more comfortable, easier to use, and easier to maneuver. Dartt and Rosecrance then compared the ergonomic snip to the participant’s personal snip (2008). The majority of participants still preferred to use their personal snip even though
the narrower snip fit better in their hands. Reasons the participants gave for this were: the location and shape of the finger holds were more acceptable, there was less resistance, and it was easier to maneuver. Dartt and Rosecrance recommend one also consider familiarity and handle comfort when studying ergonomically designed tools (2008).

O’Driscoll et al. (1992) explored the position the wrist assumed during unconstrained grip, the difference between the dominant and nondominant wrists, and grip strength as the wrist is moved into different positions. Using a pilot study and repeated measures within participants design, 20 healthy, right-handed adults participated in this study. Researchers found that the natural or self-selected position in which the participants placed their wrists was at an average of 35 +/- 2 degrees of extension and 7 +/- 2 degrees of ulnar deviation. The nondominant wrists were in more extension at 40 +/- 2 degrees than the dominant hand. At the self-selected position of the wrist, the average grip strength was 41 +/- 3 kg. As the wrist is placed into more flexion the participants had less grip strength. With 15 +/- 2 degrees of extension and 5 +/- 5 degrees of ulnar deviation the grip strength was reduced to 30 +/- 2 kg. The authors state that the functional arcs of motion in the wrist are from 5 degrees of flexion to 30 degrees of extension and 10 degrees of radial deviation to 15 degrees of ulnar deviation (O’Driscoll et al., 1992).

Ergonomic Gardening Research Literature

Tebben and Thomas (2004) compared an ergonomically labeled trowel to a standard trowel in terms of their effects on wrist range of motion. The study hypothesized that the extremes of wrist deviations, and palmar and dorsiflexion would be less when using a trowel labeled ergonomic. The researchers also hypothesized that the participants would rate the ergonomically labeled trowel as more comfortable and easier to use than the standard-design trowel. There were 63 healthy females between the ages of 20 and 50 who participated in the
study. Using a repeated measures, counterbalanced design the participants used both the ergonomically labeled trowel and standard trowel. The results for dorsiflexion were not significantly different and the results for palmar, ulnar, and radial deviations were in the opposite direction of the hypotheses. The participants also rated the two trowels similarly in comfort.

Tebben and Thomas recommend that future research use different populations, different gardening tools, and a more naturalistic setting (2004). A limitation to the study is that the questions asked for comfort, ease of use, and preferences had no reliability or validity data.

Mizen (2005) investigated an ergonomically labeled bulb planter compared to a standard design and the effects on wrist range of motion during a garden occupation. The study participants were 60 female adults who were over the age of 55. The ergonomically labeled bulb planter advertised an ergonomically designed comfort grip handle. This study used a randomized repeated measure, counterbalanced design. Mizen did not find significant differences in extremes of wrist movement between the ergonomically labeled bulb planter compared to the standard tool (2005). There was a statistically significant difference in perceptions of comfort. The participants rated the ergonomically labeled bulb planter as more comfortable to use than the standard design bulb planter. No difference was found in the participants’ perceptions of ease of use. Mizen suggests some limitations that future researchers should consider. This would include investigating the elbow and shoulder joints, and different populations such as men or people with wrist conditions (2005). Researchers should also try to further understand participants’ preferences for comfort and ease of use for tools.

A replication and extension of Tebben and Thomas’ study was done by Linton (2005). This study hypothesized that there would be no difference in the extremes of wrist deviation, palmar and dorsiflexion with the use of an ergonomically labeled trowel compared to a standard
trowel. She also hypothesized that there would be no difference in terms of comfort or ease of use. The study’s participants were women who were over the age of 55. There were no differences in the average amount of movement at the wrist for palmar flexion, ulnar deviation, or radial deviation. There was a statistical difference for dorsiflexion with the ergonomically labeled trowel requiring less dorsiflexion than the standard-design trowel. Participants rated the standard design trowel significantly easier and more comfortable to use. Recommendations for future research include using tools of similar color in order to eliminate variability. This may help researcher more clearly understand what the decision making factors are. Linton also suggests using a different population such as men or people with musculoskeletal disorders of the wrist (2005).

Based on the previous literature review, it is evident that gardening is an occupation enjoyed by many people. The ability to garden may be limited due to physical limitations caused by arthritis. Ergonomically labeled tools claim to help individuals garden with comfort and ease, but the previous ergonomic gardening studies do not support the idea that ergonomic hand tools will limit the extremes of motion in the wrist. Only Linton (2005) found a statistically significant difference in favor of the ergonomically labeled tool for dorsiflexion. Palmar flexion, radial deviation, and ulnar deviation have showed no differences between the ergonomically labeled and standard tools. The previous studies have not included people who have a disability in the hands or wrists. This study will include people who have arthritis in order to see if the extremes of wrist range of motion will differ with this population when using an ergonomically labeled trowel compared to a standard trowel.

Present Study
The present study will investigate an ergonomically labeled trowel compared to a standard trowel using women 55 years of age and older who report to have arthritis. The researchers will also be exploring the preferences of the participants in relationship to the tools being compared. The Natural Radius Grip (2008) trowel was chosen for the study and will be referred to as an ergonomically labeled trowel for the remainder of the study. This ergonomically labeled trowel was chosen because the label states that the tool will minimize hand and wrist stress while maximizing power and comfort. The packaging states that the unique curvature of the handle encourages a safer, natural, and wrist-neutral approach to gardening. It is designed with a wider handle to decrease the pressure exerted to squeeze the tool, making it easier to grip. The ergonomically labeled trowel states that people with conditions like arthritis often find this grip increases their enjoyment of gardening. Since the company states the design of this tool will decrease extremes of wrist motion, the first hypothesis is that there will be a difference between the ergonomically labeled trowel and standard trowel in the degree of wrist ulnar deviation, radial deviation, palmar and dorsiflexion when used by women with arthritis. The degrees of movement will be measured in terms of extremes of motion, average positioning, and total range of movement. The secondary hypothesis will determine whether women have differences in perceptions of comfort, ease of use, and preferred choice of trowel with and without knowing the cost of the ergonomically labeled trowel and standard trowel.

Method

Participants

This study expanded upon the Linton (2005) study. The participants were women ages 55 and over who described themselves as having arthritis in their hands or wrists. Using only
participants of one gender helped to decrease the anthropometric differences between a female’s and a male’s hand. There were 62 women who participated in the study. Participants were recruited by word of mouth, through flyers, through email, at the Toledo Hospital Promedica Arthritis and Osteoporosis Center, physician offices, support groups, and senior independent living centers. Exclusion criteria included any condition that interfered with the ability to complete the movements necessary to engage in the study’s protocols. This could include cognitive conditions or neuromuscular conditions that may limit the ability to understand the study or the movements needed for gardening. The participants needed to be able to read and understand the instructions that were written in English. A $25.00 gift certificate for Kroger’s was given to all participants upon completion of data collection.

Design

A randomized repeated measure, counterbalanced design was used. This study was part of a larger study that included the evaluation of the effects of an ergonomically designed and labeled wedge tool (Zinnecker, 2010). It was randomized as to which tool: wedge, ergonomically labeled, or standard, would be used first. The participants were first randomly assigned through a computer-generated number system to the order of the conditions. The first condition, for this study, consisted of using the ergonomically labeled first, wedge second, and the standard trowel third. The second condition was composed of the standard trowel, ergonomically labeled trowel, and the wedge tool last. The third order consisted of the wedge tool, standard, and ergonomically labeled trowel. This design allowed each tool to be used first, second and third to assess the possibility of an order effect. This design permitted the participants to be compared to themselves. It also permitted two planned sets of comparisons;
one between the ergonomically labeled tool and the standard tool and a second comparison between the wedge tool and the standard tool.

**Instruments and Apparatus**

Similar to the Linton (2005) study, a table that was adjustable in height that measured 168 cm by 118 cm was used for the experiment. There was one window box for each gardening tool and a window box that was used for demonstrations. Each window box measured 88.5 cm long. The middle of the window box (44.25 cm) was placed in the center of the table (84 cm). The width of the window box was 18 cm. The front of the window box was 13 cm away from the edge of the table (see Figure 1). The window boxes were filled up to 11 cm with dirt. A plywood piece was placed on top of the dirt in the window box between participants. Two five pound weights sat on top of the plywood, one at each end of the window box. This helped keep the same amount of soil density in all of the window boxes. The window boxes were placed in front of the participant and centered with midline. A separate table held the computer and switches for the Biometrics Ltd. elgon (2007).

A Biometrics Ltd. elgon was used to measure the amount of wrist movement during this occupation. The Biometrics Ltd. elgon sensors are used to measure dorsiflexion, palmar flexion, and radial and ulnar deviation. The accuracy of the Biometrics Ltd. elgon is +/- 2 degrees measured over 90 degrees from neutral position. The repeatability is better than +/- 1 degree (Biometrics Ltd, 2007). The data collected from the Biometrics Ltd. was sent directly to the computer.

Two trowels were used for this portion of the experiment. The ergonomically labeled trowel has a net weight of 7.125 oz. It measured 11.75 inches long with a blade width of 3.25 inches. The handle of the trowel is curved and the height of the curved handle is 3.5 inches. The
ergonomically labeled trowel packaging states that it will minimize hand and wrist stress while maximizing comfort. The handle is made of a non-latex material (see Figure 2). The standard trowel is 10.5 inches long with a blade width of 3.0 inches. The net weight of the standard trowel is 5.44 oz (see Figure 3). A comparison of the two tools can be found in Figure 4.

An ordinal scale was used to measure frequency of gardening, the ease of trowel use, and comfort of the tools. The participants were asked how often they garden on a 1 (never) to a 4 (very often) scale. Participants were asked how comfortable the ergonomically labeled tool and standard trowel were also asked on a 1 (very uncomfortable) to a 4 (very comfortable) scale. The ease of use question was asked on a 1 (very difficult) to a 4 (very easy) scale. The following questions were asked in combination with the corresponding study in order to reduce redundancy. The participants were asked which tool, ergonomically labeled, wedge, or standard trowel will be most likely to be used in the future with and without the knowledge of the cost of the tools (see Appendices A, B, C and D).

**Procedure**

The study was conducted at the University of Toledo Scott Park Campus. The University of Toledo Institutional Review Board approved the study’s protocols and informed consent document. All the participants were given the informed consent document prior to participation. After the participants signed the consent forms, researchers asked and recorded age and hand dominance. Participants were then asked how often they garden. Next, the participants were randomly assigned to one of the three orders of conditions. The participants were instructed to take off any wrist splints, jewelry, and/or watches for the procedure. The researcher then had the person stand next to the table. The height of the table was adjusted to 16 cm below the participants’ elbow when flexed at approximately 90 degrees. Prior to beginning the occupation
the researchers asked the participant to adduct her shoulder while flexing her elbow to 90° with her forearm in full pronation. The elgon was worn on the dorsum of the dominant hand with the end blocks in line with the third metacarpal and the midline of the forearm (see Figure 5). The elgon leads were placed over the shoulder and taped to the outside of the participant’s shirt in order to keep the leads out of the participant’s way. The biometric unit was placed on the back of the participant’s belt loop. If there was not a belt loop then ace wrap was placed around the participant in order to hold to the biometric unit. The purpose of the elgon was explained to the participants while it was being attached. After the elgon was placed on the participant then the computer program and elgon were activated.

The participants were asked to stand in front of the table that held one window box centered on the table. The participants were then assigned to one of the three orders of conditions. A demonstration on how to use each gardening tool was done prior to the use of each tool. After the demonstration the participant was asked if there were any questions. If there was a question it was addressed prior to the start of data collection. If there were not any questions then the data collection began. The standard trowel and ergonomically labeled trowel required the participant to press the tool into the soil and scoop soil out of the window box and into a green flower pot. The flower pot was placed directly behind the window box. One practice trial was given for each tool using the demonstration window box. A total of four practice scoops were done for the standard and ergonomically labeled tools. A different window box was used for each tool. The participants were asked if there were any questions. If there were not any questions the participants were told to dig four holes in the window box (see Figure 6). Three of the four holes dug were recorded. A switch was activated at the start of the second hole when the tool hit the dirt. The switch remained activated until the holes were big enough to
fit the flowers sitting to the left of the window box. The switch was deactivated when the last of the dirt was placed into the flower pot after digging the fourth hole. The participants were given a chair to sit in and given a five-minute rest break between conditions. During this time period, questions of comfort and ease of use were asked for the tool that was just used. After the third condition the researcher held the forearm steady with the shoulder adducted against the body and the elbow flexed 90 degrees. The extremes of wrist range of motion were recorded with the elgon. The participants were instructed to move their wrists into dorsiflexion first, palmar flexion second, radial deviation third, and ulnar deviation last. If the participant was left handed the order consisted of dorsiflexion, palmar flexion, ulnar deviation, and then radial deviation. The elgon was then removed from the participant. The participants were told that they could plant the flowers if desired.

After completing the three conditions, the participants were presented the remaining ordinal questions concerning the trowels. The participants stated the answers as the researcher recorded the answer. This experiment was conducted in one session and required approximately 30 minutes.

Results

Participants

The data for two participants were not included due to Biometrics elgon errors. The sample size analyzed was 60. The age range of the participants was 55 years to 87 years of age. The mean age was 69.7 years and the standard deviation was 8.9 years. Of the 60 women in the study 57, or 95% of the women, were right hand dominant. In this study 55 women reported to be Caucasian, 3 Latino, and 2 African American. When asked the question about frequency of
gardening 35% of participants, reported to garden very often, 28% reported to garden often, 28% reported to garden sometimes, and 8% of participants stated that they never garden.

Data Analysis

The elgon recorded the degrees of wrist ulnar and radial deviation, and palmar and dorsiflexion. Analyses were conducted on the data compiled from the start of the second hole until the end of the fourth hole for each of the trowels. The means, standard deviation, and range of movement were calculated for each dependent variable. These dependent variables include the extremes of motion used, the average positioning, and the range of motion used while gardening with the tools. The extreme degrees of movement were calculated in the direction of palmar flexion, dorsiflexion, ulnar deviation, and radial deviation. The average positioning calculated the average position used while digging holes with the tools in the flexion and extension plane and the radial and ulnar deviation plane. The degrees of range of motion calculated the total number of degrees used while digging in the flexion and extension plane and in the radial and ulnar deviation plane. The dependent variables were calculated for each participant and then these figures were averaged across all participants.

Skewness and order effects were tested. No skewness for the dependent variables analyzed was found. There were also no order effects found for the presentation of the tools. Planned comparisons were used to compare each ergonomically labeled tool to the standard tool. Due to multiple analyses conducted on 8 movement variables the alpha value was set at $p \leq .00625 (.05/8)$ to determine the significance of the results. A Pearson correlation was conducted to better understand the strength of the relationship between participants’ potential range of motion and range of motion used when digging. Little to no correlation is between 0-.25. A fair correlation is found between a .25 and .5 and a moderate correlation is found between .5 and .75.
An excellent or strong relationship occurs above a .75 correlation (Portney & Watkins, 2009). The effect sizes were also determined (Cohen, 1998). An effect size of .1 is small, .25 is medium, and a .4 is a large effect size.

The ordinal scale data from the Gardening and Trowel Questions were analyzed via nonparametric Wilcoxon Signed Ranks Tests. It was used to compare responses to the ease of use, comfort, and preference of trowels. These questions also allowed participants to comment on their use and selection of trowels. These comments were used to discuss participants’ preferences for the two trowel types.

**Descriptive Statistics, Planned Contrasts, and Effect Sizes**

After it was determined the data were not skewed and no order effects were found, the data were grouped according to trowel type. The wrist movement data were transferred into a Window Excel program. The Statistical Package for the Social Sciences (SPSS) Version 17 was used to analyze the ordinal data (2008).

The means, standard deviations, and range of degrees of extreme movement used for the trowels were calculated for each direction of movement (ulnar and radial deviation; palmar and dorsiflexion). Descriptive data for the extremes of movement for both trowels can be seen in Table 1. This table also includes the planned contrasts and effect sizes between the standard and ergonomically labeled trowels. There was a significant difference and a medium effect size in the extremes of palmar flexion with the ergonomically labeled tool performing better. The standard tool performed significantly better in the movement of dorsiflexion and radial deviation with both directions having a large effect size. No difference was found in the direction of ulnar deviation and it was found to have a negligible effect size.
Pearson correlations, or ‘r’ values, were calculated between a participant’s potential range of motion and the range of motion actually used with the tools. A strong correlation may signify that the participant’s limited range of motion may be affecting tool use. There was no relationship between the participants’ range of motion ability and the range of motion used with the tools for palmar and dorsiflexion (r = .007). Radial and ulnar deviation showed a fair correlation (r = .3) between the range of motion available and range of motion actually used. Since neither correlation is very strong, it can be assumed that limitations in range of motion that the participants may have had did not limit the range of motion used when digging with the tools.

Results of the comparison for average wrist positioning during digging and total range of motion used during digging with the two tools can be found in Table 2. The ergonomically labeled tool performed significantly better than the standard tool in the plane of palmar and dorsiflexion for average positioning and had a large effect size. The ergonomically labeled tool also performed significantly better for average positioning in the plane of ulnar and radial deviation with a large effect size being found. The wrist spent more time closer to a neutral position with the ergonomically labeled trowel. However, the results for total range of motion used while planting showed that the standard tool performed significantly better than the ergonomically labeled tool. The standard tool used significantly less overall range of motion than the ergonomically labeled tool and these were large effect sizes for the palmar flexion and dorsiflexion plane and for the radial and ulnar deviation planes.

All the participants responded to the ordinal questions concerning ease of use, comfort, and preferred choice of trowel with and without knowing the price throughout the experiment. The results of the ordinal scales can be found in Table 3. There were no significant differences in perceptions of ease of use between the standard and ergonomically labeled trowels (Z = -.985,
There also were no significant differences in perceptions of comfort between the standard and ergonomically labeled trowel (Z = -.294, p = .769). Without knowing the prices of the tools, 23 people (38.3%) chose the ergonomically labeled tool and 24 (40.0%) chose the standard tool. After seeing the price of each of the tools, 22 (36.7%) chose the ergonomically labeled tool with a price of $12.99 and 29 (48.3%) chose the standard tool that had a price of $6.99. There was no significant difference in choice of preferred tool. (Z = -.879, p = .380). The rest of the people not reported chose the wedge tool due to this being part of a larger experiment.

Discussion

This study investigated the biomechanical measures of wrist palmar and dorsiflexion, and wrist ulnar and radial deviation while using an ergonomically labeled trowel and a standard trowel. It is important to note that not all tools that are labeled ergonomic are carefully designed (NIOSH, 2007). This study was conducted to see if an ergonomically labeled trowel provided wrist range of motion benefits to women with arthritis. Hypotheses for this study expected that there would be a difference in the extremes of range of motion, average wrist positioning, and total range of movement in the direction of ulnar deviation, radial deviation, palmar flexion, and dorsiflexion between the ergonomically labeled trowel and standard trowel. The results supported the hypothesis for extremes of movement for palmar flexion, dorsiflexion, and radial deviation; however, the results did not support the hypothesis for extremes of movement for ulnar deviation. The maximum range of extremes used for the ergonomically labeled trowel for palmar flexion was significantly less than the standard trowel. In other words, the ergonomically labeled trowel offered a benefit for palmar flexion by requiring less extremes of palmar flexion range of motion. On the other hand, the standard tool was significantly better in using less extremes of motion in the dorsiflexion and radial deviation positions. These significant
differences also demonstrated a very large effect sizes. Finally, there was no significant
difference between the two tools in the extremes of movement for ulnar deviation.

The ergonomically labeled tool performed significantly better in average wrist
positioning for the flexion and extension plane and for the radial and ulnar deviation plane. The
participants’ wrists spent more time closer to a neutral position with the ergonomically labeled
tool than the standard tool. The hypothesis for total degrees of movement used was also
supported by finding a difference between the ergonomically labeled and standard tool. The
standard tool performed significantly better in the flexion and extension plane and in the radial
and ulnar plane by using less total degrees of range of motion when digging holes in the window
boxes.

The literature concerning ergonomics states that the safe zone for movement of the wrist
is 15 degrees in all directions (UCLA Ergonomics, n.d.). In this study, the average maximum
range of motion used with both tools exceeded this 15 degrees safe zone. The one exception to
this was for the standard tool which used less maximum range of motion in the direction of
dorsiflexion. It is important that the occupation being performed does not have the wrist move
rapidly or repetitively at the extremes of motion because this is when an injury is likely to occur
(NIOSH, 2004). Women with arthritis are likely to have decreases range of motion and have
pain when the extremes of motion are reached (Carter et al., 2003).

Grip strength is also associated with wrist positioning. O’Driscoll (1992) found that the
average position participants placed the wrist in for a strong grasp when gripping an object was
35 degrees of extension and 7 degrees of ulnar deviation. As the wrist is placed more into
palmar flexion and radial deviation, grip strength is reduced (O’Driscoll, 1992). The
ergonomically labeled tool required significantly less movement in the extreme of palmar
flexion. This would allow the participants to have more grip strength throughout the duration of the gardening occupation. The average extreme of movement in dorsiflexion for the ergonomically labeled tool was 37 degrees. This is very close to the position the participants in O’Driscoll’s study naturally put the wrist in when grasping an object. Although the ergonomically labeled tool had more degrees of dorsiflexion than the standard tool, the average range of motion for the women’s wrists were in a more neutral position for the ergonomically labeled tool. Women with arthritis often have decreased range of motion and it is best to keep wrists in a neutral position.

Rothert stated that lightweight tools are usually easier to use and recommends one with a longer handle (1994). This should reduce the amount of force needed to perform the task. The ergonomically labeled tool weighed 1.685 oz more than the standard tool in this study. Women with arthritis may have difficulty using heavier tools because of the weakness that may occur from arthritis. This may decrease the amount of force that can be used during a gardening occupation. The ergonomically labeled tool had a longer handle than the standard trowel. A tool only becomes ergonomic when it fits the task that is being performed (CDC, 2001).

These mixed results of this study are similar to the previously conducted ergonomic gardening tool studies. The Tebben and Thomas (2004) results showed that the standard design trowel was significantly better in limiting the extremes of motion in the directions of palmar flexion, ulnar deviation, and radial deviation. Dorsiflexion was the only direction that was not significantly different, which differs from the results that were found in the present study. Linton (2005), on the other hand, only found a significant difference in the movement of dorsiflexion with the ergonomically labeled tool requiring less movement. In this study, the standard tool was significantly better in limiting the amount of movement required for
dorsiflexion and radial deviation in the extremes of range of motion. The ergonomically labeled trowel decreased the extremes of motion used by women with arthritis in the direction of palmar flexion.

This study also examined the average wrist position in flexion and extension plane and the radial and ulnar deviation plane for the ergonomically labeled and standard tool while digging. A tool that puts the wrist in a more neutral position is better for persons using the tool, including women with arthritis. The ergonomically labeled tool performed better in both planes, palmar and dorsiflexion plane and the radial and ulnar deviation plane, at putting the wrist in a better average position that was closer to neutral than the standard tool. The significant difference between the two trowels also demonstrated a large effect size. On the other hand, while comparing the degrees of range of motion used in the flexion and extension plane and the ulnar and radial deviation plane the standard tool did better. The standard tool did significantly better at using less total range of motion in both planes. This also demonstrated large effect sizes. Although the ergonomically labeled tool had a better average wrist position, the standard tool was significantly better at using less total range of motion. Persons with arthritis need a tool that keep the wrist in neutral and requires less range of motion.

It was also hypothesized that there would be differences in perceptions of comfort and ease of use between the ergonomically labeled trowel and standard trowel. The participants in Linton’s study (2005) found the standard trowel easier and more comfortable to use. Mizen’s study found that the participants significantly rated the ergonomic bulb planter as more comfortable than the standard tool (2005). No difference was found in the ease of use. Similar to the Mizen study, no difference was found in perceptions of ease of use between the ergonomically labeled trowel and standard trowel. However, this study also found no difference
in perceptions of comfort between the two tools. Over two-thirds of the participants found the ergonomically labeled tool to be easy or very easy to use. Only one person found the ergonomically labeled tool to be very difficult to use. The majority of participants also chose easy or very easy for the standard tool. A total of five people chose difficult or very difficult to use for the standard tool. In terms of comfort, the majority of people found both the standard and ergonomically labeled trowel comfortable or very comfortable to use. The participants were also required to select the trowel that they would choose to use in the future with and without knowing the price of the trowels. When the participants did not know the price, the preference was pretty evenly spread between the standard and ergonomic trowels. After the price was presented, there were only a few people who switched to the less expensive standard-design trowel. The price of the ergonomically labeled trowel is $12.99 and the standard trowel costs $6.99. This was not enough to make a significant difference in choice based on price.

After analyzing the comments the women gave about each of the tools used, there were several themes that were apparent. For the ergonomically labeled tool, most of the women who chose the tool felt that it was very easy to grasp. One woman stated, “The tool was comfortable because the handle was thicker. It was very easy to lift a quantity of soil.” Another participant commented, “I like the feel of it and it wasn’t painful to hold.” Another comment was, “I thought it looked awkward, but it was easy.” The majority of participants who liked the ergonomically labeled tool again chose that tool after knowing the price. “I know it is more money, but it works nicely and I wouldn’t have problems spending it.” This comment by one of the women was a popular response by the participants. If the participants chose the ergonomically labeled tool, they continued to choose it after knowing the prices. The participants stated that they would not have problems spending more money on a tool that was
more comfortable. One woman said, “If I find something that does the job right I don’t let the price stop me.” On the other hand, there were quite a few participants who did not like the ergonomically labeled tool. A lot of women felt that the ergonomically labeled tool was bulky and awkward to use. “It is different than what I am used to using. I have to hold it differently,” was a comment by one participant.

When asking the women about the standard tool, approximately a third commented that the standard tool was what they have used in the past or are currently using. One participant stated, “The black (standard) tool hurts the palm of my hand, but I have one similar to it. I am more used to the traditional shape of it.” There were some mixed feelings about the standard tool. Some women found the tool lighter and easier to use, while others thought it was difficult and more painful to use. Another woman who picked the standard tool with and without knowing the price of it commented, “It was more comfortable to use. Tools are very personal.” Choosing a tool to use for the occupation of gardening has to be one that a person feels comfortable and familiar with using. Proper selection of a tool is very important. It is imperative to pick a tool that does not cause pain in the occupation that is being performed (Rothert, 1994).

**Implications for Occupational Therapy**

Occupational therapists help people obtain the highest functional performance in all areas of life. There is an important role for occupational therapists in ergonomics in order to help clients maximize functional performance. Occupational therapists are aware of typical human abilities and a person’s physical, cognitive, and psychological limitations and capabilities (Berg-Rice, 1999). Occupational therapists also have the skill sets to implement interventions that are focused on the client’s needs and wants. This knowledge and treatment of injuries can be
applied to musculoskeletal ergonomics and injury prevention. When executing occupations that are meaningful and purposeful to the clients, the occupational therapist needs to be aware of proper biomechanics and body positioning. The gardening workplace should be set up to avoid extremes of reaching, and to avoid extreme range of motion in the wrists (Cooper Tools, 1999). This is extremely important for women with arthritis as common symptoms include pain, decreased range of motion, weakness, and fatigue (Carter et al., 2003). The extremes of range can exacerbate the symptoms experienced by women with arthritis.

The results of this study did not demonstrate a clear consensus that one tool eliminates more wrist range of motion than another. The ergonomically labeled tool performed better in regards to preventing excessive palmar flexion, but the standard tool prevented more dorsiflexion and radial deviation. One of the most common types of arthritis is rheumatoid arthritis. It is found that dorsiflexion of the wrist is one of the first movements to be limited for persons with rheumatoid arthritis (Orchanian, 2007). If the person with arthritis has limited range of motion in all directions, then these two tools may not provide enough benefit to limiting range to be useful. If range of motion is limited in just one direction, the standard tool may offer some benefit in preventing movements in the direction of dorsiflexion and radial deviation. On the other hand, the ergonomically labeled tool may be beneficial for people that have limited palmar flexion.

Neither tool placed the wrist in an average position that was close to the recommended 35 degrees of extension for maximum grip strength (O’Driscoll, 1992). The average positioning for the standard tool placed the wrist in the palmar direction. As the wrist is moved into the palmar direction the person will experience less grip strength. The ergonomically labeled tool kept the participants average positioning of the wrist in slight dorsiflexion. As a person with arthritis
loses grip strength, a tool that places the wrist in dorsiflexion may need to be used to maximize the grip strength a person has left.

The findings to this study are relevant for occupational therapists and may need to be taken into account when working with clients who have arthritis. Many of the clients that occupational therapists treat may enjoy gardening. Clients who are having difficulty with performing occupations and hobbies of interest may ask the occupational therapists for recommendations on tools that are said to provide ergonomic benefits. After taking into consideration the results from this study, occupational therapists need to be careful when recommending ergonomic tools over standard-design tools, especially ergonomically labeled gardening tools. Not all tools will provide the benefits that the tool labeling says it provides.

Occupational therapists should make recommendations based on what is best for the client since this is a client-centered profession. It would be best for the occupational therapist to have the clients try various tools to see which one is best for that particular individual. Since there are so many different types of arthritis, each client may have arthritis in different areas and experience different symptoms. The tool has to be one that does not cause pain, is comfortable, easy to use, and one the individual likes to use. Occupational therapists need to keep the individuals preferences in mind when choosing tools for clients to use. The comfort, ease of use, and price, in addition to range of motion required, are factors that might influence a client’s choice in trowel.

Limitations

One limitation to the study was the setting of the experiment. It was in a lab, which is not naturalistic for gardening. An elgon was attached to the participants’ hand and forearm with the transmitter box attached to the waist. This experiment had the participants standing while
digging with the tools and cannot be generalized to all gardening positions, i.e. on hands and knees. These factors did not make the gardening that occurred naturalistic and could have influenced the way the participants moved. In addition, the results from this study can only be applied to the trowels that were used. The results cannot be generalized to all ergonomically labeled tools.

This study specified that the women had to have arthritis in their wrists. Some women also had arthritis in their fingers, elbow and shoulder joints. This may have influenced some of the differences in the preferences of the tools. Also, only the movements of the wrist were measured. The elbow and shoulder were also used throughout the occupation. Movements at these joints, such as shoulder abduction, forearm supination, and forearm pronation could have had an impact on the wrist movement and this was not investigated. The question for asking what tool would be chosen to garden with before and after knowing the price of the tools was asked in part of the larger study. Asking this question in regards to just the ergonomically labeled tool and standard tool may have led to different answers.

Future Research Recommendations

Future studies could be conducted to investigate the elbow and shoulder joints that are involved while gardening. Also, researchers could use ergonomic and standard tools that are more alike in color and weight. This would help to eliminate the variability between tools and to better understand the factors in choosing a tool. More detailed follow-up questions could be asked after the use of the tools to better understand the qualities that were liked and disliked about each of the tools. Research about the perceptions of the tools could also be conducted in a more naturalistic setting.
Using a different population, such as men or people with other musculoskeletal disorders besides arthritis, are suggested for replication of this study. Other ergonomically labeled tools, not limited to just gardening, could be compared to standard-design tools. This could include screwdrivers, wrenches, pliers, or other work tools.

**Conclusion**

This study investigated wrist range of motion for women with arthritis while using an ergonomically labeled trowel compared to a standard-design trowel. The ergonomically labeled trowel required significantly less palmar flexion than the standard trowel. The standard trowel required significantly less dorsiflexion and radial deviation than the ergonomically labeled trowel. The two trowels did not differ significantly in the movement of ulnar deviation. In terms of average wrist positioning, the ergonomically labeled trowel was significantly better than the standard trowel at keeping the wrist in a more neutral position. The standard trowel used less degrees of total range of motion in both the palmar flexion and dorsiflexion plane and in the radial and ulnar deviation plane. Ratings for ease of use, comfort, or choice in trowel did not differ significantly between the ergonomically labeled and standard trowel.

Occupational therapists should be careful when recommending a gardening tool that is labeled ergonomic. Not all tools that are ergonomic actually provide ergonomic benefits. Tools need to be found for women with arthritis that will help keep the wrist in a neutral position and decrease the amount of range used while gardening. Symptoms of arthritis may affect individuals differently so preference, comfort, and ease of use are just a few of the factors that need to be considered in order to fit the person with the right tool. A variety of tools should be tried out by clients prior to recommendation of a tool. By matching the needs of the client to the
tool that is preferred, the occupational therapist can help the client be more satisfied with gardening occupations and other daily and leisure occupations.

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References


Tebben, A.B., & Thomas, J.J. (2004). Trowels labeled ergonomic versus standard design: Preferences and effects on wrist range of motion during a gardening occupation. *The
American Journal of Occupational Therapy, 58, 317-323.


Appendix A

Age __________

Hand Dominance ____________

Gardening Question: (circle a number 1-4)

Please rate how often you garden

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

Trowel Questions

Please answer the following questions

1. How easy was the Green Handled tool to use?
   
   1 2 3 4
   (very difficult) (very easy)

2. How easy was the Black Handled tool to use?
   
   1 2 3 4
   (very difficult) (very easy)

3. How easy was the Yellow Handled tool 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)

Please state any comments about the two tools you may have:
Appendix C

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:
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.
Table 1

*Descriptive Data for Extremes of Wrist Movement in Degrees, Planned Contrasts between the Standard and Ergonomically Labeled Trowels, and Effect Sizes for Each Direction of Movement*

<table>
<thead>
<tr>
<th>Direction of Movement (degrees)</th>
<th>Palmar Flexion</th>
<th>Dorsiflexion</th>
<th>Ulnar Deviation</th>
<th>Radial Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ergonomic Tool</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Mean</td>
<td>35.0°</td>
<td>37.1°</td>
<td>29.8°</td>
<td>18.6°</td>
</tr>
<tr>
<td>- SD</td>
<td>13.1°</td>
<td>11.1°</td>
<td>8.8°</td>
<td>8.0°</td>
</tr>
<tr>
<td>- Range</td>
<td>54.0°</td>
<td>45.0°</td>
<td>47.0°</td>
<td>40.0°</td>
</tr>
<tr>
<td>- Maximum</td>
<td>59.0°</td>
<td>56.0°</td>
<td>48.0°</td>
<td>40.0°</td>
</tr>
<tr>
<td>- Minimum</td>
<td>5.0°</td>
<td>11.0°</td>
<td>1.0°</td>
<td>0.0°</td>
</tr>
<tr>
<td>Standard Tool</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Mean</td>
<td>41.7°</td>
<td>6.3°</td>
<td>29.3°</td>
<td>7.6°</td>
</tr>
<tr>
<td>- SD</td>
<td>13.8°</td>
<td>9.6°</td>
<td>8.5°</td>
<td>8.8°</td>
</tr>
<tr>
<td>- Range</td>
<td>62.0°</td>
<td>51.0°</td>
<td>46.0°</td>
<td>39.0°</td>
</tr>
<tr>
<td>- Maximum</td>
<td>76.0°</td>
<td>26.0°</td>
<td>50.0°</td>
<td>32.0°</td>
</tr>
<tr>
<td>- Minimum</td>
<td>14.0°</td>
<td>-25.0° a1</td>
<td>4.0°</td>
<td>-7.0° b2</td>
</tr>
<tr>
<td>Contrast Estimate</td>
<td>6.667</td>
<td>30.867</td>
<td>.450</td>
<td>11.0</td>
</tr>
<tr>
<td>Error</td>
<td>2.314</td>
<td>1.897</td>
<td>1.529</td>
<td>1.743</td>
</tr>
<tr>
<td>P-value</td>
<td>.004</td>
<td>.000</td>
<td>.769</td>
<td>.000</td>
</tr>
<tr>
<td>Effect Size</td>
<td>.25</td>
<td>1.49</td>
<td>.03</td>
<td>.66</td>
</tr>
</tbody>
</table>

Note: N = 60

1 = Negative indicates that the degrees were in palmar flexion
2 = Negative indicates that the degrees were in ulnar deviation
### Table 2

*Descriptive Data for the Average Wrist Positions and Total Range of Motion Used With the Standard and Ergonomically Labeled Trowels, Planned Contrasts, and Effect Sizes*

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Palmar and Dorsiflexion Average Position</th>
<th>Ulnar and Radial Deviation Average Position</th>
<th>Palmar and Dorsiflexion Range of Motion</th>
<th>Ulnar and Radial Deviation Range of Motion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ergonomic Tool</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Mean</td>
<td>2.4°</td>
<td>4.1°</td>
<td>72.1°</td>
<td>48.4°</td>
</tr>
<tr>
<td>- SD</td>
<td>12.2°</td>
<td>8.1°</td>
<td>11.6°</td>
<td>8.0°</td>
</tr>
<tr>
<td>- Range</td>
<td>48.4°</td>
<td>36.5°</td>
<td>58.0°</td>
<td>39.0°</td>
</tr>
<tr>
<td>- Maximum</td>
<td>23.2°</td>
<td>22.0°</td>
<td>101.0°</td>
<td>66.0°</td>
</tr>
<tr>
<td>- Minimum</td>
<td>-25.3° ¹</td>
<td>-14.5° ²</td>
<td>43.0°</td>
<td>27.0°</td>
</tr>
<tr>
<td><strong>Standard Tool</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Mean</td>
<td>20.8°</td>
<td>12.1°</td>
<td>48.0°</td>
<td>37.0°</td>
</tr>
<tr>
<td>- SD</td>
<td>10.6°</td>
<td>8.6°</td>
<td>12.3°</td>
<td>10.3°</td>
</tr>
<tr>
<td>- Range</td>
<td>55.5°</td>
<td>41.0°</td>
<td>64.0°</td>
<td>50.0°</td>
</tr>
<tr>
<td>- Maximum</td>
<td>1.0°</td>
<td>27.7°</td>
<td>90.0°</td>
<td>68.0°</td>
</tr>
<tr>
<td>- Minimum</td>
<td>-54.5° ¹</td>
<td>-13.2° ²</td>
<td>26.0°</td>
<td>18.0°</td>
</tr>
<tr>
<td><strong>Contrast Estimate</strong></td>
<td>18.395</td>
<td>7.959</td>
<td>24.2</td>
<td>11.45</td>
</tr>
<tr>
<td><strong>Error</strong></td>
<td>2.081</td>
<td>1.508</td>
<td>2.171</td>
<td>1.708</td>
</tr>
<tr>
<td><strong>P-Value</strong></td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td><strong>Effect Size</strong></td>
<td>.80</td>
<td>.48</td>
<td>1.01</td>
<td>.62</td>
</tr>
</tbody>
</table>

**Note:** N=60  
¹ = Negative number indicates that the position is in palmar flexion  
² = Negative number indicates that the position is in radial deviation
Table 3

Ratings of Ease of Use and Comfort for Standard and Ergonomically Labeled Trowels

<table>
<thead>
<tr>
<th></th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of Use</td>
<td></td>
</tr>
<tr>
<td>1 – Very Difficult/Very&lt;br&gt;Uncomfortable</td>
<td>2 (3.3)</td>
</tr>
<tr>
<td>2 – Difficult/Uncomfortable</td>
<td>1 (1.7)</td>
</tr>
</tbody>
</table>

| Comfort        |               |
| 1 – Very Difficult/Very<br>Uncomfortable | 2 (3.3) | 11 (18.3) | 36 (60) | 11 (18.3) |
| 2 – Difficult/Uncomfortable | 3 (5.0) | 19 (31.7) | 19 (31.7) | 19 (31.7) |

Note: N = 60
Figure 1. The set-up of the planting table includes from right to left: ergonomically labeled or standard trowel, window box filled with soil, and the flowers. The flowerpot to place the scooped dirt was placed directly behind the midpoint of the window box.
Figure 2. The ergonomically labeled trowel and its packaging indicating why it is considered ergonomic.
Figure 3: A view of the standard trowel used in the experiment.
Figure 4: The standard and ergonomically labeled trowel. The standard tool is in the foreground. The ergonomically labeled tool is in the background.
Figure 5: Photo of how the elgon endblocks were placed on the participants.
Figure 6: Photograph of a participant using the ergonomically labeled trowel during the experiment with the elgon endblock place on the dorsum of the hand and the forearm.