OBJECTIVE. The purposes of this study were to determine whether a garden trowel labeled ergonomic provided better wrist positioning when planting than a standard-designed trowel and whether participants perceived the ergonomic labeled trowel as more comfortable and easier to use than the standard-designed trowel.

METHOD. Participants included 64 females, ages 20–50 years, with no self-reported disease or disability impairing their preferred upper extremity. Participants used both trowels to fill flowerpots with soil in a randomized, repeated measures, counterbalanced design. The wrist movements of ulnar and radial deviation, and palmar and dorsiflexion were measured with an electrogoniometer (Penny and Giles Biometrics Limited Goniometer XM65). Participants answered questions regarding their interest in gardening, ease of use and comfort of each trowel, and trowel preference.

RESULTS. A one-tailed paired t test showed that the trowels did not differ in the extremes of dorsiflexion elicited and the extremes of the other wrist movements were not in the predicted direction. Participants rated the trowels similarly for comfort and ease of use. Participants were evenly divided on personal preference for the two trowels.

CONCLUSION. Occupational therapists should be cautious when recommending a gardening trowel based on it being labeled ergonomic, as it may not produce better wrist positioning than a non-ergonomically labeled trowel. Fitting a person with the right trowel involves an assessment of tool-influenced wrist positioning as well as individual perceptions of comfort and ease of tool use.


For Americans, gardening is the number one outdoor leisure occupation, with 84% of households involved in at least one form of gardening (Virginia Cooperative Extension, 1994). Gardening as leisure offers many psychological (Goodban & Goodban, 1990; Harnish, 2001; McBey, 1985; Smith, 1998; Unruh, Smith, & Scammell, 1999) and physical benefits (Adil, 1994; Harnish, 2001; McBey, 1985). However, if improper biomechanics and tools are used in gardening, physical demands could result in negative impacts. According to Pascarelli (1999), proper biomechanics and ergonomics are major components of preventing cumulative trauma disorders. Therefore, research on the effects of tools designed to be ergonomic is needed to document the efficacy of their use. The purposes of this study were to compare a trowel labeled ergonomic to a standard-designed trowel in terms of the differences in range of wrist motion used, perceptions of comfort and ease of use, and preference for type of trowel.

Chapanis (1991) provided a comprehensive definition of ergonomics also known as human factors:

Human factors is a body of knowledge about human abilities, human limitations, and other human characteristics that are relevant to design. Human factors engineering is the application of human factors information to the design of tools,
machines, systems, tasks, jobs, and environments for safe, comfortable, and effective human use. (p. 2)

Additionally, Adil (1994) suggested, “letting the tools work with you rather than against you, you’ll conserve energy and avoid unnecessary strain and fatigue” (p. 120). The literature on ergonomics has stressed the importance of fitting the right person to the right tool to be truly “safe, comfortable, and effective [for] human use” (Chapanis, 1991, p. 2). An overall fit should match products and environments with the abilities, needs, and perceptions of the people who use them (Berg Rice, 1999).

Despite the lack of industry standards for use of the term ergonomic, labels with ergonomic claims can be seen on many products from computer keyboards to car dashboards. The labels have stated claims such as “causing less fatigue,” “providing more comfort,” and “causing less stress on the joints.” Martin and Andrew-Thurhill (1999) cautioned that these labels do not necessarily ensure quality or satisfaction for every person, emphasizing the important principle of fitting the right person to the right tool.

The human anatomy and biomechanics literature has emphasized the importance of the wrist being in a neutral posture when using the hands and hand tools. Neutral posture of the wrist is achieved when it is aligned with the forearm, and uses minimal ulnar or radial deviation, and minimal palmar flexion or dorsiflexion (Grandjean, 1988). Parker and Imbus (1992) stressed the importance of avoiding extreme wrist postures. They defined extreme postures as ulnar deviation greater than 45° from neutral; any amount of radial deviation; palmar flexion greater than 30°; and dorsiflexion greater than 15° from neutral. Zabel and McGrew (1997) added that muscle strength is greatest when “working in and out of neutral positions” (p. 351). Also, extreme postures such as finger flexion combined with wrist palmar flexion cause stress to the tendons and connective tissue and reduce gripping force. Blair, Bear-Lehman, and McCormick (1984) explained that a “tool should be designed for operation with a straight wrist; the tool should be bent, not the wrist” (p. 920). Adil (1994) described a good tool as being lightweight, but sturdy and fitting one’s grip comfortably. Zabel and McGrew suggested that the desired diameter of the tool handle is about 1.5 inches “to accommodate a power grip” and the handle length should “accommodate the 95th percentile of hand breadth (4 to 5 in.)” (p. 355). The handle should also be contoured to provide maximum contact between the surfaces of the hand and handle, thereby evenly distributing forces and reducing slippage (Blair, Bear-Lehman, & McCormick, 1984; Pitt-Nairn, Relf, & McDaniel, 1992).

Gardening tools that are labeled ergonomic are found at most garden centers, but only one study was found that investigated the ergonomic design of gardening tools. Pitt-Nairn et al. (1992) tested 50 active, older adults in their use and preference for four differently designed hand pruners. They found a significant difference in preference based on gender, which was related to hand length and grip strength. We found no studies that shed light on how people interpret ergonomic labeling. Therefore, we do not know whether ergonomic labels evoke favorable responses or influence purchasing decisions.

It is important to assess both the preferences of the ergonomic tool user and the effects of the ergonomic design of the tool on the user. This study focused on the biomechanical measures of wrist ulnar and radial deviation, and palmar and dorsiflexion used with both a trowel labeled ergonomic and a standard-design trowel to complete a gardening occupation. Since ergonomic tools would have the assumed goal of decreasing extremes of wrist motion, we hypothesized that the extremes of wrist deviations, and palmar and dorsiflexion would be less with the use of a trowel labeled ergonomic than with the use of a standard-design trowel. We also hypothesized that participants would rate the trowel labeled ergonomic as more comfortable and easier to use than the standard-design trowel.

Method

Design

The study used a repeated measures counterbalanced design. Participants were randomly assigned through a computerized random number algorithm to one of two orders of trowel use (ergonomic trowel first, then the standard-design trowel; order two was reversed). As every participant may have had an individual way of scooping, this design offered the advantage of comparing participants with themselves.

Participants

The participants were 64 females between the ages of 20 and 50 years ($M = 29.1, SD = 9.4$) recruited verbally and through notices posted at three Midwestern colleges over a 3-month period. All participants expressed a preference for using their right hands and did not have any self-reported disease or disability in their right upper extremities. This sample was chosen to reduce potential variability related to sex, aging, and hand preference.

Instruments and Apparatus

The ergonomic trowel had a label on which the manufacturer stated that it had an “ergonomically designed cushion grip handle.” The trowel was manufactured by Hi-Point1 and purchased at a local home improvement store. It was
35.5 cm long and weighed 333 g. The standard-design trowel was manufactured by Ames Lawn and Garden Tools and purchased at a local garden center. It was 28 cm long and weighed 155 g (see Figure 1).

A 167.6-cm x 121.9-cm (66-in. x 48-in.) adjustable height table was used as the planting table. The researcher adjusted the height of the table for each participant to 15 cm below the participant’s elbow, when flexed to 90° (Kroemer & Grandjean, 1997). The following items were placed on the table from the participant’s right to left: the ergonomic trowel or the standard-design trowel, a 18.9 liter plastic tub filled with approximately 18 cm of Scotts™ Garden Soil, a standard 23-cm (8-in.) plastic flowerpot, and a 4-cell pack of plants (see Figure 2).

The researcher centered a plastic tub on the midline of the table, 13 cm from the front edge. The trowel lay 24 cm from the right edge of the tub and the end of the handle was 13 cm from the front edge of the table. A dot was placed between the tub and trowel and 6 cm from the front edge of the table to designate the starting hand placement. The flowerpot was 34 cm from the left edge of the table. The cell pack of plants was on another dot 24 cm beyond the flowerpot. A separate table held the computer, switches, and the Biometrics K100 Base Unit.

Tape was used to cover the drain holes on the bottom of the flowerpot. The flowerpot had an inner ledge, which was 13 cm from the bottom. The number of scoops required to fill the flowerpot to this ledge depended on the amount of soil scooped on each transfer. Through pilot testing, we determined that 6 maximum scoops from the larger trowel was the minimum number required to fill the flowerpot.

To measure the amount of wrist movement, participants wore a Penny and Giles Limited Goniometer XM65 (referred to as an elgon) on the dorsum of their right wrists. The manufacturer reported repeatability of the elgon to be better than ± 1° and accuracy of ± 2° measured over a range of 90°. The elgon interfaced with a 200 MHz Gateway Pentium P5-200 desktop computer. Data were sampled at 100 Hz using a KPCMCIA-16AI analog to digital acquisition card with Testpoint data acquisition software version 3.2B.

Rating scales from 1 (strongly disagree) to 4 (strongly agree) (Rosenthal & Rosnow, 1991) were used for the gardening question and the trowel questions. Specifically, the gardening question asked participants to rate how much they enjoyed gardening on a scale of 1 (dislike) to 4 (enjoy). The two trowel questions asked participants how easy the trowel was to use with ratings from 1 (very difficult) to 4 (very easy) and how comfortable the trowel was to use (from 1 [very uncomfortable] to 4 [very comfortable]). An open-ended statement followed the trowel questions soliciting comments from participants about the trowels.

The final preference question asked participants which trowel they would choose if they were going to use it to plant in their garden. They then wrote their reason(s) for choosing their preference.

Procedure

The institutional review board approved the study and participants gave informed consent prior to participation. They completed the gardening question first. When finished, the researcher set up the planting table and explained the procedure. The researcher explained the elgon and attached it to align the third metacarpal and the midline of the forearm (Carlson & Trombly, 1983). The elgon was calibrated with the participant’s right elbow flexed at approximately 90° and the forearm and hand in neutral position. The researcher adjusted the table height for the participants and instructed them to stand in front of the tub containing the potting soil at the center of the table.

The researcher entered the participant’s number and age with the keyboard and the computer displayed which
trowel was to be used first. The assigned trowel was placed according to markings on the planting table.

The participants familiarized themselves with the trowel during a practice period of four scoops. The soil in the flowerpot from the practice period was returned to the tub. The researcher instructed the participant to fill the flowerpot to the designated inner ledge when prompted (see Figure 2). The researcher activated the elgon when the participant started scooping. The researcher pressed a switch when the trowel touched the soil in the tub at the start of the third scoop, which marked the initiation of the data collection period. She pressed another switch when the trowel touched the soil in the tub at the start of the seventh scoop, which inactivated the elgon. The participant continued filling the flowerpot to the inner ledge while the data were saved. Once the soil was up to the inner ledge, the participant could pot a plant in the filled flowerpot, if she wished.

Participants rested for 5 minutes between conditions. The researcher placed the filled flowerpot with or without the plant in it at the back of the table, along with the used tub of soil. The cell pack of plants remained on its marking to be used in the next condition. The researcher placed another flowerpot, an identical tub with the same amount of soil, and the second trowel in their designated positions on the table.

The participant repeated the procedure with the second trowel. Next, the first trowel the participant used was presented with the form with the trowel questions. When she finished, the researcher removed those two items and presented the second trowel with another set of trowel questions. Finally, the researcher presented the preference question with both trowels displayed.

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 third scoop until the start of the seventh scoop for each of the trowels. GraphPad Prism Version 2.06 was used to analyze the wrist movement data via one-tailed paired $t$ tests. Alpha was set at .05.

The ordinal rating scale data from the gardening and trowel questions were analyzed via Wilcoxon signed ranks test with the Statistical Package for the Social Sciences (SPSS, 1999). The trowel and preference questions allowed the participants to comment on their use of the trowels. These comments were summarized and used to discuss participants’ preferences for the two trowel types.

Results

We excluded the data of one participant due to a computer error; thus, the analyzed sample size was 63. The data were not skewed and there were no order effects. We grouped the data according to trowel type. For each participant, we identified the extremes of range used over the four scoops for ulnar deviation, radial deviation, palmar flexion, and dorsiflexion. These extremes for each of the movements were then averaged across all participants (see Table 1). The $t$ test for the extremes of dorsiflexion was not significant and therefore did not support the hypothesis ($t = .653, df = 62, p = .258$). The $t$ tests for the extremes of movement used for radial deviation ($t = 1.27, df = 62, p = .104$), palmar flexion ($t = .597, df = 62, p = .276$), and ulnar deviation ($t = 2.12, df = 62, p = .019$) were meaningless because the means for deviation and palmar flexion were in the opposite direction of the directional hypotheses. Therefore, the original hypotheses could not be supported.

Participants’ were evenly split, 32 (standard design) to 31 (ergonomic) for trowel preference. Forty-one participants (65%) offered comments regarding the standard-design trowel following the trowel question, and 51 participants (81%) commented on the ergonomic trowel. We calculated frequency distributions of responses from the gardening question and the trowel questions. We excluded one participant’s gardening question response based on the participant never having gardened before; thus, $N = 62$. Participants reported ratings from 1 (dislike) to 4 (enjoy) for gardening ($M = 2.82, SD = .9$). We hypothesized that participants would rate the ergonomic trowel as more comfortable and easier to use than the standard-design trowel. However, participants rated the two trowels similarly for comfort

| Table 1. Extremes of Range of Wrist Movement in Degrees Using the Two Trowel Types. |
|------------------------------------------|----------|----------|----------|----------|
|                                        | Radial Deviation | Ulnar Deviation | Palmar Flexion | Dorsiflexion |
| Ergonomic                               |           |           |           |           |
| Mean                                    | 5.07      | 34.40     | 36.95     | 26.18     |
| Standard Deviation                      | 11.83     | 9.80      | 14.71     | 16.65     |
| Range                                   | 33.66–53.24| 73.49–57.96| 72.00–60.17|           |
| Standard Design                         |           |           |           |           |
| Mean                                    | 3.61      | 32.98     | 36.21     | 27.16     |
| Standard Deviation                      | 10.04     | 8.65      | 15.31     | 15.79     |
| Range                                   | 17.46–48.78|          |           |           |

$N = 63$
standard design \( (M = 3.43, SD = .69) \) and ergonomic \( (M = 3.14, SD = .95) \). Participants rated the standard-design trowel \( (M = 3.65, SD = .63) \) as easier to use than the ergonomic trowel \( (M = 3.24, SD = .73) \) \( (Z = 2.88, p = .004) \), however, as we saw with several wrist movements, the means for comfort and ease of use were in the opposite direction of the directional hypotheses. Therefore, the Wilcoxon signed ranks tests are meaningless and the original hypotheses could not be supported. All participants responded with their reason(s) for preferring one trowel to the other on the preference question.

Comments on the trowel questions indicated a mixed reaction to the comfort of the handle on each trowel. Some participants liked the “gripped handle” of the ergonomic trowel and others felt obligated to keep their hand in that designated position. Most of the comments about the handle of the standard-design trowel focused on it being smaller, shorter, and firmer than that of the ergonomic trowel. Again, some participants preferred these characteristics as it was “easier to grip,” but others found it “wasn’t quite as easy to hold.”

The weight of the trowels also influenced the ratings of comfort. All comments concerning the weight of the ergonomic trowel were about it being heavier than the standard-design trowel. Some participants felt the heaviness was a positive attribute, making the trowel feel “sturdy” and “balanced.” Others felt that its heaviness made it “harder to hold” and “less comfortable.” On the preference question, one third of the participants reported the standard-design trowel as “lightweight” or “it wasn’t as heavy” as their reason to prefer it to the ergonomic trowel.

Participants commented on the different scoop sizes. They reported that the trowel labeled ergonomic had a bigger scoop to hold more soil in one transfer and that it took more scoops to fill the flowerpot with the standard-design trowel. Some participants related the difference in scoop size to fatigue. They described the standard-design trowel as making them “a little bit more tired” and their “wrist seemed to tire more using this one” because it took more scoops to fill the flowerpot. The fatigue comments about the ergonomic trowel were mixed. Some felt they “would get tired more quickly using this one” and they “were a little bit more fatigued with this one” because of its heavier weight. Others felt that since it took less time to fill the flowerpot with the larger scoop of the ergonomic trowel, “you did not fatigue as quickly or feel as tired.”

Discussion
This study compared the movements of ulnar and radial deviation, and palmar and dorsiflexion while using a trowel labeled ergonomic and a standard-design trowel during a gardening occupation. Our hypothesis that the range of these wrist movements would be less when using the ergonomic trowel than with the standard-design trowel was not supported. The participants’ extreme wrist positions were similar for the two trowel types.

The literature on ergonomics advises that tools constructed using ergonomic principles should promote neutral postures of the wrist and avoid extremes of movement (Blair et al., 1984; Grandjean, 1988; Parker & Imbus, 1992; Zabel & McGrew, 1997). During this particular occupation of filling a pot for planting, both trowels appeared to require wrist movements that exceed Parker and Imbus’ recommendations especially during the extremes of palmar flexion and dorsiflexion.

Participants were evenly split on preference between the ergonomic and standard-design trowels. The mixed responses reflect the individuality in the participants’ preferences. The overall weight and size, characteristics of the handle, and ability to control the trowel were key influences on participant preferences for trowel type.

As Martin and Andrew-Tuthill (1999) suggested, labels do not necessarily ensure quality or satisfaction for every person. It is difficult to tell what the term ergonomic means within the general population. A layperson might generalize from the “ergonomically designed cushion grip handle” statement on the label to include more favorable feelings about the trowel’s other qualities or expected performance. In this study, the ergonomic-labeled trowel did not result in markedly less range of motion demands nor consistently favorable perceptions of comfort and ease of use. Therefore, one could question whether there is a benefit to this trowel based on its ergonomic label.

As gardening is a popular leisure occupation for many people, it is within the role of occupational therapists to provide recommendations to maximize an individual’s ability to use garden tools properly and minimize potential negative effects of garden tool use. Many principles already used by occupational therapists are applicable to gardening, such as body mechanics, energy conservation, and joint protection. This study was concerned with proper biomechanics of the wrist during the gardening occupation using both trowel types. As the one trowel was labeled ergonomic, it should have promoted a neutral posture of the wrist (Blair et al., 1984; Grandjean, 1988; Parker & Imbus, 1992; Zabel & McGrew, 1997) with minimal ulnar and radial deviation, palmar flexion, and dorsiflexion (Grandjean, 1988; Parker & Imbus, 1992). Our results showed that the wrist movements used with the trowel labeled ergonomic and the standard-design trowels were quite similar for all movements with the possible exception of ulnar deviation.
As a means of identifying future research directions, we did a two-tailed \( t \) test on the extremes of ulnar deviation used and the difference between the two trowels was significant \((t = 2.12, df = 62, p = .038) \) with the ergonomic trowel requiring more ulnar deviation than the standard-designed trowel. If this potential result is confirmed in future research, it will provide evidence that an ergonomic label does not necessarily mean that the trowel will perform according to suggested biomechanical principles. Additionally, any added expense for a trowel labeled ergonomic may not be warranted. The occupational therapy practitioner would want to determine client preferences based on multiple factors before recommending a style of trowel for a particular person (Berg Rice, 1999).

We tried to closely simulate a common indoor gardening occupation by using real soil, typical flowerpots, and living plants. However, some aspects such as the presence of the elgon, transmitter, and computer were not naturalistic; furthermore, it is not known how the elgons and their leads may have affected natural movement patterns. This study used just one common gardening task. The range of gardening tasks in which one uses a trowel is diverse and this study is not representative of all such tasks. It is possible that one's perceptions of comfort, ease of use and trowel preference could vary with different task demands. Additionally, the questions used were created for the study and do not have reliability or validity data available.

This study measured wrist movements during the occupation but excluded elbow and shoulder movements that may have been equally important in completing the task. The lack of significant differences in wrist movements may be due to varying compensatory actions of shoulder abduction, and pronation and supination while scooping the soil. Future studies could compare how the two trowel designs affect the amount of movement elicited at the shoulder and elbow.

In response to participants' comments about fatigue, a study could be designed to compare the amount of muscle recruitment and perceptions of fatigue with each trowel. Thus, it could be determined if the lighter, but smaller standard-design trowel or the heavier, but larger ergonomic trowel would cause differences in muscular effort and perceptions of fatigue. This study used a single planting occupation to evaluate the effects of the different trowels. Future studies could examine different types of gardening and trowel uses that require more exertion, endurance, or repetitive motions to see if similar results are obtained.

Results of this study cannot be generalized to other trowels or to other populations. Replication of this study using other populations such as individuals with wrist conditions, the elderly, and men is recommended to determine if these populations respond in different ways. Also, to better generalize results, other trowels or gardening tools labeled as ergonomic could be compared to standard-design models. This study did not delve into the possible meanings persons attribute to ergonomic labels. A qualitative study designed to investigate these meanings would help therapists understand how the general public applies the concept of ergonomic labeling to tool selection, expectations for performance, and purchasing decisions.

Conclusion

This study compared the wrist movements used during a gardening occupation with a trowel labeled ergonomic versus a standard-design trowel. Participants used very similar amounts of wrist movement with the trowel labeled ergonomic and the standard-design trowel. Participants rated the two trowels similarly for ease of use and comfort and were evenly split as to which trowel they preferred.

Occupational therapists should be cautious when recommending a gardening trowel based on it being labeled ergonomic. Ergonomic labels may not translate into performance advantages during use. Many factors influence the right fit between a person and a tool. Occupational therapists must consider whether tools promote desired work positions and match the abilities and preferences of people to the trowels they use while gardening.

Acknowledgment

We thank Martin S. Rice, PhD, OTR/L, for providing technical assistance for this study.

References


Endnotes

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