DO HANDLE DESIGN AND HAND POSTURE AFFECT POINTING ACCURACY?

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The design of ergonomic tools has focused on reducing the awkward wrist angles during tasks. However, anecdotal evidence shows that the adoption of ergonomic tools has been slow. This may be due, in part, to the ergonomic handles reducing accuracy of the task performed. A pilot study employing 20 subjects (9 men, 11 women) was undertaken to evaluate 4 handles, with two handles being used both in a pistol-grip and an inline-grip. All handles were evaluated while either seeing the target or blindfolded and either using the index finger extended as a guide or not. Each subject performed 24 total trials, which consisted of aiming at a sheet of vertically mounted A3 paper. The center point was marked and positioned such that the subject, when holding a pistol grip tool, had an adducted shoulder, a right angle at the elbow and a neutral wrist position. Each subject was asked to aim and puncture 10 holes in each target paper at a fixed pace. The results of the pilot study show that the dependent variables of the vector distance from the origin and the vector distance from the centroid of the points is affected primarily by the sight condition, but that the handle orientation with the inline condition was significantly better than the pistol grip for accuracy. In addition, the main effects of gender and tool type were significant for the dependent variable of the vector distance from the centroid. The overall implication is that the most 'ergonomic' handle may not yield the most accurate cluster or grouping when pointing and that handles held in an ergonomically awkward wrist posture (average 23° ulnar deviation).

INTRODUCTION

Many manufacturers have designed ergonomic tools with large contact areas, loads distributed evenly over the hand, and which encourage neutral wrist postures. However, these tools are often not adopted by the common user. There may be many reasons for non-adoption such as higher cost, lack of availability, tradition, etc. However, even when 'ergonomic tools' are in the workplace, often the workers do not utilize them. Again, this can be explained partially by lack of willingness to change or a training effect with the old tools. However, it may be that the ergonomically designed tools, while reducing the risks for a cumulative trauma disorder (CTD), may actually also reduce the feedback from and control of the tool which limits the ability of the user to aim or guide the tool. Hence, the tool that reduces risk may also reduce performance. However, one reason for this performance reduction may be bad proprioception, or the feel of the tool as one performs work possibly related to wrist angle, with a final hypothesized reason being the way the task is performed.

METHODS

Apparatus

Four distinct handle types were employed in this study, ranging from a contoured handle with a large contact area that was very directional, through commercial knife-type and hand tool-type handles to a complete cylinder with approximately the same diameter as the knife-type and hand tool-like handles. Each handle had a stylus that extended approximately 50cm from the point on the handle corresponding to the center of the palm to the end that contacted the paper. The stylus was pointed and punctured a hole in the target when pushed into the target paper.

There were four handles employed in this study. The first handle was a contoured prototype handle (Figure 1a: right side, finger contour visible 1b:left side), which was a right-handed model with a very large contact area in the hand and clear orientation of the handle (only used in the pistol grip). The second was a handle, which was very like a commercial knife handle (Figure 2). The third was a commercial handsaw handle (Sandvik), which was also only used in the pistol grip position. The fourth handle was a cylinder (35mm in diameter), which gave no indication of stylus orientation. The knife-type handle and the cylinder were mounted in an apparatus, which allowed the angle of the handle and the stylus to be adjusted. Therefore, these two handles were used both in a pistol grip (approximately a 110° included angle) and an inline position (180° included angle).

The target was a piece of A3 paper with a vertical and horizontal line that intersected at the center of the paper. The long axis of the paper was vertical when placed in position. The paper was mounted vertically on a fabric room divider with the center point at the stylus point height when the subject was in the starting position. To ensure that all subjects began with the stylus point 20cm from the target for each trial, a physical stop was placed behind their elbow and they were asked to make elbow contact with it between each puncture trial.

A fabric eye mask was used for the non-sighted trials for each handle. A plastic goniometer was used to measure wrist angles at the target position for each handle type, handle angle, finger placement combination. A metronome provided the pace for the experiment (80 beats/minute). Each target was punctured 10 times at a rate of 40 holes per minute.

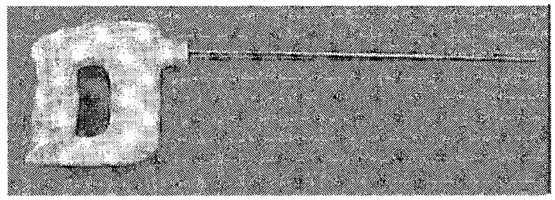

Figure 1a. Right side of contoured handle with finger indentation

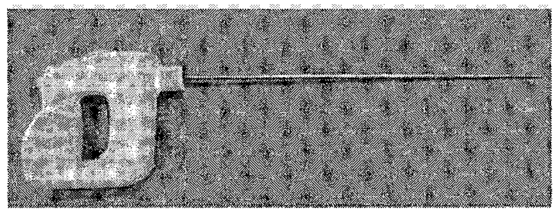

Figure 1b. Left side of contoured handle with large palmar contact area

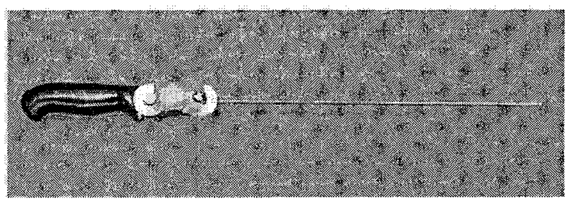

Figure 2. Knife-type handle in the inline orientation

Subjects

20 right-handed volunteers (9 men and 11 women) participated in the study. They ranged in age from 20 to 59 years of age (male age 45.9 (12.9), female age 38.9 (10.7), average and standard deviation) and in height from 156 to 195cm in stature (male height 179.2 (7.4) cm, female height 165.4 (4.6) cm, average and standard deviation). All stated that they had normal or corrected normal vision and they did

not suffer currently nor had they suffered in the past from injury or illness in the upper limb.

Experimental Design

The dependent variable in the GLM ANOVA was accuracy. Accuracy was split into two dependent variables, the vector distance from the center of the target (in mm) and a vector from the centroid of the ten points for a single trial that gave a measure of the grouping of the points. The centroid of the 10 points was determined and from that point, the vector distance for each observation was calculated for the centroid vector measure (in mm).

There were four handles in two handle angles (two of the four handles had two positions (pistol grip and inline) employed in this study. Each handle was employed with either the finger out as a guide or with the hand in a power grip around the handle. Each handle and finger placement had 10 paper punctures (location of which was the dependent variable), performed two times, once sighted and once blindfolded. All 20 subjects (9 men and 11 women) performed all 24 combinations of variables. The resultant design is a 4(handle) x 2(orientation) x 2(finger position) x 2(vision condition) x 2(gender) mixed-factor design. The main effects for each dependent variable were analyzed using SAS (v. 8) GLM ANOVA.

Procedure

Each subject was asked to hold the contoured handle and aim at the center of a target. The height of the target was fixed such that the stylus (with the pistol grip tool) hit the center when the upper arm was adducted and was at a right angle to the floor, the elbow had a 90° included angle, and the wrist was 'neutral'. For this study, neutral wrist position was functionally defined as the position where the long axis of the third metacarpal was inline with the center of the forearm.

A physical stop was placed behind the elbow such that the distance from the tip of the stylus to the center of the target was 20cm with the arm fully retracted. A piece of tape was placed on the floor at the subject's toes to allow for consistent body placement over all trials. The metronome was set at 80 beats/minute. A randomized order for the 12 handle, tool angle and finger placement combinations was made for each subject. The first handle was placed in the subject's hand with instructions on the index finger placement (either pointing toward the target or wrapped around the handle). The wrist deviation was measured at the target for each handle type, handle angle, finger position combination with a goniometer. A subject performing the task is shown in Figure 3.

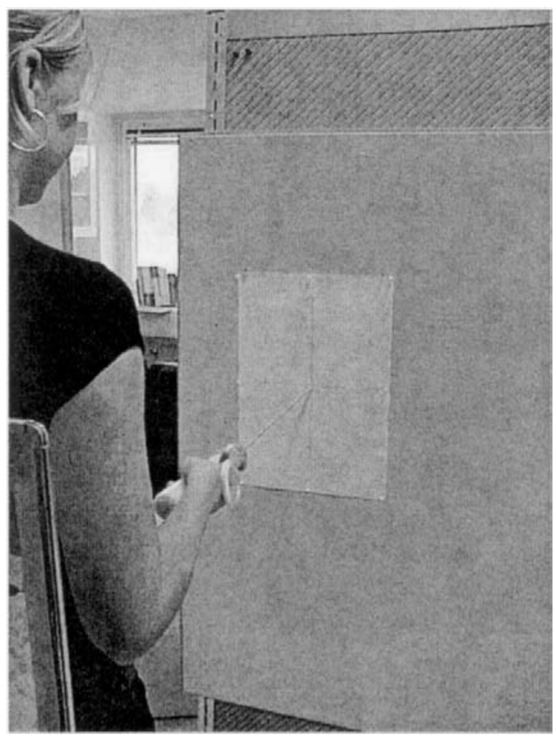

Figure 3. Subject puncturing A3 paper using the cylinder handle in the inline orientation.

Every measurement period was started by holding the stylus in target position without puncturing the target. Each subject was then asked to withdraw the arm 20 cm to where the elbow contacted the elbow stop on one tick of the metronome and then to move the arm forward while aiming at the target and puncture it with end of the stylus on the next tick of the metronome. This oscillatory movement was repeated with the highest possible target accuracy until ten holes were made in the target paper. The target was then changed and the subject was blindfolded. The subject then performed another 10 paper punctures without seeing the target for that same combination or handle, tool angle and finger placement. Initially the subjects were allowed to practice 10-20 movements before the real measurements began to get familiar with the task and pace. The next randomly assigned handle type, handle angle, and finger placement combination was tested, until all 12 combinations were completed.

RESULTS

Dependent variable Vector Distance from the Origin

The overall ANOVA on the mean vector distance (in mm) from the origin showed that the significant main effects were the orientation of the tool ($p < 0.0001$), and the vision condition ($p < 0.0001$). Post-hoc (Tukey's) tests were performed on these significant main effects and are shown in tables 1 (orientation) and 2 (vision condition).

				Measured Wrist Angle	
Orientation	Mean (mm)	Std. Dev.	Tukey Grouping	Avg.	Std. Dev.
Pistol	24.7	24.8		14.3° Radial	9.9
Inline	22.5	22.5		23.0° Ulnar	10.7

Table 1. Tukey's Test for the Vector distance by Orientation of Handle.

Vision Condition	Mean	Std. Dev.	Tukey Grouping
Blind	41.0	23.7	
Sighted	6.9	4.7	

Table 2. Tukey's Test for the Vector distance (mm) by Sight Condition.

Dependent variable Vector Distance from the Ten-point Centroid

For the dependent variable of the vector about the trial centroid, the significant main effects were the gender of the subjects ($p = 0.0007$), tool type ($p = 0.0084$), orientation ($p = 0.0226$) and sight condition ($p < 0.001$). The post-hoc (Tukey's) test results are show in tables 3-6 for gender, tool type, orientation and sight condition, respectively.

Gender	Mean	Std. Dev.	Tukey Grouping
Female	12.77	10.73	
Male	12.02	10.07	

Table 3. Tukey's Test for the Vector from the Centroid distance (mm) by Gender.

Tool	Mean	Std. Dev.	Tukey Grouping
Saw	13.03	10.32	
Knife-type	12.75	11.04	
Contour	12.14	10.64	
Cylinder	11.96	9.75	

Table 4. Tukey's Test for the Vector from the Centroid distance (mm) by Tool Type.

Orientation	Mean (mm)	Std. Dev.	Tukey Grouping
Pistol	12.63	10.54	
Inline	12.04	10.24	

Table 5. Tukey's Test for the Vector from the Centroid distance (mm) by Orientation of Handle.

Vision Condition	Mean (mm)	Std. Dev.	Tukey Grouping
Blind	18.64	11.25	|
Sighted	6.22	3.80	|

Table 6. Tukey's Test for the Vector from the Centroid distance (mm) by Sight Condition.

CONCLUSIONS

This pilot study shows that the inline orientation of the handle for a vertical task, while causing extreme ulnar deviation (average of 23 degrees), yielded a significantly better accuracy than the pistol grip. This was true not only for the vector distance from the origin, but for the size of the grouping as measured by the vector distance from the centroid of the ten points for each trial. Thus, not only is the average vector distance from the origin closer when the wrist is extremely ulnarly deviated, the grouping is smaller about the centroid point for the inline condition than the pistol grip trials.

As expected, the blindfolded subject trials were significantly worse than the sighted trials, despite the practice the subjects had with each condition of tool type, orientation, and finger condition of the sighted trial just prior to the blind trial.

Males had a significantly tighter grouping for the centroid vector than female subjects. This was an unexpected outcome; especially since the vector distance from the origin was not significant for gender.

The factor of tool type was not significant for the vector distance from the origin, but it was for the distance from the centroid. The results showed that that cylinder, knife-type, and contoured handles did not differ, but as a group were significantly better than the grouping of the knife-type, contoured and saw handles. As ergonomists, we would expect that the ranking for accuracy of use would be the contoured, saw, knife-type, and cylinder handles, in order from best accuracy to worst, based upon the idea that more contact surface area and more alignment information would increase accuracy. However, the cylinder had the best performance in this study. In addition, anecdotal evidence that workers use the finger out to help aim was not supported by this study.

The overall results of this study show that there may be a trade-off between reduction of awkward wrist posture and accuracy of aim, which partly may explain the poor acceptance of bent handles.

ACKNOWLEDGMENTS

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