Evaluation of an Ergonomic Laparoscopic Handle Design and Upper Extremity Musculoskeletal Disorder Risk Factors

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Background

Upper Extremity Musculoskeletal Disorders (UEMSDs) in surgeons have been attributed to the awkward postures, long shift durations, and high hand forces surgeons experience when operating on their patients[1].

A laparoscopic tool handle utilizing a pistol-grip was designed to reduce wrist flexion and required hand forces while operating the cutting/grasping mechanism. The purpose of this study was to evaluate a commonly used tool utilizing a pinch grip against this novel design utilizing a pistol grip.

Figure 1. a) Pistol grip (ergonomic) and b) Pinch grip (traditional) design

Hypotheses

For the pistol grip design there will be:

- Decrease in wrist flexion/extension angles

  H$_o$: $\mu_{pinch} = \mu_{pistol}$ H$_a$: $|\mu_{pistol}| < |\mu_{pinch}|$
- Shorter time to task completion for all FLS tasks

  H$_o$: $\mu_{pinch} = \mu_{pistol}$ H$_a$: $\mu_{pistol} < \mu_{pinch}$
- A reduction in required grip forces

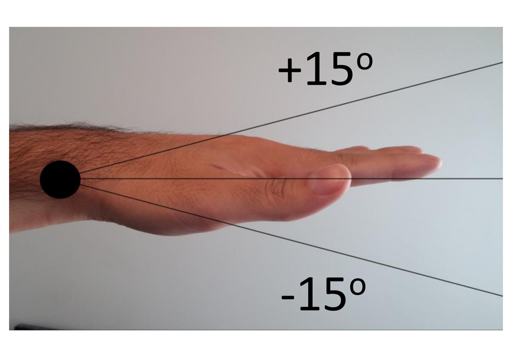
  H$_o$: $\mu_{pinch} = \mu_{pistol}$ H$_a$: $\mu_{pistol} < \mu_{pinch}$

Methods

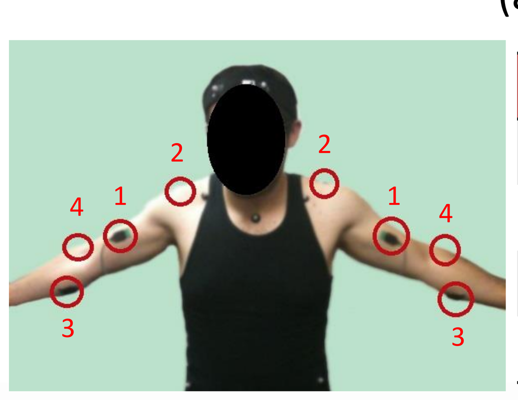
23 participants with no prior experience handling laparoscopic surgical tools participated in this study (Table 1).

Table 1. Participant parameters

Participants (N=23, 13M/10F)	
Age (years)	26.2 + 3.3
Body Mass (kg)	154.5 + 34.4
Height (in)	67.9 + 3.4
All participants were right handed	



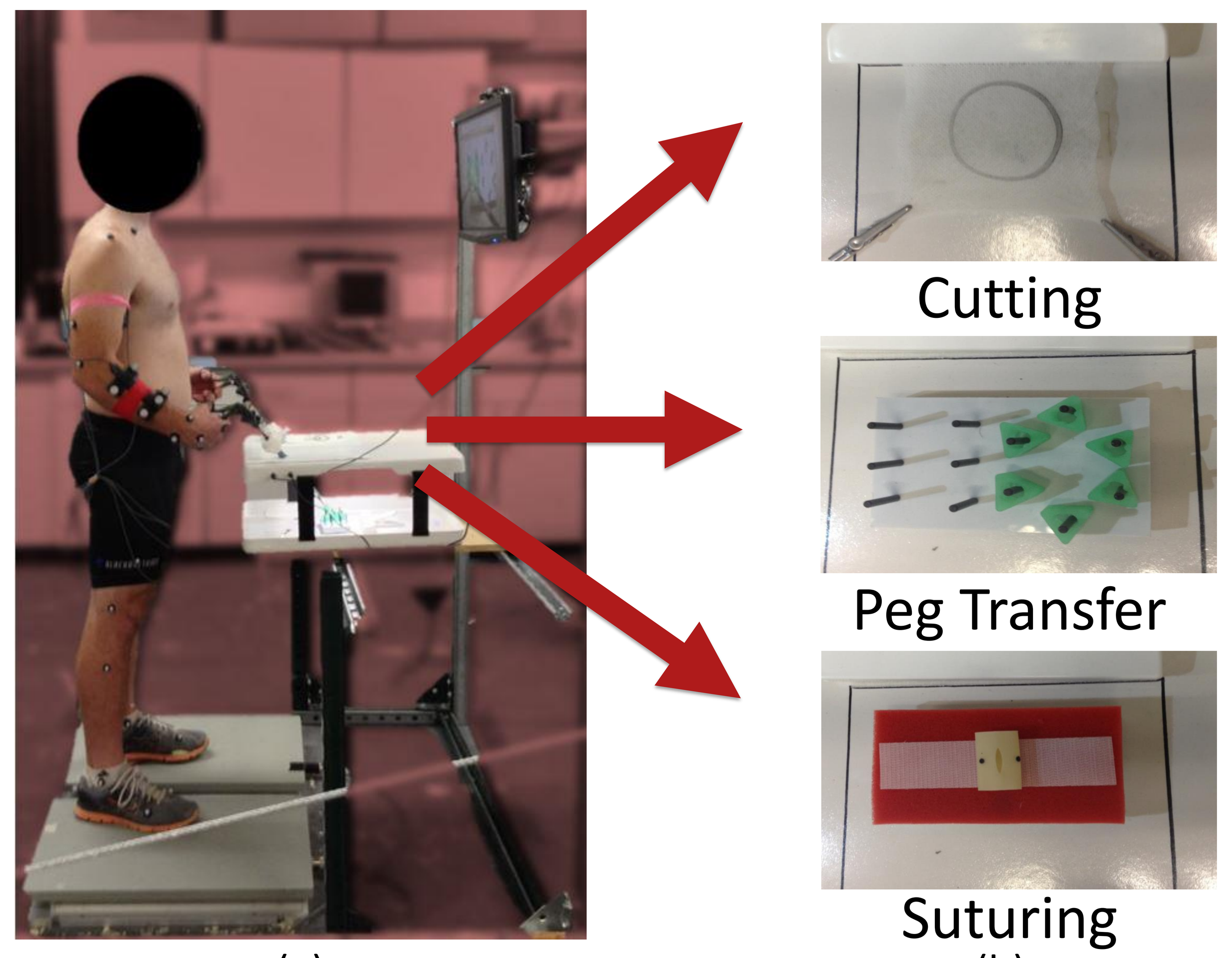
(a)



EMG Electrode Placement
1: R/L Biceps Brachii
2: R/L Trapezius
3: R/L Flexor Carpi Radialis
4: R/L Extensor Digitorum

(b)

Figure 2. a) Wrist angle neutral criteria (right hand) and b) EMG placement diagram



(a) (b)

Figure 3. a) Experimental setup and b) evaluation tasks

Task completion time was recorded for each trial. Wrist angles were quantified with a 3D motion capture system (NaturalPoint Inc., Corvallis, OR) and Visual 3D (C-Motion, Inc, Germantown, MD) using a 65 marker model (Figure 2a). Finally, an 8 channel EMG system (Delsys Inc., Boston, MA) sampled at 1000 Hz to measure muscle activation (Figure 2b). EMG signals were processed into percentage of maximal exertion values obtained through a calibration task that involved participants applying force to a pinch dynamometer. A calibration curve was created to verify the validity of the data, but only the maximal exertion was utilized in the actual processing.

Participants performed 3 unique tasks inside an FLS box trainer (Figure 3). The cutting and peg transfer tasks evaluated the difference between the pistol and pinch grip while the suturing task served as a partial control condition since a third party designed needle grasper was used in the dominant hand.

Results

Participants consistently completed cutting and peg transfer evaluation tasks faster with the pistol grip tool ($p<0.05$) (Figure 4). It is important to note however, that there is no significant difference between tools for the suturing task, which was expected since it was performed using the same needle grasper in the dominant hand.

Looking at the wrist angle output (Figure 5), the participants' wrists were primarily in a neutral posture (-15° < x < +15°) while using the pistol grip tool for the cutting and peg transfer tasks. Conversely, the majority of participants performed both of these tasks with a flexed wrist posture (<u><</u>-15°) while using the pinch grip tool. Finally, there was no significant difference between the two suturing trials since participants used the same needle grasper in their dominant hand.

The effect of hand tool design on muscle activation of the flexor carpi radialis and extensor digitorum muscles was investigated. A significant difference was not found between EMG signals for any of the three tasks (Figure 6) due to the high degree of variability in the data ($p>0.05$).

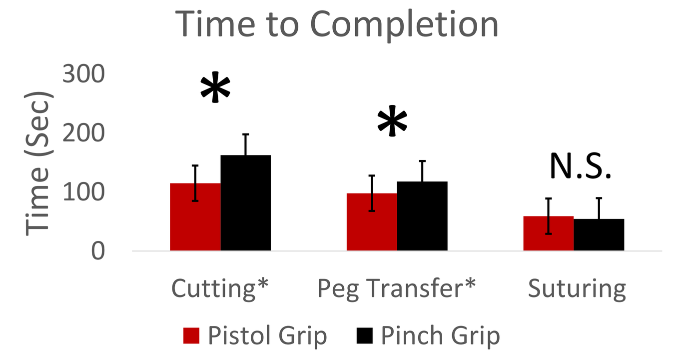


Figure 4. Average time to completion for each task. * denotes significance ($p<0.05$)

Wrist Angle Output

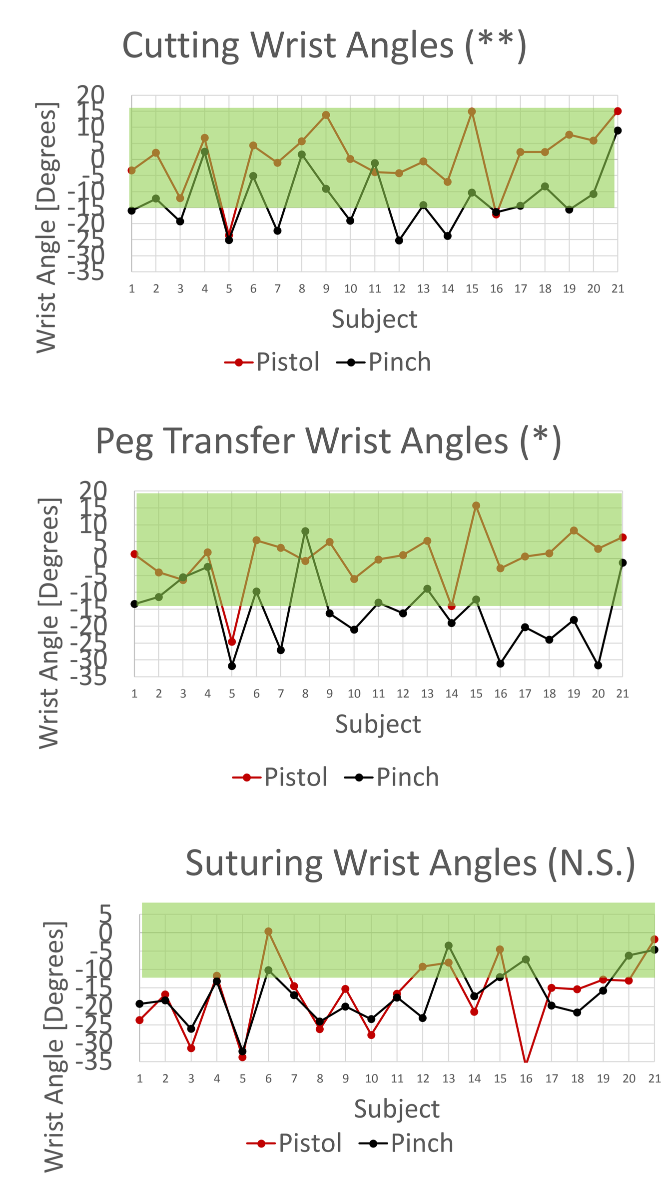


Figure 5. Within subject comparison of wrist flexion/extension angles experienced when using each tool, the green area represents neutral wrist posture (-15 < x < +15); * denotes significance ($p<0.05$) and ** ($p<0.01$)

EMG Output

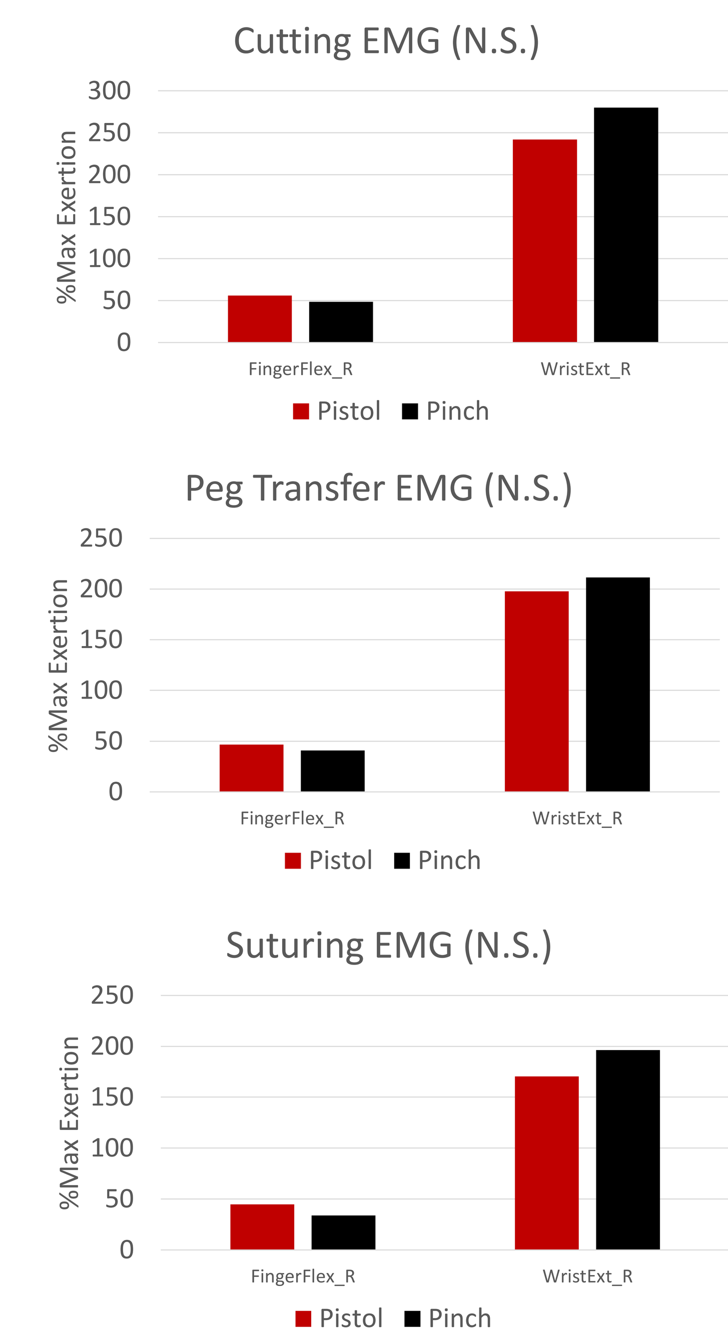


Figure 6. Between tools comparison of wrist flexion/extension angles of the dominant hand. * denotes significance ($p<0.05$)

Conclusion

Hand tool design significantly decreased time to task completion ($p < 0.05$) and improved operating wrist posture for both evaluation tasks ($p < 0.05$). However, there was no significant difference in muscle activation while using the pistol grip design versus the pinch grip design ($p > 0.05$). One possible explanation for this finding could be that participants had no experience handling laparoscopic surgical tools before this study, there was a lack of motor learning/training. Consequently, participants with more precise control of their hands require lower muscle activation[2] to operate tools. This lack of training may have increased the variance of the measurements reducing the power to detect a difference.

The results from this study suggest the following may be obtainable using an improved tool handle for laparoscopy:

- Lower operation times
- More neutral wrist postures

Our results suggest that the use of an ergonomically designed tool handle may significantly reduce the risk factors for carpal tunnel syndrome in surgeons over time, thus increasing their work lifetime.[3]

References

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