A METHOD FOR QUANTIFYING PIPETTE ERGONOMICS

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INTRODUCTION

Work involving pipetting has been associated with elevated rates of musculoskeletal disorders of the hand and wrist. From an ergonomic perspective, force, posture and repetition are recognized as major contributing factors to these potential disorders. Biomechanical investigations of muscle activations (electromyography) and the strain imposed on the hand-arm-shoulder musculature have been performed to compare various designs of pipettes and conditions of the task [1,2]. In general, the resistance of the plunger and the deviation of the extremity from an ergonomically-favorable position have been found to minimize the strain. The plunger resistance depends not only on the design, but also the viscosity of the fluid. Furthermore, the precision of the task could also influence the muscle force and activity.

This purpose of this work is to present a method for assessing the biomechanics of the hand while pipetting with a manual pipette. The methodology is presented along with the data from nine subjects. Biomechanical data quantifying the mechanics of the pipette, as well as the effect of pipette design on posture and joint loading, can lead to improved pipette designs that will potentially reduce the incidence of hand and wrist pathologies.

METHODS

Phase 1: Pipette mechanics

Plunger mechanics (normal and overshoot) and ejector mechanics were obtained on a material testing machine (Figure 1). A 25 lb load cell (Transducer Techniques, Temecula, CA) was used in conjunction with the load cell installed on the test machine to minimize the noise observed in the experimental data. Load and displacement data were recorded for each test using MTP (Natick, MA) software supplied with the MTS (MTS Corporation, Eden Prairie, MN) software operating system.

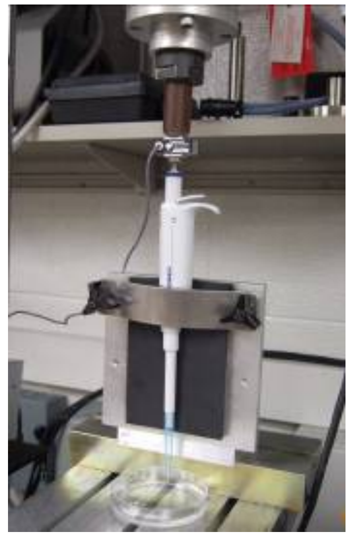

Figure 1: Testing of plunger mechanics in material testing machine.

The pipette was tested at multiple loading rates, two liquid viscosities, and three liquid volume conditions. Two rates of loading were tested, representing slow (5mm/sec) and fast (30mm/sec) action. These rates were determined by observation of normal use of pipettes (obtained by video analysis). Two different fluids of different viscosities were used, Sigma Triton X-100 surfactant (Brookfield, viscosity 240 cps at 25 C, cps=centipoise) for high viscosity and distilled water (1 cps) for low viscosity. The three liquid volumes (10, 100, and 1000µL) required three different pipettes. In each condition, three trials were collected, followed by a single trial with just air in the pipette. Load versus displacement curves were obtained for each trial. Data were obtained at 50 Hz for the 5mm/sec rate and 350 Hz for the 30mm/sec rate.

Forces required to eject the tips from the pipette were recorded in a similar manner on the MTS. After the tip was inserted onto the pipette, the pipette was placed on a jig on the test machine and the injector tip pushed with the indenter on the load cell at 5 mm/sec until the tip was ejected. The data was recorded at a rate of 200 Hz.

Phase 2: Subject measurements

Nine experienced pipette users were recruited for study involvement according to IRB guidelines. Subjects were asked to pipette at a slow rate (5mm/sec) using the 1000µL pipette with low viscosity fluid. The top surface of the plunger and ejector were fitted with paper-thin pressure sensors (Tekscan, Inc.) for use in detecting the various phases of the pipetting trials. Electromagnetic sensors (Liberty, Polhemus Inc.) were fixed and reinforced with tape to the pipettes and the subject's lower arm, dorsal side of the hand, and the thumb metacarpal and first and second phalanges (Figure 2).

Anatomical coordinate systems were set up on each segment of interest, and points were also tracked on the pipette for use in locating the long axis (plunger axis) of the pipettes for determining the moment arm (to the CMC joint). In addition, a point on the distal, palmar side of the tip of the thumb was located for tracking the displacement of the thumb in 3D space.

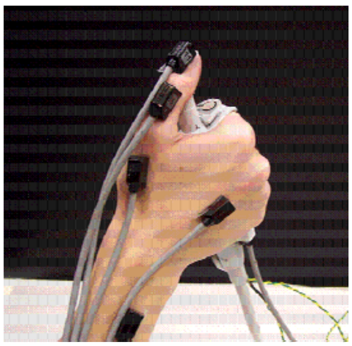

Figure 2: Subject setup including electromagnetic and pressure sensors.

All subjects were asked to use the pipette in a standardized manner. They were asked to draw in water, dispense the water, and finally eject the tip. Dynamic translation and rotation data were synchronously obtained from all of the sensors at 100 hz during the trials. Joint rotations were determined at each time point for each joint (PIP, MCP, CMC) using a helical axis decomposition method. CMC joint moment arms were determined at each time point as the perpendicular distance from the position of the CMC joint to the long axis (plunger axis) of the pipette. Three trials were performed.

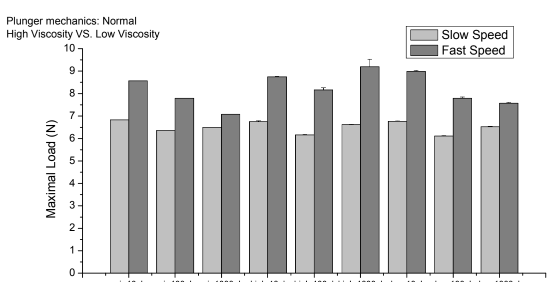

Figure 3: Comparison of maximal plunger load across all fluid viscosities, and slow and fast speed.

RESULTS AND DISCUSSION

The following graphs depict representative data that were obtained using the methods described. The maximal plunger load as a function of fluid viscosity and speed is presented (Figure 3).

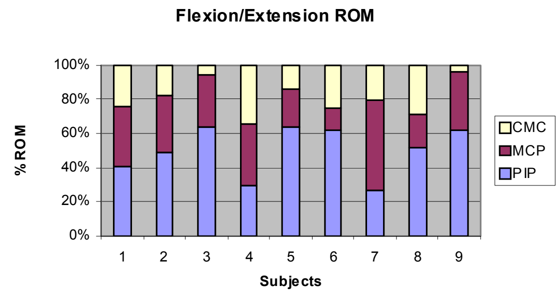

Figure 4: Joint ranges of motion during the plunging phase of the movement.

With knowledge of the plunger mechanics and joint positions obtained from the subjects (Figure 4), moment at the CMC joint can be approximated (Figure 5).

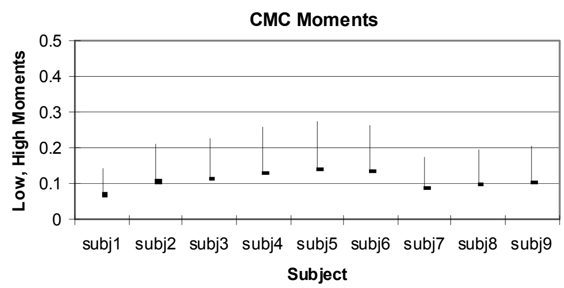

Figure 5: Potential CMC moments experienced by each subject during the plunging phase of motion.

Ergonomic investigations of manual pipetting can be used to assess pipette design parameters and their effect on musculoskeletal parameters such as joint loading. This will help lead to improved pipette designs or usage instruction that will potentially reduce the incidence of hand and wrist pathologies.

REFERENCES

1. Asundi, KR et al. *Human Factors* **47**(1), 67-76, 2005.
2. Fredriksson, K. *Ergonomics*. **38**(5),1067-73, 1995.

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