Development and Evaluation of an Ergonomic Pipette to Reduce Musculoskeletal Injuries in Laboratory Workers

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Introduction

The use of manual pipettes has been associated with a high prevalence of upper extremity and neck cumulative trauma disorders (CTD's) and work-related musculoskeletal disorders (WMSD's) among laboratory workers. The primary risk factor for these disorders are poor ergonomics in three specific areas: posture, repetition and force.

To address these concerns, VistaLab Technologies, Inc. recognized that a significant departure from the decades old axial approach to pipette design was needed. Certified professional ergonomists from Ergonomic Technologies Corporation, a leading firm specializing in the field of ergonomic science, and industrial designers from frogdesign, one of the world's top design firms, were consulted. Together, the group studied the risk factors involved in manual pipetting, and identified the critical design features affecting user effort, comfort, preference and posture. Following lengthy research and extensive user interaction, several concept prototypes were developed that incorporated desirable features into a new technical architecture based on the principles of ergonomic science. After additional testing and feedback from a variety of user settings, the concepts were narrowed to a specific design recommendation known as the Ovation BioNatural Pipette.

Objective

To develop, evaluate and validate an ergonomic pipette that would reduce the risks of musculoskeletal injuries in laboratory workers who perform manual liquid transfer. A series of key design factors were identified that would improve user ergonomics and reduce risks from the process of pipetting. These included:

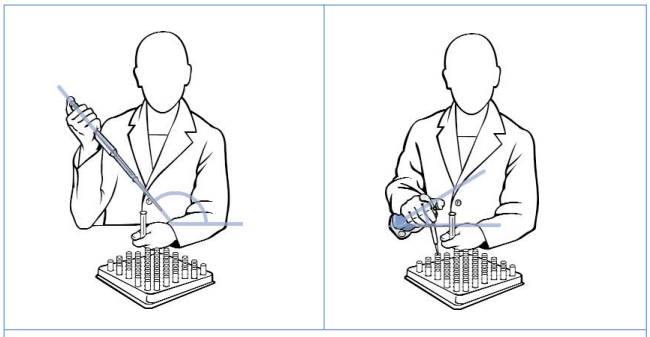
- Replacing the elongated (axial) design with a architecture that would enable the user to keep their arm/hand elevation within 12"of the work surface and wrist in a neutral position
- Providing tactile feedback to indicate when a disposable tip is properly seated to reduce the amount of excessive force often expended by users when compensating for the perception of a poor-fitting tip
- Mechanical assistance to reduce tip ejection effort
- A contoured body to properly support hand grip during aspirating and dispensing of fluids, as well as tip acquisition and ejection
- Minimized contact pressure on the hand and fingers throughout pipetting tasks
- An adjustable grip support to minimize holding effort as well as accommodate a wide range of user hand anthropometry (size)
- Improved operational functions such as volume adjustment, storage and handling, contamination risks, and a simple user interface

Design Process

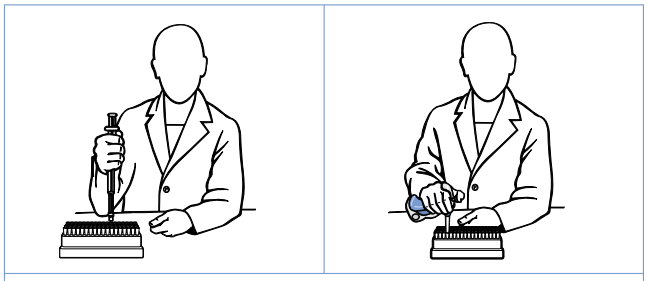
To validate the proposed design factors, interdisciplinary teams from VistaLab Technologies, Ergonomic Technologies Corporation, and frogdesign visited several hospitals and research organizations to observe laboratorians in their work environments and conduct interviews. The cumulative data collection was used in a variety of brainstorming sessions where the principles of ergonomic science, creative industrial design techniques, and decades of liquid handling technology and experience were combined into rough sketches, foam models and computer renderings. These concepts were then evaluated in focus groups with manual pipette users. By acquiring additional feedback and preference data from these sessions, the interdisciplinary teams were then able to construct several working prototype concepts for further evaluation, ultimately leading to a single design architecture that incorporated the most desirable attributes and features from the various concepts and addressed the major ergonomic concerns.

Final Prototype Development and Operation

The resulting design architecture represented a major departure from traditional pipettes. Most significant is the non-axial design which permits the user to perform pipetting operations at or near neutral alignment with the body's natural posture (see comparisons at right). A series of prototype devices were built and tested, incorporating a number of ergonomic features:



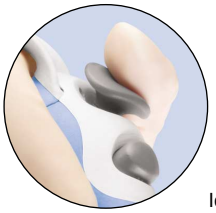
Comparison of forearm and wrist angles during aspirating and dispensing – axial design pipettes vs. prototype device



Comparison of arm and wrist posture when applying tips – axial design pipettes vs. prototype device

Tip Ejection

An energy-release button releases the force captured during acquisition to discard tip. Extremely low force is required to activate button.



Aspirating & Dispensing

Aspirating and dispensing are performed comfortably by a low-force, form-fitting plunger that minimizes force and pressure.

Tip Acquisition

The user inserts the pipette's nozzle into a tip and lightly presses down until an audible "click" is heard. Unlike axial pipette designs, almost no grip pressure is required to apply a tip.

Non-Axial Design

Non-axial design allows the wrist to remain in a neutral range of motion throughout all pipetting operations.

Electronic Volume Adjustments

Simple key pad relieves the user from having to repeatedly rotate a volume adjustment knob.

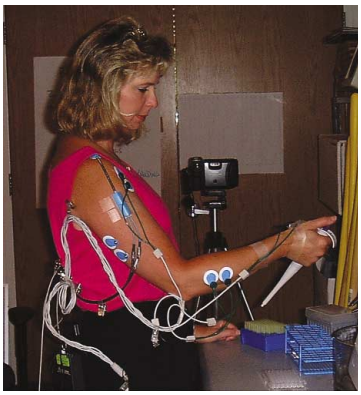
Grip

When a user picks up the Ovation pipette, the pipette body follows the contour of their palm to provide secure feedback. An adjustable hook can be positioned to provide a custom fit for left or right-handed individuals.

Design Validation

Ergonomic testing was performed using 10 laboratory workers as study participants. Users were tested for dynamic postures of upper extremity joints as well as range of motion for each joint and maximum voluntary contraction (MVC) using an average muscle activity threshold level of 15% MVC as a guideline to signal potential increases in muscle fatigue. The Rapid Upper Limb Assessment (RULA)[1], a risk factor checklist, was used to establish thresholds for upper extremity deviation. Testing was done over the complete pipette cycle and during each of the four phases: tipping, aspirating, dispensing and detipping. A baseline assessment of effort associated with holding the device in a neutral position was also conducted. Four commercially available, axially-designed pipettes were included in the study as comparators. All testing was conducted from a seated position, and the location of tips, vials, and waste receptacle were standardized. Pipettes were set to aspirate 200µL of fluid, and subjects were instructed regarding the proper operation of each device. Subjects who participated in the testing spent on average 22.9 hours per week performing manual pipetting. All participants were of good heath and had reported no recent musculoskeletal injuries that affect pipetting.

EMG Testing



EMG (electromyogram) testing was used to measure the activity of five muscle groups. Each muscle group was calibrated to the individual's maximum voluntary contraction (MVC), and signals collected during testing were then expressed as a percentage of the MVC (%MVC). Muscle groups tested were:

- Opponens Pollicis/Flexor Pollicis Brevis (OP/FPB)
- Flexors
- Extensors
- Tricep
- Deltoid Anterior/Middle

[1] McAtamney, L. and Corlett, E.N. (1993) RULA: A survey method for the investigation of work-related, upper limb disorders. Applied Ergonomics, 24 (2), 91-99.

Electrogoniometry

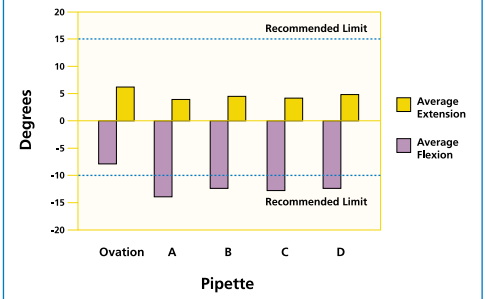
The dynamic postures of the wrist and shoulder joints were measured using a series of electrogoniometers. The placement of the goniometers were as follows:

- Goniometer 1 was placed across the glenohumeral joint to measure upper arm flexion/extension and adduction/abduction.
- Goniometer 2 was placed over the dorsal side of the wrist joint to measure flexion/extension and ulnar/radial deviation during pipetting tasks.

Results

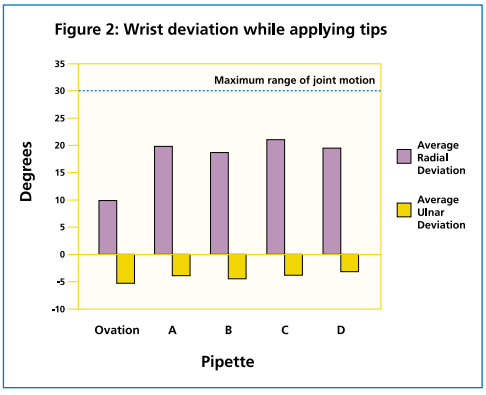
The testing revealed that the Ovation pipette had significant reductions in the ergonomic stress levels compared to traditional, axial-design pipettes, consistently producing less wrist flexion, less upper arm abduction and less arm flexion. Overall, the positions of the wrist and upper arm were maintained in a more neutral, low stress position throughout the entire pipette cycle *(Figure 1)*. Each of the pipettes, except the Ovation pipette, exceeded the threshold for wrist flexion.

Figure 1: Uninterrupted full cycle measurement of wrist extension and flexion

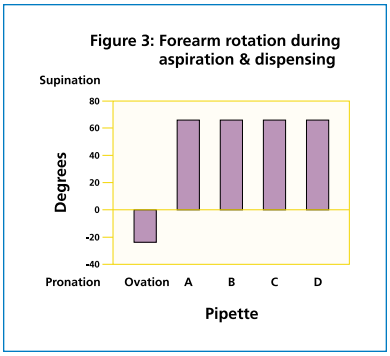


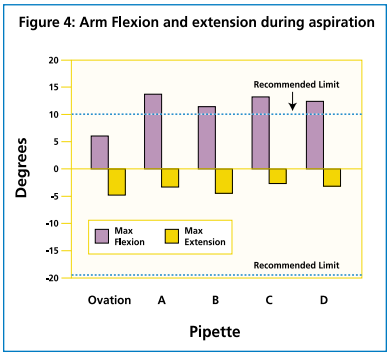
During the tipping portion of the pipette cycle, the Ovation pipette required significantly less bending of the wrist toward the thumb (radial deviation) compared to the comparator pipettes *(Figure 2)*. This finding is attributed to the design of the pipette that permits holding the hand in a horizontal position and that minimizes side-to-side bending of the wrist.

Figure 2: Wrist deviation while applying tips

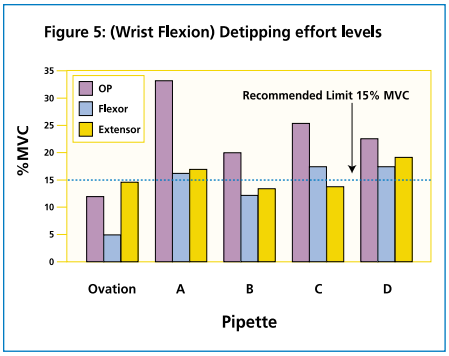


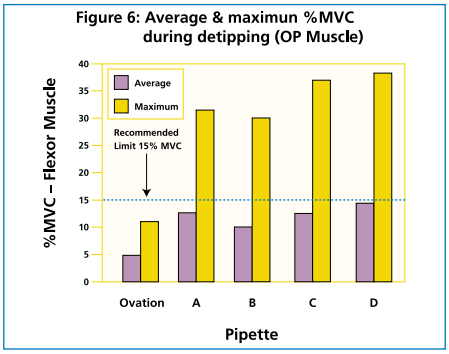
During aspirating and dispensing, the study participants used preferable forearm rotation angles with the Ovation pipette compared to the axially-designed pipettes *(Figure 3)*. On average, they held the Ovation pipette at a forearm pronation angle of 25˚ (palm in a downward facing position), whereas they held the comparator pipettes with an average forearm supination angle of 72˚ (palm in an upward facing position). Wrist positions were likewise pronated with the Ovation pipette, and supinated while using the comparators. All of these findings suggest an increased risk of injury to the wrist when using the axially-designed pipettes. Moreover, as with the tipping results, significantly less upper arm and wrist flexion and abduction was required during aspirating and dispensing while using the Ovation pipette, indicating an improvement in working posture *(Figure 4)*.





The Ovation pipette was also more ergonomically favorable during detipping. Study participants used 142% less wrist flexion compared to the axially-designed pipettes. Significantly less wrist flexor muscle effort (189%) was needed to operate the prototype during detipping *(Figure 5)*. Perhaps most significant were the wrist and thumb muscle efforts required for detipping when women used the axially-designed pipettes. Measurements were above the recommended guidelines of 15% MVC, especially for the opponens pollicis (thumb muscle) which is used for pushing the plunger or button during detipping. Muscle efforts were less than the recommended limits when women used the Ovation pipette *(Figure 6)*. These findings suggest that there is less risk of injury and discomfort during detipping, especially for women.





Conclusion

The new Ovation® BioNatural Pipette developed by VistaLab Technologies is an entirely new pipette design that reduces ergonomic risk. Ergonomic studies show that the shape of the pipette encourages the hand, wrist, and arm of the user to adopt more neutral postures during all phases of the pipetting cycle. The Ovation pipette is particularly advantageous for women to use because of its powered tip ejection. The design of competitive pipettes require thumb muscle forces that are well above the recommended threshold for women and predisposes them to injury from detipping. Other features such as an adjustable grip support, a contoured grip and plunger, a digital volume adjustment, and a stand-up design make the Ovation pipette easier and more comfortable for everyone to use than its predecessors. All of these findings suggest that users of the Ovation pipette are less likely to develop WMSD's.

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