VistaLab Technologies

Results of an Investigation into the Design of an Ergonomic Pipette

Study by: **Ergonomic Technologies Corporation**, July 5, 2001

Text not affecting data, results or conclusions edited October 19, 2018

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Think Differently. Feel Better.

Background

The use of manual pipettes has long been associated with a high prevalence of upper extremity and neck cumulative trauma disorders (CTDs) among pipetters. One study involving 128 laboratory technicians (M.G. Bjorksten et al, 1994) found that 44% reported hand problems, 58% reported shoulder problems and 44% reported neck problems attributed to pipetting. A similar study (G. David, P. Buckle, 1996) identified significant increases in hand and elbow injuries among pipetters. Separately a Health Hazard Evaluation completed by the National Institute of Safety & Health (NIOSH) stated that "a biomechanical hazard exists from exposure to pipetting operations…"

Risk factors:
- High Repetition
- Excessive Force
- High Contact stress
- Awkward Posture

Can result in:
- Carpal Tunnel Syndrome
- Tendinitis
- Trigger Finger
- Tension Neck Syndrome
- etc.

Background

To reduce the risks of ergonomic injury to pipetters, a project was undertaken by VistaLab Technologies to identify the underlying factors contributing to the development of these injuries and to reduce those factors attributed to the design of the pipette.

The project involved:

- On-site investigation of pipetting operations at hospitals, clinics, and R&D facilities
- A review of published studies of pipetters
- An examination of injury statistics among pipetters
- An examination of the design of pipettes and the pipetting workstations

Background

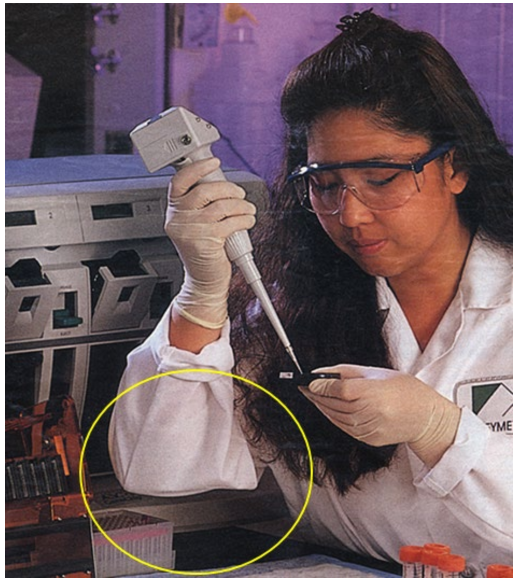
Evaluating “state-of-the-art”

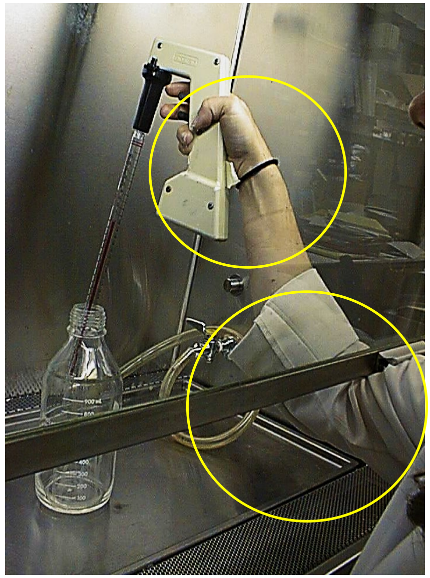
An evaluation of the “state-of-the-art” in ergonomic pipette design revealed that each of the major manufacturers produce an axial grip pipette. However, the ergonomic focus appears to be limited to the plunger effort levels and grip contouring. Unfortunately, all of these designs fail to address the fundamental issue of working posture, in particular, the stresses to the upper extremity beyond the hand itself.

Background

Results of on-site investigations

As a result of the on-site investigations it was clear that pipetting produced numerous ergonomic risks. In particular it is the upper extremity and neck that are primarily stressed as a result of awkward and static working postures. Upper arm flexion (lifting the upper arm in front of the body) between 45° and 90° was common throughout the pipetting task. In addition, frequent abduction of the arm was common (lifting the elbow out to the side of the body). Worst of all were fume hood or booth operations where static abduction and flexion of the arm focused stress to the shoulder and neck.

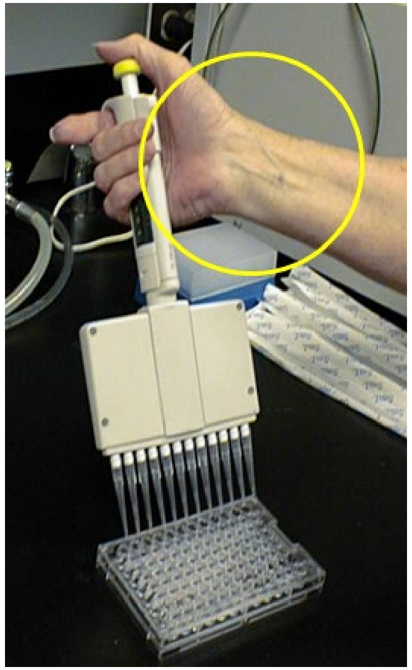




Background

Results of on-site investigations (cont'd)

Observations also included repetitive pronation & supination of the forearm throughout the pipetting operation (twisting the forearm between the palm down and palm up positions). Forearm rotation throughout the full range of motion was common (approx. 180°). This postural technique is commonly associated with the development of elbow injury, specifically epicondylitis (tennis elbow).



Background

Results of on-site investigations cont'd

The hand stressers were common among pipetters. These included frequent pinch grasps (to open vials or pick up tubes) and thumb exertions on the pipette plunger. However, the highest force requirements were associated with the application and removal of the tip. Pipetters would typically exert a significant force to seat the tip to ensure that it would not fall off. This in turn produced excessively high tip ejection forces. Comments from 7 of 13 users surveyed identified de-tipping as a major source of physical stress.

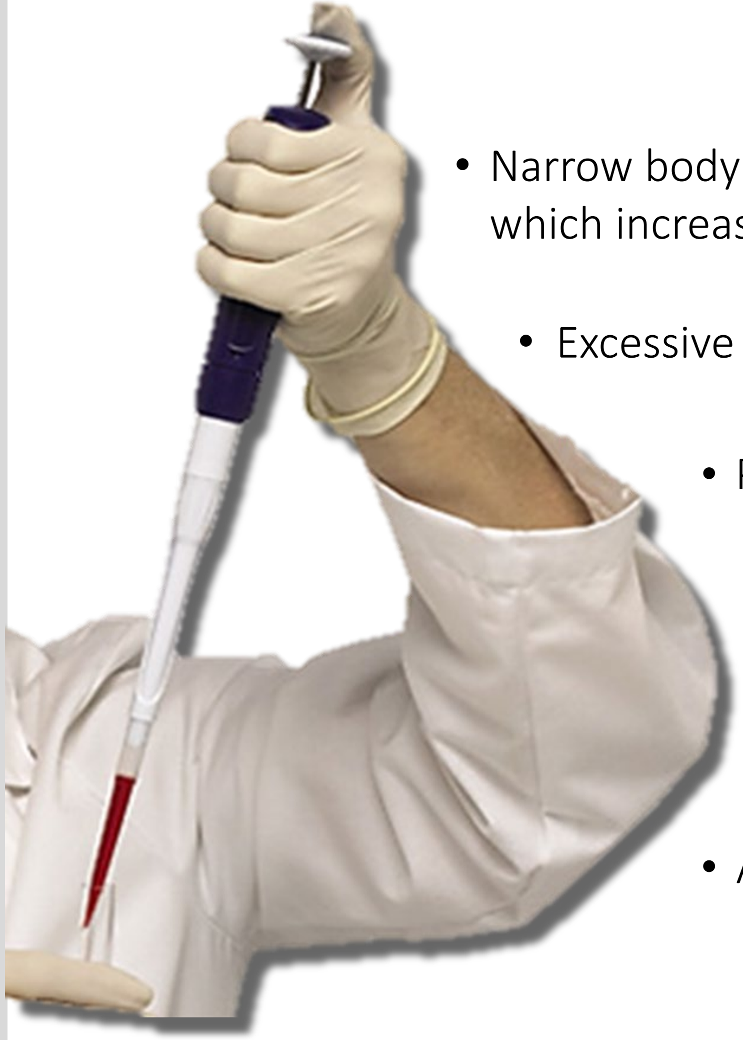
Background

Results of on-site investigations cont'd

The neck, shoulder and elbow stressers are largely driven by the design of the devices. The elongated (axial) device shapes required users to raise their hand at least 25.4 cm off the work surface to clear the protruding pipette tip. It is not the weight of the device that causes the problem here; rather, it is the weight of the user's arm which is often held suspended (static) over the work surface throughout the pipetting tasks. This requirement was the primary source of the upper extremity postural stressers.

Background

Key ergonomic issues with axial pipettes

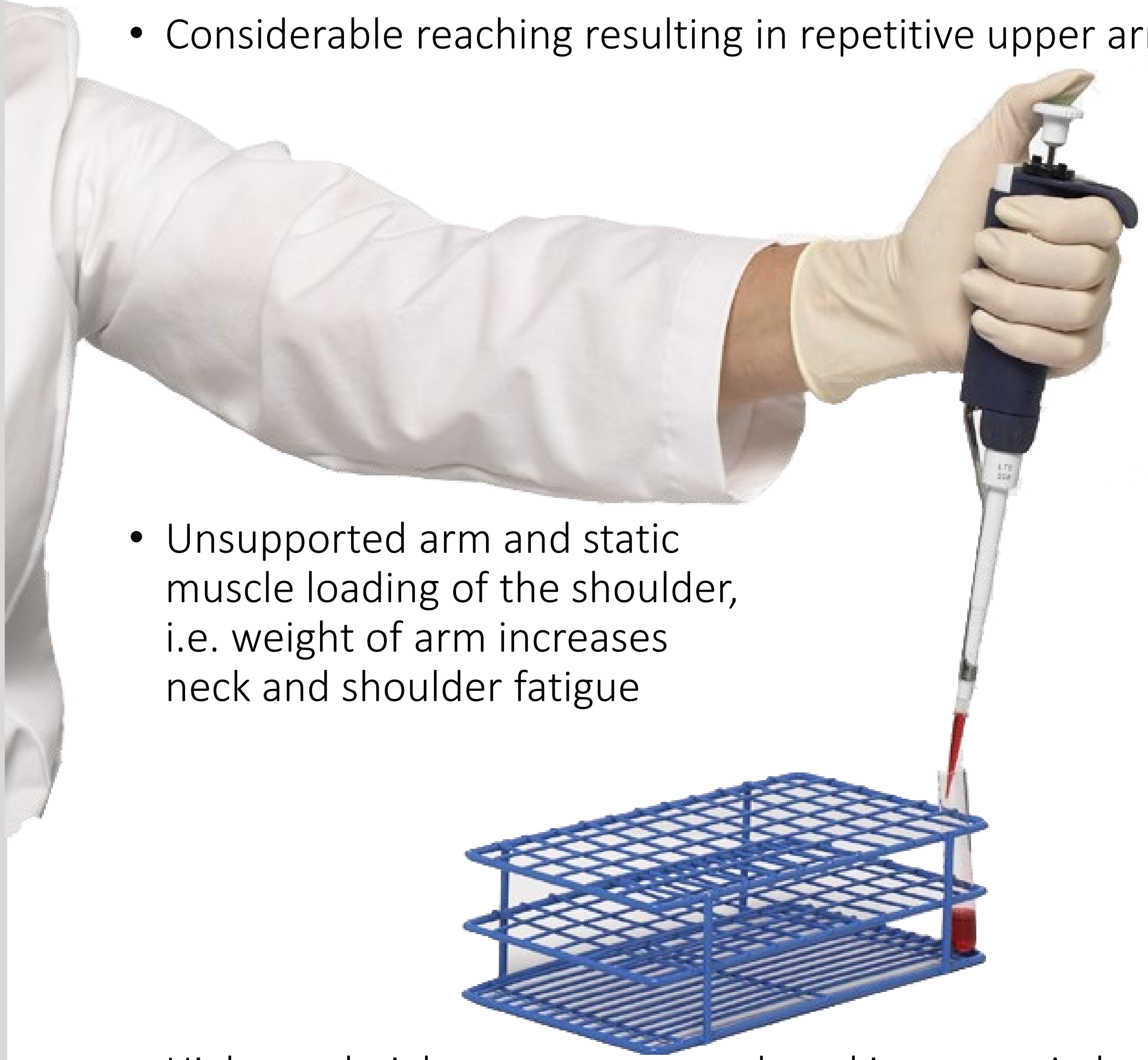


- Narrow body shape requires a tight "Clenched Fist" grip, which increases stress, reduces available hand strength
- Excessive wrist flexion and arm supination (twisting "out") required
- Pipette length requires user's arm to be at an excessive height
- Awkward posture increases risk of injuries

Background

Key ergonomic issues with axial pipettes cont'd

- Considerable amount of neck flexion
- Considerable reaching resulting in repetitive upper arm flexion and abduction



- Unsupported arm and static muscle loading of the shoulder, i.e. weight of arm increases neck and shoulder fatigue
- High arm height causes cramped working space in hood

Background

Key ergonomic issues with axial pipettes cont'd

- Tip of the thumb used almost exclusively
- Excessive finger flexor muscle use (during aspirating and dispensing)
- Over rotated wrist / excessive supination (twisting "out") increases carpal tunnel pressure
- Elevated "winged elbow" increases stress on neck and shoulder
- Excessive force used for tip attachment
- Excessive force used for tip ejection

Background

Key design factors identified to reduce ergonomic risk

The background study identified several key pipette design factors that would reduce the user's ergonomic risks. These included:

- Replace the elongated (axial) design with a design that will enable the user to work closer to table height. This would reduce the poor upper extremity postures.
- Provide positive tactile feedback to indicate that the tip is seated properly. This will reduce the amount of tip attachment effort and potentially the tip ejection effort.
- Incorporate some form of mechanical assist to reduce tip ejection effort.
- Provide appropriate grip contouring to support hand during tip application and ejection.
- Minimize contact pressure on the hand and fingers throughout the pipetting tasks.
- Provide an adjustable grip support to minimize holding effort and to accommodate a wide range of user hand anthropometry.

VistaLab Creates Pipette Prototype

As a result of the investigation, VistaLab constructed a pipette that addressed the major ergonomic concerns.

The device is a significant departure from traditional axial designs and incorporates several unique features with the specific purpose of reducing ergonomic stressers:

- Non-axial structure
- Contoured easy-grip shape
- Adjustable hook
- Large contoured low-force plunger
- Low-force “click” on tip attachment
- Easy spring-loaded “flick” off tip ejection
- Large functional buttons
- Freestanding

Ergonomic Testing

Key ergonomic factors

Ergonomic testing was conducted using five 200 µl pipettes to determine the overall effect of each product on the key ergonomic factors. The factors were measured using the following techniques:

- Muscle effort associated with the use of each device
- Dynamic postural requirements of pipetting
- Surveys of user comfort & preference
- Anthropometric measurement of test subjects

Ergonomic Testing

Products Tested

Eppendorf and Gilson pipettes were selected as a result of their widespread use. The Rainin and Hamilton were selected as they were promoted as providing ergonomic benefit to users. These devices were tested alongside the VistaLab Prototype to quantify the ergonomic effects of each design.

Eppendorf™

Hamilton™

Gilson™

Rainin™

VistaLab™ Prototype

Ergonomic Testing

Subjects (Pipetters)

A total of 10 subjects participated in the testing (5 male, 5 female). The average age of the test subjects was 42.1 years. The average years of experience performing pipetting was 16.7 years. On average, the subjects performed approximately 22.9 hours of pipetting a week. Subjects were recruited from hospitals and clinical laboratories. All subjects were of good health and had reported no recent musculoskeletal injuries that may have affected pipetting.

Ergonomic Testing

Pipetting Tasks Tested

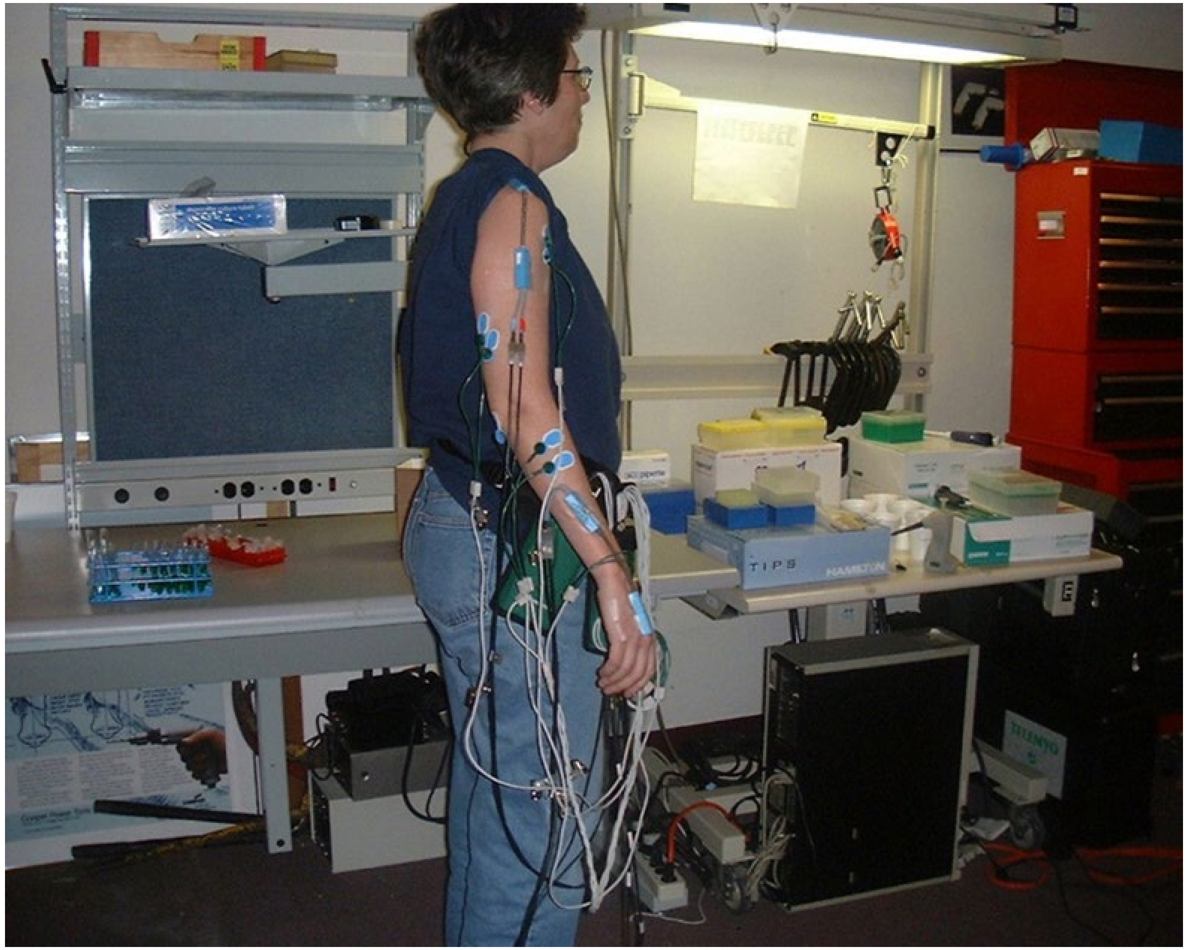
Each pipetter was tested during a series of typical pipetting tasks:

- Tipping (attaching the tip)
- Aspirating
- Dispensing
- De-tipping
- Full Cycle (includes tipping, aspirating, dispensing, de-tipping)

Ergonomic Testing

Test subject wired for EMG testing

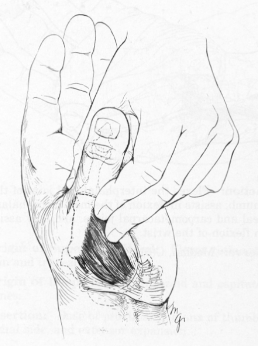
EMG (electromyogram) testing to measure the activity of muscle groups used during pipetting.

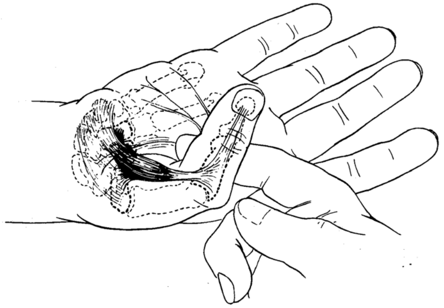


Ergonomic Testing

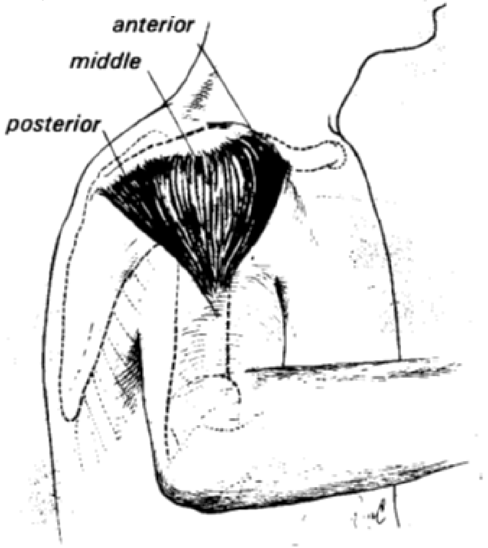
Muscle groups monitored for testing

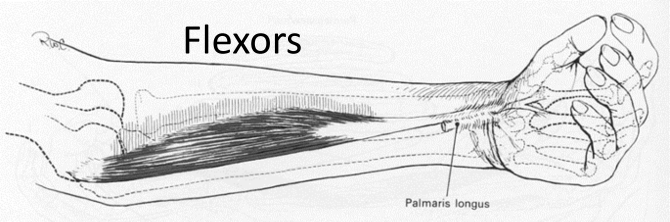
Opponens Pollicis/Flexor Pollicis Brevis (OP/FPB)



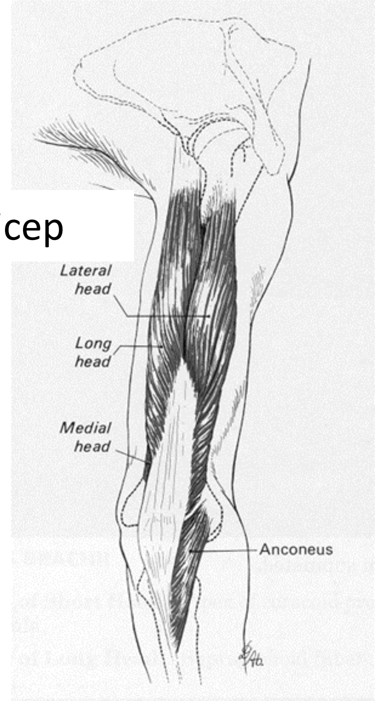


Deltoid Anterior/Middle

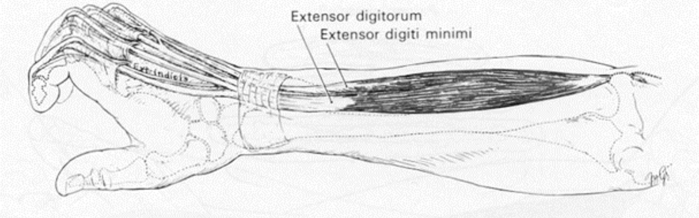




Tricep



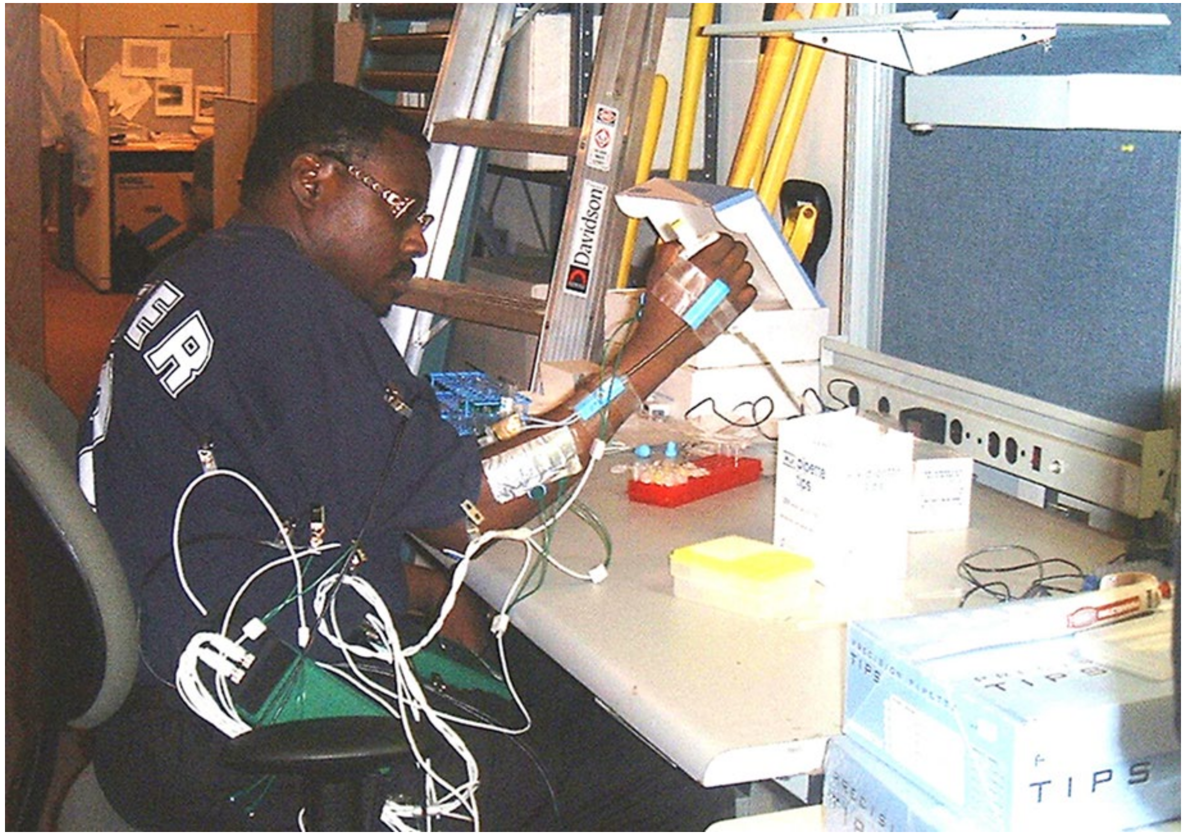
Extensors



Ergonomic Testing

Test subject wired for posture testing

Electrogoniometers used to measure dynamic postures of the wrist and shoulder joints.



Objective Test Results

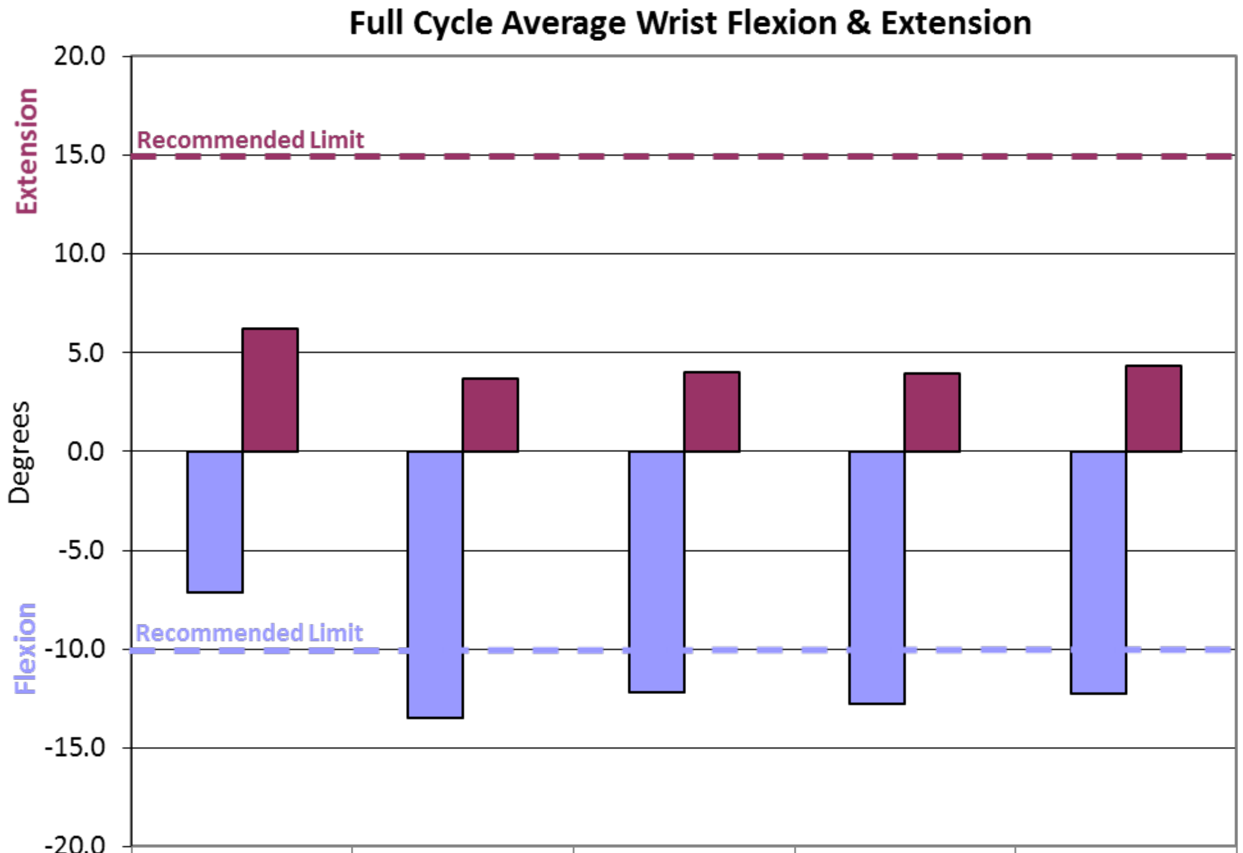
The results of the testing were compared to guidelines and thresholds for determining generally acceptable levels of ergonomic “stress”. The postural analyses of the upper extremities considered the degrees of deviation from the neutral (low stress) position for each body joint. Reference to risk factor checklists were used for establishing thresholds for acceptable upper extremity deviation (Rapid Upper Limb Assessment, RULA). Normal range of joint motion as defined by the American Academy of Orthopedic Surgeons was also considered.

An average muscle activity threshold level of 15 % MVC was used as a guideline to signal potential increases in muscle fatigue. This level assumes continuous muscle exertions performed throughout the course of a day.

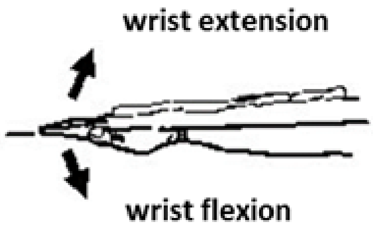
Statistical analyses were performed to determine significant differences between the pipettes tested. Overall, the only significant differences were associated with the VistaLab pipette design (i.e. there were no significant differences between the four axial pipettes). The statistical analysis involved t-tests using a confidence interval of 95% ($P<0.05$).

Results

Full Cycle



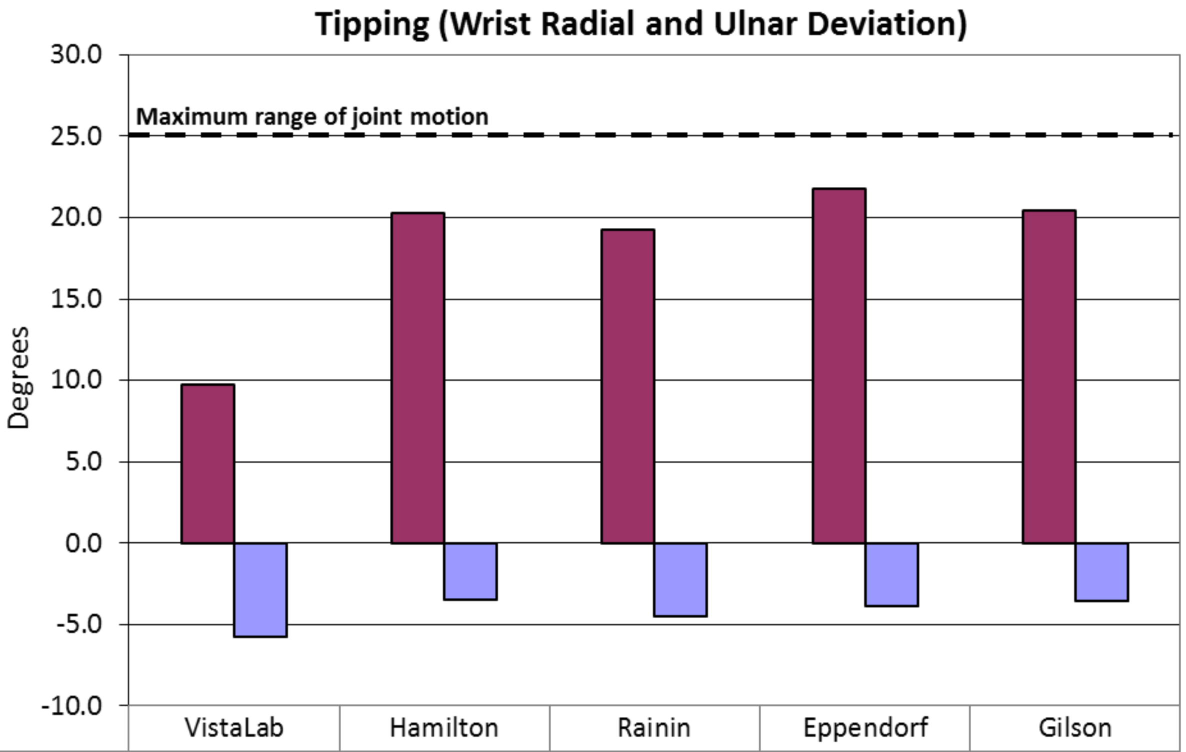
	VistaLab	Hamilton	Rainin	Eppendorf	Gilson
Avg Flexion	-7.1	-13.5	-12.2	-12.8	-12.2
Avg Extension	6.2	3.7	4.0	3.9	4.3



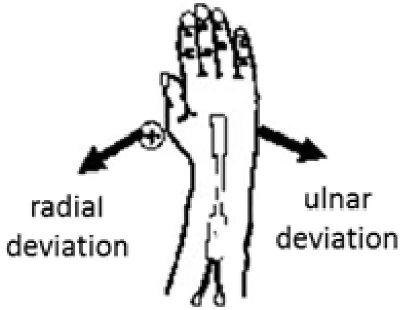
In comparison to recommended postural limits defined by the RULA methodology, each of the pipettes, with the exception of the VistaLab, exceeded the threshold for risk with regards to wrist flexion.

Results

Tipping



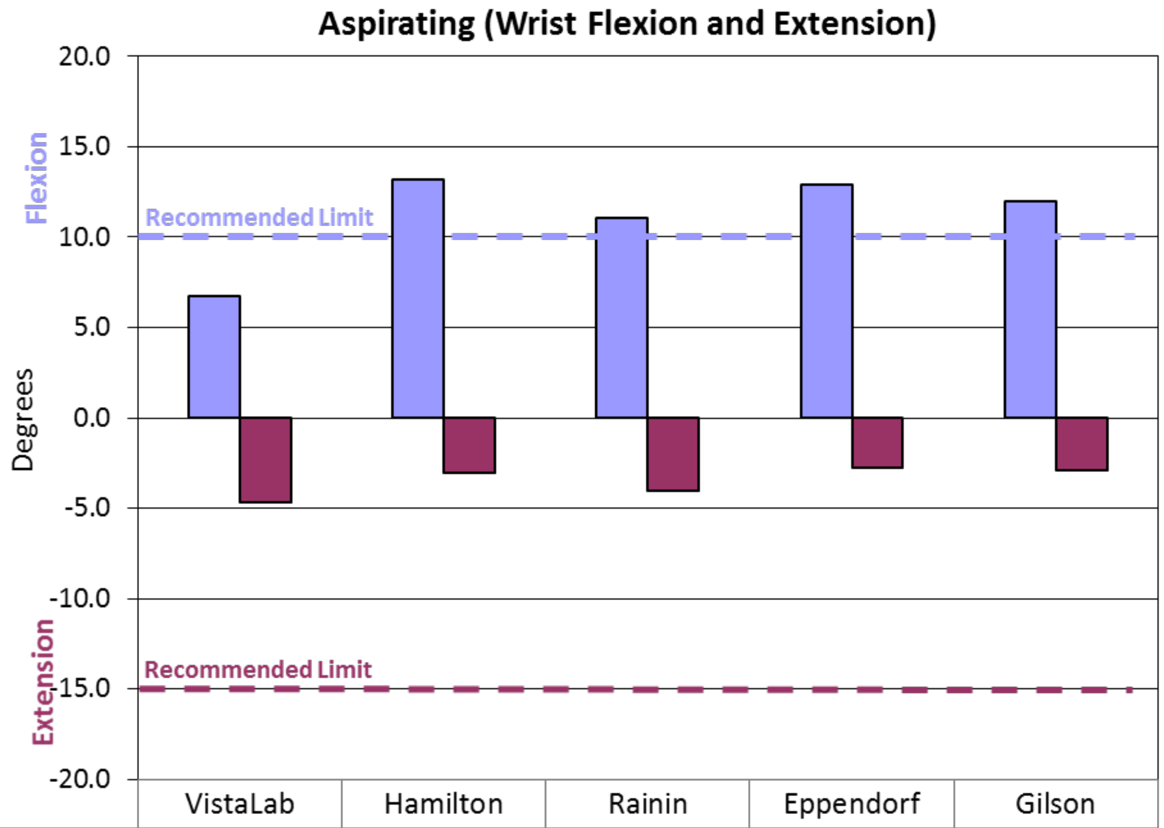
	VistaLab	Hamilton	Rainin	Eppendorf	Gilson
Avg Radial Deviation	9.7	20.3	19.3	21.8	20.4
Avg Ulnar Deviation	-5.8	-3.5	-4.5	-3.9	-3.6



The VistaLab prototype required significantly lower radial deviation (bending wrist toward the thumb) compared to all other pipettes (P= 0.025). On average the axial pipette designs required approximately 20° of radial deviation. This is close to the normal population's maximum angle of 25° for the wrist in this direction (according the American Academy of Orthopedic Surgeons). Hence, the postural risks for the axial designs are considerable. The VistaLab device required less than 10° of radial deviation. This is attributed to the horizontal orientation of the hand on the device during tipping that minimizes side to side bending.

Results

Aspirating

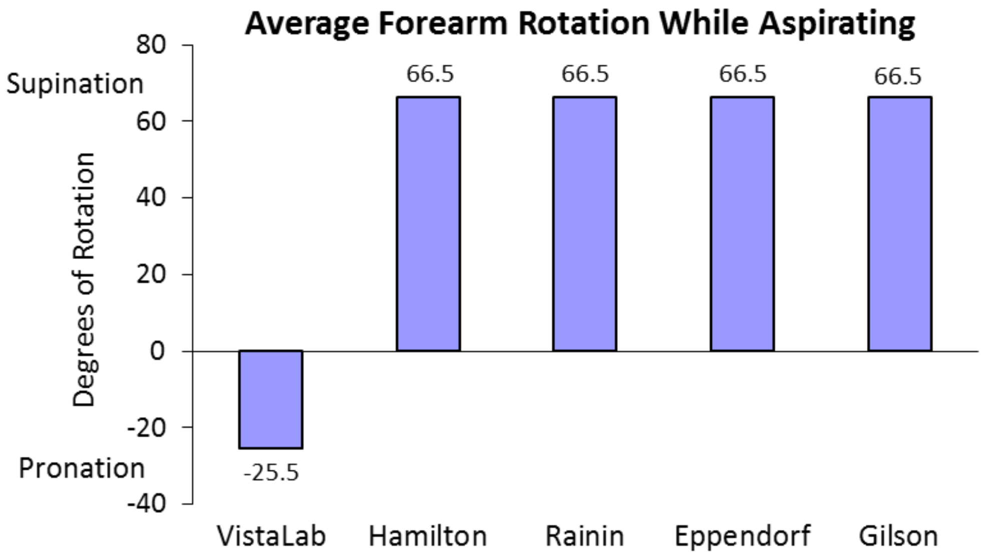


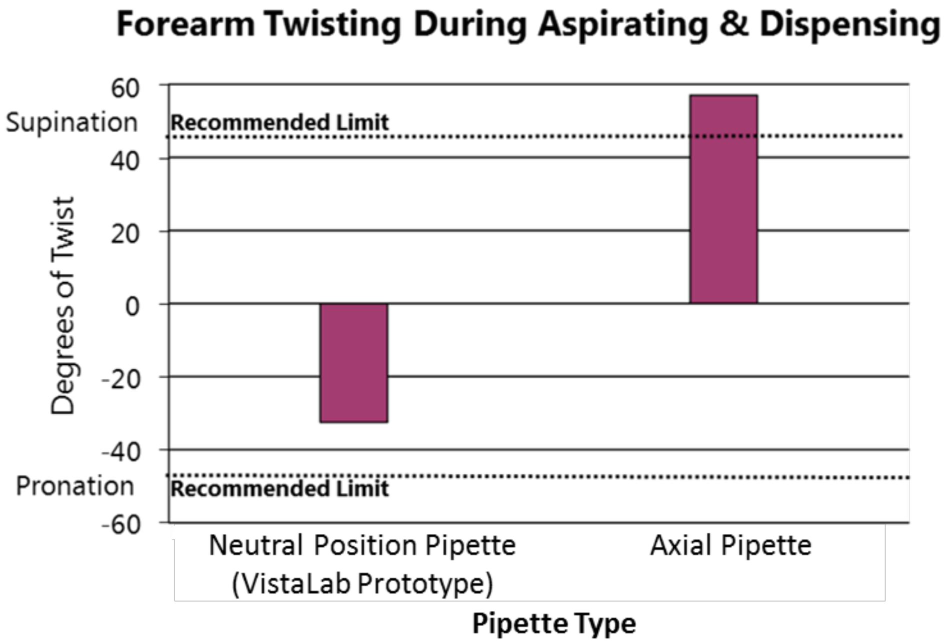
	VistaLab	Hamilton	Rainin	Eppendorf	Gilson
Max Flexion	6.7	13.2	11.0	12.9	12.0
Max Extension	-4.7	-3.0	-4.0	-2.8	-2.9

The postural data revealed considerable differences in the average wrist flexion while pipetting. The VistaLab device required average flexion below the 10° threshold, while each of the axial designs required flexion above the threshold.

Results

Aspirating cont'd

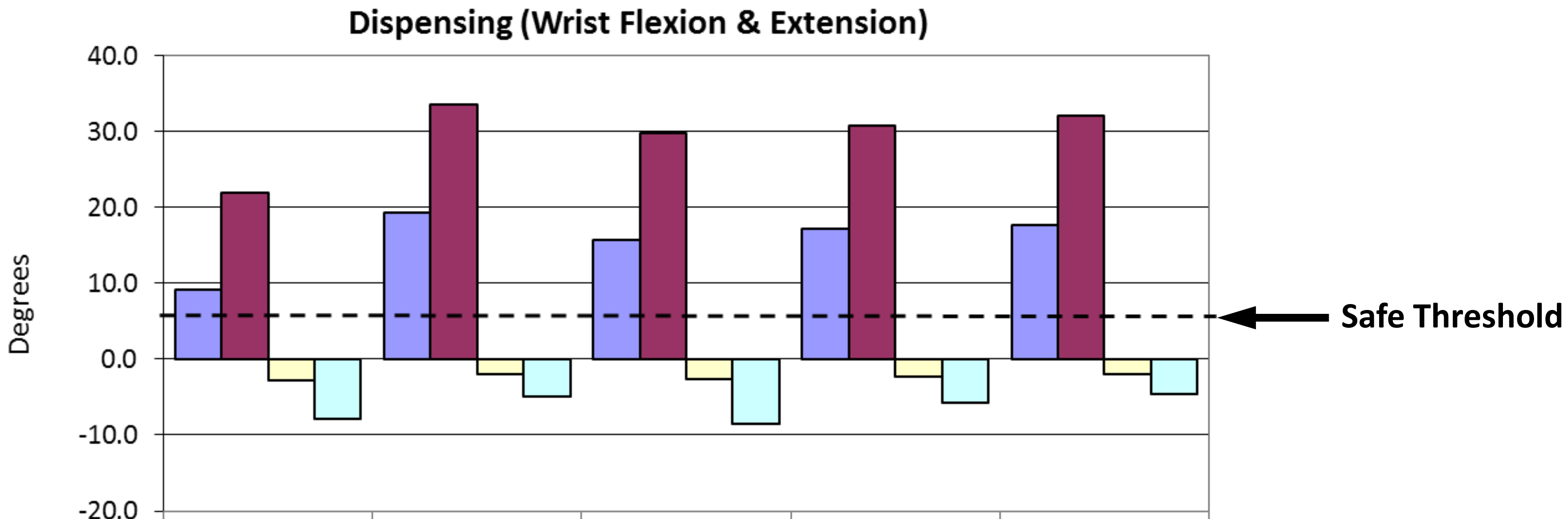




A video analysis of the forearm rotation (twisting) angles revealed dramatic differences in the user technique. The VistaLab prototype was used at an average pronation angle of approximately 25° from the natural angle verses the axial designs that were used at approximately 66° of supination from the natural angle.

Results

Dispensing



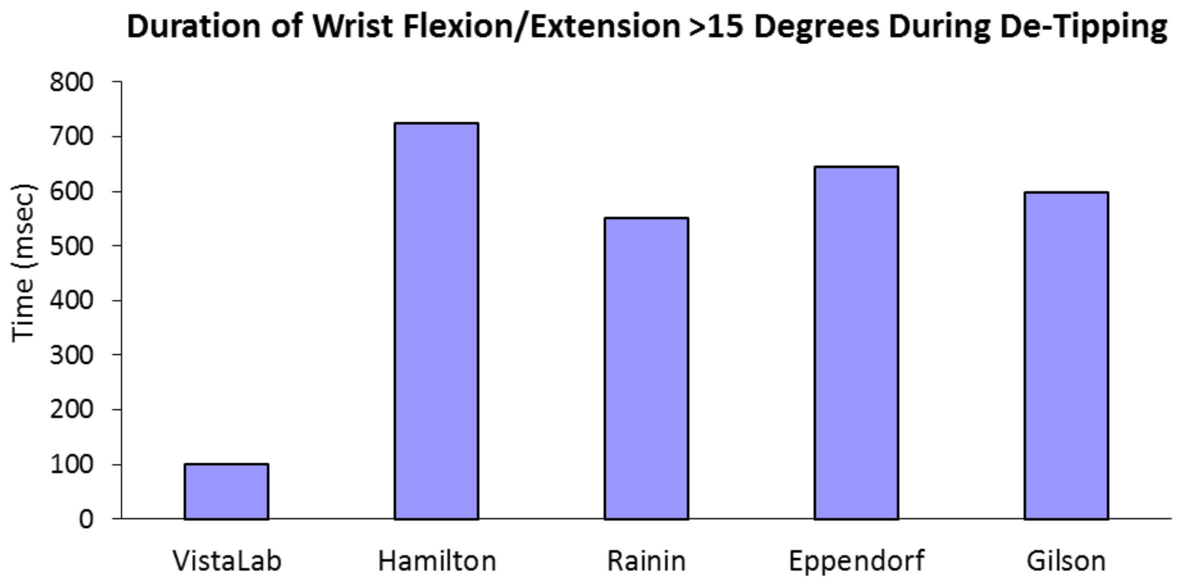
	VistaLab	Hamilton	Rainin	Eppendorf	Gilson
Avg Flexion	9.1	19.3	15.7	17.1	17.7
Max Flexion	21.9	33.5	29.8	30.7	32.1
Avg Extension	-2.8	-2.0	-2.6	-2.3	-2.0
Max Extension	-7.9	-4.9	-8.5	-5.8	-4.5

The VistaLab pipette required significantly less wrist flexion (P=0.033) during the dispensing task. On average the VistaLab pipette required 9.1° of flexion while the axial devices required an average of 17.6° of flexion. Wrist flexion beyond the 10° threshold are indicative of increased ergonomic risk.

Results

De-tipping

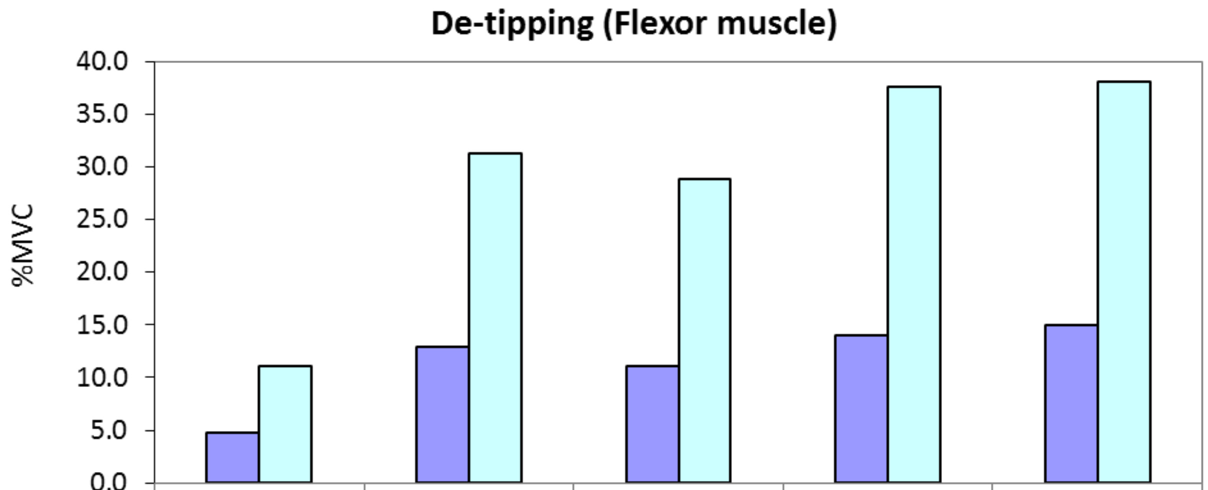
The VistaLab prototype required significantly less wrist flexion during de-tipping. On average, the VistaLab device required 7.6° of flexion verses an average of 18.4° of flexion for the axial designs (P=0.002). This represents a 142% reduction in the flexion required during de-tipping.



An examination of the time that the wrist was exposed to flexion or extension beyond 15° revealed that the VistaLab device required significantly less time in these postures (P= 0.005) during the de-tipping task.

Results

De-tipping cont’d

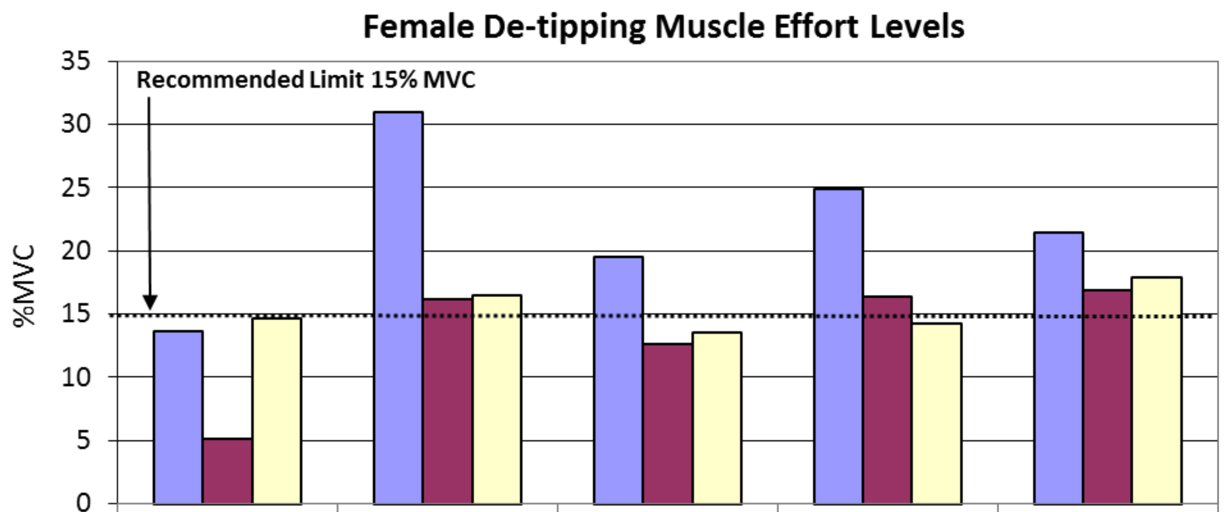


	VistaLab	Hamilton	Rainin	Eppendorf	Gilson
Average	4.78	12.91	11.11	14.02	14.95
Maximum	11.11	31.23	28.87	37.56	38.06

The VistaLab Prototype required the least amount of flexor muscle effort during the de-tipping task (P=0.007). On average the VistaLab device required 4.8 % MVC, while the axial designs required an average of 13.9% MVC. This represents a 189% reduction in the flexor muscle effort associated with de-tipping.

Results

De-tipping cont'd

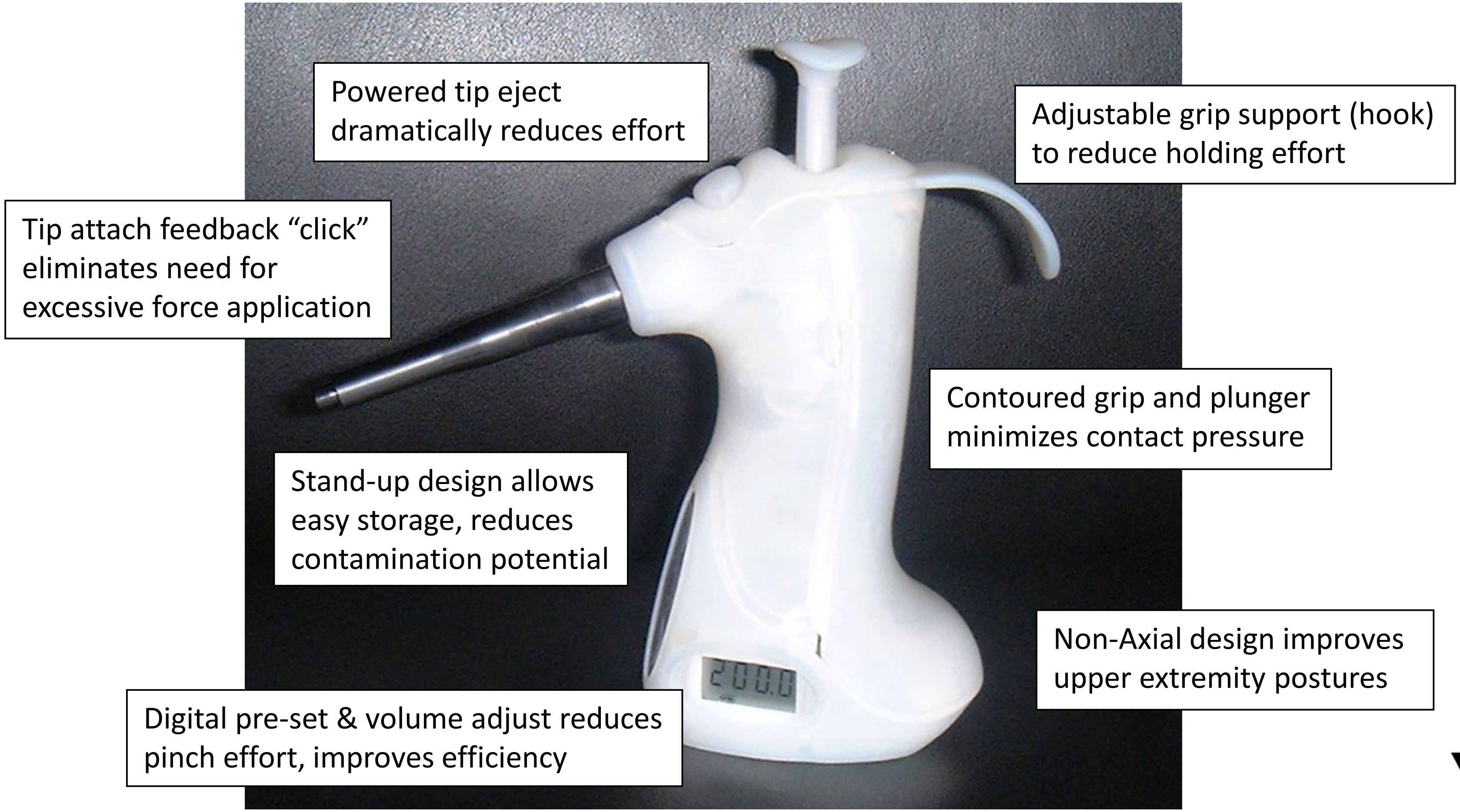


	VistaLab	Hamilton	Ranin	Eppendorf	Gilson
OP	13.6	30.97	19.52	24.87	21.45
Flexor	5.11	16.18	12.59	16.41	16.84
Extensor	14.63	16.47	13.54	14.26	17.91

A further analysis of the de-tipping muscle effort levels indicated that for the females tested, each of the axial designs required exertions above the recommended guideline of 15% MVC. The VistaLab prototype device maintained exertions below these limits.

Conclusions

Overall the VistaLab pipette design offers a dramatic ergonomic alternative to the traditional axial pipette designs with unique features for reducing many ergonomic risk factors associated with upper extremity stress. A summary of the ergonomic features are:



Conclusions

The testing revealed significant reductions in the ergonomic stress levels associated with the natural grip of the VistaLab pipette. In general there were dramatic improvements in upper extremity postures and reduced effort levels. These benefits extended beyond simple reductions in plunger force **by reducing the stresses associated with the overall working postures.**

Conclusions

Advantages of the VistaLab Pipette:

- The **natural grip of the VistaLab pipette produced low levels of wrist flexion and extension.** These differences were significant in comparison to the axial designs. In addition, each of the axial designs exceeded the recommended postural limits for flexion.

- Overall **improvements in upper extremity posture including reduced upper arm abduction and flexion** compared to axial designs.

- The **natural grip pipette produced significantly lower muscle effort levels associated with the de-tipping**. Users identified de-tipping as a major source of stress while pipetting. This difference was greatest among female users where the axial designs exceeded the recommended guideline for muscle exertion.

- A **reduction in the risk factors associated with the development of elbow cumulative trauma disorders (CTDs).** In particular, the rotation of the forearm (pronation/supination) was dramatically reduced throughout a majority (65%) of the pipetting cycle.

Conclusions

While it appears that users may need some initial explanation of the devices proper use, it is clear that the benefits can be long lasting. As with any device, training in proper work method is critical to ergonomic success. It was clear from on-site testing of axial pipette users that many of the ergonomic risks were compounded by poor technique. This was observed as poor postural methods, inefficient workstation layout, and bad workstation design. Achieving the total ergonomic solution will require a combination of proper pipette selection, education of personnel, and improvements to the design and layout of pipetting workstations.

VistaLab Technologies

Designing products for your health so you can focus on the Science

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