The Ergonomics of Pipetting

Forces are Affected by Pipette Selection

The process of pipetting is well understood by scientists around the world. Pipettes are ubiquitous, providing a simple mechanism to complete workflow requirements, from the starting liquid sample preparation to introducing the sample into a final analysis system. Using many different pipettes throughout the day is common and each unit may have its own unique challenges – high volume, low volume or multichannel. The ergonomic factors associated with a variety of pipettes and applications is an important consideration – poor ergonomics can lead to fatigue, pain and the risk of injuries.

Several critical areas have been identified as key to degrading the comfort level of the pipette and subsequent development of various painful ailments, generally called Repetitive Stress Injuries (RSIs). This information has been published by ergonomics scientists in an effort to create awareness of the usability issues associated with pipetting.[1, 3, 4, 5, 6, 7] A common theme among all studies is that pipetting is a forceful and repetitive activity, and that there is a strong association between pipetting and developing RSIs. In fact, pipetting just over an hour a day over the course of a year is enough to put you at risk, and the chances increase exponentially with workload and age.[1, 3, 4, 7]

A key reference point is the amount of force required to perform an activity, such as depressing the plunger or ejecting tips. Most of these forces are transmitted through the thumb. Generally speaking, the goal of pipette manufacturers has been to lower pipetting forces as much as possible in order to improve their ergonomic impact.

Part of the GPP - Good Pipetting Practice Series

Tip loading and tip ejection

Loading a tip on the end of a pipette and subsequently ejecting it at the end of the pipetting cycle are very closely linked and constitute some of the heaviest forces associated with pipetting. With most pipetting systems the design of the distal end of the pipette is conical in shape.

The process of loading the tip on the pipette requires a certain amount of force to ensure an adequate seal of the system – too little force and there is a risk of leakage and volumetric error. User technique for tip loading can vary as there is no clear way to know when enough force had been used to seal the system.

Typically a user will adopt a technique that provides reasonable assurance that the tip has sealed and will stay with that technique for most of their working life. Unfortunately, for traditional conical tip systems, there is a strong correlation between the amount of force needed to load the tip and the amount of force required to eject it, so for those who adopt a technique that uses high force to add the tip, a high force will be required to eject it (see Figure 1, red line).

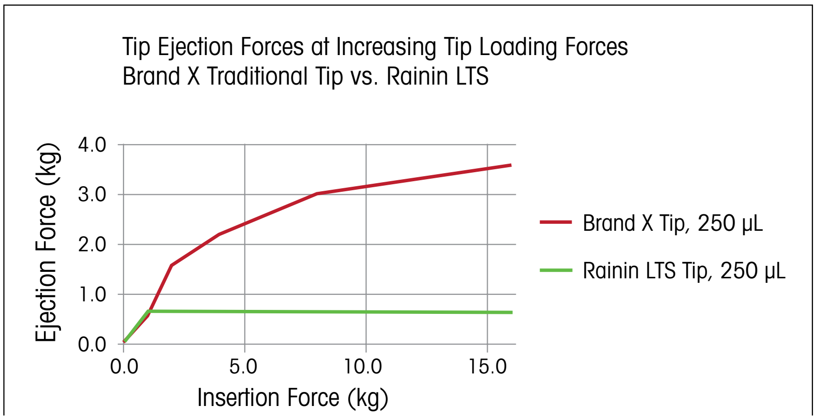

Figure 1

The relationship between tip loading and ejection forces – a traditional conical tip compared with a Rainin LTS tip.

In the paper by Lichty et al,[6] a number of different manufacturer's pipettes are reviewed and force measurements compiled for plunger forces and tip ejection forces. It is clear that tip ejection forces are the most significant force associated with the many steps involved in pipetting, but there is great variation in tip ejection forces between pipettes (See Figure 2).

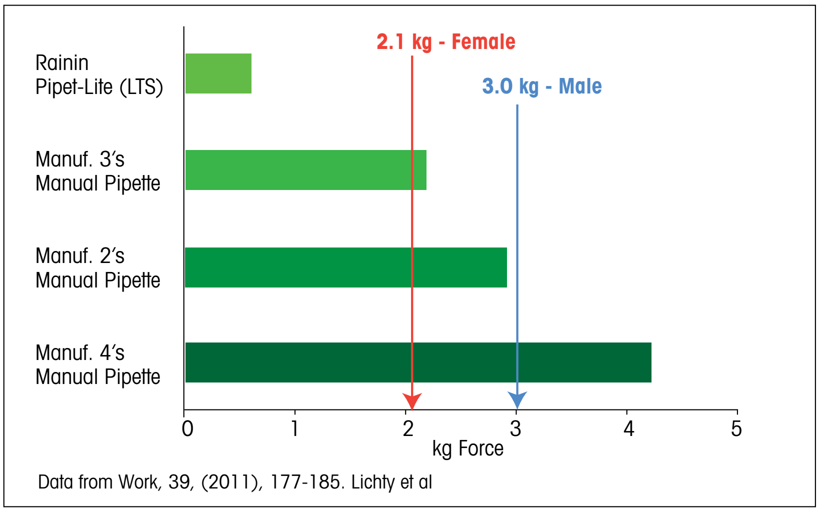

Figure 2
Comparison of tip ejection forces from four popular pipettes. The maximum recommended thumb exertion force is 2.1 kgf for females and 3.0 kgf for males.[2]

Rainin solved this problem with LiteTouch System (LTS) of pipettes and tips (See Figure 3). Here both the distal end of the pipette and the inside of the tip have a closely matched cylindrical surface. LTS tips also have a sealing system close to the entry point and a hard stop end point inside the tip. The end stop prevents the shaft from being pushed further into the tip with increased force. This strictly limits the maximum sealing force, while still guaranteeing that there will be no leakage. A strict limit on sealing force ensures a minimal ejection force (See Figure 1). This unique yet simple design provides a tool that significantly reduces one of the major sources of muscle fatigue and causes of RSI for pipettors.

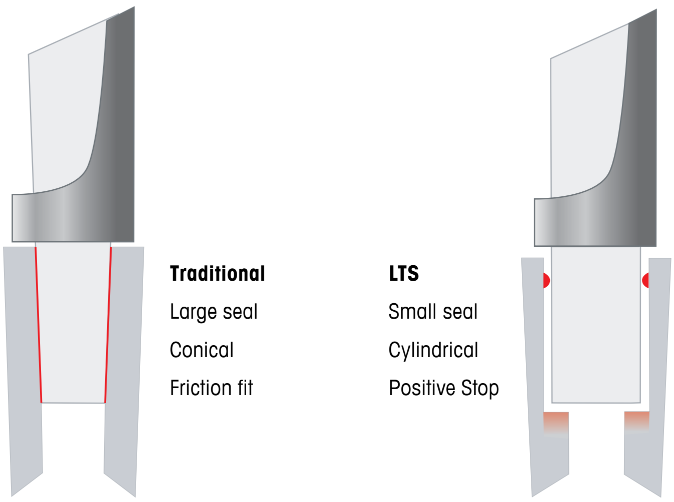

Figure 3
Mechanics of Rainin LTS tip sealing system compared to traditional conical tip sealing systems

Plunger forces

The plunger system of manual pipettes constitutes the second area of ergonomic interest to the user where repetitive tasks can influence the outcome of RSI's. After tip insertion, pressing the plunger down to the first stop against the stroke spring (See Figure 4) prepares the pipette/tip system for aspiration. A clear distinctive first stop is critical in that it defines the distance needed to move the plunger and aspirate the desired volume.

Figure 4
Pressing manual pipette plunger to show home position (start dispense), first stop (full dispense) and second stop (blowout)

Mechanically, this first stop is created by the plunger hitting a stiffer pre-loaded blowout spring that has greater resistance than the stroke spring. After the plunger is pressed down to the first stop, the tip is inserted into the solution and the plunger slowly released to aspirate. The stroke spring performs the aspiration by pushing the plunger back up to the home position. The sample is dispensed at the last step – pushing the plunger down against the force of the stroke spring, through the first stop position and then against the force of the blow-out spring to remove all of the liquid. With all liquid dispensed, the plunger is released and returns back to the home position.

In the paper by Lichty,[6] blow-out forces are the second largest force in the process of pipetting (after tip ejection forces) and stroke spring forces the smallest.

An important aspect of the forces in this process is the internal piston seal system (Figure 5). The seal produces a partial vacuum that enables liquid to be drawn into the tip as the piston moves up the shaft. The seal system must be tight and strong enough to hold the vacuum required for the entire operating range of the pipette. If the seal is too tight the force required to push the plunger down and then return it to the home position will be excessive. If the seal is relatively loose, the forces required to move the plunger back and forth will be less, but the potential for leakage increases.

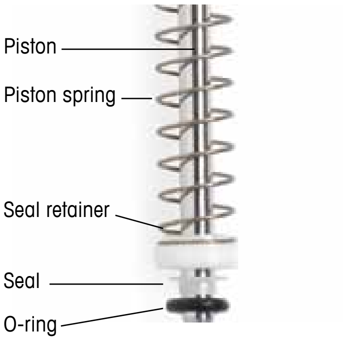

Figure 5
Sealing system in manual pipettes

For manufacturers of pipettes there is a balance between the seal design and the stroke spring forces that must be considered in order to meet both the technical needs for accurate pipetting and the individual user's need for an ergonomic solution. This challenge is met differently by various manufacturers, resulting in variable plunger forces (See Figure 6).

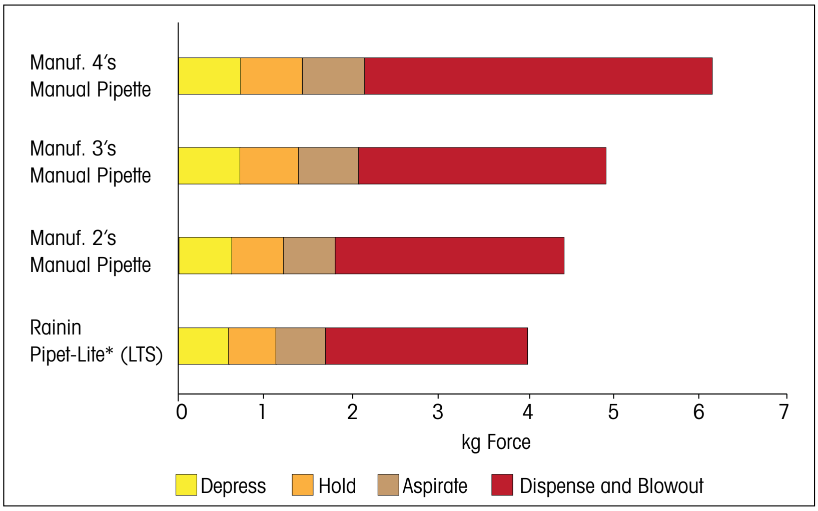

Figure 6
Comparison of plunger forces from four popular pipettes. The maximum recommended thumb exertion force is 2.1 kgf for females and 3.0 kgf for males[2] *New Pipet-Lite XLS reduces plunger forces by up to 43%

Rainin developed high precision, low friction seals to help reduce stroke spring plunger forces. These seals require minimal force to move while maintaining a vacuum, which allows for a lighter stroke spring. A lighter stroke spring allows for a lighter blow-out spring, because the difference in spring forces defines the first stop. Thus blow-out forces are reduced as well.

Ultimately, the best solution for avoiding plunger forces is to use an electronic pipette, where a microprocessor-controlled motor moves the plunger, resulting in near zero plunger forces. This can be particularly helpful with multichannel pipettes, which have the highest plunger forces, and when a researcher needs to perform intensive repetitive mixing of the liquid samples.

Volume setting – changing the aspiration volume

Changing the volume of a manual pipette is often necessary to meet the requirements of the experiment (e.g., changing the setting of a 200 µL pipette down to 50 µL for specific buffer addition, and then back up to 200 µL for the next buffer). The process of changing the volume setting screw – normally a small diameter button – requires several turns of the hand-fingers-thumb combination. Experienced pipettors may even do this with one hand, both holding and adjusting the pipette at the same time, while holding a liquid sample in the other hand.

A study by Asundi et al[5] indicates that volume adjustment is an activity that requires high muscle activity. In the four different thumb-related muscles that were tested, volume changes generated significant muscular response, indicating a potential for fatigue. Different pipette designs can either reduce or increase the forces required for changing volume. A further study by Lichty et al[6] found a positive correlation between ease of volume adjustment and worker productivity, probably because significant time is spent adjusting the volume setting during routine operation.

Rainin reduced the forces associated with volume adjustment by providing a large easy-grip button and low-friction screw mechanism. An adjustable lock prevents the inadvertent changing of the volume setting between pipetting steps. With this combination an operator can easily unlock, adjust and lock the volume setting mechanism with one hand and with minimal force requirements, (see Figure 7).

Figure 7
Setting the pipette volume with one hand

Repetition

Pipetting once will not affect your hand, but pipetting hundreds of times over the course of several hours certainly will. The chance of getting injured increases greatly with repetitive work. Fortunately there are several straight-forward solutions.

The first kind of solution is to use products that do the work for you. Multichannel pipettes and 96-well pipetting platforms reduce repetition by pipetting multiple samples at once. Electronic pipettes can semi-automate certain functions, such as dispensing multiple aliquots from a single aspiration, automatically mixing, or automatically changing the programmed volumes in a pre-determined sequence.

The second kind of solution is to modify pipetting habits to decrease the effects of repetitive work. Try to take regular breaks, switch hands, stretch your limbs and maintain good posture (minimize twisting of your shoulders, arms and wrists; manipulate objects at shoulder height or below).

Grip

Grip comfort has been positively associated with reducing hand and arm discomfort[6]. Factors important for grip comfort include the shape of the pipette body and fingerhook, and the distance your thumb needs to reach to the top of the plunger. Try to grasp the pipette with as little force as necessary to maintain control.

Conclusion and Recommendations

The ergonomics of pipetting are generally well understood. Higher pipetting forces and long hours of pipetting are associated with developing RSIs. The following recommendations will assist researchers in minimizing their chance of developing RSIs.

Look for lower plunger forces

Check spring forces associated with the plunger.

Compare new pipettes with old ones.

Use electronic pipettes when possible.

Service your pipettes regularly to maintain optimal mechanics.

Keeping the piston and seals clean will both lower friction, thus reducing pipetting force, and maintain better accuracy and precision.

Look for lower tip ejection forces

Compare the tip ejection forces of different pipettes. Consider that a pipette with a high tip loading force will probably have a high tip ejection force. Remember that multichannel pipettes have generally higher forces and can be particularly hard on the thumb.

Other considerations

Use pipettes with a finger hook that fit comfortably in your hand without gripping tightly.

Lower the forces associated with volume change by using a pipette with a volume lock, low-friction volume change mechanism and a large dial with good grip.

Reduce repetitive pipetting by using electronic pipettes, multichannels and 96-well pipetting platforms. Take breaks and, if possible, switch hands and stretch arms and hands.

References

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Rainin Instrument, LLC
7500 Edgewater Drive, Oakland, CA 94621
Phone +1 510 564 1600

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