Andrew Alliance

APPLICATION NOTE
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Pipetting Ergonomics: challenges and solutions

THE REIGN OF THE MANUAL PIPETTE

Ergonomics has revolutionized the way we all think about workstation design. Ergonomically designed workstations enable millions to perform their tasks every day without pain or strain. The success in adapting the computer workspace (desks, chairs, monitors, keyboard and mouse) for ergonomic considerations has been, to date, unmatched in the research laboratory. There are several unique challenges in adapting biological research workflows to ergonomic solutions unlike a computer workstation. These include infrastructure designs which are based on safety requirements, highly variable working environments, as well as experimental limitations to adapting protocols. Whereas ergonomics is the science of adapting the workplace to the job, often in scientific research, the job is adapted to the science to be done. And that job has been changing in recent years.

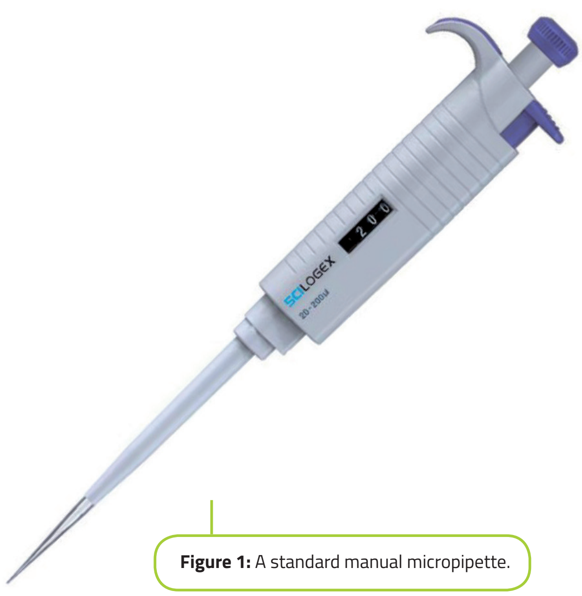

Figure 1: A standard manual micropipette.

Over the past 20 years, there has been a large shift in what type of research is most common. Once a niche subject, Molecular Biology and its study of genes, proteins and individual cells have been incorporated into most other disciplines such as biochemistry, cell biology, microbiology, medical diagnostic testing and especially drug development. This has influenced both the course of drug development and the nature of work being done by research technicians, scientists and students. The manual pipette **(Figure 1)** now reigns supreme in the lab, and is used for almost all liquid handling, experimental set up, and sample processing today. They enable scientists to move, mix, and aliquot extremely small volumes of liquid samples with extremely high precision. Unfortunately, manual liquid handling raises some serious ergonomic red flags, with the rising number of operating hours per year drastically increasing the number of users who report pain while pipetting **(1, 2)**. Ergonomic pipetting solutions are required for manual liquid handling methods. Of the main considerations for ergonomic assessments, manual pipetting raises issues in terms of repetition, force and posture **(2)**.

Several research studies have been conducted on the risk for repetitive strain injuries faced by research technicians and the information paints a stark picture. Relative to non-pipetting coworkers, a research technician who is pipetting **300 hours per year** (less than 2 hours a day) already faces increased risk of hand and shoulder pain. Workplace surveys find, however, that pipetting activities can take up 54% to 88% of the workday for a technician or research scientist **(3)**. Using a standard work week as a guide, this puts current estimates of pipetting activities between 1,200 and 1,900 hours per year. **This places workers at 4 to 6 times the identified time limit for increased risk of workplace injury.** In the United States, lost productive time as a result of repetitive strain disorders is estimated at 61 billion dollars, and a workplace repetitive strain injury can result in up to 185 days of missed work per year **(4, 5)**. While these statistics paint a worst case scenario picture, even technicians who have not yet experienced debilitating pain may alter their pipetting technique with compensatory moves to avoid pain, thus decreasing the accuracy of their work and wasting valuable resources and samples.

Ergonomic solutions addressing individual steps	Standard Pipetting Workflow	Force relative to recommended maximum force for individual step
	1 Adjust volume setting	Not measured
Ergonomic manual pipettes engineered to reduce tip application force	2 Insert disposable tip	231% – 475% 166% – 333%
Ergonomic manual or electronic pipettes engineered to reduce thumb depressing force	3 Depress plunger to first stop	43% / 30%
	4 Aspirate sample by slowly releasing plunger	47% / 33%
	5 Expel sample by depressing plunger to second stop	195% / 136%
Ergonomic manual pipettes engineered to reduce thumb depressing force	6 Eject tip by depressing plunger past second stop into waste container	190% – 230% 135% – 165%

Pipetting steps which can be completely automated by Andrew

Figure 2: Example workflow for one pipetting action (1,5).

REPETITION AND FORCE INVOLVED IN PIPETTING AND REPETITIVE STRAIN INJURIES

The majority of commonly used manual pipettes are handheld, operated primarily using the thumb in an extremely repetitive fashion. One standard pipetting cycle typically includes 6 steps **(Figure 2)**. The NIH found that this 6-step procedure is commonly carried out between 6,000 and 12,000 times a day for an average pipette user in the United States **(6)**. Mixing by pipetting is also a common addition to this protocol which involves vigorously depressing and releasing the plunger with the thumb. Each single mixing step encompasses 60 to 90 repetitive movements per minute. In addition to being highly repetitive, the forces required to depress and release the plunger with the thumb is often much higher than recommended for safe working conditions. The standard calculation notes that for each dynamic movement the force required should be less than 30% of the maximum strength capacity. This limits force applied in each movement of the thumb to 3 and 2.1 kg of force for men and women respectively **(6)**. While some of the steps involved in pipetting are under this limit, depending on the pipette and method used, half of the movements requiring force applied by the thumb are over it **(Figure 2)**. In particular, depending on the method of inserting a disposable tip onto the end of the pipette, the forces involved in tip attachment and ejection can require up to 475% of the recommended maximum limit **(1)**. With thousands of replications per day and forces which can drastically exceed the recommended limits, the risk for repetitive strain disorders for research scientists and technicians cannot be overstated.

PIPETTING POSTURE AND ITS ROLE IN WORKPLACE INJURY

Technicians and scientists pipette to precisely move and combine liquids of very small volumes. To accomplish this precision, proper pipetting technique is essential, as recommended by ISO 8655. This generally requires the arm to be held elevated and extended away from the body for long periods of time. The pipette must also be held vertically, which requires rotation and hyperextension of the wrist and thumb. Any alteration of this posture reduces the accuracy of the pipetting process. The pipette must also be lifted higher at several steps to accommodate the dimensions of tips and consumables, as well as bins for disposal of contaminated tips. While dispensing samples into destination tubes, high precision and concentration is required and many users adopt awkward positions with their neck and head to allow precise manipulation of the pipette tip into small wells. Many protocols involve dangerous chemicals or high risk biological samples, and these require research scientist to pipette inside fume hoods or biosafety cabinets which force users to adopt even more awkward and extended postures **(Figure 3)**.

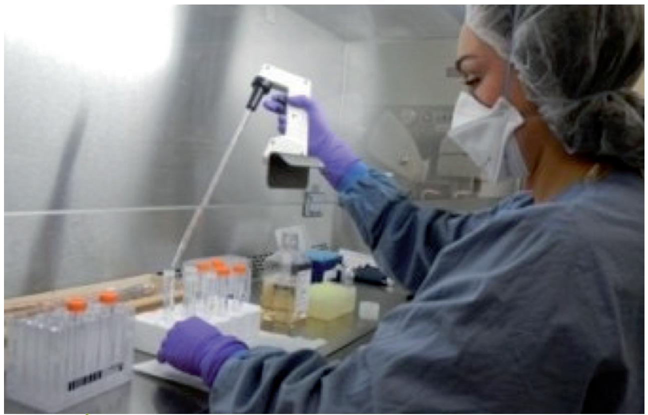

Figure 3: A technician uses an electronic pipette inside a fume hood.

ERGONOMICS AND THE RESEARCH LAB

Ergonomic solutions to address pipetting workflows ideally would address all the issues raised by repetition, force, posture and duration. Common recommendations for improving the ergonomics of a workstation include changing the workstation heights (desk, monitors or keyboards being common examples), adjusting posture, rotating tasks and taking breaks. These solutions are effective where easily introduced, however are not often suitable, or cost effective modifications for a research laboratory **(Table 1)**. There are several solutions available to effectively address individual steps in the pipetting workflow **(Figure 2)**, but none of which tackle all the areas of concern simultaneously.

One solution introduced with good effect is cappers and decappers, used upstream of the pipetting workflow. These reduce the number of pinching, gripping and twisting movements required in the course of a day to take off and put on lids. Another solution is ergonomic pipettes that require reduced forces for accurate plunger depression, and several also incorporate a more neutral arm position. These do address several concerns with pipettes; however, a user survey of several manufacturers found that even when these ergonomic features are improved, there is often a trade-off between speed and ease of use for experienced users **(6)**. Ergonomically designed pipetting workbenches have been designed by different manufacturers, but the design is so far from what is currently in place that they require a complete overhaul of the infrastructure of research labs, and also are not applicable to biosafety cabinets or fume hoods. There is a real need for cost effective solutions which require minimal adaptation of the current infrastructure, address fume hoods and safety cabinets, and can also be positively embraced by technicians and scientists.

ERGONOMIC SOLUTIONS	CHALLENGES TO IMPLEMENTING THEM
Adjusting workstation height	Size constrains for lab benches encompass many different functions, safety requirements and equipment storages
Rotating tasks	Highly specialized techniques require highly trained individuals. Research grant structures also do not easily allow shared personnel resources
Taking breaks	Biological protocols have time constraints
Keep arms close to body	Biosafety cabinets, fume hoods and built in face shields are all constructed for safety and containment and are not adjustable.

Table 1: Research labs can pose challenges to introducing ergonomic solutions.

ANDREW, A SOLUTION FOR A START-TO-FINISH ERGONOMIC PIPETTING WORKFLOW

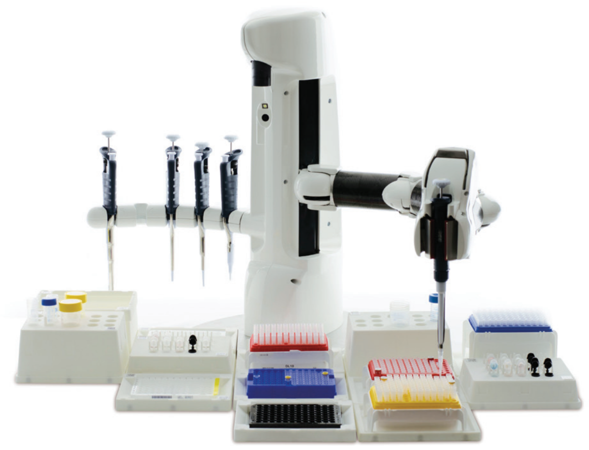

Figure 4: Andrew, the pipetting robot.

At Andrew Alliance, we have introduced Andrew - an automated liquid handling solution to the ergonomic challenges posed by the pipetting workflow **(Figure 4)**. The Andrew suite of robotic pipetting solutions are vision assisted automated liquid handling robots. They are designed to use Gilson and Rainin manual pipettes, which are commercially available, and commonly found in most labs already. Handling these pipettes just like a human operator would, Andrew can grab and change pipettes, set and change the volume, insert and eject tips, aspirate, mix, and dispense liquids, all in an accurate and reproducible manner. No proprietary plastic ware is required as Andrew is designed to work with commercially available consumables. **Furthermore, Andrew can conveniently function inside standard fume hoods and biosafety cabinets, removing the need for manual pipetting inside them**. The easy-to-use software requires little training and enables all lab members to design and program pipetting protocols for execution by Andrew. These protocols allow walk-away fully automated pipetting procedures from start to finish, completely liberating users from repetitive strains on their hands and shoulders. With this all-in-one solution, no longer are there needs to adjust lab infrastructure, replace all the manual pipettes, hire additional technicians to enable task rotation, and solve the problem of fume hoods and safety cabinets. Reducing the risk of repetitive strain injuries for research technicians and scientists, Andrew will keep them happy, healthy and productively focused on what really matters: Science!

GLOSSARY

Ergonomics: the scientific study of people at work, the goal of which is to reduce stress and eliminate injuries and disorders associated with the overuse of muscles, bad posture, and repeated tasks.

Fume hood/Biosafety cabinet: a cabinet with an enclosed space and local ventilation system designed to protect workers from dangerous chemicals or pathogenic samples.

NIH: National Institutes of Health, USA. A prominent, government non-for-profit biomedical research institute.

Repetitive strain injury: a general term used to describe the pain felt in muscles, nerves and tendons caused by repetitive movement and overuse. It's also called work-related upper limb disorder or non-specific upper limb pain.

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Get in touch for more information about how Andrew can improve the ergonomics of your research institution.

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