



9. The design of pipettors can prevent Pipetting Related Upper Limb Disorders (PRULD)

Sari Mannonen, Ph.D.

Most laboratories today use plunger-operated pipettors to dispense precise amounts of liquid. The pipettor may be used only for short periods of time but many research projects require pipetting at an intensive pace. As a part of the routine research may include short series but numerous projects. In many cases, the laboratory technicians may perform repetitive pipetting tasks for a full working day several days a week throughout the year.

In recent decades there has been a change in the design of the laboratory pipettors. Suction using glass pipettors have been replaced with modern plunger-operated pipettors, first mechanical, then electronic. These devices use a disposable tip that must be placed precisely in order to aspirate liquid. Most often an air cushion separates the sample in the tip from the piston inside the pipettor (air-displacement pipettor). A variety of mechanical plunger-operated pipettors are available on the market - however, most with a common design pattern (Fig 1.).

The plunger at the top of the handle is controlled by downward pressure of the thumb. Most models have two stop positions for the plunger - pressing the plunger to the first stop discharges the fluid and to the second stop blows out the residual fluid. In addition, these pipettors have a tip ejector, which also requires thumb pressure. The volume of the dispensed fluid can be adjusted by rotating the plunger and the setting is shown in the display. The physical strain upon the shoulder, arm and hand when pipetting with these devices has been described in detail by Fredriksson (1987):



Fig 1. The major design of mechanical pipettors on the market resemble each other. However, some manufacturers have added special features, like Biohit has filters on tip cone of the pipettor to prevent contamination.

- * The neck is bent forward 30° with the neck muscles contracted
- * The upper arm is held in 20° abduction
- * The arm is flexed forward 45° each time the fluid is transferred into test tubes
- * Upper arm is abducted and rotated inwards when the test tubes are held in opposite hand
- * The elbow joint is held in 90° flexion
- * The lower arm is supinated 30°
- * The wrist is kept in 30° dorsal flexion and also flexed radially
- * The thumb is abducted radially and rotated inwards in the CMC joint
- * The MCP joint is extended according to the length of the thumb and the height of the tangent
- * The IP joint is flexed 90°
- * The tangent is pushed down by flexing the MCP joint

As a summary, the handling of these pipettors demand a high degree of precision and a considerable amount of static work for the muscles of the whole arm and shoulder. Pipetting work may also require extended periods of time spent in other static working positions if performed under sterile conditions, for example when working inside biological containment cabinets. In addition to static working positions, pipetting requires significant amount of strength, especially from the thumb. The force needed to depress the plunger to the first position is 4.2 N and for the second position 14.2 N! As an example, if pipetting more than 1000 samples a day with a mechanical pipettor, one creates a total force for the thumb enough to lift an elephant! No wonder serious fatigue in the muscles of the hand, wrist and arm occur.

Occupational physicians involved with laboratory workers report a number of individuals complaining pain in the forearm and neck particularly during periods of heavy pipettor use. Many workers have reported general discomfort following prolonged pipetting sessions and several have been diagnosed as having De Quervains tendosynovitis. Pipetting Related Upper Limb Disorder (PRULD) is a subset of the more commonly known "Work Related Upper Limb Disorder (WRULD)". However, in many countries this ailment is still known as Repetitive Strain Injury (RSI). These disorders have been attributed to a number of factors involved in pipetting: Firstly, whether the person is predisposed to this type of ailment or injury, secondly the type and duration of the work, and thirdly the tools in use.

Increasing number of scientific studies have been undertaken on the use of plunger-operated mechanical pipettors and the problems that arise from their use. In addition to the studies done by Fredriksson (1987), musculoskeletal stress on the neck and shoulders (Wallin, 1990) and prevalence of hand and shoulder ailments in laboratory technicians (Björkstén et al., 1994) have been studied. Björkstén et al. (1994) found that there is an increased risk of hand and shoulder ailments associated with more than 300 hours of pipetting per year, which corresponds to one to two hours of pipetting daily. In a more recent study (David and Buckle, 1995) the reported occurrence of hand complaints were significantly higher for those individuals who spent more than 30 minutes continuously doing pipetting work compared to those doing pipetting for shorter periods of time. There was also a noticeable increase in the percentage of those reporting hand complaints as the exposure duration was extended.

Research undertaken recently in a leading ergonomics institute has provided valuable information concerning elements of the design of commercial products that may lead to these problems. The difficult features and suggestions to their improvement are listed below (in order of importance):

1. Make plunger operation lighter and easier
2. Improve tip ejection
3. Improve heavy cumbersome grip design
4. Reduce weight
5. Improve volume adjustment
6. Miscellaneous

There is now a range of products on the market that can help reduce the risks of WRULD and have most of the above complaints solved - They are hand-held electronic pipettors, the Biohit Proline range. The development of microprocessor controlled instruments offers accurate, precise, rapid and effortless liquid handling. The instruments are infatigable and no longer require the enduring muscular efforts typical for mechanical pipettors. The thumb pressure required for both pipetting and blow-out is only 60-70 grams, less than 10% of the pressure needed for a mechanical pipettor. Furthermore, using an electronic pipettor removes the majority of human error in pipetting, and increases the accuracy and especially precision of liquid handling. The invention in electronic pipettors has made it possible to cover the most important liquid handling operations in a single device: Accurate transfer of required quantities of liquid (actual pipetting), as well as reverse pipetting, dispensing, diluting and mixing liquid samples. Yet, there is no increase in size compared with the conventional devices (Fig 2.).

Fig 2. The Biohit Proline Electronic pipettors have been designed to minimise the risk for Pipetting Related Upper Limb Disorders (PRULD) and featuring all necessary liquid handling functions in one instrument.



Ergonomic design of the Proline range has been carefully planned: The instrument fits comfortably in hand, the ergonomic finger support and light weight reduce fatigue, the actuating button sits conveniently under the thumb and the whole hand tip ejector is precisely placed for minimal exertion. Furthermore, the volume setting can be done electronically and a simple keyboard and LCD display showing the present function also help to eliminate operator error (Table I). In addition, the multichannel models incorporate a stepped ejection mechanism and elastomer tip cones, which guarantee one handed ejection even with 12-channel units, and ensure perfect tip seal with Biohit tips. The results is less strain, while preserving the control feel of the mechanical pipettor.

Feature	Various Mechanicals	Biohit Electronics
Weight to move plunger in pipetting	800–1700 g	60 g
Weight to move plunger in blow-out	1800–5000 g	60 g
Type of pressure to move plunger	continuous pressure	light click
Plunger travel distance	up to 50 mm	2 mm
Tip ejection	thumb	4-finger
Grip thickness (top)	25–39 mm	30 mm
Volume adjustment	manually	electronically
Volume adjustment	rotation	click

Table I. The benefits of Biohit Proline Electronic pipettor compared to various mechanical pipettors on the market.

Based on the current research there will soon be published a list of recommendations for pipettors in use and elements of a pipettors design that may be considered prior to purchase to limit the possibility of PRULDs. Health and Safety at Work regulations are very specific about the duties of manufacturers and compliance with the law. The first cases of litigation against employers in Europe are now appearing.

References

1. Björkstén M.G., Almby B., Jansson E.S. Hand and shoulder ailments among laboratory technicians using modern plunger-operated pipettes. *Applied Ergonomics* 25 (2) 88-94, 1994
2. David G and Buckle P. A questionnaire survey of the ergonomic problems associated with pipettes and their usage with specific reference to work-related upper limb disorders. *Applied Ergonomics* 28 (4) 257-262, 1995
3. Fredriksson, K. "Laboratoriearbete med automatpipett. En studie hur tummen belastas vid pipetteringsarbete" (Laboratory work with plunger-operated pipettes, a study on the loading of the thumb during pipetting). Examensarbete, Arbetarskyddsstyrelsen kurs i företagshälsövård för legitimerade sjukgymnaster (in Swedish), 1987
4. Wallin, M. Ergonomisk studie av belastningen på nackeskuldra vid pipettering (Ergonomic study of the load on the neck and shoulders during pipetting). Examensarbete, Arbetarskyddsstyrelsen kurs i företagshälsövård för legitimerade sjukgymnaster (in Swedish), 1990

Sari Mannonen, Ph.D. is a Marketing Manager of Biohit Plc, Finland

Published in *International Biotechnology Laboratory*, August 1998, *International Laboratory Pacific Rim*, November/December 1998 and *American Biotechnology Laboratory*, April 1999.