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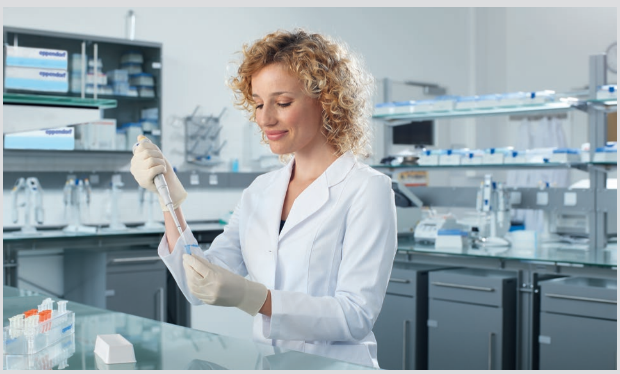
Pipetting in harmony with Ergonomics



Let's recall: The pipette is the workhorse of the laboratory and therefore takes center stage in critical ergonomic considerations within the first sphere of the PCC. Health problems are caused by long term physical strain over a period of months and years. Therefore even small differences in weight between the pipettes used on a daily basis may make the difference between the development or the continued absence of a health problem. A difference in weight of only 40 g results in 4 kg if lifted 100 times, and a ton after 225 work days per year. Thus, a pipette intended for daily use should be as light as possible. Furthermore, the balance of a pipette plays an important role, as a badly balanced pipette requires more intense gripping and holding, placing unnecessary strain on the muscles of the hand and fingers. This is more often the case with electronic pipettes, due to an angled and heavy "head". Therefore, an ergonomic pipette should not be top-heavy; its center of gravity should be located in the geometric center of the pipette. At the same time, it should exert slight pressure on the ring finger, alleviating the feeling of needing to hold or grip at all times.

During the pipetting action, the thumb is the main actor among the fingers. It is moved by two antagonistic and two agonistic muscles. Repetitive strain on these muscles, in connection with extension of the metacarpophalangeal joint (the tip of the thumb moves the push button up and down: a constant switch between extension and flexion) may lead to tenosynovitis [1] in particular, or to more generalized repetitive strain injuries (RSIs). Regrettably, the aspect of repetitive movement cannot be eliminated, even with an ergonomic pipette; however, low operational forces reduce the strain during each individual pipetting stroke.

During the latter, clearly defined first and second stops are crucial for reliable work. The resistance for reaching the second stop (expelling of remaining liquid) is higher than that for reaching the first stop (aspiration and dispensation of the liquid). This difference in haptic feedback enables easy differentiation between the two processes. From an ergonomic perspective, this is important. At the same time, the forces of resistance, while easily differentiated, should be low altogether. The sum of force applied may make a difference in determining whether strain or even injuries will develop or not. Differences in operational forces between different pipettes are easily detected by pressing two pipettes horizontally against one another, their push buttons touching. The age-old wisdom "The smarter one gives in" prevails.

During processes which require high precision, low operational forces are much more relevant, since precision tasks such as gel loading and removal of supernatants are associated with increased physical strain on the thumb muscles mentioned earlier and thus pose a risk for fatigue and injury in conjunction with the local tendons [1].

The harm caused by static muscle activity has been demonstrated in many different studies [2] [3] [4] [5].

Typically, electronic pipettes require the lowest operational forces for pipetting and are therefore to be favored with regard to this ergonomic aspect.

However, operational forces do not only play a critical role during the pipetting action itself, but also during fitting and disposal of the pipette tips. An ergonomic pipette optimized in this regard is characterized by easy and comfortable tip fitting, secure and reproducible fit, as well as equally easy disposal of the tip. In some pipettes, an integrated spring absorbs excessive force which is exerted during tip fitting (spring loaded tip cone). This prevents "rocking". From an ergonomic perspective, this is particularly harmful, as it is associated with increased physical strain and simultaneous repetitive movement and vibration. The ergonomically relevant operational forces include those for volume setting. From a physiological perspective, volume setting is not to be underestimated, as it encompasses a highly complex pattern of movements and as such requires extraordinary muscle activity.

An ergonomically designed volume dial ring should be large in order to provide high friction with the fingers (with and without gloves), and it should require low torsion force, as well as a small number of rotations. Considering these aspects, electronic pipettes offer certain advantages over manual pipettes, as the ring is replaced by keys. However, this advantage must not be compensated by the necessity to operate the keys extensively. Apart from physical-ergonomic aspects, cognitive-ergonomic considerations are relevant during the process of volume setting. This is with respect to the volume display of the pipette. The latter should not be covered by the hand holding the pipette, as in this case unnecessary and possibly harmful movements are necessary in order to view the volume setting. The volume display should be readable equally well for left and right handed people. If this is not the case, additional movements and actions will also be required at this step, the sum of which may be harmful. Furthermore, the display should be intuitive. This implies that the set volume may be read at a glance without having to think about it. In reality, these requirements are not met for all commonly available pipettes.

For electronic pipettes, these deliberations may be taken one step further. The display of an electronic pipette should be readable from all standard working positions. At the same time, the menu should not be divided into too many sub-menus, and programming should be easy.
The ergonomic angle of the pipette head and background illumination should allow readability from all positions. The intensity of the background illumination should be variable and selectable, and it should be sufficiently bright at maximum illumination that easy reading is possible under all possible lighting conditions encountered in the laboratory. Finally, user-friendly software creates an intuitive interface for the user with the instrument. The handle of a pipette should be made from a skin-friendly material which feels pleasant to the user. A slip-resistant surface precludes the need for constant holding and gripping of the pipette. The latter are associated with strain. Furthermore, high expectations are placed on the design shape of the pipette handle. As early as the 1970s, the Institute for Labor Science at the TU Darmstadt with its former head Professor Walter Rohmert conducted studies on handling conditions of pipettes in co-operation with Eppendorf.

One result of these studies was the design of the Eppendorf Pipette 3130 with its characteristic handrest. In contrast, many commonly available pipettes do not consider the ergonomic knowledge available and are therefore too short, too wide or too thin, their inner radius is too narrow, or they do not provide a clearly identifiable handrest. All these ergonomic deficiencies are potential sources for harmful and tiring hand positions during pipetting. At the same time, esthetic considerations must not be left out during the design of grip conditions, since especially the handle of a pipette is typically a hallmark of design.
Ergonomically correct pipetting is not solely based on the ergonomic pipette; the user must play his part. He should hold the pipette in a vertical position during pipetting, and little force should be exerted on the grip. The wrist should remain straight (no angles), without cramping. The arms are to be held close to the body (which supports the vertical pipetting position of the hand). Simultaneously, the resting of arms and elbows on hard surfaces is to be avoided. The arms should not be lifted (as erroneously practiced by a majority of users). Chairs (or tables, if applicable) need to be adjusted to individual height. Furthermore, steep leaning of the neck and upper body, as well as uncomfortable positions, should always be avoided.
Finally, the habit of "rocking" during tip fitting is to be broken, or, better, not taken up at all.
Cognitive ergonomics requires the design of an intuitive interface between the instrument and the user. Intuitive design of the interface of a pipette may be reflected in the volume display, the ease of reach and intelligibility of keys and the practicality of software, as well as the degree of difficulty encountered when assembling or disassembling the pipette, respectively.
Taken together, this means that an instrument should be understood and used without the need to consult the user manual. The rules of usable design are to be followed (keyword: usability) [6]. Electronic pipettes in particular may be seriously flawed with respect to cognitive ergonomics.

Literature

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