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Reducing thumb extensor risk in laboratory rat gavage

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ABSTRACT

Gavage is a common technique for orally administering compounds to small laboratory animals using a syringe. It involves highly repetitive thumb extensor exertions for filling the syringe, a risk factor for DeQuervain's tenosynovitis. As an intervention, a series of bench tests were performed varying fluid viscosity, syringe size and needle size to determine the forces required for drawing fluid. Forces up to 28 N were observed for a viscosity of 0.29 Pa s. A guide is presented to minimize thumb forces for a particular combination of syringe (3 mL, 5 mL and 10 mL), fluid viscosity (0.001 Pa s, 0.065 Pa s, 0.21 and 0.29 Pa s), and needle length (52 mm, 78 mm and 100 mm) based on maximum acceptable exertion levels. In general, a small syringe and large needle size had a greater number of acceptable rat gavages per day due to the lower forces experienced as compared to all other syringe and needle combinations.

1. Introduction

Work-related musculoskeletal disorders among laboratory professionals are highly prevalent (Agrawal et al., 2014). It is well documented for example that pipette users often experience hand and shoulder ailments (Björksten et al., 1994), and are exposed to highly repetitive forces (Lu et al., 2008). Hand complaints among manual pipette users increase with longer exposures, larger volumes of materials that vary with pipette size (Lintula and Nevala, 2006), and greater plunger forces make the task more difficult to perform (David and Buckle, 1997). The physical demands of working with laboratory animals are also recognized as having potential risk for work related injuries (Kerst, 2003).

Rat gavage is a common laboratory technique for orally administering compounds. The procedure is performed using a syringe with a blunt plastic needle inserted into the esophagus of an animal and injecting the drug directly into the stomach. While many methods are available for oral administration in the laboratory, gavage is one of the most widely used procedures due to its efficiency, accuracy and simplicity (Waynforth and Flecknell, 1980). Similar to pipetting, gavage is performed repetitively by a technician, and while pipetting utilizes the thumb flexor mechanism, drawing materials into the gavage engages the thumb extensors. Although the practice may differ from one laboratory to another, a commercial laboratory technician may perform as many as 200 to 500 rat gavages per day.

The activity involved in drawing the syringe in rat gavage was observed for the current study in a commercial laboratory. The operator typically draws materials of various viscosities from a beaker while holding a syringe in one hand and pulling against the plunger by abducting and extending the thumb, often while deviating the wrist (Fig. 1). Repetitive and forceful thumb extensor exertions are risk factors for DeQuervain's syndrome, which can result in painful swelling of the sheath surrounding the extensor pollicis brevis and abductor pollicis longus (Harrington et al., 1998). The disorder is associated with repeated or sustained wrist bending in extreme posture (Le Manac'h et al., 2011). DeQuervain's syndrome has previously been reported among lab workers performing manual pipetting of high viscosity fluids (Asundi et al., 2005).

Based on a biomechanical analysis of tendon displacements in pipetting for estimating loads on the flexor pollicis longus tendon, Wu, et al. (2013) estimated it was within the range of those observed in other occupational activities, such as typing and nail gun operation. A study by Lintula and Nevala (2006) found that perceived strain on the wrist and thumb after pipetting was the least when the shortest pipette among three different sizes was used. Lin and Chen (2009) using EMG observed that use of a large syringe in pipetting increased thumb loading and muscle activity.

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We anticipate that similar extensor and abductor loading in relationship to syringe size might occur in rat gavage tasks. Given that median right hand female thumb abductor strength in comparison to thumb adductor strength is 12 N–58 N respectively (Rozmaryn et al., 2007), it is anticipated that even more stress and strain on the thumb may be associated with gavage activities that involve thumb abduction.

The current study considered factors that can reduce or eliminate risk in the gavage task for a large-scale commercial laboratory. The problem was addressed by establishing recommendations for gavage practice that can be performed using the minimum exertion necessary for different combinations of syringe diameter, fluid viscosity, and needle size. A laboratory bench study was performed for measuring the syringe drawing forces acting against the thumb while systematically varying syringe size, needle size and viscosity. These forces were then compared against the maximum acceptable abduction exertion for the thumb and used to control exposure in repetitive gavage tasks.

2. Methods

2.1. Forces due to pulling action of the thumb

The syringes and needles typically used for rat gavage are available in various sizes and the rate of filling a syringe is related to the flow rate of material while drawing, which is dependent on the rate of pulling and the material viscosity. The variables from Hagen-Poiseulli's equation are related to the pulling forces for a syringe plunger (Schaschke, 1998). The equation for fluid flow used to estimate the set of relevant factors involved in syringe pulling are described in Equation (1) as:

$$\Delta P = \frac{8\mu LQ}{\pi r^4} \quad (1)$$

where μ is the dynamic viscosity, L is the length of the pipe, Q is the volumetric flow rate, and r is the syringe radius. The equivalent factors considered are therefore the viscosity of the fluid, diameter of the plunger, diameter of the syringe needle, flow rate, and length of the gavage needle. A variation of each of the factors induces change in the required pulling force.

2.2. Design of experiment

The study included combinations of four levels of viscosity, three syringe sizes and three needle lengths, and a flow rate of 1 mL/s to characterize the pulling force. The test materials used in the laboratory for this study are known to have viscosity less than 0.3 Pa s. Hence, four liquid compounds with different viscosities ranging from 0.001 Pa s to 0.29 Pa s were used for testing. These four liquids were water (viscosity = 0.001 Pa s), extra light olive oil made by Pompeian Inc. (viscosity = 0.065 Pa s), motor oil SAE 10W-40 made by Mobil (viscosity = 0.21 Pa s), and motor oil SAE 15W-40 made by AMSOIL (viscosity = 0.29 Pa s).

It was observed that an air vacuum formed when the liquids with greater viscosities were withdrawn for large flow rates. The liquids would slowly reach the top of the plunger after a considerable delay time. In the lab, this would not be ideal, as the lab technicians would need to maintain constant force as liquid rises. Thus flow rates of 1 mL/s were chosen as the maximum rate.

The disposable syringes (Nipro Corporation) included small (3 mL), medium (5 mL) and large (10 mL) sizes. The animal feeding needles included small (Dispo Fuchigami, 52 mm length, 0.86 mm inner diameter, 1.46 mm outer diameter, 2.4 mm silicon tip), medium (Dispo Fuchigami, 78 mm length, 1.19 mm inner diameter, 1.79 mm outer diameter, 2.8 mm silicon tip) and large (Instech Solomon, 100 mm length, 1.2 mm inner diameter, 1.8 mm outer diameter, 2.8 mm silicon tip).

Lab technicians typically choose a syringe that is closest to the dosage needed. Those syringes are normally paired with one of three available needles with varying lengths depending on the size of the animal. Larger animals require the longest needle as the distance from the mouth to stomach is the longest. A total of 36 different combinations of flow rate, viscosity, syringes and needles were tested.

2.3. Force measurement

The syringe drawing force was measured using an MTS Criterion Model C43 materials testing machine (MTS Systems Corporation, Eden Prairie, MN, USA). The MTS machine was equipped with a force sensor for measuring changes in force as a function of time. The movements of the MTS machine were bidirectional: upwards and downwards. The configured experimental set up on the MTS machine is shown in Fig. 2.

In order to simulate the draw-up phase of the rat gavage, the syringe plunger was firmly anchored to the MTS machine fixture. The MTS screw action grip was then used to hold the other end of the syringe, which connects to the needle. It was essential that the grip was not located on the body of the syringe where the plunger rests, but rather located on the ring surrounding the thread that connects the syringe to the needle. Gripping the body of the syringe caused a significant increase to the syringe withdrawal force because the rubber piston had difficulty moving through the gripped portion. The tip of the threaded needle became submerged in the appropriate liquid contained by a weigh boat. Using this setup, the plunger of the syringe always moved upwards together with the MTS machine while the body of the syringe stayed in

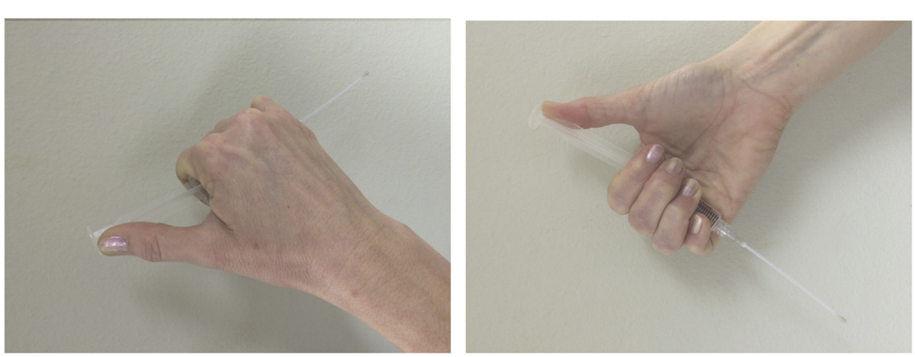

Fig. 1. Thumb position when drawing materials for gavage into a syringe.