ASSESSMENT OF MUSCULOSKELETAL DISORDER RISK WITH HAND AND SYRINGE USE IN CHEMOTHERAPY NURSES AND PHARMACY ASSISTANTS

ASSESSMENT OF MUSCULOSKELETAL DISORDER RISK WITH HAND AND SYRINGE USE IN CHEMOTHERAPY NURSES AND PHARMACY ASSISTANTS

By

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ABSTRACT

The purpose of this thesis was to examine hand actions required of nurses and pharmacy assistants involved with chemotherapy drug administration over a work shift, and propose associated risk control strategies. There is a need to evaluate and redesign manual "pushing" and mixing of chemotherapy drugs to prevent musculoskeletal disorders and associated healthcare costs. Muscle activity of the forearm flexor and extensor muscles, and thumb forces, were measured from 5 lab nurses, 5 floor nurses and 5 pharmacy assistants who had their actions recorded throughout their shift. Lab nurses performed an average of 1.85 ± 0.48 hand efforts per min, floor nurses performed 1.62 ± 0.09 per min, while pharmacy assistants performed 5.29 ± 1.27 per min. Syringe use accounted for 17% of the pharmacy assistants' shift and 12% each for the floor and lab nurses. The tasks of drawing fluid and manually pushing treatment represented 10% of the work day. The left forearm flexors generated the highest activity over the workday and across tasks while only resting for 6% of the workday. The high number of hand efforts, combined with prolonged durations, and lack of muscular rest show evidence of muscular overload over the course of the shift as well as illustrate that the pharmacy assistants are at higher risk for WMSD. The results may also help explain the documented injury statistics and complaints associated with the arm, hand and thumb and support the implementation of a chemotherapy robot to reduce the risk associated with tasks performed by the pharmacy assistants. Further, the findings of this thesis can act as a guide for future evaluation and research of workplaces with similar syringe and hand

demands. The risk reducing strategies presented may also be applied to other jobs where hand and syringe use is repetitive and prolonged.

Keywords: Musculoskeletal disorders, EMG, syringe, nurses, observation

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CHAPTER 1

INTRODUCTION

In the healthcare sector, work-related musculoskeletal disorders (WMSD) represent nearly 42% of all lost time injuries, and the medical costs associated with the claims, greatly impact the healthcare industry (MOL, 2014). Musculoskeletal disorders (MSD) typically develop over a period of time (Barr et al., 2004; Mani & Gerr, 2000) and include a variety of inflammatory and degenerative diseases such as carpal tunnel syndrome, epicondylitis, tendinitis and tenosynovitis (Occhionero et al., 2014; Fan et al., 2009; Shiri et al., 2006). High hand force, forceful gripping, repetitive and prolonged use of the hands, as well as lack of muscular rest have been shown to contribute to increased risk of WMSDs (Hansson et al., 2009; Bystrom & Fransson-Hall, 1994; Veiersted et al., 1990).

WMSDs in the healthcare sector exist where syringe use is prevalent. The use of syringes, typically 60 ml, is common in healthcare professions such as nursing, pharmaceuticals, medical assistants, and dietetics, which require blood work, mixing and/or administering medications, intravenous solutions or other fluids such as infant formula. Syringes are also used to care for and maintain intravascular devices (Keogh et al., 2014). To provide chemotherapy, it is common practice for nurses to manually administer ("push") treatments by depressing a syringe plunger at a slow rate (1-2 ml/minute) for up to 30 minutes continuously. Pharmacy assistants use syringes to repetitively mix the chemotherapy drugs. When performing blood work for chemotherapy, nurses must repeatedly flush intravascular devices using syringes until effective blood flow is obtained. Work tasks that are repetitive and prolonged, even at low force levels, minimize tissue recovery time (Nordander et al., 2009; Latko et al., 1999; Veiersted et al., 1990). Furthermore, periods of long duration and continuous activity have been reported to be risk factors for WMSD (Sjogaard et al., 2000).

It is important to note the role that the nurses and pharmacy assistants play within a chemotherapy department. These jobs should not be treated as separate entities but rather as professions that are interconnected by the patients they care for and the importance of the quality service they provide. If one job suffers, it affects the others resulting in unfavourable outcomes that ultimately impact the organization as a whole. In an ongoing review of the chemotherapy unit at a local hospital, both nurses and pharmacy assistants working with syringes have been prone to high turn-over rates, with documented and anecdotal complaints of musculoskeletal disorders. The common causes for the complaints listed in the reports include, repetitive work in the lab, pushing chemo drug (IV pushes), mixing IVs, flushes, and donning gloves. Some worker comments in the reports were 'left upper arm became aching and throbbing', 'both thumbs ache' and 'after doing a push drug this morning, the lateral aspect of right wrist is slightly swollen. Pain noticed across top of hand radiating to last two fingers and from inner wrist to elbow'. Similar anecdotal complaints of thumb, hand, and arm pain continue to be reported. Furthermore, a lost time injury occurred in the pharmacy and the worker has not been able to return to the job because of the syringe tasks required.

The problem may be greater than statistics indicate as occupational upper extremity disorders are often underreported (Pransky et al., 2002), even though these disorders may result in discomfort and impair work performance. The decision to report can be influenced by peer pressure, and personal, social, and economic conditions (Armstrong et al., 1993). Actual incident rates are expected to be significantly higher than those reported (Mani & Gerr, 2000). Further investigation into the risk factors contributing to these work place injuries as well as strategies of WMSD risk reduction, is required.

As a result of the review, preliminary assessments of the hand tasks performed by nurses and pharmacy assistants were completed by an internal ergonomist. The Moore-Garg strain index (1995) and the threshold limit values (TLV) for hand activity (American Conference of Governmental Industrial Hygienists, 2002) are frequently used by practicing ergonomists as these tools have been shown to be reliable and valid (Spielholz et al., 2008; Wurzelbacker et al., 2010) in the evaluation of risk for WMSDs related to the hand and wrist. The results of the assessments indicated an increased level of risk associated with both high repetition and prolonged static efforts and further illustrated the need for quantitative investigation into the risk of WMSD.

The British Columbia Cancer Agency also completed an ergonomics assessment of chemotherapy drug administration tasks performed by their nurses. Sustained and awkward hand and wrist postures combined with prolonged grip force, were identified as a moderate-to-high risk of injury to the hand, wrist, forearm, and elbow of the nurses who administered chemotherapy via large volume syringes (20 ml and greater) (Hall, 2011). Also, the University Health Network's Health Technology Safety Research Team completed a human factors analysis and observational study of a Chemotherapy Daycare

Centre and identified the need for a risk assessment of the repetitive strain injury risk for tasks of the pharmacy assistant role (Easty et al., 2012).

As an ergonomist in a healthcare setting, obtaining quantitative experimental data associated with in-field syringe use and risk for WMSD is challenging due to limited collection methods as well as social and environmental factors. Therefore, to obtain initial data related to syringe use, a laboratory study examining maximum pinch grip strength associated with grip postures used when performing syringe tasks was completed by MacDonald et al. (to be submitted to *Human Factors*). Twenty female administrative workers performed maximal isometric exertions on the plunger of a standard 30 ml syringe using four common pinch grip types at two plunger lengths (chuck, chuck variation, thenar, and two-handed). The thenar (103.6 ± 22.9 N) and two-handed (104.7 ± 17.1 N) pinch grips were found to produce the highest force suggesting that the thenar and two-handed pinch grips may be the preferred pinch grip type to lower the relative efforts required to use a syringe. This finding may be considered strategy to assist with reduction of musculoskeletal disorder risk associated with syringe use.

The physical load, muscle activity, and exposures associated with work tasks, are important determinants when assessing risk factors of WMSD, during repetitive and continuous work (Nordander et al., 2013; Hansson et al., 2009; Bernard et al., 1997; Veiersted et al., 1990). Limits for muscular load were developed by Jonsson (1982). He suggested that, for a full day of work, load levels (from EMG) should not exceed 2-5% of maximum for the10th percentile, while the median level (50th percentile) of EMG should not exceed 10-14% (continuous work more than one hour), and a worker should spend less than 10% of their day (90^{th} percentile) with EMG above 50-70% (maximum for tasks of 10 minutes in duration) (Jonsson, 1982). If the muscular load over the course of a full work shift exceeds the lower limits, then the risk for WMSDs increases and a modification to the job is required.

In addition to high muscle activity, limited muscular rest has been related to increased WMSD risk. In particular, EMG "gaps" have been used to quantify muscular rest during repetitive and continuous work. Gaps have been defined as short time periods (at least 0.2 seconds) with muscle activity below 0.5% of maximum voluntary efforts (Veiersted et al., 1990). The findings of Veiersted et al. (1990 & 1993) and Hagg & Astrom (1997) identified a link between fewer gaps and incidence of WMSD. Workers with musculoskeletal complaints in a chocolate packing factory were found to have less muscular rest and fewer 'gaps' than those with no complaints thus illustrating that muscle activity patterns may play an important role for the development of WMSDs (Veiersted et al., 1990; 1993). In a study of 23 medical secretaries performing 40 minutes of "ordinary" work including typing medical records, secretaries without musculoskeletal complaints had more frequent episodes of total muscle relaxation (Hagg & Astrom, 1997).

Further to muscular effort and repetition, an equation (Equation 2) was developed by Potvin (2012). The equation predicts maximum acceptable effort (MAE) associated with repetitive tasks and characterizes the relationship between MAE and a duty cycle (DC).

$$MAE = 1 - DC^{0.24} \qquad (2)$$

The duty cycle is defined as the percentage of time that the worker is performing the effort. The equation was found to predict MAE very well with an exponent of 0.24 (r^2 = 0.87%, root mean square error = 7.2% maximum voluntary efforts) (Potvin, 2012). The ability to predict MAE provides an opportunity when evaluating repetitive tasks, to recommend acceptable efforts and acts as a WMSD risk reduction strategy.

1.1 Purpose

To date, there are no published data associated with in-field syringe use. To my knowledge, this will be the first detailed analysis of tasks performed by nurses and pharmacy assistants; specifically tasks involving the hand and syringe use. The purpose of this thesis is to examine and chronicle hand actions and tasks required of workers involved with chemotherapy drug administration over a 7.5 hour shift. Additionally, this thesis aims to propose strategies to reduce the risk of musculoskeletal injury associated with syringe use by the nurses and pharmacy technicians.

1.2 Hypotheses

1. There will be evidence of muscular overload over the course of the work shift, especially during syringe tasks.
2. The risk of WMSD will be different between the floor nurses, lab nurses, and pharmacy assistants. The pharmacy assistants will be at an increased risk.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Work-related Musculoskeletal Disorders of the Distal Upper Extremity

While the fingers and thumb can create large forces (Imrhan, 1991), workplace demand can still exceed the tissue capacity of some workers and increase the risk of a musculoskeletal disorder (MSD) (Nussbaum & Johnson, 2002; Snook et al., 1999; Viikari-Juntura & Silverstein, 1999, Bernard et al., 1997). Work-related musculoskeletal disorders (WMSD) characterize approximately 42 percent of all lost time claims in the healthcare sector in Ontario. In 2012, new claims in Ontario accounted for more than 3000 lost-time MSD related injuries representing more than 47,000 working days lost, and greater than $7.5 million in medical aid costs (MOL, 2014). Musculoskeletal disorders (MSD) that typically develop over a period of time are frequently referred to as cumulative trauma disorders, repetitive trauma disorders, repetitive strain injuries, or overuse syndrome (Barr et al., 2004; Mani & Gerr, 2000). MSDs include a variety of inflammatory and degenerative diseases, which result in pain and functional impairment (Buckle & Devereux, 2002). WMSD of the distal upper extremity include carpal tunnel syndrome, epicondylitis, tendinitis and tenosynovitis (Occhionero et al., 2014; Fan et al., 2009; Shiri et al., 2006; Barr et al., 2004). An acute injury like a strain or sprain, results from a single load exceeding the capacity of the muscle, tendon, or ligament, while chronic conditions have a gradual onset primarily due to repetitive use, and can lead to greater long term function impairments than acute injuries (Pransky et al., 2002; Zakaria et al., 2002; Bernard et al., 1997). With continued exposure, functional impairments may be permanent.

Chronic injuries, like lateral epicondylitis, result from high hand force with repetitive use of the hands and arms (repetitive rotation of the forearm), as well as forceful gripping with wrist extension (Fan et al., 2009; Mani & Gerr, 2000). Physical workload and prevalence of lateral epicondylitis was examined by Fan et al. (2009). Seven hundred and thirty three workers in manufacturing and health care were surveyed about several physical load factors related to lateral epicondylitis. Odds rations (OR) were used to illustrate the prevalence and they found that the frequency of forceful exertion ($\geq$ 5 vs. $<$ 1 times/min = OR of 5.17 & $\geq$ 1 to $<$ 5 vs. $<$ 1 = OR of 4.47) was a significant physical factor (Fan et al., 2009).

With respect to tenosynovitis, an increased risk occurs with repetitive hand motion with frequent extension of the thumb and extreme lateral wrist deviations (Houvet & Obert, 2013; Mani & Gerr, 2000). Also, the risk for tendinitis increases with repetitive and forceful use of the hands, use of the hands in extremes of joint range of motion, and performance of unusual or unaccustomed tasks. Carpal tunnel syndrome risk increases with forceful use of the hands, and repetitive use of the hands, as well as hand-arm vibration (Barr et al., 2004; Mani & Gerr, 2000; Viikari-Juntura & Silverstein, 1999). Pransky et al. (2002) found that workers with gradual-onset conditions had jobs with significantly higher risk than those with acute-onset conditions. The point at which the tissue fails depends on the level, duration, and the frequency of the load (Viikari-Juntura & Silverstein, 1999).

2.1.1 Risk Factors

Forceful grip, awkward postures, repetition, and prolonged duration are the main risk factors for upper extremity WMSD (Barr et al., 2004; Tanaka et al., 2001; Fredriksson et al., 1999; Bernard et al., 1997). These factors may occur in isolation, however, in most cases, occur in combination thus further increasing the risk for musculoskeletal disorders (Ahlgren et al., 2012; Houvet & Obert, 2013; Barr et al., 2004). Individual risk factors such as impairment in capacity caused by disease, genetic code, physical fitness, age, and gender should also be considered when assessing for musculoskeletal disorder risk (Barr et al., 2004; Nordander et al., 2000; Kilbom et al., 1996).

For distal upper extremity disorders, the risk factors of force and repetition are well studied (Gallagher & Heberger, 2013; Bernard et al, 1997; Higgs et al., 1992). Repetition has been the most widely studied risk factor and the classification of it is varied in both quantitative and qualitative assessments (Houvet & Obert, 2013; Descatha et al., 2009; Latko et al., 1999). Repetition is generally defined in terms of the number of exertions per unit time and the ratio of work to rest (Kilbom et al., 1996). Repetitiveness may be defined as substantial if the time cycle is less than 30 seconds or if activities of the same type are performed for 50% of the work time (Kilbom, 1994). Workers who were highly exposed to repetitive work were examined over a 3 year period and surveyed on the health effects of repetitive tasks related to the upper extremity (Descatha et al., 2009). It was found that workers with hand or wrist disorders had a moderate rate of recovery (22 out of 119), suggesting persistent or reoccurring disorders. When investigating WMSD risk associated with work across a range of occupations such as nurses, industrial, office, hairdressers, and dental hygienists, elevated levels of risk were found to be related with repetitive/constrained work (Nordander et al., 2009). Latko et al (1999) performed a cross-sectional study investigating repetition with respect to hand activity, or how busy the hands are during the work cycle with 352 manufacturing workers. The ratings considered two factors. The first being the amount of recovery time within the cycle, and the second, how fast the hands are moving. Odds ratios (OR) were used to quantify how strongly repetition is associated to the prevalence of reported discomfort. Repetition was found to be associated with worker-reported discomfort in the wrist, hand, and fingers (OR = 1.17 per unit of repetition), tendinitis of the distal upper extremity (OR = 1.23 per unit of repetition), and with symptoms consistent with carpal tunnel syndrome (OR = 1.16 per unit of repetition) (Latko et al., 1999), and resulted in an increased rate of injury. In a laboratory setting, odds ratios were used to associate the prevalence of hand problems with technicians who are exposed to repetitive and prolonged pipetting. Laboratory technicians who reported greater than 300 hours of pipetting annually had a significant risk of hand ailments with an OR of 5 (Bjorksten et al., 1994).

The risk factor of repetition is also present in the operating room environment. Perioperative nurses reported perceived stress associated with exposure to work-related activities of handling or grasping small objects and performing the same task over and over (Sheikhzadeh et al., 2009). The nurses frequently held instruments for about 15 seconds, repeatedly for prolonged periods of time, especially during certain phases of a surgical procedure. Similar findings of repetitive grasping and handling of small dental instruments were found with dental hygienists (Horstman et al., 1997). Repetitive action was also identified as a risk factor for to dental practitioners who regularly experienced pain, tingling, or numbness in their fingers, wrists, hands, and forearms as reported in 37.9% of reported cases (Estrich, 2014). Furthermore, in a systematic review of 23 manuscripts related to musculoskeletal disorders among dental professionals, the most prevalent region of musculoskeletal pain for dental hygienists was the hands and wrists at 69.5% (Hayes et al., 2009). These findings further illustrate the importance of evaluating tasks requiring repetitive and prolonged hand efforts specific to grasping and handling small objects.

2.2 Muscular Rest

Lack of muscular rest has been linked to increased risk for WMSD. Chronic low-level loading is important to consider when evaluating risk for WMSDs (Wells et al., 1994). When a muscle is continually fatigued without appropriate recovery, musculoskeletal disorders are likely to occur (Armstrong et al., 1993; Veiersted et al., 1990). Static and sustained work results in prolonged or cumulative loading without rest or recovery (Konz, 1998).

The use of electromyography (EMG) is considered a powerful tool in ergonomic epidemiology, and may be a useful method to assess hand loading in manual tasks (Takala & Toivonen, 2013; Mogk & Keir, 2003). It has been used to examine the associated muscle activity patterns and fatigue (Akesson et al., 2012; Nordander et al., 2000;Veiersted et al., 1990) and as an indicator of peak and cumulative workload (Village et al, 2005). Village et al. (2005) examined muscle loading and cumulative load of the shoulders and back of 32 care aides over a full-shift. Peak and cumulative spinal compression forces were significantly correlated with lost-time and musculoskeletal injury rates and total tasks observed (Village et al., 2005). Further to muscle loading, limits associated with EMG and muscular load have been suggested by Jonsson (1982). He identified that muscular load should not exceed 2-5% maximum voluntary excitation (MVE) for the 10^{th} percentile (full day of work), 10-14% MVE for the 50^{th} (continuous work for more than one hour) or 50-70% MVE for the 90^{th} percentile (continuous work for more than 10 minutes).

Muscular rest was operationalized using EMG “gaps” to quantify muscular rest during repetitive and continuous work (Veiersted et al., 1990). They defined gaps as short time periods (at least 0.2 seconds) with muscle activity below 0.5% of maximum voluntary efforts and identified the link between a reduction in the number of gaps and incidence of WMSD (Veiersted et al., 1990 & 1993; Hagg et al., 1997). Workers who operated a chocolate packing machine and had musculoskeletal complaints were found to have less muscular rest and fewer ‘gaps’ than those with no complaints thus illustrating that muscle activity patterns may play an important role for the development of WMSDs (Veiersted et al., 1990).

Muscular rest has been defined as average accumulated EMG gap time by Nordander et al, (2000). Work tasks of hospital cleaners and office workers were compared and it was found that the cleaners had less muscular rest (time below 0.5% MVE) and a higher incidence of neck/shoulder pain. Further to this study, quantitative exposure-response relationships between physical load and WMSD in the elbows and hands were examined by Nordander et al. (2013). Muscular rest was negatively associated with complaints from workers of highly similar work tasks who were evaluated over a full work day. Thus, more muscular rest was associated with fewer complaints (Nordander et al., 2013). In a study of dental hygienists, the degree of head flexion, constrained position of the neck, and a short time of muscular rest of the trapezius combined with low upper arm velocities were the most plausible risk factors for developing muscular disorders in the neck and shoulder regions (Akesson et al., 2012).

Low threshold motor units also referred to as 'Cinderella fibres' (first up, last to bed) are the first to be recruited and remain active until total relaxation of the muscle Hagg (1991). When activated for too long, with too little rest, risk of WMSD increases. The opportunity to rest during repetitive low-force contractions was examined by Qin et al (2014). Twenty participants performed four 20-minute task (reaching for, picking up and stacking washers onto an assembly piece of 15 dowels) sessions separated by short 2 minute breaks. They found that kinematic and kinetic parameter changes over discrete time periods were sensitive to breaks, even short pauses in the work task. These studies highlight the importance of assessing repetition and prolonged low level exertions as risk factors related to distal upper extremity disorders, especially in occupations requiring the handing and grasping of small objects.

2.3 Summary

The lost time claims associated with WMSD in healthcare are significant. Upper extremity WMSDs, such as tendinitis, tenosynovitis, epicondylitis and carpal tunnel syndrome have been associated with repetitive and/or prolonged hand and arm tasks in industry, dentistry, and laboratories. However, little focus has been put on upper extremity WMSDs associated with hand and syringe use within healthcare professions. The application of musculoskeletal disorder prevention strategies in healthcare work-system design is essential to reduce WMSDs, improve worker satisfaction, and decrease worker absenteeism, as well as increase productivity. The proposed study is a step in addressing the need for quantitative guidelines, specific to hand and syringe tasks performed in the healthcare industry.

CHAPTER 3

METHODS

3.1 Participants

Between July and December 2013, the nurses and pharmacy assistants volunteered from the Chemotherapy Suite and Systemic Pharmacy departments at the Juravinski Cancer Centre, Hamilton, Ontario. Fifteen female workers, consisting of 10 nurses (5 floor nurses and 5 lab nurses) and 5 pharmacy assistants, with 9.0 ± 8.5 years of work experience, participated in this study. The height, mass, and age of each participant were also recorded (Table 1).

Table 1. Mean height, mass, and age of the pharmacy assistants, floor nurses, and lab nurses with standard deviation.

Job	Height (cm)	Mass (kg)	Age (years)
Pharmacy Assistant	162.6 ± 8.0	63.5 ± 12.2	43.2 ± 12.0
Floor Nurse	163.1 ± 7.1	64.5 ± 9.6	51.8 ± 8.3
Lab Nurse	164.3 ± 8.9	78.3 ± 10.6	47.6 ± 13.5

Floor nurses administer chemotherapy treatment for patients through intravenous (IV) lines and pumps. They cover a large floor space to attend to various patients, access supplies and perform a variety of tasks including; preparing IV lines by attaching IV tubing to IV bags, preparing various supplies for each treatment, starting IV lines, and programing IV pumps to dispense ordered volumes by tapping on a touch screen of the pump. Lab nurses remain in small 'lab' rooms and start IV lines for blood work tasks, collect blood work, flush intravascular devices for patients who arrive for clinic visits, as well as provide treatment injections. One floor nurse and 2 lab nurses were left handed. Chemotherapy nurses were analysed separately as lab and floor nurses. It should be noted that the chemotherapy nurses rotate between these roles on a daily basis depending on scheduling. For example, a nurse may be scheduled to work as a lab nurse one day and then as a floor nurse the following day.

Pharmacy assistants work in a small clean room and have two roles, between which they may rotate throughout the day. The mixer role requires that they mix the treatments while seated at a biological safety cabinet. The checker role requires that they 'check' the mixed treatments to ensure accuracy of volumes, which requires them to stand at a counter handling supplies and paperwork while at the same time monitoring the 'mixer'. All pharmacy assistants were right handed.

All participants provided written informed consent. The study was approved by the Hamilton Health Sciences/Faculty of Health Science Research Ethics Board. The study was conducted from July to December 2013.

3.2 Experimental Protocol

3.2.1 Observation of Workers

The number and duration of tasks were observed and recorded throughout the shift. Events were coded by task (Table 2) and recorded using observational software (Observer

XT 11, Pocket Observer 3.2, Noldus, Leesburg, VA, USA) on a tablet (Samsung Galaxy Notebook 10.1, Samsung Electronics Ltd, USA). Events were displayed as a block on the tablet and were selected by tapping the appropriate event box (Appendix F). For each participant, the day shift (9 am-5 pm) was observed mid-week. Events were recorded as either a 'point' event (time-stamp), or a 'state' (time-based) event. The terms associated with the events are listed and defined in Table 2. The coding of 'point' events denoted an instant in time and described tasks such as removing the caps off of syringes, IV bags or vials, opening a package, applying a label, inserting IV tubing into an IV bag (spike), and twisting connections of syringes and IV tubing. 'State' events indicated an event that occurred for a period of time. For example, when observing the drawing of fluid from a vial using a syringe, the observer would tap 'draw' to indicate the nature of the syringe task and initiate timing of the event. The state event of 'draw' would end with tapping another state event.

Some state (i.e. handle, write, draw) and all point tasks (Table 2) were common between the 3 groups while other state tasks were only performed by specific groups. For example, pharmacy assistants were the only group to perform the clave and port tasks while only the lab nurses performed the injection task. After collection, state (time-based) and point (time stamp) hand tasks were classified into groups of syringe, pinch, finger press, computer and handle (Table 3) to assist with analysis. The hand posture used during syringe tasks was also noted with a state event modifier label to indicate the type of hand posture used during the specific syringe task. These included (1) chuck (index and middle fingers on syringe flange while the thumb on plunger), (2) thenar (index and middle finger on the syringe base, thenar eminence on plunger), (3) chuck variation (like chuck but middle and ring fingers), (4) two-handed (index and thumbs of both hands used), (5) lateral (thumb on plunger with fingers around syringe), and (6) palm (like the thenar but with the palm of the hand on plunger) (Appendix D: Hand postures). For example, when a worker was performing an 'IV push' state task, the observer would tap 'IV push' and then a choice of hand posture would show up on the screen. The observer would then tap to select the type of hand posture used. Other state tasks that linked with hand postures included; clave, port, flush, and injection (Table 2, Figure 1). The draw and hold tasks were not included due to the difficulty to classify between the various postures. Additional tasks and notes were also recorded if needed. Furthermore, events were synchronized with the muscle activity and force by tapping a pre-coded 'sync' label on the tablet screen with the right thumb (with the FSR attached). Synchronization occurred at the start of the observed work shift and after each break.

Table 2. Identification of terms used for specific tasks and the associated task description. Point events are italicized. Nurses enter patient data electronically and this was tracked as 'STV' during the colleciton however in anaylsis it is refered to as 'Chart'.

Task	Description
Auxiliary	Includes scheduled break time, talking, walking, and waiting for orders or patients
Bag Seal	Closing and sealing a 'Ziploc' bag
Bloodwork	Connecting blood collection tubes to either a peripheral or central line
Clave	Use of a specific connection (sits perpendicular to the work surface) on the IV tubing to dispense fluid from syringe to IV bag
Draw	'drawing' fluid from an IV bag, vial, or another syringe, using a syringe
Finger Press	Tapping the touch screen of the IV pumps to program volumes and duration of treatment
Flush	Use of a syringe to move saline through an IV line or intravascular device to 'flush' the line or device to clear for blood work or treatment
Glove	Donning or doffing gloves
Handle	Handling of supplies/items, including opening drawers and retrieving and preparing supplies, as well as preparing the patient to receive the treatment and assisting the patient during treatment
Hold	Holding filled syringes up for quality assurance checks
Injection	Use of a syringe to inject a treatment into the patient (without the use of IV tubing or intravascular devices)
IV Push	Use of a syringe to manually administer a treatment to the patient (flow rate is monitored at 2ml per minute)
IV Start	Locating a site on a patients arm to insert a needle for IV purposes
Port	Use of a connection (sits parallel to the work surface) on the IV bag to dispense and draw fluid using a syringe
Prime Lines	Preparing IV tubing and connecting tubing to IV bags
Computer	Typing and mouse work – entering patient information electronically (Chart)
Write	Writing patient information, initialling orders
Cap	*Removing the cap from IV tubes, vials, syringes, or IV bags*
Label	*Applying labels to syringes, IV bags, or vials*
Package	*Opening packaging of various supplies*
Spike	*Inserting IV bag tubing into the port of the IV bag*
Twist	*Connecting tubing and syringe, and attaching safety connectors to IV tubing*

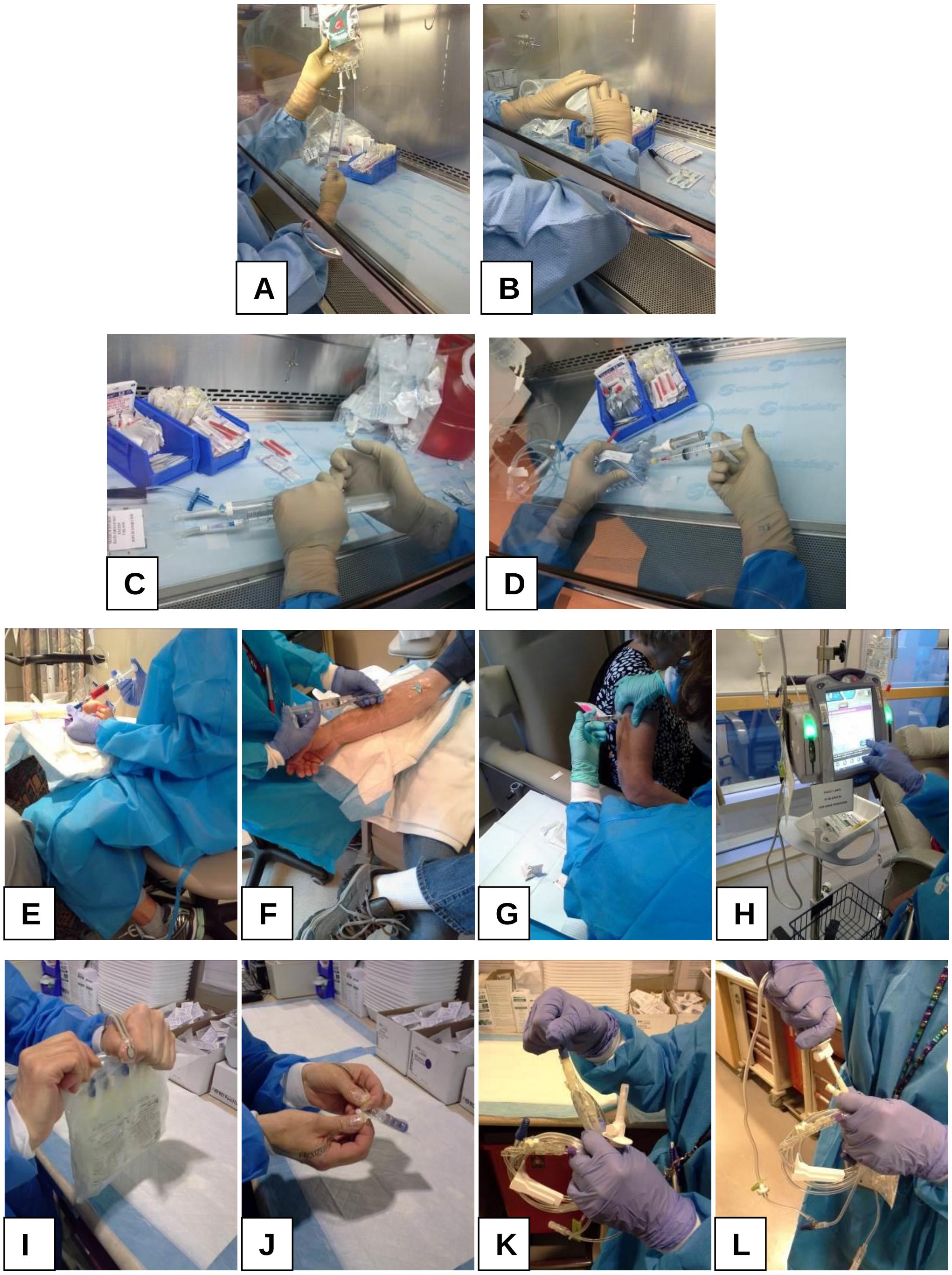

Figure 1. Hand and syringe tasks performed by the pharmacy assistants and nurses; (a) Draw, (b) Clave, (c and d) Port, (e) IV Push, (f) Flush (g) Injection, (h) Finger Press, (i and j) Package, (k) Cap, (l) Spike.

Table 3. Tasks labels grouped by common features. Point tasks are italicized and occurred during handling, priming lines, blood work and IV start, state tasks. Handle includes the handling of supplies/items, including opening drawers and retrieving and preparing supplies, as well as preparing the patient to receive the treatment and assisting the patient during treatment. Finger press includes tapping on the IV pumps to program specific dispensing volumes. Nurses enter patient data electronically and this was tracked as 'STV' during the colleciton however in anaylsis it is refered to as 'Chart'.

	Event					
Job	**Syringe**	**Pinch**		**Finger Press**	**Computer**	**Handle**
		State	**Point**			
Nurse	Draw	Bag seal	*Cap*	Finger Press	Chart	Handle
	Flush	Blood work	*Label*		Mouse	
	Injection	Gloves	*Package*			
	IV Push	IV start	*Spike*			
		Prime Lines	*Twist*			
		Write				
Pharmacy	Clave	Bag seal	*Cap*	None	None	Handle
	Port	Gloves	*Label*			
	Draw	Write	*Package*			
	Hold		*Spike*			
			Twist			

3.2.2 Electromyography and Thumb Press Forces

Forearm muscle activity and thumb press forces, were monitored using a portable data acquisition unit (DataLOG MWX8, Biometrics Ltd, Gwent, U.K.). This system allowed continuous collection at 1000 Hz for the entire shift. Bipolar, differential EMG sensors with a fixed electrode distance of 20 mm were used (gain 1000, bandwidth 20Hz - 450 Hz, input impedance > 10^{15} Ω, CMRR @ 60Hz >96 dB).

The participant's skin was clean and dry prior to placement of the EMG sensors. One participant did shave both arms for the study. EMG sensors were placed over the bulk of the forearm flexor and extensor compartment mass in line with the fibre direction (Figure 2). The location of the EMG sensors was chosen based on findings presented by Takala & Toivonen (2013), and Mogk & Keir (2003). It was suggested that the EMG placements on the forearm flexor and extensor compartments effectively capture general muscle activity for hand loading in manual tasks understanding that skin movement occurs during pronation and supination of the forearm.

Thumb forces were collected using force sensing resistors (FSR) on both thumbs (Flexiforce A201, Tekscan, Boston, MA, USA). One FSR was placed on the right thumb pad and another on the left thumb pad (Figure 2) and secured by an adhesive thin transparent dressing (provided by the nurses). The FSRs were removed from the thumb before hand washing to avoid water contamination, and reapplied once hands were dry. All methods were piloted and further evaluated with workers on the floor to ensure appropriate measures were taken for the sterile environment and worker constraints (time). For example, double sided tape was initially used to adhere the FSR to the thumb pad, however, over time it failed to stick due to hand washing and glove wearing, thus, the FSR did not remain in place. As such, the thin dressing was applied to the FSR and thumb.

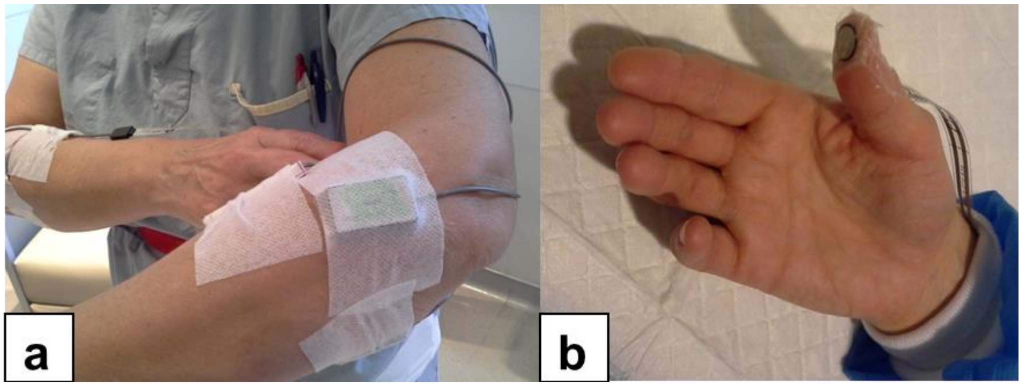

Figure 2. EMG sensors placed on the flexor and extensor compartments of the forearm (a – extensor compartment shown) and (b) FSR sensors placed on the thumb pad.

Maximum voluntary thumb press force and the maximum voluntary excitation (MVE) for EMG were obtained at the start of the shift. Participants performed a series of maximum EMG trials using the forearm flexors and extensors of the fingers and wrist. For the flexors, the participants elbow was bent at approximately 90° with the forearm supine and wrist flexed with flexors in a shortened state. Participants performed maximal isometric resistance against an opposing isometric exertion performed by the investigator. A similar setup was used for the extensors but with the forearm prone and wrist extended with extensors in a shortened state. Trials were 5 seconds in duration with 1 minute rest between trials. Each trial was performed twice. Maximum thumb press force of both right and left sides were collected using syringe attached to a digital force gauge. Participants performed a series of maximal isometric exertions using a chuck pinch and a two-handed pinch grip. Trials were 5 seconds in duration with 1 minute rest between trials. Each trial of each posture was performed twice.

During collection, each FSR was calibrated and tested using known loads (5 lb, 10 lb, and 15 lb) at the start of the day, throughout the day during breaks (for convenience of workers), and at the end of the day. After pilot testing, the FSRs were found to degrade over the day and were switched during lunch break. The calibration allowed for a linear correction equation which was later used to accommodate for the loss of force over time.

CHAPTER 4

DATA ANALYSIS

4.1 Observations

Descriptive statistics, of the number and duration of each task, were compiled to provide the total and mean number of tasks (incl. hand efforts per minute) and cumulative task duration. The frequency of the tasks by hour and type, and the number and duration of hand postures used during syringe tasks were also analysed. To synchronize the event observations with the muscle activity and force data, event information was exported from Observer software into Microsoft Excel and task duration files were created. The task files were entered into a custom MatLab program (MatLab v. R2011b; The MathWorks Inc., Natick, MA, USA) that gathered and matched the associated muscle activity and force data. 'Representative' time windows were used for the state and point observer events. For the state events, the window had 1000 samples (1 second) removed from the start and end of the observer task file to account for lag between the observer and DataLOG systems. The point event window included 500 samples prior to, and 500 samples after, the observer recorded occurrence to capture the actual point occurring in the muscle activity and force data. Furthermore, the maximum value occurring during the point event window was used to define the point task. The resulting information was used to illustrate the activity and force occurring over the work day and for each task performed by the nurses and pharmacy assistants.

4.2 Electromyography and Force

Raw EMG was full wave rectified, then dual low pass filtered using a 2nd order Butterworth filter with a 3 Hz cut-off and normalized to maximum voluntary excitation (MVE). Forces were low-pass filtered at 10 Hz using a dual pass, 2nd order Butterworth filter and normalized to the maximum voluntary force (MVF) using a custom program (MatLab v. R2011b; The MathWorks Inc., Natick, MA, USA). MVF was defined as the peak force for the left thumb and peak force for the right thumb during the filtered MVF trials. MVE was defined as the as peak EMG of the left forearm extensors, right forearm extensors, left forearm flexors, and right forearm flexors during the filtered MVE trials. Due to degradation of the force sensors throughout the day, a linear correction factor was used to accommodate for the loss in force over time. The force data of one floor nurse was excluded from the analysis due to external interference that occurred during the collection. EMG and force data were analysed using the 10th, 50th, 90th percentiles of the Amplitude Probability Distribution Function (APDF) (Jonsson, 1982). The 99th percentile was also analysed to estimate maximum loads of the state tasks. For point tasks, the maximum normalized value was analysed to estimate the associated loads. Muscular rest was analyzed by quantifying the distribution of short spontaneous EMG gaps of at least 0.5 s under 1% MVE as suggested by Hansson et al. (2000). The gap criteria were chosen because of the increase in sensitivity to task differences as reported by Hansson et al. (2000).

The duration of tasks, hand efforts per minute, EMG and force data (10th, 50th, 90th, 99th percentile, normalized maximum of EMG and force) for the common tasks (handle, write, draw, cap, label, package, spike, twist) performed by the groups (and over the day) were compared between floor nurses, lab nurses and the pharmacy assistants using mixed analyses of variance (ANOVA) for all measures (SPSS Statistics v. 17.0). The same statistical analysis was used to compare the duration of tasks, hand efforts per minute, EMG and force data (10^{th}, 50^{th}, 90^{th}, 99^{th} percentile, normalized maximum of EMG and force) for the common tasks of the nursing groups (IV start, IV push, finger press, flush, gloves, prime lines, chart) between the floor nurses and lab nurses.

A total of 30 ANOVAs were performed. Dependent measures included the duration of tasks, hand efforts per minute, EMG gaps, EMG amplitude, and force while the independent measures were the shift duration (shift) and common tasks of the nurse and pharmacy assistant groups, the right and left thumbs, and the forearm flexor/extensor muscle compartments. The efforts per minute of common tasks (draw, handle, write, cap, label, package, spike, twist) were compared between the groups using a 3 (group) × 9 (task) ANOVA. Common tasks (IV start, IV push, finger press, flush, gloves, prime lines, chart) between the nursing groups were compared using a 2 (group) × 7 (task) ANOVA. The duration data of 4 common tasks (draw, handle, write, auxiliary) was compared between the groups using a 3 (group) × 4 (task) AVOVA. The duration of common tasks between the nursing groups were compared using, 2 (group) × 7 (task) ANOVAs. The EMG gaps and muscle activity (10^{th}, 50^{th}, 90^{th} percentiles) over the day (duration of shift) were compared between the right and left forearm flexor and extensor muscle compartments and groups using a 3 (group) × 3 (shift) × 4 (muscle) ANOVA. For the EMG data (10^{th}, 50^{th}, 90^{th}, 99^{th} percentile, normalized maximum activity) of the common tasks between groups, a 3 (group) × 9 (task) × 4 (muscle) ANOVA was used. The EMG data (10^{th}, 50^{th}, 90^{th}, 99^{th} percentile, normalized maximum activity) of the common tasks between the nursing groups was compared using a 2 (group) × 7 (task) × 4 (muscle) ANOVA. For the force data (10^{th}, 50^{th}, 90^{th}, 99^{th} percentile, normalized maximum force) of the left and right thumbs and the common tasks, a 3 (group) × 9 (task) × 2 (hand) ANOVA was used. The forces (10^{th}, 50^{th}, 90^{th}, 99^{th} percentile, normalized maximum force) of the common tasks between the nursing group were compared using a 2 (group) × 7 (task) × 2 (hand) ANOVA. The force data (10^{th}, 50^{th}, 90^{th}) over the day (duration of shift) was compared between the groups using a 3 (group) × 3 (shift) × 2 (hand) ANOVA. Significant findings were followed up with Tukey's HSD test. All statistical tests were considered significant at $p < 0.05$. In cases where sphericity was violated, the Greenhouse-Geisser correction value was used.

CHAPTER 5

RESULTS

Observation times ranged from 4h 16 min to 6h 19 min which excluded breaks, and occasional technical issues. The data collection duration including observed work and break time, ranged from 7h 39 min to 8h 29 min. The observed shift duration for each group was 275.4 ± 27.5 minutes (mean ± standard deviation) for pharmacy assistants, 353.3 ± 17.3 minutes for floor nurses, and 336.0 ± 26.7 minutes for the lab nurses.

5.1 Event Frequency

A total of 13,124 events were observed from the 15 workers, representing a mean of 874.9 ± 446.7 events per shift. Pharmacy assistants performed significantly more tasks per shift with 5.29 ± 1.27 hand efforts per minute, than the nurses ($F_{2, 14} = 34.388$, $p < 0.001$). Floor nurses performed 1.62 ± 0.09 efforts per minute, while lab nurses averaged 1.85 ± 0.48 efforts per minute.

In terms of the hand efforts per minute of the common tasks, a task × group interaction occurred ($F_{2, 12} = 34.694$, $p < 0.001$). Pharmacy assistants performed significantly more hand efforts per minute when drawing fluid with a mean 0.33 ± 0.11 efforts/minute compared to the floor (0.03 ± 0.02) and lab (0.04 ± 0.02) nurses. Pharmacy assistants also performed more hand efforts per minute when handling, uncapping, opening packaging and using twisting movements than the nurses (Figure 3). A task × group interaction also occurred for the common tasks between the nursing groups ($F_{1, 8} = 5.128$, $p < 0.001$). Lab nurses performed significantly more line flushes per day than floor nurses (0.08 ± 0.02 efforts/minute versus 0.03 ± 0.01 efforts/minute) while the floor nurses performed more finger press movements than the lab nurses (0.14 ± 0.04; 0.01 ± 0.02). The mean number of tasks that occurred over the day (with standard variation) is illustrated in Appendix A, Figure A1.

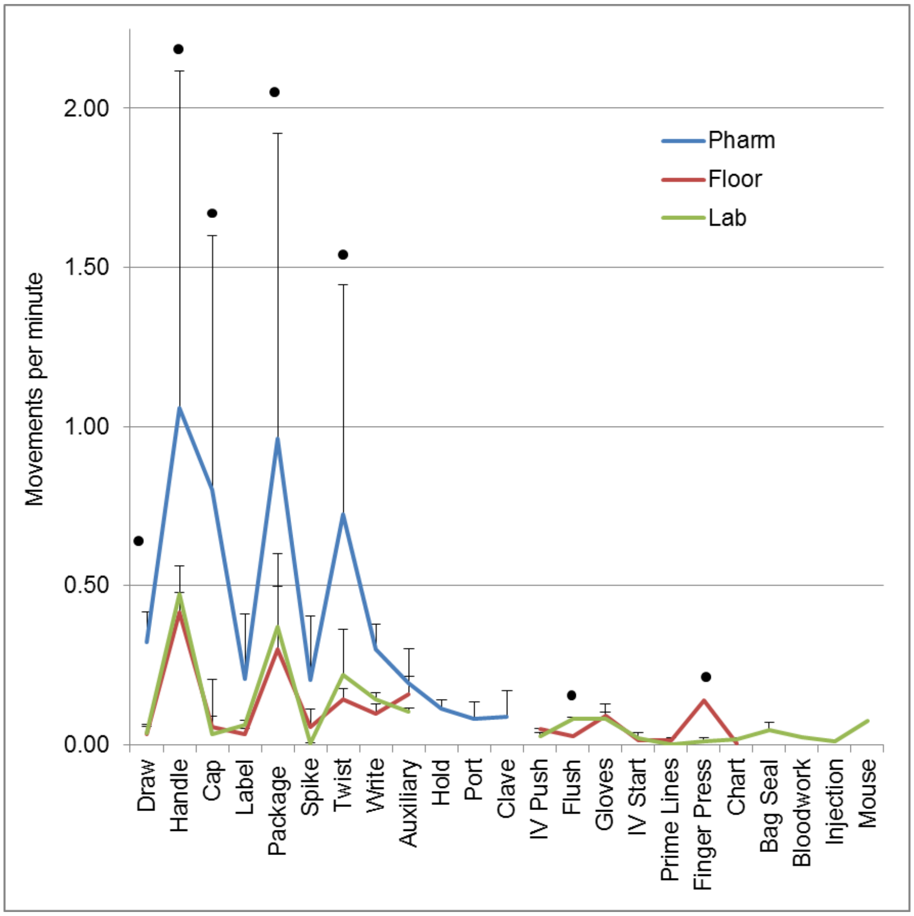

Figure 3. Mean number of hand efforts per minute for observed tasks for pharmacy assistants, floor and lab nurses (with standard deviation, n=15). Tasks performed by only one job are included (i.e. hold, port, clave, bag seal, bloodwork, injection, mouse) to illustrate job specific tasks. Significance between groups noted by a solid circle (●).

5.2 Event Duration

All groups spent the most time performing handling (Figure 4) which is due to the inclusion of a variety of tasks (outlined in Table 2). A task × group interaction was found for the duration of common tasks between the 3 groups ($F_{2, 12} = 9.415$, $p < 0.01$). Pharmacy assistants spent significantly more time drawing fluids with a syringe (10.6 ± 14.0% of the shift) than the floor (0.3 ± 0.5%) and lab nurses (0.8 ± 2.8%). The pharmacy assistants also spent more time writing and handling than the nurses (Figure 4). Floor nurses performed auxiliary tasks for a significantly longer percent of their shift (27.7 ± 23.8%) than pharmacy assistants (13.4 ± 13.0%) and lab nurses (15.3 ± 26.6%) which is likely due to the larger area over which they work.

With respect to the task duration for common tasks of the nurses, a task × group interaction occurred ($F_{1, 8} = 9.235$, $p < 0.05$). The floor nurses spent the most time priming lines (6.6 ± 19.1%) and performing finger press movements (4.0 ± 3.7%). Manually pushing IV treatments represented the highest duration syringe task for the nurses (Figure 4). Cumulative task duration values with standard variation are illustrated in Appendix A, Figure A2.

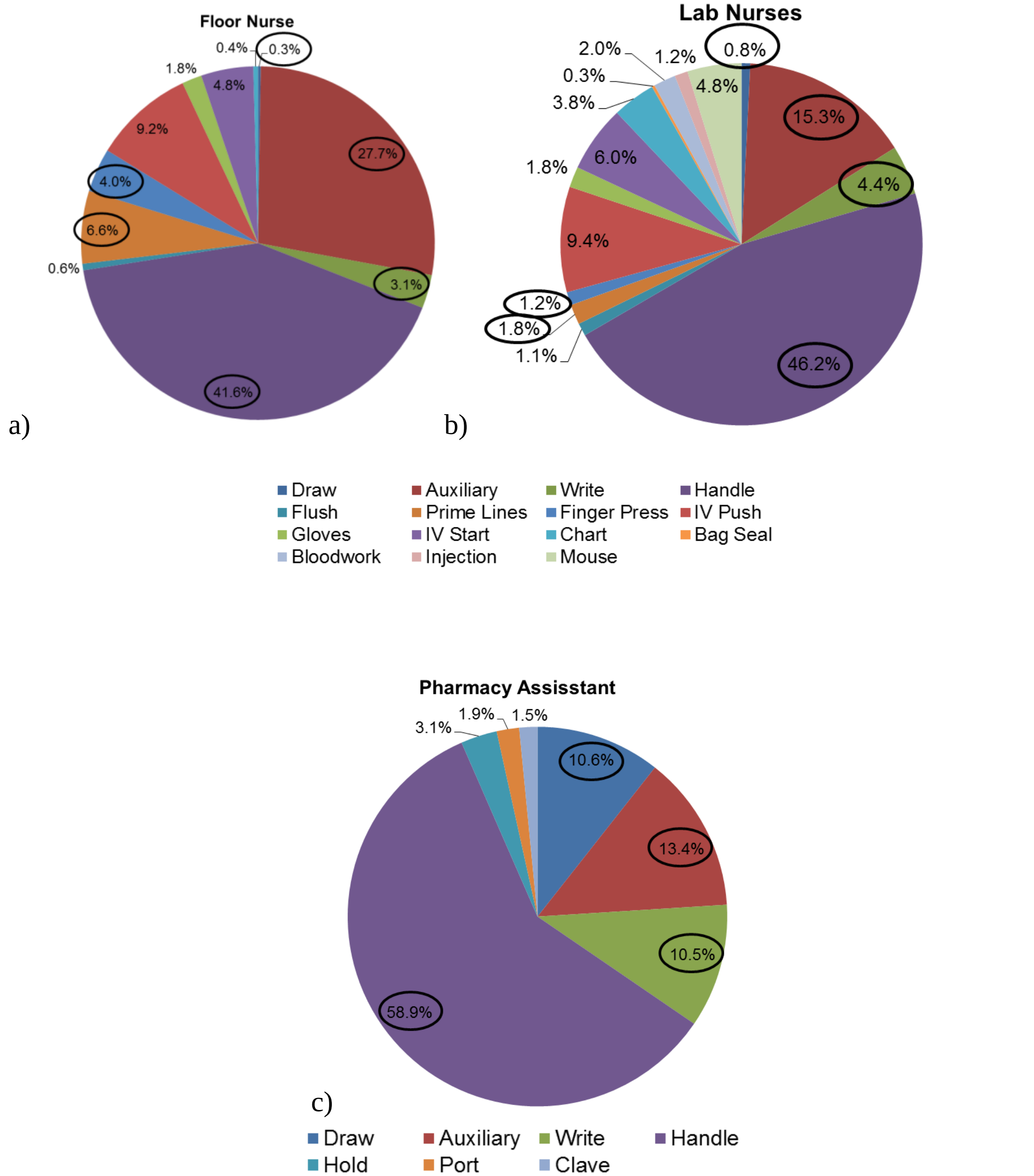

Figure 4. Cumulative task duration at a percentage of shift time for pharmacy assistants, floor and lab nurses (n=15). Values with standard deviation in Appendix A. a) floor nurses, b) lab nurses, c) pharmacy assistants. "Chart" refers to electronic documentation. Significance between groups indicated with a circle.

5.3 Hand Postures

When investigating the hand postures used during syringe tasks (IV push, flush, injection, port, clave), both nursing groups used the chuck hand posture the most for the IV push, flush, and injection tasks. The chuck posture accounted for 54.2 ± 22.2% of the time spent performing IV pushes and 69.7 ± 55.5% of the cumulative flush task time, while it was the only posture used for the injection task. Pharmacy assistants used their palm for the clave task (57.6 ± 50.1% of the time) and the lateral posture was used 51.9 ± 35.5% of the port task time.

5.4 Muscle Activity

Regarding the nurse and pharmacy assistant work shifts, there was no significant difference between groups, however a main effect of muscle compartment on EMG occurred at the 10th, 50th, and 90th percentiles ($F_{1.3. 15.9} = 10.574$, $p < 0.01$; $F_{3, 36} = 26.393$, $p < 0.001$; $F_{3, 36} = 27.077$, $p < 0.001$). The left forearm flexor muscles had the highest muscle activity (Figure 5).

When examining the common tasks between the 3 groups (handling, writing, and drawing of fluids with syringe) at the 10th percentile, a task × group interaction ($F_{2, 12} = 5.883$, $p < 0.05$) and a task × muscle ($F_{2.8, 33.9} = 5.816$, $p < 0.01$) were found. Tukey’s HSD test found significant differences between the draw (4.2 ± 1.0%) tasks of the floor nurses and the handling (0.6 ± 0.2%) tasks of the lab nurses. Furthermore, for the left forearm flexors, the draw (6.1 ± 2.4%) tasks and writing tasks (4.9 ± 2.5%) for the floor nurses were higher than handling (1.0 ± 0.6%) for the lab nurses.

a)
b)

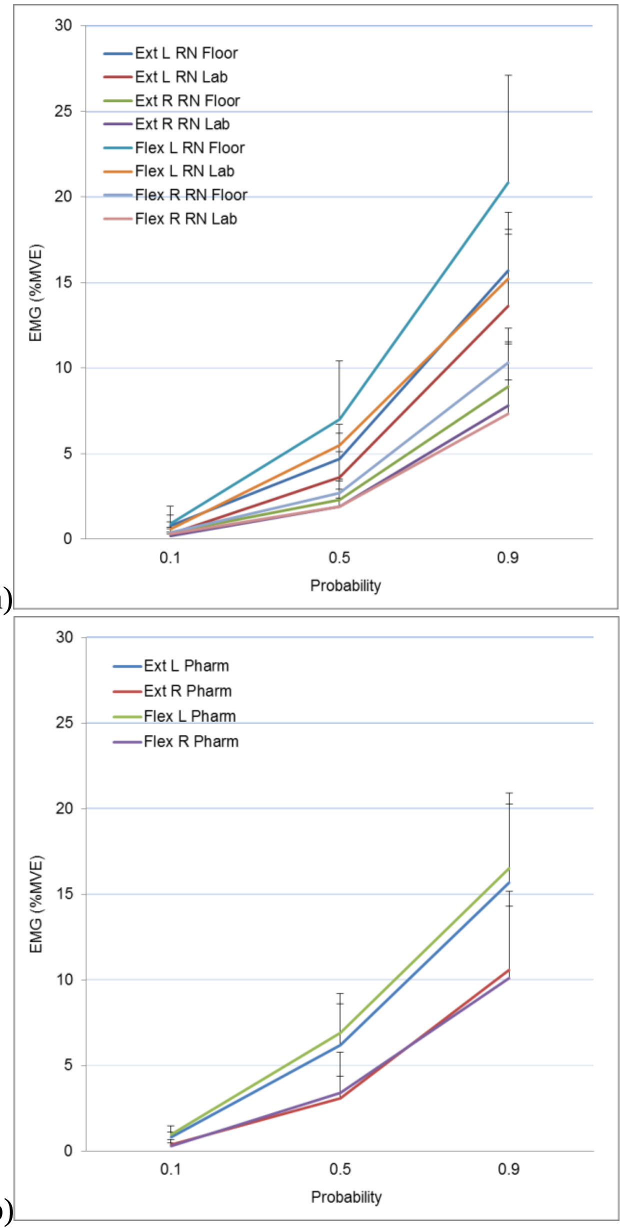

Figure 5. Distribution of EMG (%MVE with standard deviation) for the entire shift (mean plus standard deviation). a) Floor and lab nurses, b) Pharmacy assistants. Extensor left (Ext L), Extensor right (Ext R), Flexor left (Flex L), Flexor right (Flex R).

For the common tasks of the 3 groups at the 50th percentile, a significant interaction of task × group occurred ($F_{2, 12} = 4.666$ $p < 0.05$). The floor nurses had the greatest muscle activity across the tasks (Table 4: 50th percentile) with the exception of the pharmacy assistants with left extensors during the handling task (7.4 ± 2.5%). The complete set of APDF EMG data can be found in Appendix B, tables A and B.

Table 4. Median muscle activity occurring during common tasks for the 3 groups with standard deviation (n=15). Significant differences between groups noted by [a], (p < 0.05).

Muscle Compartment	Task	Floor Nurse	Lab Nurses	Pharmacy
Left Extensor	Draw	10.8 ± 3.4[a]	6.1 ± 3.4[a]	6.6 ± 1.9[a]
	Write	7.1 ± 6.6[a]	7.7 ± 8.5[a]	4.8 ± 2.6[a]
	Handle	6.7 ± 1.3	5.2 ± 2.2[a]	7.4 ± 2.5[a]
Right Extensor	Draw	3.7 ± 1.5	2.3 ± 1.6	3.1 ± 2.6
	Write	4.9 ± 1.2	4.3 ± 3.5	2.9 ± 1.3
	Handle	3.2 ± 1.3	2.6 ± 1.3	3.9 ± 1.8
Left Flexor	Draw	15.0 ± 1.8[a]	8.1 ± 2.0[a]	7.1 ± 2.6[a]
	Write	12.8 ± 4.7[a]	7.5 ± 2.3[a]	8.5 ± 4.2[a]
	Handle	9.7 ± 3.5[a]	6.2 ± 2.1[a]	7.5 ± 1.9[a]
Right Flexor	Draw	5.4 ± 0.9[a]	3.3 ± 1.1[a]	4.3 ± 2.5
	Write	5.9 ± 1.3[a]	3.9 ± 1.7[a]	3.7 ± 2.7[a]
	Handle	3.9 ± 0.8	2.6 ± 0.8	3.7 ± 2.4

With respect to the common tasks of uncapping, labelling, opening packages, spiking, and twisting hand movements and the maximum normalized muscle activity, an interaction of task × group was found ($F_{2, 12} = 8.038$, $p < 0.01$). Muscle activity was lowest for the lab nurses versus the floor nurses and pharmacy assistants for the spiking task. The maximum activity of the lab nurses ranged from 1.7 ± 3.8% (right extensor) to 7.9 ± 17.8% (left flexor), while the floor nurses ranged between 34.4 ± 11.9% (right flexor) to 58.0 ± 27.4% (left flexor), and the pharmacy assistants had a range of 27.1 ± 10.2% (right extensor) to 39.0 ± 5.5% (left extensor). For the uncapping task, the right extensor (46.7 ± 8.0%) and flexor (52.4 ± 22.6%) activity was greater for the pharmacy assistant versus the lab nurses (extensor: 26.5 ± 11.0%, flexor: 22.6 ± 6.2%).

For the nursing groups, a task × group interaction occurred at the 99th percentile ($F_{1, 8} = 11.770$, $p < 0.01$). Additionally at the 99th percentile for the nurses, a significant interaction of task × muscle occurred ($F_{4.875, 39.002} = 3.059$, $p < 0.05$). Tukey's HSD test revealed significant differences for the tasks of finger press and priming lines. For the finger press task, the left forearm flexor activity of the floor nurses (30.6 ± 6.1%) was significantly greater than the lab nurses (4.6 ± 10.4%). The floor nurses had greatest activity across all muscle compartments when priming lines with activity ranging from 28.4 ± 7.6% (right flexors) to 46.1 ± 13.1% (left flexors). The muscle activity for the lab nurses when priming lines ranged from 3.9 ± 8.8% (right extensors) to 9.1 ± 20.3 (left flexors). The muscle activity at the 99th percentile and maximum normalized activity across groups is noted in Table 5.

5.5 Muscular Rest

The amount of muscular rest between the groups was not significantly different. A main effect of muscle compartment on muscular rest ($F_{3, 36} = 6.871$, $p < 0.01$) was found. The left forearm flexors had less muscular rest than the right forearm extensors and right forearm flexors (Figure 6).

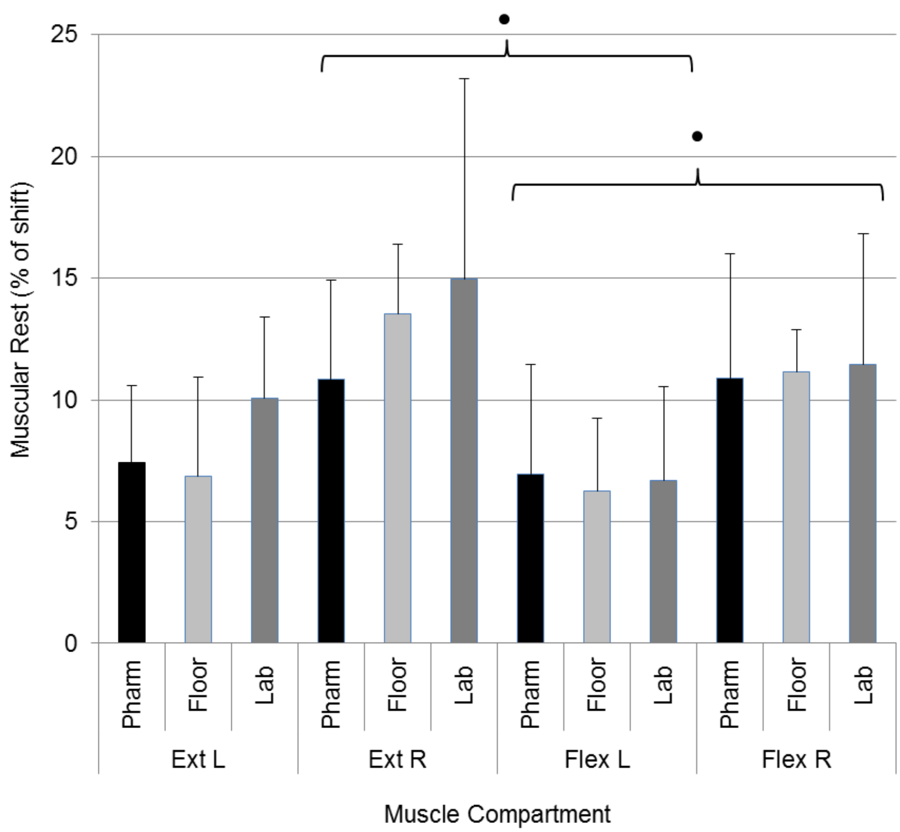

Figure 6. Muscular rest as a percent of the observed work shift for the floor and lab nurse and the pharmacy assistant with standard deviation (n=15). Muscle compartments: Left forearm extensors (Ext L), right forearm extensors (Ext R), left forearm flexors (FlexL), right forearm flexors (Flex R), significance between muscle compartments indicated as a solid circle (•).

5.6 Thumb Press Force

No significant differences in thumb force were found between the groups over the shift. In terms of common tasks, a main effect of task on force was found for the 90^{th}

percentile ($F_{1.251, 13.764} = 9.197$, $p < 0.01$). The thumb force during the task of drawing fluid using a syringe (7.3 ± 6.6%) was significantly higher than handling (3.5 ± 4.7%).

For the maximum force of the point tasks, an interaction of task × group was found ($F_{2, 11} = 6.075$, $p < 0.05$) primarily with the tasks of uncapping, labelling, spiking, and twisting movements. The maximal thumb forces of the pharmacy assistants (right and left) for uncapping and labelling were significantly greater than the nursing groups. For uncapping, the pharmacy assistants ranged between 51.7 ± 28.4% (left) to 53.5 ± 26.9% (right) while the lab nurses had 28.2 ± 8.0% (left) and 23.9 ± 16.5% (right), and the floor nurses had 21.3 ± 6.4% (left) and 31.8 ± 24.5% (right). For labelling, the pharmacy assistants ranged between 27.7 ± 19.3% (left) to 32.3 ± 25.7% (right), the lab nurses had 3.6 ± 0.7% (left) and 10.7 ± 10.8% (right) and the floor nurses had 9.8 ± 5.6% (left) and 5.0 ± 5.0% (right).

Additionally, the maximal thumb forces of the floor nurses (right and left) for spiking and twisting movements were significantly greater than the lab nurses. For spiking, the floor nurses ranged between 51.3 ± 13.4% (left) to 41.1± 20.6% (right) and the lab nurses had 13.7 ± 20.5% and 3.9 ± 8.8%, for left and right, respectively. Twisting movements generated maximal thumb forces ranging between 65.4 ± 28.1% (left) and 76.6 ± 13.3% (right) for the floor nurses and 45.0 ± 14.7% (left) and 48.7 ± 31.4% (right) for the lab nurses. The thumb force at the 99^{th} percentile and maximum normalized force across groups is noted in Table 5. The complete set of APDF force data can be found in Appendix B, tables C and D.

Table 5. EMG and thumb press force (percent maximum with standard deviation) as defined as the 99th percentile for state tasks. Point tasks are italicized and represent the maximum normalized activity (n=15). Values with large standard deviations are highlighted.

	% Maximum Force		% Maximum EMG			
	Left	**Right**	**Left Flex**	**Left Ext**	**Right Flex**	**Right Ext**
Bag Seal (n=5)	13.8 ± 5.7	16.2 ± 11.2	27.4 ± 7.3	26.3 ± 5.2	20.6 ± 17.0	17.6 ± 7.4
Bloodwork (n=5)	13.7 ± 5.5	16.3 ± 9.0	29.3 ± 18.4	25.3 ± 12.6	15.7 ± 8.3	14.1 ± 6.8
Clave (n=5)	7.6 ± 2.9	7. 9 ± 5.7	29.5 ± 8.3	34.4 ± 10.3	21.7 ± 5.6	20.4 ± 5.6
Draw (n=15)	13.0 ± 8.7	19.8 ± 13.5	30.6 ± 7.9	25.2 ± 6.7	19.8 ± 8.3	20.4 ± 10.7
Finger Press (n=10)	11.2 ± 18.0	3.7 ± 3.2	17.6 ± 15.9	12.4 ± 11.0	9.9 ± 9.0	6.9 ± 6.8
Flush (n=10)	19.4 ± 13.7	22.9 ± 17.0	37.8 ± 12.7	29.1 ± 10.9	20.3 ± 8.3	19.9 ± 9.8
Gloves (n=10)	9.9 ± 6.5	23.9 ± 32.8	52.4 ± 13.2	44.6 ± 7.9	28.5 ± 6.4	25.8 ± 9.7
Handle (n=15)	14.2 ± 6.3	24.7 ± 32.7	35.9 ± 8.5	33.0 ± 6.1	24.6 ± 6.8	24.9 ± 7.6
Hold (n=5)	6.7 ± 3.1	8.3 ± 11.3	25.8 ± 4.3	23.0 ± 6.3	16.0 ± 8.0	22.1 ± 12.5
Injection (n=5)	3.2 ± 1.9	7.7 ± 7.0	20.3 ± 5.3	19.4 ± 6.0	9.2 ± 5.5	9.1 ± 5.5
IV Push (n=10)	3.4 ± 4.2	2.7 ± 4.2	12.6 ± 11.4	10.5 ± 9.3	5.8 ± 5.3	4.4 ± 4.6
IV Start (n=10)	8.8 ± 3.4	9.5 ± 8.0	34.3 ± 11.5	31.8 ± 7.8	18.2 ± 5.3	19.8 ± 7.9
Port (n=5)	8.3 ± 3.7	14.3 ± 14.5	30.4 ± 6.9	24.7 ± 6.2	22.9 ± 12.5	20.7 ± 12.3
Prime Lines (n=10)	14.4 ± 14.9	11.6 ± 13.4	27.6 ± 25.3	21.4 ± 18.6	17.3 ± 15.7	18.4 ± 18.8
Chart (n=10)	2.2 ± 1.0	13.3 ± 16.2	12.7 ± 14.3	9.0 ± 9.8	6.0 ± 6.6	6.3 ± 7.6
Mouse (n=5)	4.5 ± 4.4	13.4 ± 19.3	24.7 ± 5.0	17.6 ± 6.8	12.4 ± 3.9	14.3 ± 4.0
Write (n=15)	7.5 ± 4.9	15.0 ± 21.0	28.0 ± 8.7	28.2 ± 14.5	17.2 ± 5.3	18.8 ± 7.8
Cap(n=15)	*34.6 ± 21.5*	*36.8 ± 25.0*	*48.0 ± 16.1*	*43.2 ± 15.2*	*36.8 ± 18.0*	*35.1 ± 11.6*
Label(n=15)	*14.0 ± 15.6*	*16.8 ± 19.8*	*34.6 ± 11.9*	*33.1 ± 11.3*	*24.2 ± 12.0*	*24.0 ±11.1*
Package (n=15)	*45.3 ± 20.8*	*51.6 ± 22.6*	*56.4 ± 15.6*	*54.8 ± 12.7*	*51.8 ± 21.9*	*50.1 ± 16.9*
Spike(n=15)	*32.4 ± 25.1*	*29.4 ± 27.0*	*32.6 ± 27.7*	*29.7 ± 20.2*	*22.9 ± 16.5*	*24.7 ± 23.4*
Twist(n=15)	*55.3 ± 23.6*	*56.6 ± 28.0*	*58.0 ± 16.3*	*49.2 ± 14.5*	*42.9 ± 14.9*	*42.5 ± 20.5*

The workload for the floor nurses remained relatively constant throughout the shift with an increase in handling noted at hour 4 and at the end of the shift while IV pushes increased between hour 4 and 5. For the lab nurses, the workload appeared to decrease over the shift with a slight rise at the end of the shift. The pharmacy assistants work load also decreased throughout the day with drops in activity due to scheduled breaks however hand efforts appeared to return to high levels immediately following the breaks (Figure 7).

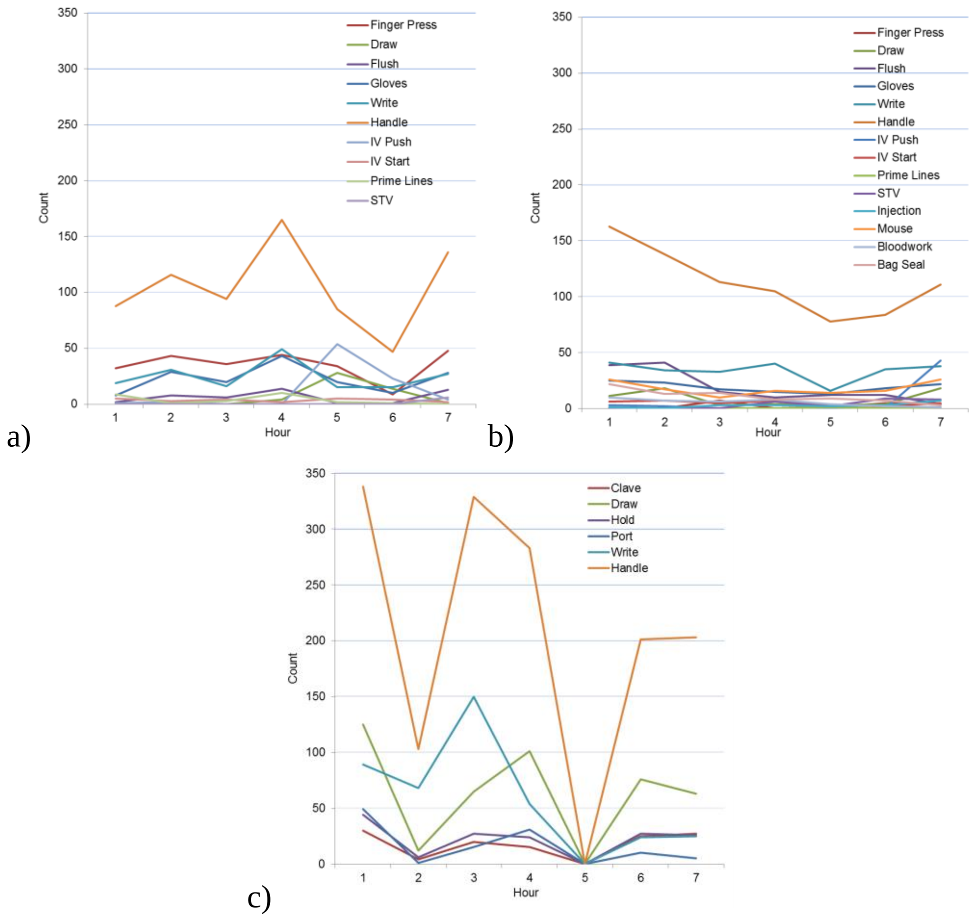

Figure 7. Total number of tasks by hour and type, a) Floor nurse, b) Lab nurse, c) Pharmacy assistant.

CHAPTER 6

DISCUSSION

Published data associated with syringe use in occupational settings is limited. To my knowledge, the current study is the first detailed analysis of tasks performed by chemotherapy nurses and pharmacy assistants; specifically tasks involving the hand and syringe use. The current approach, of combining continuous observation with forearm electromyography and thumb press force collection, allowed a unique and detailed examination of the job content of nurses and pharmacy assistants in the chemotherapy department of a local hospital. Continuous observation of 5 floor nurses, 5 lab nurses and 5 pharmacy assistants allowed generic forearm activity and thumb press force to be linked to hand and syringe use over the course of a work shift. Pharmacy assistants performed more than double the hand efforts throughout the work shift compared to the nurses. The greatest contributors to syringe use were the tasks of drawing fluid and the manual pushing of treatments through an IV line, each accounting for 10% of the work day. With respect to muscular rest, the left forearm flexors rested for only 6% of the work day while the right forearm extensors had the most rest at 13%. The detailed description of the tasks, and associated muscle activity and force data occurring throughout a typical workday, provids new insights to hand and syringe use in the healthcare setting.

Syringe use accounted for 17% of the workday for the pharmacy assistants and 12% each for the floor and lab nurses. The drawing of fluid using a syringe accounted for about 0.3 hand efforts per minute over the pharmacy assistants' shifts (Figure 3) and represented 10% of their syringe use time (Figure 4). In addition, pharmacy assistants injected fluids into IV bags using syringes through clave devices, or IV bag ports, totalling about 4 % of the work day. They spent the most time using a palm hand posture (58%) during the clave task and the lateral hand posture (52%) during the port task. Syringe use may be similar to that of pipette use in the laboratory setting, in that the thumb is used to manually operate the thumb plunger (Asundi at al., 2005; Fredriksson, 1995). WMSDs have been associated with prolonged duration and repetitive actions with the use of pipettes (David & Buckle, 1997; Bjorksten et al., 1994). David & Buckle (1997) used questionnaires related to ergonomic problems from 80 pipette users (scientists, laboratory technicians) and 85 non-pipette users (managers, secretaries) to find a noticeable increase in hand complaints as the duration of pipetting increased. In durations greater than 30 minutes, 30% of respondents reported hand complaints with an odds ratio of 6.43 (David & Buckle, 1997).

It is interesting to note that the nurses manually ‘pushed’ treatment (IV push task) for as long as the pharmacy assistants drew fluid using syringes (draw task). Administering treatment requires the nurse to press the syringe plunger while ensuring a flow rate of 2 ml per minute to ensure the safety to the patient. Up to three 25 ml syringes are used sequentially to administer treatment with the volume and number of syringes being dependent on the dose of the treatment. In the current study, this task lasted up to 25 minutes. Nurses also were observed to use the chuck grip 54% of the time during this task. Grip type and its effects on precision and task performance, were examined by Finneran & O’Sullivan (2013) who found that precision performance and task performance were highest using chuck and pulp grips. This may explain the choice of the chuck hand posture, given the hand control required during the treatment administration. It is noteworthy that only two of the floor nurses were observed to switch between right and left hands during the IV push task, and one of these nurses also used both thumbs to press on syringe plunger. This may suggest that the workers are changing posture to avoid discomfort, or are already experiencing the symptoms (Madeleine, 2010; Mathiassen, 2006).

It has been reported that some nurses may perform ‘back to back’ IV push treatments, which may result in extended ‘holding time’. Rest allowances and endurance limits were examined by Rohmert (1973). He found that longer durations of muscular work resulted in a greater a reduction in the maximum working capacity. This suggests the need to examine rest allowances for tasks like the IV push (Konz, 1998; Rohmert, 1973). For example, 10 to 30 minutes of uninterrupted work requires a 60% rest allowance (60% of the duration of work period) to minimize the effects of muscular fatigue (Rohmert, 1973). All muscles need to rest after a period of activity, and any muscle that is active for a prolonged period of time may pose an increased risk for WMSD (Veiersted et al., 1993).

Handling and writing should also be classified as important tasks because of the number of occurrences and their respective durations. The increase in handling tasks may be due to the inclusiveness of other tasks (i.e. retrieving and preparing supplies, assisting patients) and may require further analysis. The pharmacy assistants performed about 1 hand effort per minute relating to handling tasks (Figure 3), accounting for about 60% of the workday, whereas both nursing groups performed handling half as much for about

40% of their shift (Figure 4). This may be due to the increased variability of the nurses' work and work area of coverage. Median muscle activity levels ranged from just under 4% (right forearm) up to 7.5% (left forearm) for the pharmacy assistants. A high number of hand efforts, combined with prolonged durations, may lead to an increased risk of WMSD especially for the pharmacy assistants (Akesson et al., 2012; Barr et al., 2004; Bernard et al., 1997).

Similar to their syringe use associated with the drawing of fluid, pharmacy assistants spent just over 10% of the work day writing, with hand efforts occurring 0.3 times per minute. The nurses spent less than half of that time writing, representing only about 0.1 hand efforts per minute. The increase in writing for the pharmacy assistants may be due to the checker role within the job. When checking the mixed treatments (IV bags, syringes, vials) completed by the mixer, the checker scribes initials in multiple areas on every order for quality control. The large variation in the time spent writing is because the time spent in the checker role varies and is determined by the individual and work demands. For pharmacy assistants, the muscle activity that occurred during writing ranged between 3% and 8.5% at the 50^{th} percentile, while the thumb forces were minimal (1% of maximum on the left side).

In addition, pharmacy assistants performed over twice as many hand efforts associated with uncapping, labelling, opening packages, spiking and twisting movements as the nurses. These "point" tasks accounted for almost 3 hand efforts per minute over the work day. In a study of laboratory technicians in a diagnostic tuberculosis laboratory, workers who repeatedly opened and closed small bottles, over prolonged periods of time, presented with repetitive strain injury (Wong et al., 2012). In the current study, twisting hand movements resulted in the highest peak activity levels (58%) and thumb press forces (56%), which may present an increased risk. Although these point tasks do not have an identified duration in this study, it is important to note that these tasks do actually occur over a number of seconds that add up over the course of the day. The noted force levels exceed the intermittent handgrip contraction limits of 17% suggested by Bystrom & Fransson-Hall (1994). In their study, intermittent contractions were defined as contractions of 5 seconds in duration followed by relaxation periods up to 15 seconds. Also, the forces recorded in the current study were exerted by the thumb during pinch grips. It has been noted that pinch grips have notably lower strength than power grips suggesting the need for higher relative forces (Finneran & O'Sullivan, 2013). The peak activity and force observed during these tasks, provides insight with respect to increased WMSD risk given that WMSD have been associated with repetition and high-force exertions (Gallagher & Heberger, 2013, Latko et al., 1999) and strenuous work tasks of short duration (Simonsen et al., 2012). While not monitored as part of the current study, the use of awkward postures was observed (Figure 8). Awkward posture in combination with high force levels, may further increase the risk of WMSD (Viikari-Juntura & Silverstein, 1999; Bernard et al., 1997; McAtamney & Corlett, 1993).

Figure 8. Floor nurses observed to use awkward shoulder posture to 'spike' an IV bag.

In terms of muscular activity over the whole work shift, the left forearm flexors had the greatest activity in all groups (10^{th}, 50^{th}, 90^{th} percentiles), while the right forearm flexors were the lowest (Figure 5). However, even with higher EMG levels on the left side, the activity levels did not exceed the load limits at the 10^{th}, 50^{th}, or 90^{th} set by Jonsson (1982). It should be noted that the low levels of EMG may be due to the collection of generic muscle activity, and may not represent the activity of the finger or thumb flexors. The EMG levels may likely have been higher if the EMG electrodes were located closer to the motor units of the finger and thumb flexors. Also, the use of a pinch grip, in of itself, has been shown to be a risk factor for WMSD (Rempel et al., 2009). Furthermore, when examining the muscular rest of the current study, the left forearm flexors only rested for about 6% of the shift (Figure 6). This equates to a notably high duty cycle (percentage of time that the worker is performing the effort) of 94% thus exceeding the maximum acceptable effort of 1.5% when applied to the equation developed by Potvin (2012). Given the lack of muscular rest identified, the work load of the pharmacy assistants over course of the day (Figure 7) should also be considered because the hand efforts increased back to almost similar levels immediately after the breaks. This further suggests a limited opportunity to rest the arms and hands.

The majority of the hand and syringe tasks were observed to require the use of both hands and workers were primarily right hand dominant (n=12). Left forearm flexor activity was highest across many of the tasks, and confirms an account of a righted handed pharmacy assistant who reported an increased discomfort in the left hand and arm. The higher left arm activity may mainly part due to the left hand ‘holding’, and using a power grip rather than a pinch grip (Rempel et al., 2012; Sheikhzadeh et al., 2009; Asundi et al., 2005). There is evidence that muscle activity for the power grip is higher than for a pinch grip (Finneran & O’Sullivan, 2013). Additionally, the increased flexor activity may suggest the use of neutral and supinated forearm postures during gripping tasks (DiDomizio & Keir, 2010). This is true for the draw task of the pharmacy assistants, specifically of the hand holding the IV bag, vial, or syringe (Figure 9). While the one hand is pinching or performing controlled movements (draw movement), the other is using more of a power grip while the forearm is in a supinated position.

Also, understanding that one floor nurse and 2 lab nurses were left hand dominant, may help explain the increased activity on the left side during the writing tasks. It has been shown that individuals who write using their left hand use more wrist flexion than right handed individuals (Park, 2013) and this is consistent with my finding of increased flexor activity on the left side during the nursing writing tasks.

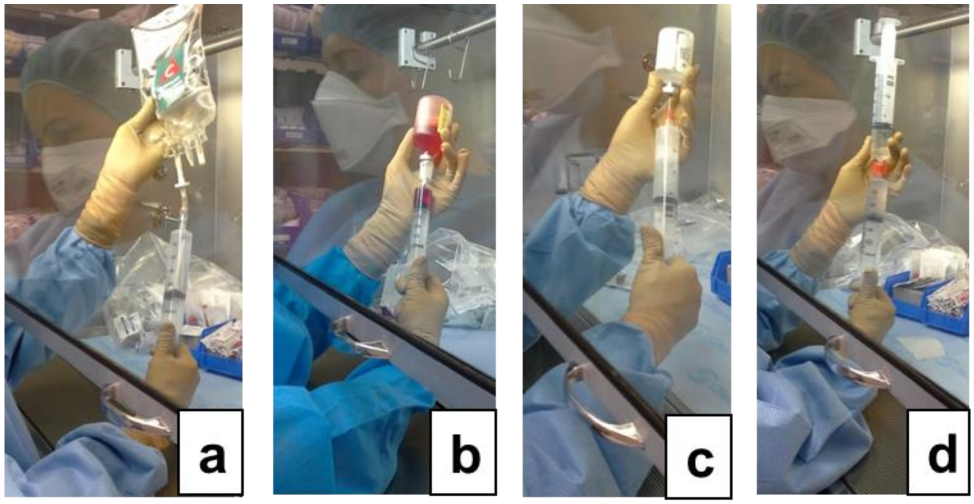

Figure 9. Forearm posture observed of 3 different pharmacy assistants drawing fluid from an IV bag (a), vials (b & c), and syringe (d) using a syringe.

The results of the current study indicate the need for strategies to help lower the risk for WSMD associated with repetition, prolonged duration, and lack of muscular rest. The large variability (standard deviation) found between workers during tasks like handling and writing as well as the noted thumb forces (Table 5), suggests that the workers performed the same tasks differently. This may illustrate why some workers get hurt and others not. The differences may be in part due work experience and the adaptations made as result of the associated discomfort experienced. Reported levels of discomfort associated with the upper limb and motor variability were compared between novice workers and experienced (~ 13 years) workers in a study done by Madeleine (2008). Motor variability was shown to be higher (larger standard deviation) in workers with high experience and results in a decreased risk of developing WMSD (Madeleine, 2008). Thus, the observed inter-subject variability could lead to a potential training protocol as a risk reduction strategy. With respect to muscular rest, optimizing patient scheduling, and the duration and timing of breaks while changing the order of tasks (e.g. avoiding back to back IV push tasks), may prove beneficial (Qin et al., 2014; Bergamasco et al., 1998; Rohmert, 1973).

Changes to the physical elements of the environment and equipment (Piligian et al., 2000; Bergamasco et al., 1998) may also allow for an increase in muscular rest and reduction of repetitive hand efforts. Automation of tasks, specifically related to the use of syringes to draw fluid in the pharmacy assistant role, such as a chemotherapy robot (shown in Appendix E, Figure E1), will reduce both the frequency and duration of the task. The implementation of a robot is currently underway in the pharmacy department where this study was conducted. With this implementation, is it expected that the pharmacy assistants are still required to mix some drugs but the overall number of drugs to be mixed will be reduced. However, during the process of implementation, a few tasks have been reported that may require further assessment. The task of spiking was noted to increase as a result of the robot. Given the EMG and force levels associated with this task (Table 5), this negative effect of the implementation of the robot should not go unnoticed. Furthermore, the robot requires frequent loading of supplies including, syringes, vials, and IV bags throughout the day. Each IV bag requires a ‘clamp’ to be fastened around the access port in order to load it into the robot. This clamp requires 4 additional hand efforts to open and secure it to the bag and, once used, the clamp must be removed from the bag.

Furthermore, concerns were reported with respect to the height of the syringe loading area. The height of the area measures approximately 55", which is just under the 95th percentile shoulder height of the female population (~56"). This height is therefore challenging to access, resulting in frequent reaching postures and presents additional risk with respect to the hand efforts required. A follow-up assessment is required to review these concerns and the results of the current study will provide the background information necessary to guide and support any necessary changes. The impact of this risk reduction strategy emphasizes the value of user testing, and the importance of the interactions between task, workplace layout and equipment design.

As with all studies in the field, there are limitations to the current study. The force sensing resistor (FSR) was used on the pad of the thumb, thus forces during many tasks were not recorded. Also, due to the nature of the tasks, the pressure was not always evenly distributed on the sensor and potentially resulted in lower readings. The type of FSR used accommodated for the functional nature of the work tasks with the intent to minimize interference with hand movements. The FSR signal showed a continuous reduction throughout the day, requiring changing of the sensors at the lunch break, testing the sensors throughout the day and applying a correction during data processing to account for the loss. Abnormal fluctuations in force were recorded for one participant requiring that data to be removed from analysis.

In addition, the sensors and observational software were synchronized using a series of taps on the tablet that occasionally resulted in a lag between the two systems. Every effort was made to 'sync' the two systems over the course of the day. Furthermore, it is possible that workers altered their natural behaviours to either highlight or hide certain aspects of the jobs. The data collections were of different lengths for a variety of reasons both technical and social.

6.1 Conclusion

The method of continuous recording of observed tasks, forearm EMG, and thumb press force allowed for a detailed assessment of hand and syringe use by the nurses and pharmacy assistants who administer and mix chemotherapy drugs. The pharmacy assistants performed over twice as many hand efforts as the nurses and spent 17% of the day using syringes. Nurses spent 10% of the work day performing the manual pushing of treatment using syringes, with continuous low level muscle activity. Over the course of the work day, and across the observed tasks, the left forearm flexors generated the highest muscle activity and only rested for about 6% of the shift. The high number of hand efforts, combined with prolonged durations, and lack of muscular rest show evidence of muscular overload over the course of the shift as well as illustrate that the pharmacy assistants are at higher risk for WMSD. The findings of this study may help explain the documented department injury statistics and ongoing musculoskeletal complaints of the thumb, hand, wrist, and arm as well as support the implementation of the pharmacy robot. The results can further act as a guide for future research of similar syringe tasks and hand demands.

CHAPTER 7

IMPACT AND FUTURE DIRECTIONS

7.1 Impact

The role that the nurses and pharmacy assistants play, within the chemotherapy department, is interconnected by the patients they care for and the importance of the quality service they provide. The link between the roles is essential, as it provides an opportunity for the sharing of skills and the knowledge that will impact the overall quality of patient care and service throughout the organization. The risk reducing strategies presented can be applied across various aspects within the nursing and pharmacy assistant professions.

The results of this study, and strategies presented, not only assist the workers in the professions studied within the chemotherapy department but, on a broader scale, may impact professions who perform similar hand and syringe tasks. Syringe, handling, writing, and other tasks, requiring a pinch grip, not only occur in the chemotherapy department, but they also occur within pharmaceuticals, laboratories, and dietetics. Many hospitals have departments where similar tasks are performed and where medications are administered to patients via syringes or IV bags. These results are far reaching and impact the healthcare sector globally due to the associated patient demands.

Another profession that may be impacted is that of medical technologists, who fill IV bags with specific solutions from vials. This requires the medical laboratory assistant, or technologist, to insert (spike) tubing into a vial. Approximately 3 to 4 vials are required per dose with up to 20 patients that may require the medication. In dietetics, specifically, the dietetic assistants within neonatal intensive care departments, mix mother's milk and infant formula using syringes because some infants require feeding via a syringe pump. If this is the case, the formula is mixed and measured into the syringe with up to 10 syringes required per patient. Mixing involves drawing up the mixture to a required volume, and then pressing the syringe plunger to dispense any additional fluid (Figure 10). Mixing is done within a biological safety cabinet, similar to the pharmacy assistants, and one dietetic assistant may be required to mix for up to 120 minutes at a time. The supplies, including the syringes are also individually wrapped, creating additional hand efforts.

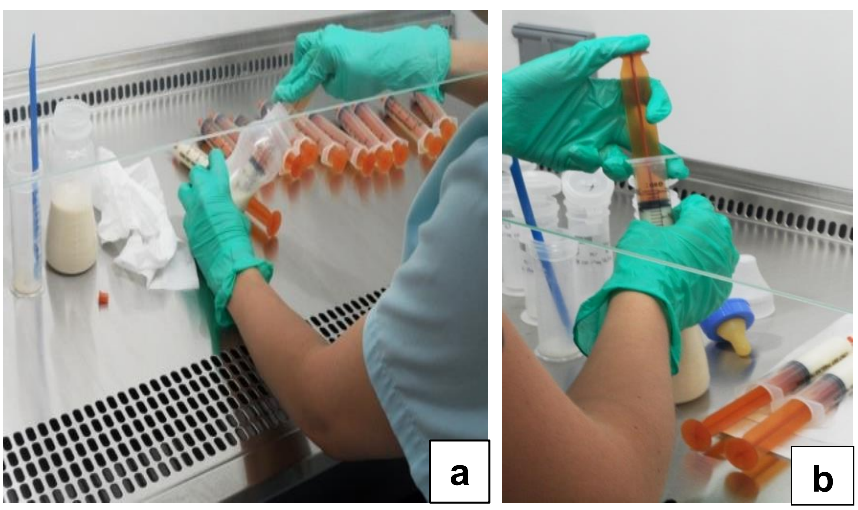

Figure 10. Dietetic assistants using 30 ml and 60 ml syringes to mix mothers milk and infant formula within a biological safety cabinet (similar to the pharmacy assistants), a) dietetic assistant drawing up the milk formula into a syringe, b) and dispensing the milk to meet volume requirements.

Lastly, nurses who work on IV teams, and travel throughout the hospital to perform bloodwork tasks, as well as the nurses who perform blood work tasks within out-patient clinics, perform similar tasks specifically related to the lab nurses that were studied. They also start IVs and flush intravascular devices.

7.2 Future Directions

Injury occurrence reports, and observations during risk assessments, provided the motivation to study the hand and syringe tasks in the healthcare setting. However, the occurrence reports may not have portrayed the risk as being as great as was verbally identified by workers in the department. Therefore, use of a discomfort survey prior to knowledge of the study may have further illustrated the discomfort cited by the workers in the department. Ratings of perceived exertion were recorded during collection, however the frequency of reporting was inconsistent and, therefore, was not complete enough to report.

Awkward upper limb postures were observed throughout the study but not monitored. Understanding that risk factors for WMSD often act in combination to further increase the risk, monitoring and assessment of the upper limb postures used throughout the study would have added value to the overall results. Therefore, use of a posture assessment method like that of the rapid upper limb assessment (RULA) created by McAtamney & Corlett, (1993) in combination with muscle activity of the shoulder muscles, may have proved beneficial in this study.

Data collection in the field has challenges and limitations. The force collection proved to be the most difficult to control, due to the nature of the tasks and the requirements for workers to wear gloves. The goal was to collect the thumb forces associated with syringe and pinch tasks, however, the tasks performed and hand postures used did not distribute the pressure evenly on the sensor and therefore did not record force accurately. Given these challenges, the force readings in this study should be used to provide overall insight into the tasks. EMG collection, specific to tasks requiring pinch grip, is also challenging in the field. The sensors were placed to gather generic forearm muscle activity, therefore, the activity of specific muscles involved in tasks requiring pinch grips were not effectively illustrated. In future studies, it would be helpful to investigate alternative methods to record EMG and the forces related to pinch grips associated with these tasks.

The recruitment of participants was more challenging than initially thought due to both worker and investigator time constraints. Thus, participants were accepted regardless of their age, weight, and whether they were right or left handed. Also, the sample size was small and did not allow for appropriate statistical power. Therefore, if the opportunity exists, future studies may need to investigate alternative recruitment strategies. To increase the sample size, it may be beneficial to include those other occupations, such as the dietetic assistants, medical lab assistants, and the IV nurses who are familiar with the use of syringes and repetitive hand efforts.

Further to syringe design, a study was done investigating the internal joint forces when pipetting, and used kinematics and force sensors to create a multi-body biomechanical model. It was proposed that the results be used to help design pipettes to minimize associated risk of injury (Wu et al., 2012). It would be interesting and beneficial to complete a similar biomechanical analysis of the hand when using a syringe and explore the internal joint forces to determine a foundation for a well-designed syringe.

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Appendix A: Figures with mean number and duration of tasks.

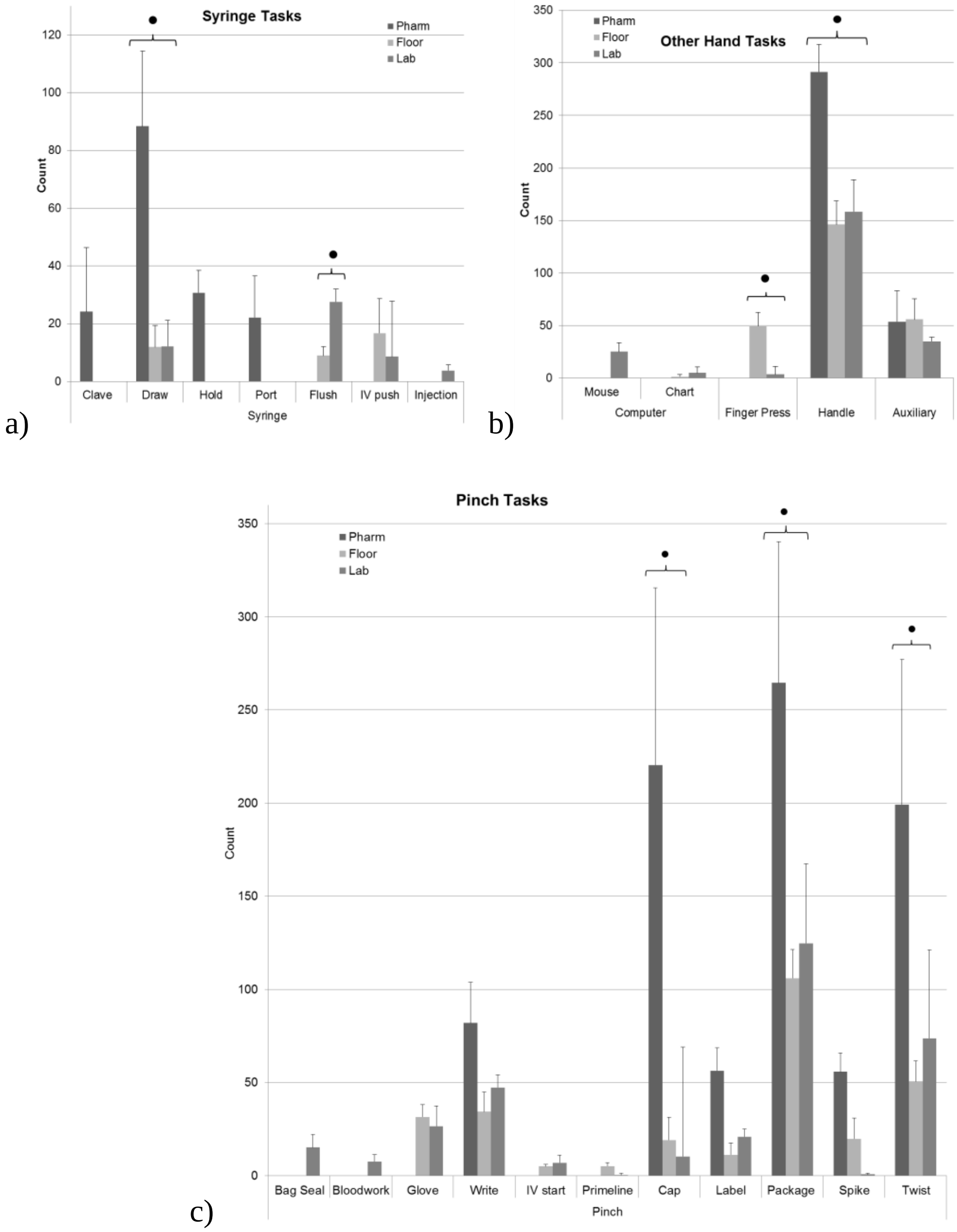


Figure A1. Mean number of hand tasks for pharmacy assistants, floor and lab nurses (with standard deviation, n=15). a) Syringe tasks, b) other hand tasks, c) pinch tasks (including point events 'cap', 'label', 'package', 'spike', 'twist'). Chart refers to electronic documentation. Auxiliary tasks include scheduled break time, talking, walking, and waiting for orders or patients (Significance indicated by solid circle (●).

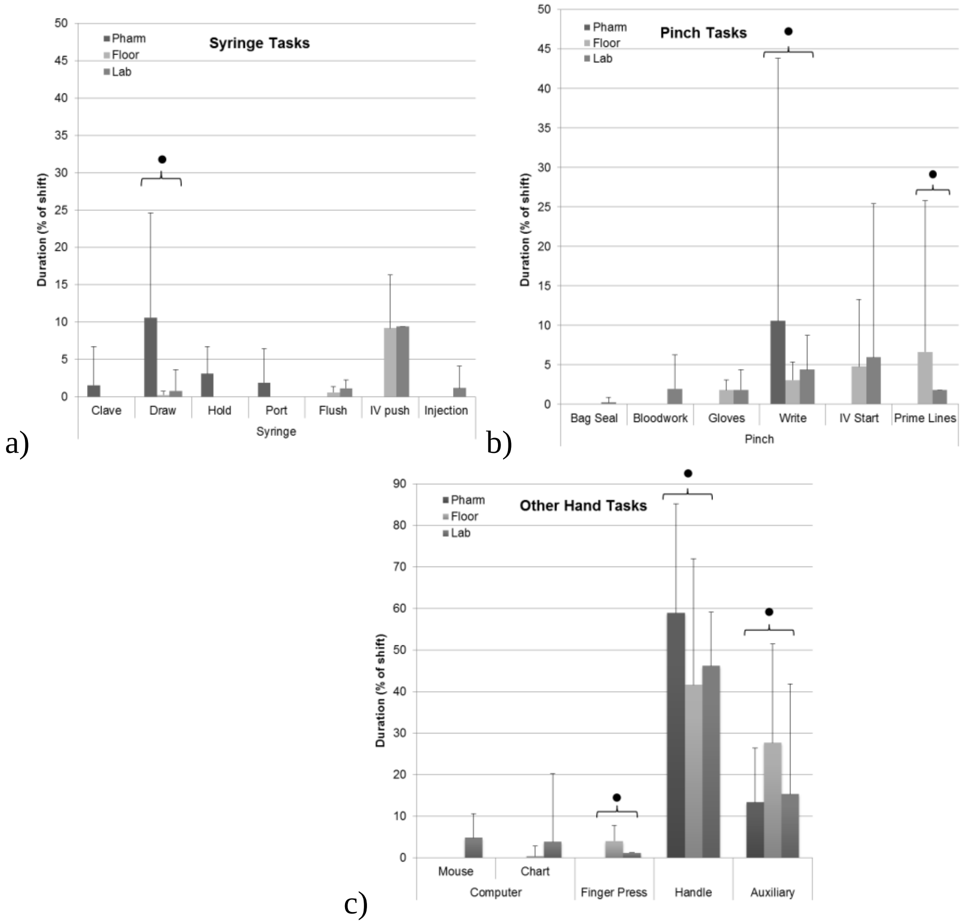


Figure A2. Cumulative task duration at a percentage of shift time for pharmacy assistants, floor and lab nurses (with standard deviation, n=15). a) Syringe tasks, b) pinch tasks, c) other hand tasks. “Chart” refers to electronic documentation. (Significance indicated between groups with a solid circle (●).

Appendix B: Tables for APDF EMG and Thumb Force Values

Table A. The APDF EMG (% MVE) values of shift associated with muscle compartment and group with standard deviation (n=15).

Muscle Compartment	Probability	Floor Nurse	Lab Nurse	Pharmacy
Left Extensor	0.1	0.8 ± 0.6	0.3 ± 0.1	0.8 ± 0.3
	0.5	4.7 ± 1.5	3.6 ± 1.5	6.2 ± 2.4
	0.9	15.7 ± 2.1	13.6 ± 5.5	15.7 ± 4.6
Right Extensor	0.1	0.4 ± 0.3	0.2 ± 0.1	0.4 ± 0.3
	0.5	2.3 ± 1.1	1.9 ± 1.0	3.1 ± 1.3
	0.9	8.9 ± 2.6	7.8 ± 3.6	10.6 ± 3.7
Left Flexor	0.1	0.9 ± 1.0	0.6 ± 0.4	1.0 ± 0.5
	0.5	7.0 ± 3.4	5.5 ± 1.2	6.9 ± 2.3
	0.9	20.8 ± 6.3	15.2 ± 2.9	16.5 ± 4.4
Right Flexor	0.1	0.4 ± 0.2	0.3 ± 0.1	0.3 ± 0.2
	0.5	2.7 ± 0.8	1.9 ± 0.5	3.4 ± 2.4
	0.9	10.3 ± 2.0	7.3 ± 2.0	10.1 ± 5.1

Table B. The APDF EMG (% MVE) values of tasks associated with muscle compartment and group with standard deviation (n=15). The asterisk represents that the task was not performed by the group.

Muscle Compartment	Task	Probability	Floor Nurse	Lab Nurse	Pharmacy
Left Extensor	clave	0.1	*	*	2.3 ± 1.5
		0.5	*	*	7.0 ± 3.0
		0.9	*	*	18.8 ± 5.4
	port	0.1	*	*	1.5 ± 0.7
		0.5	*	*	5.5 ± 2.9
		0.9	*	*	13.6 ± 4.0
	hold	0.1	*	*	0.8 ± 0.4
		0.5	*	*	3.2 ± 1.8
		0.9	*	*	10.6 ± 2.4
	draw	0.1	4.2 ± 1.0[a]	2.1 ± 1.9	3.0 ± 0.1
		0.5	10.8 ± 3.4	6.1 ± 3.4	6.6 ± 1.9
		0.9	19.0 ± 5.0	13.7 ± 6.7	14.0 ± 3.2
	flush	0.1	3.8 ± 3.5	2.5 ± 1.5	*
		0.5	9.7 ± 6.5	7.7 ± 6.0	*
		0.9	18.8 ± 7.4	16.0 ± 10.6	*
	injection	0.1	*	3.2 ± 3.9	*

		0.5	*	6.0 ± 4.1	*
		0.9	*	9.8 ± 3.4	*
	IV push	0.1	0.7 ± 0.2	0.1 ± 0.1	*
		0.5	2.3 ± 0.3	0.3 ± 0.7	*
		0.9	6.9 ± 2.7	1.1 ± 2.4	*
	bag seal	0.1	*	4.3 ± 1.9	*
		0.5	*	9.1 ± 3.4	*
		0.9	*	16.8 ± 5.3	*
	bloodwork	0.1	*	1.1 ± 0.8	*
		0.5	*	6.1 ± 4.2	*
		0.9	*	13.8 ± 7.5	*
	finger press	0.1	0.7 ± 0.4	0.1 ± 0.2	*
		0.5	2.8 ± 2.0	0.6 ± 1.3	*
		0.9	8.7 ± 3.0	1.9 ± 4.3	*
	gloves	0.1	3.0 ± 1.0	2.2 ± 1.0	*
		0.5	10.4 ± 1.1	8.8 ± 3.3	*
		0.9	24.6 ± 3.4	23.2 ± 6.8	*
	IV start	0.1	3.7 ± 2.9	1.7 ± 0.5	*
		0.5	8.0 ± 2.5	6.3 ± 1.7	*
		0.9	18.1 ± 3.1	14.9 ± 4.3	*
	prime lines	0.1	2.2 ± 1.0	0.5 ± 1.0	*
		0.5	8.2 ± 1.1	1.5 ± 3.3	*
		0.9	19.2 ± 1.6	3.6 ± 8.1	*
	write	0.1	2.1 ± 1.5	1.9 ± 1.5	2.0 ± 1.9
		0.5	7.1 ± 6.6	7.7 ± 8.5	4.8 ± 2.6
		0.9	17.8 ± 15.6	18.6 ± 19.5	13.0 ± 3.8
	mouse	0.1	*	0.2 ± 0.1	*
		0.5	*	1.1 ± 0.7	*
		0.9	*	7.1 ± 4.1	*
	chart	0.1	1.1 ± 1.5	0.1 ± 0.1	*
		0.5	2.1 ± 2.9	0.6 ± 0.8	*
		0.9	5.4 ± 7.6	4.3 ± 4.0	*
	handle	0.1	1.4 ± 0.7	0.6 ± 0.2	1.4 ± 0.4
		0.5	6.7 ± 1.3[b]	5.2 ± 2.2	7.4 ± 2.5
		0.9	17.5 ± 2.1	15.3 ± 5.3	17.2 ± 4.8
Right Extensor	clave	0.1	*	*	1.4 ± 0.8
		0.5	*	*	5.8 ± 2.5

		0.9	*	*	12.6 ± 4.5
	port	0.1	*	*	0.8 ± 0.4
		0.5	*	*	3.2 ± 2.4
		0.9	*	*	9.2 ± 7.0
	hold	0.1	*	*	0.5 ± 0.3
		0.5	*	*	2.1 ± 1.4
		0.9	*	*	7.4 ± 5.0
	draw	0.1	1.4 ± 0.5	0.8 ± 0.7	1.0 ± 0.8
		0.5	3.7 ± 1.5	2.3 ± 1.6	3.1 ± 2.6
		0.9	8.2 ± 2.4	5.6 ± 4.2	8.6 ± 4.7
	flush	0.1	1.2 ± 0.8	0.8 ± 0.7	*
		0.5	3.3 ± 1.8	2.9 ± 2.6	*
		0.9	12.9 ± 6.6	7.9 ± 5.8	*
	injection	0.1	*	1.0 ± 1.0	*
		0.5	*	2.0 ± 1.4	*
		0.9	*	4.6 ± 2.6	*
	IV push	0.1	0.3 ± 0.2	0.01 ± 0.04	*
		0.5	1.0 ± 0.5	0.1 ± 0.1	*
		0.9	3.3 ± 1.3	0.2 ± 0.4	*
	bag seal	0.1	*	2.3 ± 2.0	*
		0.5	*	4.7 ± 3.7	*
		0.9	*	9.7 ± 7.3	*
	bloodwork	0.1	*	0.4 ± 0.3	*
		0.5	*	2.0 ± 1.3	*
		0.9	*	6.8 ± 4.5	*
	finger press	0.1	0.5 ± 0.5	0.04 ± 0.1	*
		0.5	2.3 ± 2.0	0.3 ± 0.6	*
		0.9	6.1 ± 3.2	1.1 ± 2.5	*
	gloves	0.1	1.1 ± 0.5	1.1 ± 0.7	*
		0.5	4.8 ± 2.1	4.8 ± 3.0	*
		0.9	13.4 ± 4.6	12.9 ± 7.2	*
	IV start	0.1	1.1 ± 0.5	0.6 ± 0.3	*
		0.5	3.1 ± 1.3	2.5 ± 1.5	*
		0.9	8.6 ± 2.2	7.2 ± 4.3	*
	prime lines	0.1	0.8 ± 0.3	0.1 ± 0.2	*
		0.5	3.5 ± 1.1	0.4 ± 0.8	*
		0.9	11.5±3.4	1.3 ± 2.8	*

	write	0.1	1.5 ± 0.4	0.8 ± 0.5	0.7 ± 0.4
		0.5	4.9 ± 1.2	4.3 ± 3.5	2.9 ± 1.3
		0.9	12.4 ± 6.6	10.4 ± 7.3	9.3 ± 4.1
	mouse	0.1	*	0.3 ± 0.5	*
		0.5	*	1.0 ± 0.6	*
		0.9	*	4.9 ± 1.9	*
	chart	0.1	0.1 ± 0.2	0.1 ± 0.1	*
		0.5	0.4 ± 0.6	0.6 ± 0.6	*
		0.9	1.9 ± 2.8	3.1 ± 2.9	*
	handle	0.1	0.7 ± 0.5	0.4 ± 0.2	0.8 ± 0.6
		0.5	3.2 ± 1.3	2.6 ± 1.3	3.9 ± 1.8
		0.9	10.1 ± 2.9	9.1 ± 3.5	11.8 ± 4.2
Left Flexor	clave	0.1	*	*	2.6 ± 2.6
		0.5	*	*	8.4 ± 4.4
		0.9	*	*	19.1 ± 5.7
	port	0.1	*	*	3.9 ± 2.4
		0.5	*	*	9.8 ± 3.8
		0.9	*	*	20.2 ± 6.2
	hold	0.1	*	*	0.5 ± 0.5
		0.5	*	*	3.1 ± 1.7
		0.9	*	*	12.1 ± 1.8
	draw	0.1	6.1 ± 2.4	2.7 ± 1.4	2.7 ± 1.3
		0.5	15.0 ± 1.8	8.1 ± 2.0	7.1 ± 2.6
		0.9	24.1 ± 2.0	17.4 ± 5.2	17.4 ± 4.1
	flush	0.1	3.5 ± 1.3	2.5 ± 0.5	*
		0.5	11.5 ± 6.1	7.2 ± 2.3	*
		0.9	27.4 ± 11.0	18.4 ± 6.2	*
	injection	0.1	*	4.4 ± 3.5	*
		0.5	*	5.8 ± 3.8	*
		0.9	*	11.0 ± 4.5	*
	IV push	0.1	1.1 ± 1.2	0.1 ± 0.2	*
		0.5	3.2 ± 2.5	0.4 ± 0.9	*
		0.9	8.7 ± 5.4	2.2 ± 4.9	*
	bag seal	0.1	*	5.0 ± 1.2	*
		0.5	*	9.9 ± 2.8	*
		0.9	*	18.11 ± 5.4	*
	bloodwork	0.1	*	2.1 ± 0.9	*

		0.5	*	6.6 ± 1.4	*
		0.9	*	17.5 ± 12.2	*
	finger press	0.1	2.3 ± 2.0	0.2 ± 0.4	*
		0.5	7.8 ± 3.7	0.8 ± 1.9	*
		0.9	15.5 ± 6.1	5.6 ± 7.7	*
	gloves	0.1	4.7 ± 1.6	2.8 ± 1.1	*
		0.5	14.2 ± 4.4	10.3 ± 2.3	*
		0.9	33.4 ± 9.3	26.1 ± 6.6	*
	IV start	0.1	3.7 ± 2.9	2.5 ± 1.8	*
		0.5	10.1 ± 4.6	7.7 ± 2.0	*
		0.9	22.0 ± 7.6	15.2 ± 3.2	*
	prime lines	0.1	3.4 ± 1.9	0.7 ± 1.6	*
		0.5	11.6 ± 4.2	2.3 ± 5.0	*
		0.9	26.8 ± 8.7	4.9 ± 10.9	*
	write	0.1	4.9 ± 2.5	1.9 ± 0.8	3.6 ± 1.9
		0.5	12.8 ± 4.7	7.5 ± 2.3	8.5 ± 4.2
		0.9	23.5 ± 9.6	15.9 ± 3.8	14.8 ± 4.8
	mouse	0.1	*	2.0 ± 1.5	*
		0.5	*	8.1 ± 2.8	*
		0.9	*	14.9 ± 2.4	*
	chart	0.1	3.0 ± 4.8	1.1 ± 1.4	*
		0.5	5.1 ± 7.5	4.6 ± 4.4	*
		0.9	8.6 ± 12.1	7.9 ± 7.4	*
	handle	0.1	1.7 ± 1.1	1.0 ± 0.6	1.7 ± 0.3
		0.5	9.7 ± 3.5	6.2 ± 2.1	7.5 ± 1.9
		0.9	23.5 ± 6.5	16.5 ± 4.1	17.6 ± 4.1
Right Flexor	clave	0.1	*	*	2.3 ± 2.5
		0.5	*	*	6.0 ± 4.0
		0.9	*	*	13.1 ± 6.8
	port	0.1	*	*	2.5 ± 2.2
		0.5	*	*	5.7 ± 3.3
		0.9	*	*	13.0 ± 7.6
	hold	0.1	*	*	0.2 ± 0.2
		0.5	*	*	1.6 ± 2.0
		0.9	*	*	6.6 ± 4.4
	draw	0.1	2.4 ± 0.3	1.3 ± 0.1	1.1 ± 0.9
		0.5	5.4 ± 0.9	3.3 ± 1.1	4.3 ± 2.5

		0.9	13.3 ± 3.7	7.5 ± 2.5	11.0 ± 4.5
	flush	0.1	1.3 ± 0.5	1.2 ± 0.3	*
		0.5	3.9 ± 1.3	3.4 ± 1.3	*
		0.9	12.5 ± 4.6	8.6 ± 4.0	*
	injection	0.1	*	1.3 ± 1.3	*
		0.5	*	2.6 ± 1.9	*
		0.9	*	4.9 ± 3.5	*
	IV push	0.1	0.5 ± 0.2	0.1 ± 0.2	*
		0.5	1.0 ± 0.5	0.4 ± 0.8	*
		0.9	3.7 ± 1.3	0.7 ± 1.6	*
	bag seal	0.1	*	1.5 ± 0.8	*
		0.5	*	3.4 ± 0.9	*
		0.9	*	7.5 ± 2.9	*
	bloodwork	0.1	*	1.0 ± 0.7	*
		0.5	*	2.9 ± 1.8	*
		0.9	*	6.6 ± 3.2	*
	finger press	0.1	0.7 ± 0.3	0.1 ± 0.3	*
		0.5	3.3 ± 1.1	0.5 ± 1.1	*
		0.9	8.2 ± 2.2	1.8 ± 4.0	*
	gloves	0.1	1.5 ± 0.5	1.2 ± 0.4	*
		0.5	5.6 ± 0.9	4.4 ± 1.1	*
		0.9	15.4 ± 3.3	13.0 ± 3.2	*
	IV start	0.1	1.0 ± 0.5	0.6 ± 0.3	*
		0.5	3.4 ± 1.1	2.5 ± 1.2	*
		0.9	9.6 ± 1.9	7.2 ± 3.5	*
	prime lines	0.1	1.1 ± 0.4	0.2 ± 0.5	*
		0.5	4.1 ± 0.8	0.9 ± 1.9	*
		0.9	13.0 ± 3.5	2.4 ± 5.4	*
	write	0.1	1.7 ± 0.6	0.8 ± 0.4	1.0 ± 1.0
		0.5	5.9 ± 1.3	3.9 ± 1.7	3.7 ± 2.7
		0.9	11.8 ± 4.5	8.8 ± 3.4	8.5 ± 4.5
	mouse	0.1	*	0.6 ± 0.3	*
		0.5	*	1.4 ± 0.5	*
		0.9	*	4.6 ± 1.5	*
	chart	0.1	0.3 ± 0.5	0.2 ± 0.2	*
		0.5	1.2 ± 1.8	0.6 ± 0.5	*
		0.9	3.2 ± 4.5	2.3 ± 2.1	*

	handle	0.1	0.7 ± 0.3	0.6 ± 0.3	0.6 ± 0.4
		0.5	3.9 ± 0.8	2.6 ± 0.8	3.7 ± 2.4
		0.9	11.9 ± 2.0	8.7 ± 2.3	10.9 ± 5.7

Table C. The APDF thumb press force (% MVF) values of shift associated with muscle compartment and group with standard deviation (n=14).

Muscle Compartment	Probability	Floor Nurse	Lab Nurse	Pharmacy
Left Side	0.1	0.5 ± 0.3	0.3 ± 0.1	0.3 ± 0.2
	0.5	0.9 ± 0.5	0.8 ±0.3	0.8 ± 0.5
	0.9	2.5 ± 1.3	2.2 ± 0.6	2.7 ± 1.4
Right Side	0.1	0.1 ± 0.1	0.8 ± 1.8	0.1 ± 0.1
	0.5	0.4 ± 0.5	1.1 ± 2.2	0.4 ± 0.6
	0.9	1.7 ± 1.9	5.6 ± 6.0	2.3 ± 2.1

Table D. The APDF thumb press force (% MVF) values of tasks associated with muscle compartment and group with standard deviation (n=14). The asterisk represents that the task was not performed by the group.

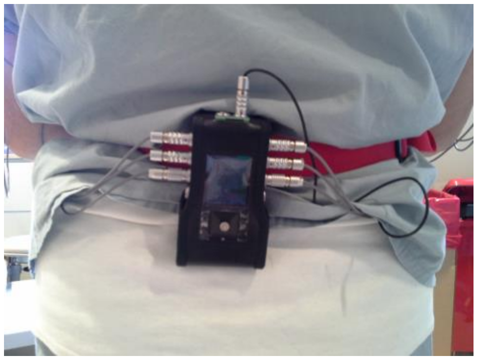
Muscle Compartment	Task	Probability	Floor Nurse	Lab Nurse	Pharmacy
Left Side	clave	0.1	*	*	0.5 ± 0.4
		0.5	*	*	1.0 ± 0.7
		0.9	*	*	3.3 ± 1.7
	port	0.1	*	*	0.6 ± 0.6
		0.5	*	*	1.2 ± 1.1
		0.9	*	*	2.9 ± 1.5
	hold	0.1	*	*	0.5 ± 0.3
		0.5	*	*	1.2 ± 0.9
		0.9	*	*	2.6 ± 1.3
	draw	0.1	0.9 ± 0.2	0.6 ± 0.2	0.6 ± 0.5
		0.5	1.9 ± 0.8	1.9 ± 0.7	1.6 ± 1.4
		0.9	6.8 ± 3.7	5.2 ± 2.5	4.7 ± 3.2
	flush	0.1	1.0 ± 0.8	0.5 ± 0.2	*
		0.5	1.9 ± 1.1	1.5 ± 0.8	*
		0.9	11.4 ± 9.1	6.6 ± 5.7	*
	injection	0.1	*	0.7 ± 0.5	*
		0.5	*	1.1 ± 0.7	*
		0.9	*	2.0 ± 1.3	*
	IV push	0.1	0.7 ± 0.7	0.2 ± 0.4	*
		0.5	1.3 ± 1.1	0.5 ± 1.2	*
		0.9	3.0 ± 2.1	1.1 ± 2.4	*
	bag seal	0.1	*	0.4 ± 0.2	*
		0.5	*	1.3 ± 0.4	*
		0.9	*	7.4 ± 3.0	*

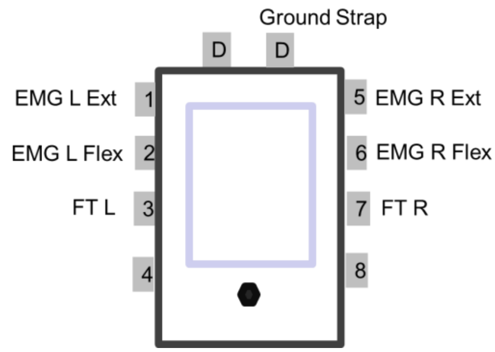
	bloodwork	0.1	*	0.5 ± 0.1	*
		0.5	*	1.3 ± 0.5	*
		0.9	*	6.9 ± 2.5	*
	gloves	0.1	0.5 ± 0.3	0.5 ± 0.2	*
		0.5	1.0 ± 0.7	0.9 ± 0.3	*
		0.9	3.1 ± 1.0	3.2 ± 2.4	*
	finger press	0.1	0.5 ± 0.6	0.4 ± 0.1	*
		0.5	1.0 ± 0.9	0.3 ± 0.2	*
		0.9	2.9 ± 2.4	0.9 ± 0.6	*
	IV start	0.1	0.6 ± 0.4	0.4 ± 0.2	*
		0.5	1.1 ± 0.7	0.7 ± 0.3	*
		0.9	3.1 ± 1.0	2.2 ± 0.6	*
	prime lines	0.1	0.4 ± 0.5	0.1 ± 0.2	*
		0.5	1.4 ± 1.0	0.2 ± 0.4	*
		0.9	4.2 ± 2.0	1.0 ± 2.3	*
	write	0.1	0.6 ± 0.4	0.5 ± 0.1	0.3 ± 0.2
		0.5	1.1 ± 0.6	1.1 ± 0.4	1.0 ± 0.7
		0.9	4.0 ± 2.0	3.0 ± 1.5	1.9 ± 0.8
	mouse	0.1	*	0.7 ± 0.8	*
		0.5	*	1.0 ± 0.9	*
		0.9	*	1.9 ± 1.1	*
	chart	0.1	0.6 ± 0.3	0.5 ± 0.2	*
		0.5	0.8 ± 0.3	0.9 ± 0.5	*
		0.9	1.1 ± 0.2	1.3 ± 0.7	*
	handle	0.1	0.5 ± 0.3	0.4 ± 0.2	0.3 ± 0.2
		0.5	1.0 ± 0.4	0.8 ± 0.3	0.7 ± 0.5
		0.9	3.1 ± 0.9	2.3 ± 1.0	2.9 ± 1.4
Right Side	clave	0.1	*	*	0.1 ± 0.1
		0.5	*	*	0.2 ± 0.3
		0.9	*	*	1.2 ± 0.9
	port	0.1	*	*	0.1 ± 0.1
		0.5	*	*	0.5 ± 0.7
		0.9	*	*	4.3 ± 4.3
	hold	0.1	*	*	0.1 ± 0.1
		0.5	*	*	0.4 ± 0.6
		0.9	*	*	1.8 ± 1.4
	draw	0.1	0.7 ± 0.5	5.5 ± 12.0	0.2 ± 0.2

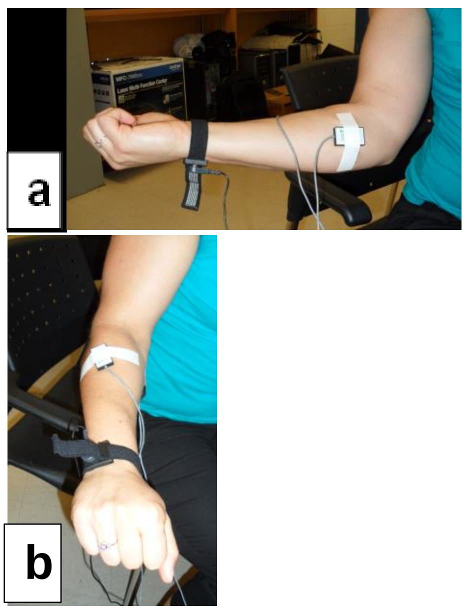
		0.5	2.2 ± 1.8	6.3 ± 11.8	1.3 ± 1.8
		0.9	7.0 ± 3.7	9.8 ± 12.9	10.3 ± 7.8
	flush	0.1	0.2 ± 0.2	5.2 ± 11.5	*
		0.5	0.5 ± 0.5	5.9 ± 12.4	*
		0.9	5.7 ± 5.1	10.4 ± 15.6	*
	injection	0.1	*	1.2 ± 2.1	*
		0.5	*	2.1 ± 2.3	*
		0.9	*	4.2 ± 1.7	*
	IV push	0.1	0.1 ± 0.1	0.03 ± 0.1	*
		0.5	0.2 ± 0.2	0.1 ± 0.2	*
		0.9	1.9 ± 2.4	0.4 ± 0.8	*
	bag seal	0.1	*	0.0 ± 0.0	*
		0.5	*	1.8 ± 3.4	*
		0.9	*	8.7 ± 10.5	*
	bloodwork	0.1	*	0.04 ± 0.1	*
		0.5	*	2.0 ± 2.7	*
		0.9	*	7.6 ± 4.6	*
	gloves	0.1	0.1 ± 0.1	0.7 ± 1.4	*
		0.5	0.3 ± 0.3	1.2 ± 2.3	*
		0.9	1.7 ± 1.2	7.9 ± 9.6	*
	finger press	0.1	0.1 ± 0.2	0.0 ± 0.0	*
		0.5	0.2 ± 0.3	0.3 ± 0.02	*
		0.9	0.9 ± 0.9	0.9 ± 0.4	*
	IV start	0.1	0.03 ± 0.1	0.1 ± 0.1	*
		0.5	0.3 ± 0.3	0.9 ± 1.7	*
		0.9	2.2 ± 1.3	2.2 ± 2.2	*
	prime lines	0.1	0.2 ± 0.4	0.0 ± 0.0	*
		0.5	0.5 ± 0.9	0.1 ± 0.2	*
		0.9	2.9 ± 3.2	0.8 ± 1.8	*
	write	0.1	0.1 ± 0.1	1.0 ± 2.1	0.1 ± 0.1
		0.5	1.6 ± 1.7	1.8 ± 3.7	0.2 ± 0.2
		0.9	6.0 ± 5.8	11.9 ± 13.7	1.5 ± 1.7
	mouse	0.1	*	0.9 ± 2.7	*
		0.5	*	1.1 ± 3.0	*
		0.9	*	2.6 ± 3.7	*
	chart	0.1	0.4 ± 0.1	2.3 ± 4.5	*
		0.5	0.7 ± 0.4	2.6 ± 4.9	*

		0.5	1.2 ± 0.6	3.7 ± 5.4	*
	handle	0.1	0.1 ± 0.1	0.8 ± 1.7	0.1 ± 0.1
		0.5	0.4 ± 0.5	1.2 ± 2.3	0.2 ± 0.3
		0.9	2.0 ± 1.9	8.7 ± 9.9	1.7 ± 1.2

Appendix C: DataLOG Setup and EMG sensor locations







a) flexors b) extensors

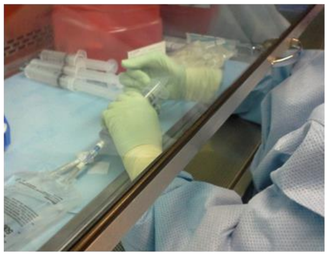
Appendix D: Hand Postures

Chuck

Thenar

Chuck Variation

Two-handed



Palm

Lateral

Appendix E: Chemotherapy Mixing Robot

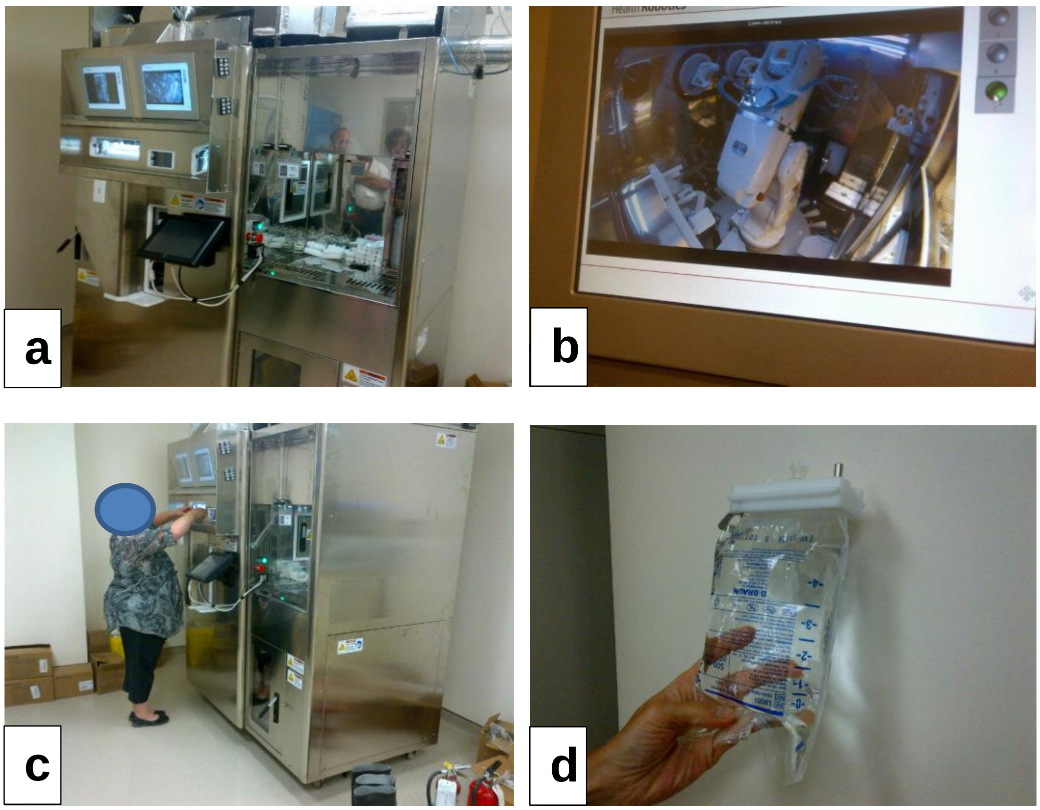
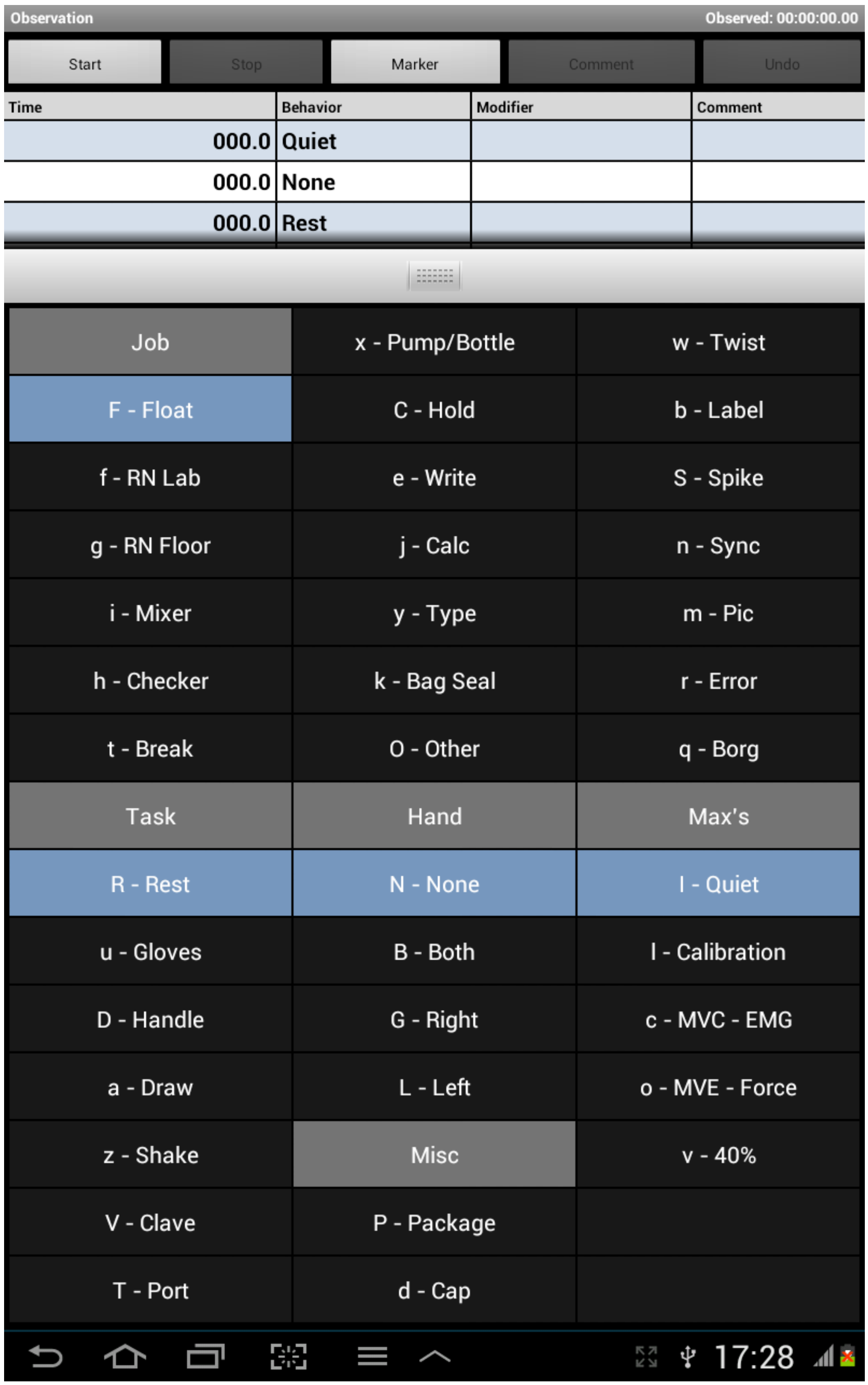


Figure E1. The new chemotherapy robot being installed in the Chemotherapy Systemic Pharmacy. a) the control panel – touch screen, b) view from inside – the robot itself, c) syringe loading height is 55”, d) ‘clasp’ attachment required for each IV bag (removed once IV bag used)

Appendix F: Coding of hand and syringe tasks on tablet



Appendix G: Ethics Consent Form

McMaster University
Inspiring Innovation and Discovery

PARTICIPANT INFORMATION SHEET

TITLE OF STUDY: Assessment of musculoskeletal disorder risk with syringe use and hand tasks in chemotherapy suite Nurses and Pharmacy Technicians

Victoria MacDonald, HBK, BA (Psychology), MSc Candidate, Department of Kinesiology, Faculty of Science, McMaster University

Peter J Keir, PhD, Department of Kinesiology, Faculty of Science, McMaster University

Funding Source: Centre of Research Expertise for the Prevention of Musculoskeletal Disorders (CRE-MSD)

You are being invited to participate in a study conducted by Victoria MacDonald because you are a Nurse or Pharmacy Technician working in the Chemotherapy Suite at the Juravinski Cancer Centre. The study will assess the tasks (syringe use), forces, and muscle activity required when mixing or administering chemotherapy drugs.

In order to decide whether or not you want to be a part of this research study, you should understand what is involved and the potential risks and benefits. This form gives detailed information about the research study, which will be discussed with you. Once you understand the study, you will be asked to sign this form if you wish to participate. Please take your time to make your decision. Feel free to discuss it with your friends and family.

WHY IS THIS RESEARCH BEING DONE?

Musculoskeletal injuries (to ligaments, tendons, muscles) are common in healthcare workers. Workers who administer medication using a syringe may be at an increased risk for musculoskeletal injury, especially of the thumb. Nurses "push" these medications at very low rates for up to 30 minutes at a time, leading to constant efforts of long duration. They also perform this task several times per day. Pharmacy Technicians also use syringes to repetitively mix the chemotherapy drugs for up to 90 minutes at a time. Hand postures and grips vary throughout the use of a syringe due to the changing length of the plunger, discomfort and fatigue. This study will observe the tasks and postures required, and measure force and muscle activity of the forearm muscles of workers throughout their shift. This study will help create guidelines for syringe use and redesigning the way the jobs are performed to help protect the workers from undue strain.

WHAT IS THE PURPOSE OF THIS STUDY?

The purpose of this study is to examine hand actions and tasks required of workers involved with chemotherapy drug administration. Observations of task frequency and duration will be combined with force and muscle activity data to establish and propose guidelines to reduce the risk of musculoskeletal injury associated with syringe use by the specialized nurses and Pharmacy Technicians over a 7.5 hour shift.

WHAT WILL MY RESPONSIBILITIES BE IF I TAKE PART IN THE STUDY?

If you volunteer to participate in this study, we will ask you to do the following things:

You will be observed and monitored throughout your 7.5 hour shift while you perform your usual tasks. We will monitor muscle activity (EMG) and force data will be collected simultaneous to recorded observations. Specialized software will be used to document the frequency and duration of hand tasks, syringe work, and associated postures.

To be consistent for all participants, we will start at 8 AM. At this time, you will be asked for a brief history (age, previous injury, hand dominance) and we will measure your height, weight and hand size (palm length, finger length, hand breath, hand span, thumb length).

To collect the activity of your muscles, small electrodes will be placed on your forearm at the start of your shift. You will also be asked to use a small force transducer on the end of the syringe plunger to record the force applied when you are pressing the plunger. The transducer will be carried with you for the duration of the shift and will be disinfected between syringes.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?

No additional risks and discomforts are expected beyond those associated with your work tasks.

HOW MANY PEOPLE WILL BE IN THIS STUDY?

Fifteen female Registered Nurses and Pharmacy Technicians, between the ages of 20-60 years old, working in the Chemotherapy Suite and Systemic Pharmacy within the JCC at HHS, will be recruited.

WHAT ARE THE POSSIBLE BENEFITS FOR ME AND/OR FOR SOCIETY?

The research will help determine musculoskeletal injury risk reduction strategies such as appropriate work flow, postures, and forces for hand tasks (i.e. syringe use). You may benefit from insights gained through the process, especially those that improve the way tasks are performed.

IF I DO NOT WANT TO TAKE PART IN THE STUDY, ARE THERE OTHER CHOICES?

Participation in this study is voluntary. Refusal to participate will not result in loss of access to any services or programs at McMaster University or Hamilton Health Sciences to which you are entitled.

WHAT INFORMATION WILL BE KEPT PRIVATE?

Your data will not be shared with anyone except with your consent or as required by law. Personal information such as your name, address, phone number or email will not be used for identification, but rather your data will be documented as a number. The data, with identifying information removed, will be securely stored in a locked office on a password protected computer. The data from this research study will be retained for ten years.

For the purposes of ensuring the proper monitoring of the research study, it is possible that a member of the Hamilton Health Sciences/FHS McMaster University Research Ethics Board, a Health Canada representative may consult your research data. However, no records which identify you by name or initials will be allowed to leave the institution/university/hospital. By signing this consent form, you authorize such access.

If the results of the study are published, your name will not be used and no information that discloses your identity will be released or published without your specific consent to the disclosure.

CAN PARTICIPATION IN THE STUDY END EARLY?

If you volunteer to be in this study, you may withdraw at any time. You have the option of removing your data from the study. You may also refuse to answer any questions you don’t want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

WILL I BE PAID TO PARTICIPATE IN THIS STUDY?

If you agree to take part, we will provide a $20 cafeteria card for your time.

WILL THERE BE ANY COSTS?

No.

WHAT HAPPENS IF I HAVE A RESEARCH-RELATED INJURY?

If you are injured as a direct result of taking part in this study, all necessary medical treatment (i.e. ice, anti-inflammatories) will be made available to you at no cost. Financial compensation for such things as lost wages, disability or discomfort due to this type of injury is not routinely available.

However, if you sign this consent form it does not mean that you waive any legal rights you may have under the law, nor does it mean that you are releasing the investigator(s), institution(s) and/or sponsor(s) from their legal and professional responsibilities.

IF I HAVE ANY QUESTIONS OR PROBLEMS, WHOM CAN I CALL?

If you have any questions about the research now or later, please contact, Victoria MacDonald 905-521-2100 ext. 74924 or Dr. Peter Keir at 905-525-9140 ext.23543.

If you have any questions regarding your rights as a research participant, you may contact the Office of the Chair of the Hamilton Health Sciences/Faculty of Health Sciences Research Ethics Board at 905-521-2100, ext. 42013.

CONSENT STATEMENT

SIGNATURE OF RESEARCH PARTICIPANT/LEGALLY-AUTHORIZED REPRESENTATIVE*

I have read the preceding information thoroughly. I have had the opportunity to ask questions, and all of my questions have been answered to my satisfaction. I agree to participate in this study. I understand that I will receive a signed copy of this form.

____
Name of Participant

____
Name of Legally Authorized Representative

____
Signature of Participant (or Legally Authorized Representative)

____
Date

Consent form administered and explained in person by:

____
Name and title

_______________________________ _____________________
Signature Date

SIGNATURE OF INVESTIGATOR:

In my judgement, the participant is voluntarily and knowingly giving informed consent and possesses the legal capacity to give informed consent to participate in this research study.

_______________________________ ______________________
Signature of Investigator Date