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The effects of Lean intervention (5S) on perceived musculoskeletal workload and perceived hazardous working conditions in a health center pharmacy

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The Effects Of Lean Intervention (5S) On Perceived Musculoskeletal Workload And Perceived Hazardous Working Conditions In A Health Center Pharmacy

A Thesis
Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
In partial fulfillment of the
Requirements for the degree of
Master of Science in Industrial Engineering
In
The Department of Construction Management & Industrial Engineering

By
Jastinder Singh Dhindsa
B.E., University of Pune, India, 2009
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DEDICATION

To my parents, who never lost faith in my ability.

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ABSTRACT

The healthcare industry involves a significant level of health and safety risks in various work processes, and healthcare professionals are at risk for work-related musculoskeletal disorders and other health problems. In recent years, Lean has been introduced in healthcare with the goal of eliminating waste and improving efficiency. Lean is also believed to affect the health and safety of workers. The present research studies the effects of Lean (5S) implementation in an acute care pharmacy of a health center. A version of the Dutch Musculoskeletal Questionnaire (DMQ) was used to record the perceived musculoskeletal workload and perceived hazardous working conditions. There were twelve participants from the two participating pharmacies and they were divided into two groups, study and control. The study group underwent Lean transformation in the form of a 5S event. Work sampling was conducted to determine any changes in the existing process in terms of percentage of value added and non-value added activities over the course of the study. Work sampling results did not indicate any significant changes in the percentage of value added and non-value added activities post 5S. The pharmacists and the pharmacy technicians reported a significant reduction in perceived musculoskeletal workload on the wrist after the 5S event. Perceived hazardous working conditions were not reduced after the 5S for either the pharmacists or the pharmacy technicians.

CHAPTER 1: INTRODUCTION

The healthcare industry has a high degree of organizational complexity, and there are many procedures that involve a significant level of risk of accidents and infections (Fillingham, 2007). Apart from errors and accidents, there are also some wasteful activities that take place in hospitals all over the world (Zidel, 2006). Waste can be defined as something that does not add any value to the final product or is not required (Womack & Jones, 2003). A non-value added activity (a type of waste) could be anything from unnecessary movement of people and material in the workplace to production of products that are not required (Womack & Jones, 2003). Factors like rising costs, staffing shortages, an increase in physician-owned care facilities, and the fact that insurance companies are no longer willing to pay for non-value added work have made hospitals work toward the elimination of non-value added activities (Zidel, 2006). Moreover, by eliminating non-value added activities hospitals can improve patient safety (eg. Kim, Spahlinger, Kin, & Billi, 2006) and realize their ultimate goal of providing better healthcare to patients (Zidel, 2006).

One way to eliminate these non-value added activities and improve patient safety is with the implementation of Lean principles and concepts, and there are many success stories to learn from. In 2002, Virginia Mason Medical Center (VMMC) in Seattle, Washington became the first hospital in the United States to implement Lean tools and techniques by adopting the Toyota Production System (TPS) (Kim, et al., 2006). VMCC made use of Lean tools like Kaizen events, and continuous improvement (Spear, 2005). They reported a 90% decrease in the number of incidents of ventilator-associated pneumonia in 2004 and this, in turn, resulted in a drastic decrease in the number of deaths caused due to such complication (Kim, et al., 2006). In a

similar example, Park Nicollet Health Services (PNHS) in Minneapolis, Minnesota benefitted from the implementation of Lean. They were able to reduce patient waiting time from 122 to 52 minutes in the urgent care unit, and they also standardized the use of surgical instruments by the general surgery group, thus reducing the number of instruments processed each month by 40,000 units (Kim, et al., 2006). These examples show that the hospitals that implemented Lean were able to improve their processes and patient safety and to reduce waste in terms of time and supplies that resulted in reduced costs to the organization.

There is one aspect of Lean implementation in healthcare organizations where not much research has been done. Lean can help an organization eliminate wastes, reduce operating costs, and make processes more efficient, but how does Lean affect the health and safety of healthcare professionals? Successful Lean implementation results in better customer satisfaction (Woodward-Hagg et al., 2007; Zidel, 2006) and reduced costs to an organization (Kim, et al., 2006) but research has little to show on effects on the lives of healthcare professionals who are an integral part of the healthcare industry.

Lessons learnt from Lean implementations for patient safety improvements can be used to better guide provider safety improvement projects. Patient safety initiatives have made use of Lean tools like Root Cause Analysis (RCA) and surveys to benchmark the frequency of different types of errors (Raab et al., 2005). As a result, researchers were able to track errors that were more serious and errors that were more frequent. This helped them design improvement interventions accordingly (Raab, et al., 2005). A similar approach can be taken for provider safety initiatives.

Healthcare is a risk-prone industry with many sources of error that exist in the system (Amalberti, Auroy, Berwick, & Barach, 2005). These sources of error include fatigue, overload

on employees, and staff shortage (Amalberti, et al., 2005). Moreover, other studies have also established the fact that healthcare professionals are at risk of infections that may cause serious illness and also occasional deaths (Sepkowitz, 1996). Apart from illness from various types of infections, healthcare professionals also have a very high risk of work-related musculoskeletal disorders (WMSDs) (Karwowski, Ren-Liu, Rodrick, Quesada, & Cronin, 2005). These disorders include back injuries, along with knee, wrist, arm, shoulder, and neck disorders, and the major cause of such injuries and disorders is patient handling (Hollingdale, 1997; Knibbe & Friele, 1996). WMSDs have accounted for over 30 percent of the total non-fatal illnesses and injuries requiring days away from work in the last two decades, and under this healthcare has been among the top three occupations with the most number of WMSD cases (US Bureau of Labor Statistics, 2011b). This shows that WMSDs are a serious problem in the healthcare industry and hence needs to be tackled more effectively.

In addition to WMSDs, healthcare professionals are at risk of illness causing infection that sometimes prove to be fatal (Sepkowitz, 1996). Since 1992 the number of fatal injuries and illnesses to healthcare workers caused by exposure to harmful substances and assaults has been in excess of a total of 140 every year (US Bureau of Labor Statistics, 2011a). In a study carried out by Orji et al. (2002), the most common occupational hazards identified were needlestick injuries, work-related stress, sleep disturbance, skin reactions, assaults from patients, and hepatitis. These accidents and disorders among healthcare professionals pose a serious risk to their health and safety. This also results in absenteeism (Tinubu, Mbada, Oyeyemi, & Fabunmi, 2010) and hence shortage of staff which puts additional stress on the workers.

Lean implementations could help with the problem of WMSDs in healthcare. Most Lean implementations in healthcare have been aimed at improving processes, customer satisfaction

(Woodward-Hagg, et al., 2007; Zidel, 2006), and reduced costs (Kim, et al., 2006). Since Lean implementations may result in changes to a process it is bound to affect the workers involved in that particular process. However, there is no substantial data to conclude whether Lean implementations have any positive effect on the health of healthcare professionals since they are directly involved in all activities. The goal of this study is to determine if successful Lean implementations may reduce the risk factors for WMSDs among healthcare professionals.

1.1 Scope of the Study

Healthcare, like most businesses, involves multiple interactions between the customer (patients) and a provider (hospitals). The primary goal of any Lean implementation is to improve a process and since both the patients and the providers are a part of this process, Lean implementation will affect both. This study focused on the providers, i.e., pharmacists and pharmacy technicians. The study evaluated the effects of Lean (5S) implementations on risk factors for WMSDs among the pharmacists and technicians with the help of a questionnaire that was provided to them. The aim was to determine if a Lean (5S) implementation would help reduce exposure to risk factors for WMSDs. The questionnaire was administered at time A and B. Time A was before the 5S event was conducted and time B was three weeks from the time 5S implementation was complete. The implementation of the Lean tool 5S happened between time A and B for the study group. A comparison of the responses at those two times was carried out and it helped determine any changes in the conditions after the implementation. A control group was also studied to improve the validity of the study. The same questionnaire was given to both the study and the control group.

1.2 Limitations of the Study

- The present research studied the effects of Lean (5S) implementations only on WMSD symptoms and not on any other type of disorders or accidents

- The questionnaire survey was conducted in two acute care pharmacies of a healthcare facility involving pharmacists and pharmacy technicians only
- 5S was the only Lean tool considered for the survey
- The research was limited to healthcare providers and was not aimed at addressing the issue of patient safety

CHAPTER 2: LITERATURE REVIEW

Lean tools and techniques have their roots in the concepts that were developed for the improvement of the automobile industry, and Lean has been implemented in healthcare with positive results (Woodward-Hagg, et al., 2007). Successful Lean implementation results in better customer satisfaction (Woodward-Hagg, et al., 2007; Zidel, 2006) and reduced costs to an organization (Kim, et al., 2006). Since there are many individuals involved in the operations and processes that are affected by the implementation of Lean, there is a great possibility that Lean will affect those individuals from a safety and health perspective.

This literature review discusses the effects of Lean implementation on healthcare professionals' health and safety. An overview of Lean has been provided in the first section including its origins, implementation, and benefits. Moreover the relation between Lean, and health and safety of professionals in industries like manufacturing, construction, and healthcare are reviewed. The final section of this literature reviews various safety measurement tools that have been used earlier in various studies on the health and safety of workers in various industries. Based on the comparison a suitable tool will be selected for the present research study.

2.1 Overview of Lean

Toyota has been benchmarked as the best in class by all the other manufacturers in the world for its manufacturing speed, high productivity, and most importantly high quality (Liker, 2004). Toyota corolla, which is the world's best-selling car, is an example of that. Toyota's success can be attributed to its production and operational practices since the production system followed at Toyota is unique and highly efficient (Shingo, Shingō, & Dillon, 1989). It is

commonly known as the Toyota Production System (TPS), mainly developed by Taiichi Ohno, and Shigeo Shingo (Emiliani, 2006).

Some of the underlying principles of the TPS are:

- Continuous improvement- Improving business operations through innovation and evolution.
- Teamwork- Maximize individual and team performance through participation.
- Identification and elimination of waste- The seven types of wastes (*Muda*)
- Standardization of tasks
- Visual control (5S)- Making work places efficient and productive, operators will spend less time looking for tools, improves work environment
- Pull system- Producing only the required material, utilization of material is monitored continuously (Liker, 2004)

TPS, which was later referred to as 'Lean', was later used in the automotive, manufacturing, and eventually healthcare sectors (Joosten, Bongers, & Janssen, 2009). Lean has evolved over the years and has been modified according to the industry where it is being used.

2.2 Lean in Healthcare

2.2.1 Origin

Until the late 1980s, Lean was being used mainly in the automobile industry. In the early 1990s Lean concepts were being used for operations management and service management in various industries, but Lean found its way in the health care industry only in the 2000s (Laursen, Gertsen, & Johansen, 2003). Lean thinking is now widely recognized in the health care sector, and there is a growing corpus of guides and journal papers (Jimmerson, Weber, & Sobek, 2005; Joosten, et al., 2009).

2.2.2 Implementation

Most Lean implementation ventures start with an introduction to Lean tools and principles, aimed at redesigning various aspects of the care delivery system (Ben-tovim, Bassham, & Bolch, 2007; Fillingham, 2007; Nelson-Peterson & Leppa, 2007). Since its introduction in the healthcare sector, Lean has been implemented in various areas. Healthcare may have different instruments and tools already in use that are in line with Lean principles and this might limit the need to use original Lean tools. For example, Care Programs and Integrated Care Pathways both are based on patient-in-process analysis which is an analysis of a patient flow through a healthcare system that can help identify non-value added activities (Joosten, et al., 2009). These tools are very similar to Lean tools since Lean tools are also used to identify and eliminate non-value added activities, hence these tools overlap with Lean tools.

Jimmerson et al. (2005) collaborated with the Community Medical Center in Missoula, Montana to determine how the TPS principles could be applied in the healthcare sector. They adopted two tools, Value Stream Mapping (VSM), and problem-solving A3 report, that Toyota uses to redesign work and solve problems and applied them to various hospital operations. Value stream maps are used to graphically represent the operators, materials, operations, and information flow required for the delivery of a product or service to the end customer (Jimmerson, et al., 2005). The second tool used was the problem-solving A3 report. An A3 report is used to tackle a specific problem in a systematic manner. The problem is stated from the customer's point of view and the current process is represented graphically. After the identification of specific problems, the root causes are investigated and a target condition is proposed in order to make the work more ideal, followed by a step-by-step implementation plan and a follow-up plan to predict the expected improvements (Jimmerson, et al., 2005). It required very little investment to implement the improvements, but there was a significant reduction in

the amount of time wasted of workers. Dollar savings resulted from reduction in overtime hours and a reduction in the staff time wastage resulted in lesser overtimes (Jimmerson, et al., 2005). All the reductions in waste result in savings in terms of money and hence profit for the organization (Murphy, 2003).

In another example of Lean implementation, the Medical Center of Ocean County in New Jersey redesigned the process of supplying drugs to the ward (Locock, 2003). The center originally used the traditional “cart system”; the pharmacy would dispense and place the medications in the cart, which were delivered to nursing stations early next morning based on the orders received the previous day. Analysis of this system showed that although the drugs on the ward cart were still those based on the previous day’s orders the medications would often change. This resulted in extensive rework in the pharmacy, and a high potential for confusion and error. In addition, nursing staff would also store additional supplies of drugs on the cart, leading to further waste and potential for mistakes. The pharmacy studied the distribution of medication orders and on the basis of this information; a new “just-in-time” delivery system was piloted in which four delivery times were introduced. A pharmacy technician was assigned to each floor of the hospital for 16 hours per day to support the new system. The technician would evaluate medication orders, input them into the system, and communicate with the clinical staff and the pharmacist. The new system reduced errors that would happen earlier due to change in orders, improved availability of the drugs at the correct time, and reduced wastage of drugs that used to happen earlier as some of the drugs would go unused because of change in the medications (Locock, 2003).

From these examples we see that the implementation of Lean resulted in waste reduction from minimum investments in terms of money and time. Moreover, the nurses and the

technicians gained valuable experience, and they will be able to apply these concepts to tackle problems that may arise in the future.

2.2.3 Benefits

Joosten et al. (2009) state that Lean has the potential to improve healthcare delivery. Lean can improve quality and safety, and at the same time it can improve staff morale and reduce operational costs (Jones & Mitchell, 2005). The benefits of Lean implementation in healthcare are numerous. Implementation of Lean tools like 5S, 5 Whys, Visual control, Kanban, and Kaizen can help organizations to launch Lean transformations (Zidel, 2006). These tools are relatively easy to use, and anyone can participate in the Lean implementation drives.

As a result of participating in Lean initiatives, participants learn to look at their work with a fresh view and can identify waste in their daily routine activities (Jimmerson, et al., 2005). Lean also lifts the morale of the front line staff for making these implementations as it involves real time participation of staff who identify problems, participate in brainstorming sessions, and make suggestions based on the current conditions (Jimmerson, et al., 2005). Lean has helped to reduce errors and eliminate wastes in the form of various non-value added activities from processes like unnecessary movement of the staff, and material handling. Some other benefits have been reduced inventories, shorter cycle times, and better coordination among the employees (Jimmerson, et al., 2005; Kim, et al., 2006).

Hospitals can improve the quality of patient care by eliminating non-value added activities and removing waste (Jimmerson, et al., 2005; Zidel, 2006). Lean tools are the most appropriate tools that can be used to create value and eliminate waste in any organization (Zidel, 2006) and this in turn may help improve the safety of both the patients and the workers. For example, Lean tools like work-standardization and a simple housekeeping tool like 5S aim to eliminate waste (Womack & Jones, 2003) by organizing the work place in a proper manner with

all the tools and other material in their respective places, and following work instructions. This can prevent accidents that happen from not following work instructions and also from tools and equipment lying in places where they should not be. Hence, Lean may help improve the safety of both patients and healthcare professionals.

2.3 Health and Safety of Healthcare Professionals

Healthcare is a comparatively hazardous industry with various processes involving a high degree of risks (Zidel, 2006). Healthcare professionals are at a high risk of infections that may cause serious illness and also occasional deaths (Fillingham, 2007). Between the years 1984 and 1997, the Centers for Disease Control and Prevention (CDC) reported 52 cases of Seroconversion (development of antibodies to microorganisms due to infection) caused due to exposure to HIV-1 by healthcare workers; 47 were exposed to infected blood, and the most common type of accident was injuries from needlestick (Sepkowitz, 1996).

In a study carried out by Orji et al. (2002) the most common occupational hazards identified were needlestick injuries, work-related stress, sleep disturbance, skin reactions, assaults from patients, and hepatitis. The participants were doctors, nurses and ward orderlies. The researchers also found that nearly half of the staff used some kind of self-medication or alcohol to deal with the stress, which might increase the risk of an accident at work.

Apart from infections and accidents, healthcare professionals are also at a risk of WMSDs. Nursing assistant (NA) and registered nurse (RN) are among the top ten occupations reporting the highest number of nonfatal musculoskeletal disorders resulting in days away from work (Marino, El-Far, Wey, & Medeiros, 2001). The highest prevalence rates of musculoskeletal disorders for nursing personnel have been found for the neck, shoulder, and back (US Bureau of Labor Statistics, 2009). One of the major causes of musculoskeletal injuries among nursing

personnel is patient handling, i.e. moving the patients using body strength (Daraiseh et al., 2003). Occurrence of WMSDs may be influenced by individual factors like gender, age, weight, height, and physical activity (Knibbe & Friele, 1996; Yassi et al., 1995). In a study conducted by Smith et al. (2006) female nurses were five times more likely to develop a WMSD as compared to male nurses. Also, WMSD symptoms have been found to be more prevalent in women and hence they are at a greater risk of WMSDs (Morken et al., 2000). Poor levels of psychosocial factors like job satisfaction and social support have been associated with WMSD symptoms like neck, shoulder, and lower back pains (Dahlberg, Karlqvist, Bildt, & Nykvist, 2004; Morken, et al., 2000; Smith, Zhang, Zhang, & Wang, 2006). Hence, unless these psychosocial factors are improved in the work place it is difficult to deal with the problem of WMSDs. As far as socio-technical systems are concerned, they have been shown to increase the risk of WMSDs in cases of partial automation and serial-line assembly production systems due to repetitiveness of tasks (Malchaire et al., 2001; Menzel, Brooks, Bernard, & Nelson, 2004).

The nursing profession requires nurses to perform several patient-handling tasks and many of these tasks are considered to be risk factors for WMSDs, such as bathing or dressing a patient, and transferring patients from stretcher to bed or bed to chair or toilet (Neumann, 2004). Some of the patient-handling tasks are considered to have higher immediate risk (e.g., moving the patient from bed to chair or from one chair to another) as compared to others that are a result of cumulative trauma (e.g., bending over) (Nelson, Lloyd, Menzel, & Gross, 2003). This means that nurses are at a greater risk of suffering from a WMSD when they are doing tasks like moving patients, which involves lifting the patients, than the tasks which involve working in awkward postures like bending over to pick something, for example, patient handling tasks are more likely to cause musculoskeletal injuries over time than the other tasks that requires a nurse

to bend over. It is necessary to identify the most hazardous nursing tasks in order to assess the risk for the occurrence of WMSDs among nursing staff (Daynard, Yassi, Cooper, Norman, & Wells, 2001; Zhuang, Stobbe, Hsiao, Collins, & Hobbs, 1999). Owen et al. (2001) concluded that insufficient staffing is one of the factors that can increase the stress of manual handling due to increased patient-to-nurse ratio, which results in increased frequency of lifts per caregiver in a shift. Traditional quality improvement programs have focused on patient's perspective, i.e. improving patient flow, schedules, and nursing care (Menzel, et al., 2004). So, in order to deal with the risks of WMSDs among healthcare professionals and to try and reduce such risks, Lean interventions in the workplace seem appropriate.

2.4 Relation between Lean and Health and Safety of Workers

Every occupation or working environment has some risk for accidents and other health related hazards. Safety and health standards have been set by various governmental organizations like the Occupational Safety and Health Administration (OSHA, USA) and the Royal Society for the Prevention of Accidents (UK) to prevent accidents and also to make sure that the working environment is ideal for workers in different industries. Since safety and health of workers depend on every action, material, and person it is an indispensable part of every process in every industry, but it is often considered separately from production processes (Hagberg, 2000).

Prior to its introduction in the healthcare industry Lean principles and tools were first implemented in the manufacturing and construction industry, respectively. There are several examples from manufacturing as well as construction where the implementation of Lean tools and principles resulted in improved safety and health to workers. Saurin et al. (2009) carried out a study in a harvester assembly plant in Brazil for the assessment of the impact of Lean Production (LP) implementation on the assembly line working conditions. They conducted direct

observations of the assembly line working, interviewed workers, and used questionnaires to gather information on the current working conditions from the workers over 10 months. The results indicated that the working conditions (e.g. workload, work pace, and stress) improved after the LP implementation. The conditions were fairly good and the workers reported that the health and safety had improved in comparison with the old system. The workers felt this was because the housekeeping had improved after LP introduction (2009). The researchers also concluded that the top management's commitment to health and safety increased due to the Lean system. In a similar study, Lean Manufacturing implementation in the Malaysian electronics and electrical industry showed an improvement in safety and ergonomics in manufacturing units (Wong, Wong, & Ali, 2009).

Similar to manufacturing, several researchers conducted studies to assess the impact of Lean implementation in the construction industry. Nahmens and Ikuma (2009) found that the construction sites where Lean practices were incorporated had safer workplaces as compared to sites where no such practices existed. Construction projects using Lean Construction had an incidence rate for days away cases and absenteeism lower than the projects that did not use Lean processes (Wong, et al., 2009).

Lean Construction has the potential to improve the health and safety of workers as a result of cleanup at the construction site, preparation of activities, continuous planning, and through continuous improvements (Jørgensen, Forman, Storgaard, & Laustsen, 2008). In a study carried out by the implementation of Lean production in a construction project resulted in 37% less labor onsite. As a result of a reduction in health and safety risks from site operations there were no reportable accidents (Court, Pasquire, & Gibb, 2009). Nahmens and Ikuma (2009)

stated that waste reduction and increased efficiency would result in reduced motion and material handling and this in turn would result in a reduced probability of occurrence of any accident.

These practical examples and theories show that whether it is construction or manufacturing, both the industries gained from the implementation of Lean tools and principles in terms of improved health and safety of the workers. Similar Lean tools and principles are currently being implemented in the healthcare sector. Housekeeping tools like 5S, Value Stream Mapping (VSM) for improved workflow (Thomassen, Sander, Barnes, & Nielsen, 2003), kaizen for continuous improvement (Womack & Jones, 2003), Kanban card system for reduced inventory (Liker, 2004), and work instructions are some of the Lean tools that have been implemented in the healthcare sector.

There is no consensus on whether Lean actually helps improve the health and safety of healthcare professionals. Fillingham (2007) has a viewpoint that Lean can be applied to healthcare but with some modifications. Moreover, Lean can help improve the health of workers in hospitals as successful Lean implementations result in improved process efficiency and hence lesser stress on the workers (Fillingham, 2007). A study conducted by Jimmerson et al. (2005) concluded that successful Lean implementations result in reduction of overtime hours and errors, and better employee satisfaction. It is appropriate to say that this may result in reduced stress on the employees and have a positive effect on their health. On the other hand, a few studies have revealed different outcomes of Lean implementations in healthcare. A study of experiments that were conducted in patient care facilities revealed that RNs reported more stress after the implementation of Lean production elements like multi-skilled teams, and Total Quality management (TQM) (Landsbergis, Cahill, & Schnall, 1999). There is a need to study the outcomes of Lean in detail to find out whether Lean has positive effects on the health and safety

of health care professionals. Based on the evidence that Lean implementation improved worker health and safety in manufacturing and construction industry and similar tools are being implemented in the healthcare sector, healthcare may see the similar results.

One of the Lean tools that has been implemented in healthcare is 5S. A 5S event is comprised of five S's that are Sort, Straighten, Shine, Standardize, and Sustain (Liker, 2004). In sorting, parts/tools are separated based on how frequently they are used and things that are rarely or never used are removed (Zidel, 2006). Straightening means creating permanent locations for parts/tools that are going to be used frequently (Liker, 2004). Shining is to make sure the workplace is clean all the time (Liker, 2004). Standardizing is to create rules to keep the workplace organized (Zidel, 2006). The last S, Sustaining is to maintain the improvements and correct process steps (Liker, 2004; Zidel, 2006).

The purpose of a 5S event is to eliminate waste that may contribute to defects, errors, and injuries to the workers (Liker, 2004). Any kind of safety process betterment may begin with sorting since sorting requires any unwanted or unsafe tools to be removed from the workplace (Ansari & Modarress, 1997). Sorting and straightening also help to reduce musculoskeletal workload and errors since these two steps are aimed at simplifying the processes (Gapp, Fisher, & Kobayashi, 2008). Higher physical workload is associated with high musculoskeletal workload (Dahlberg, et al., 2004; Menzel, et al., 2004). An error in process means the process needs to be repeated, which is classified as rework. Rework is a non-value added activity (Kilpatrick, 2003) and results in additional workload on the workers. So a reduction in both workload and errors would mean lower WMSD risk factors for workers. Similarly, shining and standardizing improves the safety and overall well-being of the workers (Gapp, et al., 2008). Routine maintenance and review of existing standards to prevent non-conformance at work are

the two main goals of the shining and the standardizing steps (Becker, 2001). This may prevent any accidents from non-conformance and routine maintenance may help trace any defects/errors and possible hazards (Becker, 2001).

In an example of the benefits of 5S, a 5S event at the Boeing Company resulted in reduced labor hours and rework (Ansari & Modarress, 1997). Also, as a result of 5S implementation the chemical usage in the wing responsibility center was eliminated completely and hazardous waste output was cut by 98 percent (Ansari & Modarress, 1997). Nahmens et al. (2009) observed a reduction in minor accident rate due to housekeeping for the industrial house builders with active Lean programs.

2.5 Safety Measurement Methods/Tools

In order to find out whether Lean can help improve the health and safety of healthcare professionals there is a need to have measurement metrics. Based on the measurements before and after Lean implementation, Lean may affect the safety of healthcare professionals positively or negatively. There is still a lack of well-defined safety assessment tools that makes it difficult to define the relationship between exposure to physical risk factors and outcome measures (Landsbergis, et al., 1999). An improvement in the measurement metrics for risk factors would be very helpful in assessing the environmental differences and better understanding the relationship between potential risk factors and musculoskeletal disorders (Spielholz, Silverstein, Morgan, Checkoway, & Kaufman, 2001).

The three most commonly used evaluation methods for measuring physical exposure to risk factors are subjective self-reports, observational methods, and direct measurements (National Academy of Sciences, 1998). Subjective self-reports can be used to collect data on worker exposure to both physical and psychosocial factors in the workplace with the help of

interviews and questionnaires (David, 2005; Spielholz, et al., 2001) and the estimates obtained from the self-reports are generally used in combination with results obtained from another method (David, 2005). Observational methods are of two types: field-based and video-based. Field observations require an expert who makes use of a checklist or a more detailed recording of various components of work and other actions (Spielholz, et al., 2001). Video observations allow the researchers to review the data from a videotape. Work sampling and time-motion studies can be done with the help of video recordings; work sampling studies are used for jobs with longer cycle times or different activities whereas time-motion studies are performed on jobs with repetitive activities (Spielholz, et al., 2001).

Direct measurements involve the use of monitoring instruments fitted with sensors and these instruments are attached directly to the subjects for taking measurements (Spielholz, et al., 2001). David (2005) and Juul-Kristensen et al. (2001) studied the postures and movements of the workers during repetitive tasks with the help of video-based observations, and direct measurements (inclinometers and goniometers). Direct measurements helped in obtaining detailed and accurate data and were found to be more accurate than the video-based observation method (Juul-Kristensen, et al., 2001).

Video observations lead to problems like occluded views and parallax i.e. the subjects move from their original position and their body parts are sometimes partially or fully hidden (Juul-Kristensen, et al., 2001). An estimated error of up to 10 degrees can be expected due to parallax (Spielholz, et al., 2001). Spielholz et al. (2001) found in a study that direct measurements resulted in the lowest measurement errors as compared to video observations and self-reports. They also concluded that the major problems with the questionnaire method are the large variability in the perception of risk factors and inconsistencies in the results due to the

subjects' comprehension or interpretation of the question. To deal with such problems the researchers described each question to the subjects and demonstrated body postures and motions.

Most researchers agree that the self-report methods are less accurate than the observational or direct measurement methods (Liu, Zhang, & Chaffin, 1997). However, self-report methods are advantageous over other methods in terms of the ease with which they can be used, and they can be used for surveying large groups with little investment (National Institute for Occupational Safety and Health (NIOSH), 1997).

Various studies have used questionnaire surveys to assess the Lean implementation. Many of such survey studies were able to establish relationships between Lean and its positive outcomes. In a study conducted by Saurin et al. (2009) an assessment of the impact of Lean Production (LP) on working conditions was performed in a harvester assembly line. The researchers used two different questionnaires, one questionnaire (56 questions) to assess worker's views on the current working conditions and another questionnaire (42 questions) to assess their views on the differences between the old system and the new Lean system. The questionnaires were constructed based on the qualitative data collected during the interviews conducted with the workers and Cronbach's alpha was calculated to determine if the questionnaire was internally consistent (Saurin & Ferreira, 2009). The questionnaire results indicated high satisfaction with health and safety and that the health and safety had improved after the new Lean system was implemented.

In a similar study conducted in the electrical and electronics industry in Malaysia, researchers used a questionnaire survey to investigate the adoption of Lean manufacturing. The questions were aimed at studying the 14 different aspects of Lean manufacturing namely, inventory, scheduling, equipment, material handling, work processes, product design, layout,

quality, employees, suppliers, customers, safety and ergonomics, management and culture, and tools and techniques (Saurin & Ferreira, 2009). Questionnaires were mailed to 350 manufacturers and were addressed to the general manager or managing director of the company. A five-point scale was used to indicate the degree of implementation for each of the 14 areas: 1 = no implementation, 2 = little implementation, 3 = some implementation, 4 = extensive implementation, and 5 = complete implementation (Wong, et al., 2009). This five-point scale was adopted from Shah and Ward (2007). With the help of the questionnaire results the researchers were able to establish a positive relationship between each of the 14 areas and the successful Lean implementations.

In another study, a version of the Dutch Musculoskeletal Questionnaire (DMQ) was used to assess the musculoskeletal workload, hazardous working conditions, and musculoskeletal symptoms among the workers in various occupations. This version contained 63 questions on the aforementioned aspects of the WMSDs and the questions can be grouped into seven categories namely, static and dynamic load, repetitive load, force, climatic factors, ergonomic environmental factors, and vibration (Shah & Ward, 2007; Wong, et al., 2009). There were 1575 participants from 24 different occupations (nurses, shipyard workers, office workers, and metal workers), and the questions in the questionnaire were formulated based on various field studies that were conducted by the authors using the preliminary versions of the DMQ. The DMQ results for nurses showed the presence of dynamic loads (bending and twisting of trunk, neck or wrists, walking, stooping, reaching, squatting) and forceful exertions (pushing, pulling, lifting, carrying, pinching) (Hildebrandt, 2001). The overall results showed that DMQ helps in the assessment of perceived musculoskeletal workload and other perceived hazardous working conditions and the indices that were used (static and dynamic load, repetitive load, force, climatic factors,

ergonomic environmental factors, and vibration) showed a significant relationship with lower back, neck, and shoulder symptoms relating to WMSDs (Institute of Medicine, 2000).

Looking at the previously discussed examples of research studies where questionnaire surveys were successfully used to assess the impact of Lean implementation, questionnaire surveys can be considered to be an effective measurement tool. In the present research study, the above mentioned Dutch Musculoskeletal Questionnaire was used. Apart from being concise and self-explanatory, this questionnaire intended to measure the perceived musculoskeletal workload. Hence, this questionnaire will be used in the present research study. This version had 63 questions to assess the perceived musculoskeletal workload, and perceived hazardous working conditions. Participants were required to answer simply with a Yes or No.

The objective of the present research study was to examine the effects of Lean implementations on the health and safety of the workers in the healthcare professional. From the review of previous Lean implementations in manufacturing, construction and healthcare industry Lean has been a very effective tool in reducing lead times and waste and hence increasing savings in terms of both time and money. Moreover, judging by the fact that Lean has helped improve the health and safety of workers in both the manufacturing and the construction industry, Lean may bear similar results for healthcare. A questionnaire survey seems to be an appropriate tool to investigate the same.

CHAPTER 3: RESEARCH METHODOLOGY

The present research study investigated the effects of Lean implementations (specifically 5S) on the health and safety of the workers in acute care hospital pharmacies. Data on perceived musculoskeletal workload was collected twice from the participants at time A and B with the implementation of a 5S event in between. The 5S took place in the pharmacy department of a healthcare facility. The assessment tool used in the present study was a version of the Dutch Musculoskeletal Questionnaire (DMQ) (Institute of Medicine, 2000). This questionnaire had 63 questions to determine perceived musculoskeletal workload and perceived hazardous working conditions.

3.1 Assessment Tool

The assessment tool that was used in the present research was a version of the Dutch Musculoskeletal Questionnaire (DMQ) (Institute of Medicine, 2000). The DMQ was developed by the Netherlands Institute for Applied Scientific Research to measure self-reported perceived musculoskeletal workload and perceived hazardous working conditions. The standard version of this questionnaire consists of 234 questions while a shorter version has 81 questions (Institute of Medicine, 2000). The version of the DMQ that was used in the present research was developed by Hilderbrandt et al. (2001) with the questions from the standard version of the DMQ. This questionnaire has 63 questions on perceived musculoskeletal workload and perceived hazardous working conditions. The questions on this questionnaire were formulated based on various field studies that were carried out using the standard version of the DMQ. The questions will either indicate the presence or absence of exposure but not the actual amount of discomfort caused by exposure (Hildebrandt, 2001).

The questions can be grouped into the following six categories:

1. Static loads that include standing, sitting, prolonged bent or twisting of trunk, neck or wrists, kneeling or squatting, and working with hands above shoulder level, 14 questions
2. Dynamic loads that include bending and twisting of trunk, neck or wrists, squatting, reaching, and walking, 22 questions
3. Force exertions that involve pinching, supporting, lifting, carrying, pushing, and pulling, 4 questions
4. Repetitive loads, 5 questions
5. Peak loads include sudden, forceful, and unexpected movements of the body parts, 3 questions
6. Ergonomic environmental conditions include climatic factors, limited working space, vibration, and slipping and falling, 15 questions (Institute of Medicine, 2000).

The participants were required to answer all 63 questions with a yes or no. For analysis purposes, a yes carried a value '1', and a no carried a value '0'. A value of '1' indicated the presence of a risk factor whereas the absence of it was indicated by a value '0' and all the questions were scored in the same way. Hence, a high score would indicate the presence of perceived musculoskeletal workload and perceived hazardous working conditions. Also, scores were calculated separately under two different categories. The first category (questions 1-47, 54) determined the presence of perceived musculoskeletal workload whereas the second category (questions 48-53, and 55-63) determined the presence or absence of perceived hazardous working conditions. There were four subcategories of questions under the perceived musculoskeletal workload category for static posture, neck, wrist, and trunk. The questionnaire also had demographic questions on age, gender, job title, years of experience, and work hours.

3.2 Hypotheses

There are six hypotheses considered in this research study. The first five hypotheses tested the effects of 5S implementation on the perceived musculoskeletal workload. The sixth hypothesis determined if Lean implementation had any effect on the perceived hazardous working conditions.

H_{01} : 5S will not reduce the overall perceived musculoskeletal workload

H_{a1} : 5S will reduce the overall perceived musculoskeletal workload

H_{02} : 5S will not reduce the perceived musculoskeletal workload on static posture

H_{a2} : 5S will reduce the perceived musculoskeletal workload on static posture

H_{03} : 5S will not reduce the perceived musculoskeletal workload on the neck

H_{a3} : 5S will reduce the perceived musculoskeletal workload on the neck

H_{04} : 5S will not reduce the perceived musculoskeletal workload on the wrist

H_{a4} : 5S will reduce the perceived musculoskeletal workload on the wrist

H_{05} : 5S will not reduce the perceived musculoskeletal workload on the trunk

H_{a5} : 5S will reduce the perceived musculoskeletal workload on the trunk

H₀₆ : 5S will not reduce the perceived hazardous working conditions

H_{a6} : 5S will reduce the perceived hazardous working conditions

3.3 Experiment Design

3.3.1 Dependent Variables

The dependent variable in this experiment was the perceived musculoskeletal workload that was further categorized into perceived musculoskeletal workload on the static posture, neck, wrist, and trunk. The DMQ questionnaire used in the present study had a total of 63 questions. There were 48 questions for the overall perceived musculoskeletal workload (1-47, 54). The questionnaire had a set of questions for each of the variables mentioned above. There were 5 questions on static posture (10, 11, 13, 39, 40), 9 on neck (24-26, 29-34), 7 questions on wrist (28, 35-38, 43, 54), and 20 on trunk (1-9, 14-23, 41). Another dependent variable in this study was the perceived hazardous working conditions assessed with 15 questions (48-53, 55-63).

3.3.2 Independent Variables

The independent variables in the present research were time and location. Time had two levels, time A and time B. Time A was before the 5S event and time B was three weeks from the time 5S implementation was complete. Another independent variable was the two pharmacy departments at two different locations where the survey was carried out at approximately the same time. Actual Lean implementation (5S event) took place in one location whereas; no such intervention happened in the other location. Hence, there was a study group (Lean intervention) and a control group (no intervention). Study group had two time levels indicated by taking a questionnaire at time A and B with the 5S implementation happening in between. Similarly, the control group completed the questionnaire twice, at time A and B.

3.3.3 Participants

The participants included the pharmacists and the pharmacy technicians, which were directly affected by the 5S implementation. The total number of participants was twelve with three pharmacists and three pharmacy technicians from each pharmacy. The participants from the pharmacy that conducted 5S were treated as the study group and the second pharmacy was treated as the control group. The average age of the participants was 36 years (SD 5.31) and there were 11 female and 1 male participants.

3.3.4 Setting

The present study was conducted in the pharmacy department of a healthcare facility where a Lean implementation in the form of a 5S event took place. The pharmacy is a place where medicines and other medical supplies are stored and dispensed as and when required within the hospital. The pharmacy staff includes pharmacists and pharmacy technicians who collaborate with each other in order to perform their job duties efficiently. A pharmacy technician's job is to enter the prescription orders into the computer system for review by a pharmacist. A pharmacist then reviews the order for accuracy, drug interactions, and therapeutic appropriateness based on the patient. Other duties of a pharmacist include dosing of antibiotics when consulted by physician, making chemotherapy and other IV's as needed, being the drug information source for the hospital, etc. Other duties of a pharmacy technician include filling the Pyxis machines (automated medication dispensing machines) with medications, filling and delivering medications not in the Pyxis machines, making IV's (Intravenous fluids), maintaining pharmacy stock, etc.

The purpose of the 5S event was to eliminate waste, generate more space, and educate pharmacists and pharmacy technicians. Some of the original goals of the 5S event were:

- I. Cleaning the pharmacy of any excess materials (unused carts, boxes, supplies, etc.).
There were complaints of congestion and not enough room to store supplies and records. Moreover, there were underutilized shelves that could be used to store more supplies.
- II. To generate open workspace to reduce distractions. The current workspace was not conducive to uninterrupted work. The pharmacists and the pharmacy technicians reported distraction from movement of co-workers close to the work area due to lack of open space. It was observed that sometimes there were interruptions from congestion in the work area with too many people in the same place.
- III. The storage room was very small and was often flooded with boxes of files. The pharmacist and the technicians sometimes had to move through all the boxes to find something and hence there were complaints of congestion and untidiness.
- IV. There was a need to educate the pharmacists and the technicians on filling pre-order forms, sending the expired drugs to the discharge bin promptly, and using the tube system correctly. Incomplete pre-order forms resulted in rework, and expired drugs increased clutter if not discharged quickly. Incorrect use of the tube system often resulted in prescriptions being lost and them having to make duplicate orders. The tube system is a medication dispensing mechanism that involves the use of small cylindrical boxes that can carry small orders and can be pushed directly to different floors through a tube system by vacuum. Pharmacists and technicians reported stress from rework, duplicate orders, and untidiness.
- V. A small partition wall was in the way of the nurse station and one side of the pharmacy where there were shelves with supplies. This wall had no purpose and the staff had to

walk around it every time to get to the shelves. The removal of this wall could generate more open workspace.

A control group was also studied in a different facility and the control group did not receive any Lean treatment. Studying a control group helped track the changes that occur with time, irrespective of any intervention.

3.3.5 Procedure

First, the purpose of the research was explained to the participants and informed consent was obtained (approved by LSU and Ochsner Health System). The participants were given necessary instructions for answering the questionnaire like the number of questions, answering category, and time. The same paper-based questionnaire was conducted in two phases i.e., at time A and B with a 5S event in between for the study group. A gap of three weeks from the time of the 5S to the second questionnaire allowed the workers to get used to all the changes in the work area. The questionnaire was also administered to a control group to measure any natural changes that may have occurred during the course of the study. The control group did not undergo any Lean intervention.

After the questionnaire was provided to the participants, they were required to answer the questions with a yes or no. There were 63 questions in total. The time required to complete the given version of the DMQ was approximately 15 minutes.

Work sampling was also conducted in the department where 5S took place and also in the control group location that did not receive any Lean treatment. Work sampling is a technique used to determine the various activities performed by workers over a span of time (eg.Finkler, Knickman, Hendrickson, Lipkin, & Thompson, 1993). Work sampling was conducted both at time A and B for the study group to determine the actual changes in the existing process and it was conducted separately for the pharmacist and the pharmacy technicians that took the

questionnaire. The work sampling data for the control group was used to measure any natural changes in the value added activities performed by pharmacists and technicians.

A spreadsheet was used to determine the schedule of observations. Observations were conducted at random times during a span of four hours. The number of observations determined the accuracy of the work sampling data. The following equation was used to determine this accuracy:

$$l = \frac{4p(q)}{n}$$

Where: p= probability of a single occurrence of a value added activity

q= (1-p)= probability of an absence of occurrence of a value added activity

n= number of observations

l= estimate of level of accuracy

(Niebel & Freivalds, 1999)

The probability of occurrence of a value added activity (VA) was determined from the data collected on value added activities and non-value added activities (NVA).

3.4 Data Analysis

In order to be able to compare the data collected at time A and B, T-tests were conducted using SPSS. Since mean scores from the same group of participants were compared in the present research, a paired T-test analysis was used here. There were two categories of questions, perceived musculoskeletal workload (MW), and perceived hazardous working conditions (HW) and three subcategories of questions on neck, trunk, and wrist. Mean scores for the two categories and four subcategories within the questionnaire taken at time A and B were compared for both the study group and the control group. In addition, an independent sample T-test was

performed for the DMQ scores between the study and the control group at the beginning of the study. The purpose of this test was to determine if the two groups were comparable. The participants were required to answer all the 63 questions with a yes or no. For the analysis purpose, a yes carried a value '1', and a no carried a value '0'. The total score obtained for each category at time A and B was used to perform a paired T-test. Questions 48 through 53 and 55 through 63 indicated the presence of perceived hazardous working conditions and rest of the questions indicated the presence of overall perceived musculoskeletal workload. The T-test was also performed for the scores for subcategories on static posture, neck, wrist, and trunk. The T-test helped determine whether the mean scores for the questions at time A and B were statistically different from each other. The t-value was used to further determine the associated p-value. These p-values were used to evaluate the five hypotheses that were made at the beginning of the study.

If the p-value obtained was less than 0.05 then we could reject the first null hypotheses, but if the obtained p-value were greater than 0.05 then the null hypotheses would hold true. The results of the T-test were used to conclude whether 5S reduced perceived musculoskeletal workload, perceived musculoskeletal workload on static posture, neck, wrist, and trunk and perceived hazardous working conditions.

The data collected from work sampling was also analyzed. The data collected at time A was compared with that collected at time B and differences in the percentage of value added and non-value added activities were documented. This comparison helped determine if there was a noticeable change in the percentage of value added and non-value added activities performed by the pharmacists and the pharmacy technicians.

CHAPTER 4: RESULTS

The present research was carried out in two acute care pharmacies of the same health center in two different locations with one of them undergoing a 5S implementation. In addition to the Dutch Musculoskeletal Questionnaire (DMQ) work sampling was used to collect data on the amount of value and non-value added activities performed. The T-test was performed to compare the DMQ scores from time A and B with Lean implementation in between these two times. Work sampling data was used to compare any changes in the percentage of value added and non-value added activities after the 5S.

4.1.Outcomes of 5S

The 5S event was conducted in the pharmacy as a result of an initiative to make some changes to the layout and the process in order to be able to work without interruptions from rework and have more workspace. As a result of the 5S implementation, some changes were made to the pharmacy layout and the process.

- I. As part of the first 'S', all the supplies were sorted and expired or worthless supplies were trashed, and excessive supplies were returned that included printer paper and unused drugs. Around \$600 worth of supply was returned to the supplier.
- II. One of the partition walls was broken down in order to generate more space within the pharmacy for the staff to move around. In addition to shelves that were cleaned of unwanted/expired supplies, space in excess of 35 square feet was generated.
- III. Break room and storage room were switched, allowing supplies to be arranged efficiently in a bigger storage room. The pharmacists and technicians no longer needed to move boxes when looking for something.

- IV. Pharmacists and pharmacy technicians were educated on filling pre-order forms and using the tube system correctly. This change is supposed to prevent unnecessary calls to clinics asking for details. Education on the tube system aims to eliminate loss of prescriptions due to incorrect use of the system and hence waste in the form of duplicate orders.

4.2.Data Analysis

4.2.1.Work Sampling Results

The work sampling data was collected for both the study and the control groups. Since there were three pharmacists and three technicians from each group, one pharmacist and one technician from each group was observed. They were observed for a period of four hours each, both at time A and B. 116 samples were collected for each participant who was observed. The samples were collected at random times over the period of four hours. The samples were collected both during the morning time and the evening. For the study group, one pharmacist and one technician were observed for four hours each during morning and afternoon times; whereas for the control group, one pharmacist and one technician were observed for four hours each during afternoon and evening times.

The work sampling data was divided into two categories, value added (VA) and non-value added activities (NVA). VA and NVA activities were decided based on the job description provided in the section 3.3.4. NVAs included activities that involved wait, travel, inspection, over processing, defects, and excessive motion. For example, activities like sitting idle, taking planned and unplanned breaks, talking to colleagues, answering the phone, and collecting orders from the floors. VA activities included activities that the staff is expected to perform according to their respective job descriptions. Entering orders in the system, filling orders, preparing medication boxes for surgeries, preparing IVs (Intravenous fluids), working with Pyxis machines

(automated medication dispensing machines), delivering orders through Tube System were some of the VA activities.

The work sampling data for the study group is shown in Figure 1. Graphs show the percentages of VA, NVA activities performed by the participants both at time A and B. VA activities increased by 3% post 5S for the pharmacists while the increase was 7% for the pharmacy technicians.

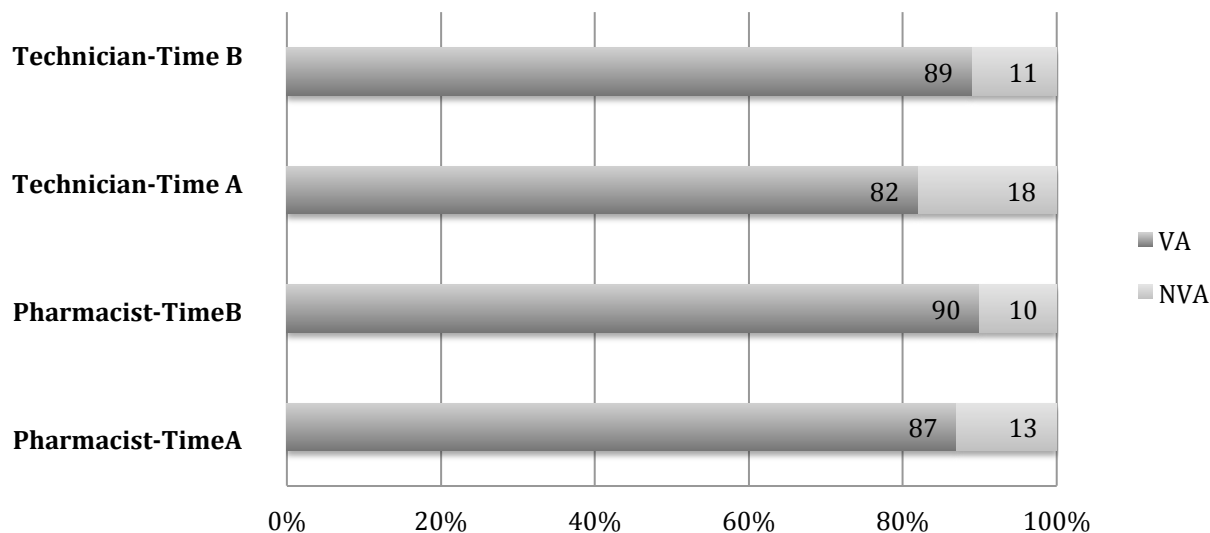


Figure 1: Study Group Work Sampling Data

The work sampling data for the control group is represented in Figure 2. Graphs show the percentages of VA and NVA activities performed by the participants at the beginning and end of the study. The VA activities decreased by 6% for the pharmacists and by 1% for the pharmacy technicians at the end of the study.

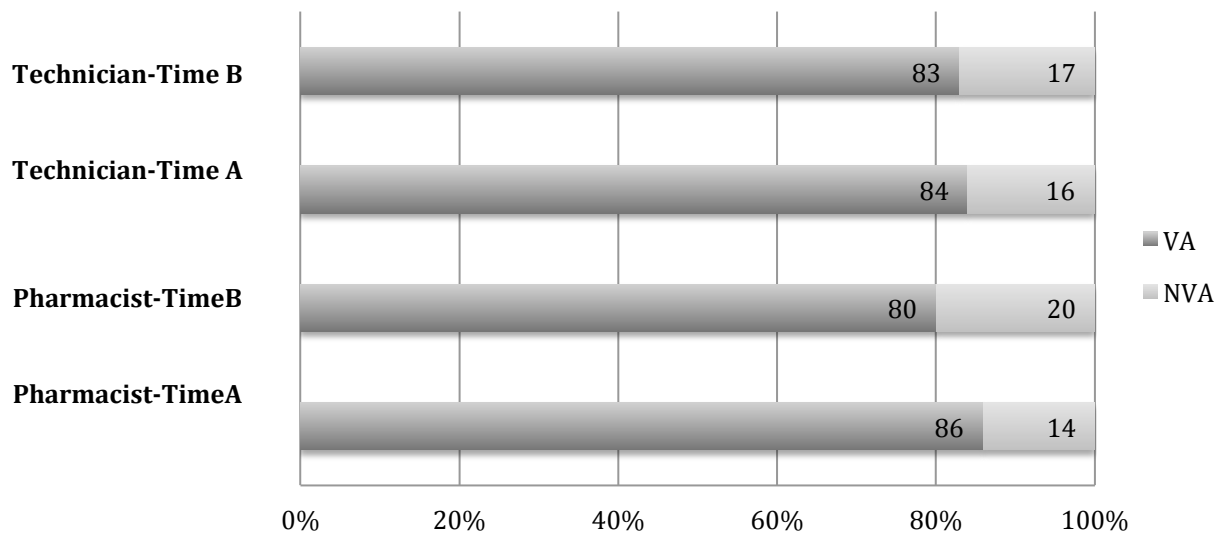


Figure 2: Control Group Work Sampling Data

In addition, the accuracy of the work sampling data was calculated to make sure the data was reliable. The accuracy percentages anywhere from 1 to 10 were considered reliable. The work sampling data accuracy percentage levels are shown in table 1. The levels of accuracy obtained for the work sampling data were between 6 and 8 percent. Since these levels were within the cutoff limit they were considered acceptable.

Table 1: Work Sampling Study Accuracy

Group	Work Sampling Time	Accuracy Percentage	
		Pharmacist	Pharmacy Technician
Study	A	6.27	7.16
	B	5.62	5.83
Control	A	6.50	6.83
	B	7.50	7.60

4.2.2. Questionnaire Results

An independent sample T-test was performed for the DMQ scores between the study and the control group at the beginning of the study. The p-values obtained from this T-test were 0.78 for the MW category and 0.59 for the HW category. Since the p-values for both the categories

were greater than 0.05, no significant difference in scores from the two groups was observed and hence the two groups were comparable.

A paired sample T-test was performed between the DMQ scores obtained from time A and time B for the control group. The p-value obtained for the MW category was 0.80, and for the HW category it was 0.88. Both the p-values were greater than 0.05 and hence no significant decrease was observed in perceived musculoskeletal workload and perceived hazardous working conditions during the course of the study. Thus no natural changes were observed in the pharmacy over the study period.

Moreover, the demographic data collected was also studied. The average age of the participants for the study group was 37 years (SD 6.51), while the average age for the control group was 34.5 years (SD 5). The study group had all female participants whereas the control group had 5 female and 1 male participant. The study and the control group were comparable on age and gender. Also, the number of work hours reported by all the participants was 40 per week.

The total DMQ score for the study group decreased by 2 after the 5S. The decrease was 1.5 for the MW category, and 0.5 for the HW category. For the control group the total DMQ score decreased by 0.99 at the end of the study. Total score for MW category decreased by 1.16, whereas the total score for the HW category saw an increase of 0.17. A lower score is considered to be good since it indicates the absence of perceived musculoskeletal workload and perceived hazardous working conditions. The DMQ scores for the study group are shown in figure 3.

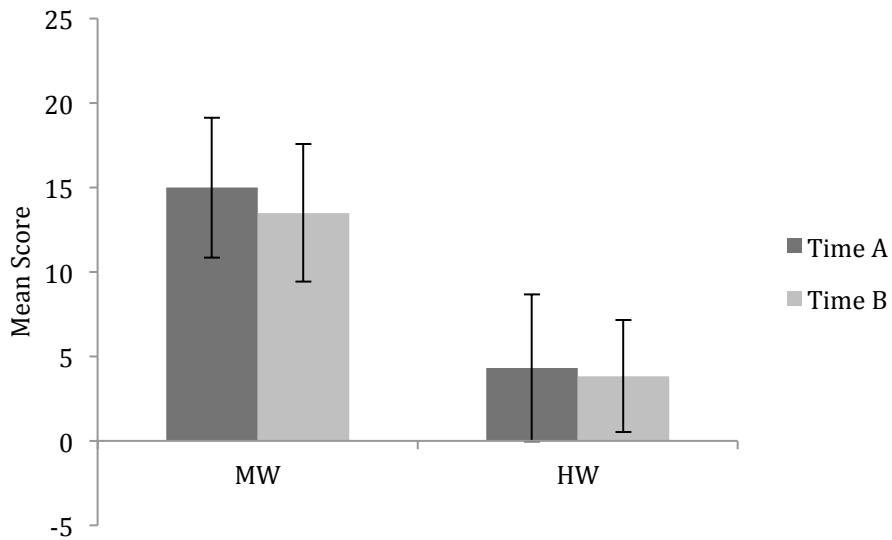


Figure 3: Study group DMQ score means, and standard deviations

The DMQ scores for the control group are shown in figure 4.

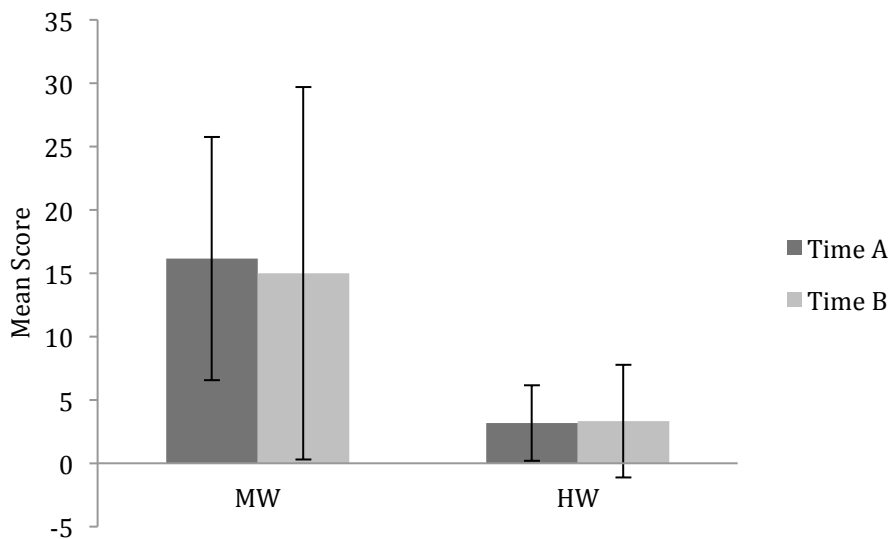


Figure 4: Control group DMQ score means, and standard deviations

The p-value obtained for the MW category for the study group was 0.34 and 0.81 for the HW category. These p-values obtained from the paired sample T-tests for the study group were greater than 0.05 and hence showed no significant difference in the scores from time A and B.

The overall results were equally true for both the pharmacists and the pharmacy technicians. Out of twelve participants six were pharmacists and other six were pharmacy

technicians, three each from each group. In order to find out if there were any differences in perceived musculoskeletal workload between pharmacists and technicians, DMQ scores and work sampling data were compared for the study group only. The DMQ scores comparison, and p-values obtained are tabulated in table 2.

Table 2: Study Group Participant DMQ Score Comparison

Category (n)	MW		P-Value	HW		P-Value
	Time A Mean (SD)	Time B Mean (SD)		Time A Mean (SD)	Time B Mean (SD)	
Pharmacist (3)	15.6 (3.53)	13.0 (7.07)	0.27	6.00 (7.78)	3.67 (0.71)	0.56
Technician (3)	16.0 (3.53)	14.0 (4.95)	0.90	5.67 (0.71)	4.00 (6.36)	0.63

Furthermore, subcategories within the MW category of questions were compared for the study group. There were three distinct subcategories that had questions specifically on neck, wrist and trunk. The mean scores for these categories are listed in table 3.

Table 3: Subcategory Means, Standard Deviations, and P-values

Subcategory	Time A Mean (SD)	Time B Mean (SD)	P-Value
Static Posture	2.00 (1.00)	2.33 (0.47)	0.36
Neck	3.16 (1.00)	3.00 (1.50)	0.74
Wrist	3.16 (1.00)	1.67 (1.37)	0.01
Trunk	4.33 (0.50)	4.16 (0.50)	0.69

A paired T-test was performed to compare the mean scores for the subcategories from time A and B. The p-values from the comparison of the mean scores of the subcategories from time A and B are shown in table 3. The p-value obtained for subcategory scores for questions on perceived static posture was 0.36. Since this was greater than 0.05, the perceived static posture did not reduce after the 5S. The p-value obtained for subcategory scores for questions on neck was 0.74. Since this was greater than 0.05, the perceived musculoskeletal workload on the neck did not reduce after the 5S. The p-value obtained for the paired sample T-test on subcategory

scores for questions on wrist was 0.01. This was less than 0.05 and hence there was a reduction in the perceived musculoskeletal workload on the wrist after 5S. The p-value for the subcategory on trunk was 0.69, which was greater than 0.05 and hence no significant reduction in the perceived musculoskeletal workload on the trunk was reported.

4.3 Hypotheses Evaluation

The following conclusions were made based on the data analysis results.

4.3.1 Hypothesis 1

H_{01} : 5S implementation will not reduce the overall perceived musculoskeletal workload

H_{a1} : 5S implementation will reduce the overall perceived musculoskeletal workload

Failed to reject null hypothesis. The p-value obtained for the category of questions on the overall perceived musculoskeletal workload was 0.34 and this value was greater than 0.05. As per the pharmacists and technicians, 5S failed to reduce the overall perceived musculoskeletal workload.

4.3.2 Hypothesis 2

H_{02} : 5S implementation will not reduce the perceived musculoskeletal workload on static posture

H_{a2} : 5S implementation will reduce the perceived musculoskeletal workload on static posture

Failed to reject null hypothesis. The p-value obtained for the subcategory of questions on static posture was 0.36 and this value was greater than 0.05. As per the pharmacists and the technicians 5S did not reduce the perceived musculoskeletal workload on static posture.

4.3.3 Hypothesis 3

H_{03} : 5S implementation will not reduce perceived musculoskeletal workload on the neck

H_{a3} : 5S implementation will reduce perceived musculoskeletal workload on the neck

Null hypothesis was rejected. The p-value obtained for the subcategory of questions on neck was 0.74 and this value was less than 0.05. As per the pharmacists and the technicians 5S reduced the perceived musculoskeletal workload on the neck.

4.3.4 Hypothesis 4

H_{04} : 5S implementation will not reduce perceived musculoskeletal workload on the wrist

H_{a4} : 5S implementation will reduce perceived musculoskeletal workload on the wrist

Null hypothesis was rejected. The p-value obtained for the subcategory of questions on wrist was 0.01 and this value was less than 0.05. As per the pharmacists and the technicians 5S reduced the perceived musculoskeletal workload on the wrist.

4.3.5 Hypothesis 5

H_{05} : 5S implementation will not reduce perceived musculoskeletal workload on the trunk

H_{a5} : 5S implementation will reduce perceived musculoskeletal workload on the trunk

Null hypothesis was rejected. The p-value obtained for the subcategory of questions on trunk was 0.69 and this value was greater than 0.05. As per the pharmacists and the technicians 5S did not reduce the perceived musculoskeletal workload on the trunk.

4.3.6 Hypothesis 6

H_{06} : 5S implementation will not reduce perceived hazardous working conditions

H_{a6} : 5S implementation will reduce perceived hazardous working conditions

Failed to reject the null hypothesis. The p-value obtained for the category of questions on perceived hazardous working conditions was 0.59 and this value was greater than 0.05. As per the pharmacists and the technicians 5S did not reduce the perceived hazardous working conditions.

In addition, based on the work sampling data, there was no major change in the amount of VA/NVA activities after the 5S implementation for the study group. Only a slight improvement in terms of VA activities was noticed for both the pharmacists and the pharmacy technicians. This indicates that the 5S did not result in any improvement in terms of VA activities for the study group.

CHAPTER 5: DISCUSSION

The present research study investigated the effects of 5S implementation on the health and safety of the workers in acute care hospital pharmacies. Data on perceived musculoskeletal workload were collected from the pharmacists and the pharmacy technicians at time A and B with the 5S event conducted in between for the study group. The 5S took place in the pharmacy department of a healthcare facility.

The assessment tool used in the present study was a version of the Dutch Musculoskeletal Questionnaire (DMQ) (Institute of Medicine, 2000). The changes in the perceived musculoskeletal workload after the 5S can be attributed to some of the changes that occurred as a result of 5S.

- I. As a result of the 5S, the pharmacists and the pharmacy technicians were educated on filling pre-order forms, discharging expired drugs, and using tube system correctly. This was aimed at preventing rework in the form of unnecessary calls to clinics asking for details, and making duplicate orders due to loss of prescriptions in tube system. So this change may have resulted in lesser rework and perhaps lesser stress and improved work satisfaction among pharmacists and technicians. Researchers have found a relationship between stress, and work satisfaction and the musculoskeletal disorders (Daraiseh, et al., 2003; Leino, 1989). Engels et al. (1996) found a positive relationship between work disturbance by unforeseen events (rework) and musculoskeletal complaints for multiple body regions including wrist and back among nurses. So it would be safe to say that a possible reduction in rework and stress may have been responsible for reduced perceived musculoskeletal workload on the wrist.

- II. After the 5S a small partition wall was broken down, thus allowing pharmacists and technicians more space to move around between their station and workspace. Also, all the supplies were sorted and expired or worthless supplies were trashed, and excessive supplies were returned to supplier. Overall, generation of more space and elimination of all the waste may have reduced the stress caused by complaints of congested and untidy workplace. Daraiseh et al. (2003) found a positive relation between work satisfaction, and working conditions and perceived risk and musculoskeletal symptoms. So there is literature to support the claim that reduction in stress may be responsible for reduced perceived musculoskeletal workload on the wrist in pharmacists and technicians.
- III. Before 5S, the storage room for records and other documents was comparatively smaller. The boxes had to be stacked on top of each other due to lack of space, and the staff had to move all the boxes. After the 5S, the storage was moved to a bigger storage room and the things were arranged in a systematic manner. These changes in the physical layout may have been responsible for reduced perceived workload on the wrist as previous studies have established a positive relation between physical layout (more workspace) and musculoskeletal disorders (Yassi, et al., 1995).

Based on the DMQ score analysis of the pharmacists and the pharmacy technicians, although 5S reduced the perceived musculoskeletal workload for the wrist, it did not reduce the overall perceived musculoskeletal workload and the perceived musculoskeletal workload on static posture, neck, and trunk. One reason for this could be the fact that since the job of a pharmacy technician involves standing for prolonged time, and working in awkward positions (*Handbook of Occupational Hazards and Controls for Pharmacy Workers*, 2011) some perceived risk for musculoskeletal perceived workload is going to exist. These activities are

considered as risk factors for WMSDs by various research studies (Owen, Keene, & Olson, 2001; Zhuang, et al., 1999). Moreover, pharmacists in the present study are required to work on computers for extended periods of time, which can lead to musculoskeletal discomfort and poses the risk of a musculoskeletal disorder (Bhanderi, Choudhary, Parmar, & Doshi, 2003; Gerr, Marcus, & Monteilh, 2004). Even in the case of significant process improvement, they are still required to perform the basic tasks and hence the presence of perceived musculoskeletal workload.

The changes in the perceived hazardous working conditions were negligible. This could be because the pharmacy is an indoor facility and the chances of any changes in the working conditions are negligible as long as there is no breakdown of any sorts. This can be explained in two ways. First, the DMQ scores for the perceived hazardous working conditions were very low, thus indicating the absence of any noticeable hazards in the work place. Secondly, the questions on the DMQ that were targeted at measuring perceived hazardous working conditions were mainly on space and environmental factors (wind, temperature, humidity). There is a possibility that the questions were skewed and failed to measure the kind of hazards that are present in a pharmacy. Some of the common types of hazards that have been found in a pharmacy are exposure to hazardous medication/chemicals like antineoplastic, cytotoxic, etc., and risk of contamination during IV preparations (*Handbook of Occupational Hazards and Controls for Pharmacy Workers*, 2011; Spivey & Connor, 2003; Stevens & Balon, 1997). The questions on the DMQ did not address any of these hazards and this could be a reason for low scores for perceived hazardous working conditions.

The version of the DMQ used in the present research had questions on perceived hazardous working conditions that were more suited for the manufacturing or the construction

industry. There were questions on changes in environmental factors like wind, humidity, and temperature, experiencing vibrations/shocks and operating tools and vehicles. Since none of these changes or activities are seen in acute care pharmacies, this version of the DMQ was probably not the best tool to measure the perceived hazardous working conditions in the pharmacy. A different questionnaire targeted at measuring the potential hazardous working conditions in a pharmacy like exposure to hazardous medication/chemicals and risk of contamination from the same would be a better tool to measure the perceived hazardous working conditions in a pharmacy.

Apart from the DMQ results the data collected from the work sampling was also analyzed. The original goals of the 5S were to eliminate waste, generate more space and educate pharmacists and technicians. The results showed that the pharmacy was cleaned up and shelves were rearranged to generate more space. Savings were made in terms of both space and money. Pharmacists and technicians were instructed on filling pre-order forms and using tube system correctly to prevent rework resulting from incomplete forms and loss of orders in tube system. The study indicated that there was a decrease in the number of non-value added activities (NVA) after the 5S implementation. NVA activities decreased from 13% to 10% for the pharmacists, and from 18% to 11% for the pharmacy technicians in the study group. The decrease in NVA could be because of clearer work instructions and cleaner work area as part of the 5S improvements. The pharmacists and technicians were instructed to discharge the expired drugs promptly upon return and also the pharmacy was cleaned of all the unwanted or excess supplies. This may have reduced the amount of time rework pharmacists and technicians spent looking for supplies/records.

The overall results of the current study were equally true for both the pharmacists and the pharmacy technicians. Out of twelve participants six were pharmacists and other six were pharmacy technicians, three each from each group. In order to find out if there were any differences in perceived workload between pharmacists and technicians, DMQ scores and work sampling data were compared between the two groups. The DMQ scores between the pharmacists and the pharmacy technicians did not differ noticeably. Even after the 5S their scores were comparable. Moreover, the work sampling results were found to be comparable between the two job titles and the VA/NVA percentages were closely related.

The assessment tool, Dutch Musculoskeletal Questionnaire (DMQ), used in the present study can be considered reliable. The same version of the DMQ was used by Hildebrandt (1995) in a research study to identify musculoskeletal symptoms and workload among agriculture workers. Their research did not address any Lean intervention. In addition to them validating the questionnaire through field studies, their results showed that DMQ helped in the assessment of perceived musculoskeletal workload and other perceived hazardous working conditions and showed a significant relationship with lower back, neck, and shoulder symptoms relating to WMSDs. DMQ has previously been used in research studies in healthcare. Engles et al. (1996) carried out a questionnaire survey using nursing professionals and found clear association between physical workload and musculoskeletal symptoms in arm, neck, and lower back. The researchers stated that it is possible that work related variables elevate musculoskeletal symptoms among nurses. In another study in healthcare, researchers used the DMQ to determine gender related differences in exposure to work-related musculoskeletal risk factors (Hoofman, van der Beek, Bongers, & van Mechelen, 2005). They reported that gender differences in exposure to risk factors indeed exist for the same job. In the present study, the DMQ results

showed that perceived musculoskeletal workload was present but based on the scores the levels were low. The perceived musculoskeletal workload was confirmed only for the wrist and the trunk region with the help of the T-test.

5.1 Limitations

- I. The results of the present study cannot be generalized to the whole healthcare industry as the 5S event was conducted in just one department with a moderate number of participants. The pharmacy does not involve any direct interaction with patients like some other departments (e.g. emergency, surgery, etc.). Departments like emergency and surgery involve moving heavier load, e.g. moving patients. It would be interesting to see what kind of impact a similar 5S event in emergency or surgery would have on perceived musculoskeletal workload. Moreover, similar studies can be performed in multiple departments with a larger sample size.
- II. The time gap between the Lean intervention and the after survey was only three weeks and only perceived musculoskeletal workload risks were studied. Future studies can consider including a longer time frame for the study. Since musculoskeletal disorders may take years to develop, perhaps a longitudinal study would reveal occurrence of musculoskeletal disorders with respect to Lean over a period of time.
- III. The Dutch Musculoskeletal Questionnaire used in the present study. Although researchers have validated this questionnaire previously (Hildebrandt, 2001), it was a self-reporting method. Self-reporting methods are considered less accurate and are often used in combination with other methods like video recording (David, 2005).
- IV. Same participants were observed for work sampling observations both at time A and time B for the control group. But due to unavailability of the same pharmacist, a different

pharmacist was observed at time B for the study group. This may have put some limitations on the reliability of the work sampling data collected for the pharmacist since different workers have a different work pattern. Also, one worker may be more efficient than the other. Since different pharmacists were observed at time A and B there is a possibility that the work sample obtained is not representative of the changes due to 5S but changes in work patterns, and efficiency.

5.2 Future Research

- I. Future research studies can consider conducting similar experiments using various other Lean tools like Kaizen, work standardization, etc. This will show how different Lean tools affect the musculoskeletal workload and hazardous working conditions
- II. Researchers can also consider using various other measurement tools like other more detailed versions of the DMQ, or any other direct measurement method like video recording or the use of goniometers. They can later compare the results to see whether the results were the same for different tools. This will help understand which measurement tools are best suited for Lean improvement measurement in healthcare or in general.

5.3 Conclusion

The pharmacists and the pharmacy technicians reported a significant reduction in the perceived musculoskeletal workload on the wrist after the 5S implementation. As per the pharmacists and the pharmacy technicians the overall perceived musculoskeletal workload and the perceived hazardous working conditions did not reduce after the 5S.

Some of the 5S outcomes were that the pharmacy was cleaned of all the overstocked/unwanted supplies, and medications and shelves were rearranged. Around 35 square feet of space was generated and around \$600 worth of supply was returned to the supplier. In

addition, pharmacists and technicians were educated on filling pre-order forms and using tube system correctly to prevent rework resulting from incomplete forms and loss of orders in tube system. The work sampling data indicated slight improvement in terms of the percentage of value added activities performed by the pharmacists and the pharmacy technicians after the 5S.

The control group data analysis indicated no significant change in the perceived musculoskeletal workload or the perceived hazardous working conditions during the course of the study. Also, the work sampling data for the control group did not highlight any significant changes in the amount of value added activities at the end of the study, thus ruling out the possibility of any natural changes or external factors to the process over the course of the study.

In conclusion, 5S implementation showed significant positive impact in terms of improved perceived musculoskeletal workload for the wrist for the healthcare professionals in the pharmacy department.

BIBLIOGRAPHY

- Amalberti, R., Auroy, Y., Berwick, D., & Barach, P. (2005). Five system barriers to achieving ultrasafe health care. *Annals of Internal Medicine*, 142(9), 756-764.
- Ansari, A., & Modarress, B. (1997). World-class strategies for safety: a Boeing approach. *International Journal of Operations & Production Management*, 17(4), 389-398.
- Becker, J. E. (2001). Implementing 5S: To promote safety & housekeeping. *Professional Safety*, 46(8), 29-31.
- Ben-tovim, D., Bassham, D., & Bolch, J. (2007). Lean thinking across a hospital: redesigning care at Flinders Medical Centre. *Australian Health Review Journal*, 31(1), 10-15.
- Bhandari, D., Choudhary, S., Parmar, L., & Doshi, V. (2003). A Study of Occurrence of Musculoskeletal Discomfort in Computer Operators. *Indian Journal of Community Medicine*, 33(1), 65-66.
- Court, P. F., Pasquire, C., & Gibb, A. (2009). A lean and agile construction system as a set of countermeasures to improve health, safety, and productivity in mechanical and electrical construction *Lean Construction Journal*, 61-76.
- Dahlberg, R., Karlqvist, L., Bildt, C., & Nykvist, K. (2004). Do work technique and musculoskeletal symptoms differ between men and women performing the same type of work tasks? *Applied Ergonomics*, 35(6), 521-529.
- Daraiseh, N., Genaidy, M., Karwowski, W., Davis, L. S., Stambough, J., & Huston, R. L. (2003). Musculoskeletal outcomes in multiple body regions and work effects among nurses: the effects of stressful and stimulating working conditions. *Ergonomics*, 46(12), 1178-1199.
- David, G. C. (2005). Ergonomic methods for assessing exposure to risk factors for work-related musculoskeletal disorders. *Occupational Medicine*, 55(1), 190-199.
- Daynard, D., Yassi, A., Cooper, J. E., Norman, R., & Wells, R. (2001). Biomechanical analysis of peak and cumulative spinal loads during simulated patient-handling activities: a substudy of a randomized controlled trial to prevent lift and transfer injury of health care workers. *Applied Ergonomics*, 32(3), 199-214.

Emiliani, M. L. (2006). Origins of lean management in America: The role of Connecticut businesses. *Journal of Management History*, 12(2), 167-184.

Engels, J. A., Gulden, J. W. v. d., Senden, T. F., & Hof, B. v. t. (1996). Work related risk factors for musculoskeletal complaints in the nursing profession: results of a questionnaire survey. *Occupational and Environmental Medicine*, 53, 636-641.

Fillingham, D. (2007). Can Lean save lives? *Leadership in Health Services*, 20(4), 231-241.

Finkler, S. A., Knickman, J. R., Hendrickson, G., Lipkin, J. M., & Thompson, W. G. (1993). A comparison of work-sampling and time-and-motion techniques for studies in health services research. *Health services research*, 28(5).

Gapp, R., Fisher, R., & Kobayashi, K. (2008). Implementing 5S within a Japanese context: an integrated management system. *Management Decision*, 46(4), 565-579.

Gerr, F., Marcus, M., & Monteilh, C. (2004). Epidemiology of musculoskeletal disorders among computerusers: lesson learned from the role of posture and keyboard use. *Journal of Electromyography and Kinesiology*, 14(1), 25-31.

Hagberg, M. (2000). Design of intervention studies to improve the health of health care personnel. In G. Wickström (Ed.), *Intervention studies in the health care work environment: Lessons learned*. Stockholm: Arbetslivsinstitutet.

. *Handbook of Occupational Hazards and Controls for Pharmacy Workers*. (2011). Alberta: Government of Alberta.

Hildebrandt, V. H. (1995). Musculoskeletal symptoms and workload in 12 branches of Dutch agriculture. *Ergonomics*, 38(12), 2576-2587.

Hildebrandt, V. H. (2001). *Prevention of work related musculoskeletal disorders: setting priorities using the standardized Dutch Musculoskeletal Questionnaire*. Doctorate, Free University, Amsterdam.

Hollingdale, R. (1997). Back pain in nursing and associated factors: A Study. *Nursing Standard*, 11(39), 35-38.

Hooftman, W. E., van der Beek, A. J., Bongers, P. M., & van Mechelen, W. (2005). Gender Differences in Self-Reported Physical and Psychosocial Exposures in Jobs With Both Female and Male Workers. *Journal of Occupational & Environmental Medicine*, 47(3), 244-252.

Institute of Medicine. (2000). *To err is human: Building a safer health system*. Washington, DC: National Academies Press.

Jimmerson, C., Weber, D., & Sobek, D. K. (2005). Reducing waste and errors: piloting Lean principles at IHC. *Joint Commission Journal on Quality and Safety*, 31(5), 249-257.

Jones, D., & Mitchell, A. (2005). *Lean Thinking for the NHS*. NHS Confederation, London

Joosten, T., Bongers, I., & Janssen, R. (2009). Application of Lean thinking to healthcare: issues and observations. *International Journal for Quality in Health Care*, 21(5), 341-347.

Juul-Kristensen, B., Hansson, G. A., Fallentin, N., Andersen, J. H., & Ekdahl, C. (2001). Assessment of work postures and movements using a video-based observation method and direct technical measurements. *Applied Ergonomics*, 32(5), 517-524.

Karwowski, W., Ren-Liu, J., Rodrick, D., Quesada, P. M., & Cronin, S. N. (2005). Self-evaluation of biomechanical task demands, work environment and perceived risk of injury by nurses: A field study. *Occupational Ergonomics*, 5, 13-27.

Kilpatrick, J. (2003). Lean Principles. *Manufacturing Extension Partnership*, 1-5.

Kim, C. S., Spahlinger, D. A., Kin, J. M., & Billi, J. E. (2006). Lean Health Care: What Can Hospitals Learn from a World-Class Automaker? *Journal of Hospital Medicine*, 1(3), 191-199.

Knibbe, J., & Friele, R. (1996). Prevalence of back pain and characteristics of the physical workload of community nurses *Ergonomics*, 39(2), 186-198.

Landsbergis, P. A., Cahill, J., & Schnall, P. (1999). The impact of Lean production and related new systems of work organization on worker health. *Journal of Occupational Health Psychology*, 4(2), 108-130.

Laursen, M. L., Gertsen, F., & Johansen. (2003). *Applying Lean Thinking in Hospitals; Exploring Implementation Difficulties*. Paper presented at the 3rd International Conference on the Management of Healthcare and Medical Technology, Warwick.

Leino, P. (1989). Symptoms of stress predict musculoskeletal disorders. *Journal of Epidemiology and Community Health*, 43, 293-300.

Liker, J. (2004). *The Toyota Way: 14 Management principles from the world's greatest manufacturer*. Madison: McGraw-Hill.

Liu, Y., Zhang, X., & Chaffin, D. (1997). Perception and visualization of human posture information for computer-aided ergonomic analysis. *Ergonomics*, 40(8), 818-833.

Locock, L. (2003). Healthcare redesign: meaning, origins, and application. *Quality and Safety in Health Care*, 12(1), 53-58.

Malchaire, J. B., Roquelaure, Y., Cock, N., Piette, A., Vergracht, S., & Chiron, H. (2001). Musculoskeletal complaints, functional capacity, personality and psychosocial factor. *International Archives of Occupational and Environmental Health*, 74(8), 549-557.

Marino, C., El-Far, F., Wey, S., & Medeiros, E. (2001). Cut and puncture accidents involving health care workers exposed to biological materials *Brazilian Journal of Infectious Diseases*, 5(5), 235-242.

Menzel, N., Brooks, S. M., Bernard, T. E., & Nelson, A. (2004). The physical workload of nursing personnel: association with musculoskeletal discomfort. *International Journal of Nursing Studies*, 41(8), 859-867.

Morken, T., Moen, B., Riise, T., Bergum, O., Bua, L., Hauge, S. V., . . . Thoppu, V. (2000). Prevalence of musculoskeletal symptoms among aluminium workers. *Occupational Medicine*, 50(6), 414-421.

Murphy, M. (2003). Eliminating Wasteful Work in Hospitals Improves Margin, Quality and Culture *Murphy Leadership Institute Research Briefing* (Vol. 4).

Nahmens, I., & Ikuma, L. H. (2009). An Empirical Examination of the Relationship between Lean Construction and Safety in the Industrialized Housing Industry. *Lean Construction Journal*, 1-12.

National Academy of Sciences. (1998). *Work-Related Musculoskeletal Disorders: A Review of the Evidence*. Washington: National Academy Press.

National Institute for Occupational Safety and Health (NIOSH). (1997). Musculoskeletal Disorders and Workplace Factors: A Critical Review of Epidemiologic Evidence for Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back. In B. P. Bernard (Ed.). Cincinnati, Ohio: Department of Health and Human Services, Public Health Service, Centers for Disease Control, NIOSH.

Nelson, A., Lloyd, J., Menzel, N., & Gross, C. (2003). Redesigning patient handling tasks. *American Association of Occupational Health Nurses Journal*, 51(3), 126-134.

Nelson-Peterson, D., & Leppa, C. (2007). Creating an environment for caring using lean principles of the Virginia mason production system. *Journal of Nursing Administration*, 37(6), 287-294.

Neumann, W. P. (2004). *Production ergonomics: identifying and managing risk in the design of high performance work systems*. Lund: Lund Technical University.

Niebel, B., & Freivalds, A. (1999). *Methods, Standards, and Work Design* (10th ed.): WCB McGraw-Hill.

Orji, E., Fasubaa, O., Onwudiegwu, U., Dare, F., & Ogunniyi, O. (2002). Occupational health hazards among health care workers in an obstetrics and gynaecology unit of a Nigerian teaching hospital *Journal of Obstetrics & Gynaecology*, 22(1), 75-78.

Owen, B. D., Keene, K., & Olson, S. (2001). Patient-handling tasks perceived to be most stressful by hospital nursing personnel. *Journal of Healthcare Safety Compliance & Infection Control* 5(1), 1-7.

Raab, S. S., Grzybicki, D. M., Zarbo, R. J., Meier, F. A., Geyer, S. J., & Jensen, C. (2005). Anatomic Pathology Databases and Patient Safety. *Archives of Pathology & Laboratory Medicine*, 129(10), 1246-1251.

Saurin, T., & Ferreira, C. (2009). The impacts of lean production on working conditions: A case study of a harvester assembly line in Brazil *International Journal of Industrial Ergonomics*, 39(2), 403-412.

Sepkowitz, K. (1996). Occupationally Acquired Infections in Health Care Workers: Part II *Annals of Internal Medicine*, 125(11), 917-928.

Shah, R., & Ward, P. T. (2007). Defining and developing measures of lean production. *Journal of Operations management*, 25(4), 785-805.

Shingo, S., Shingō, S., & Dillon, A. P. (1989). *A study of the Toyota production system from an industrial engineering viewpoint*. New York: Productivity Press.

Smith, D. R., Zhang, X., Zhang, B., & Wang, R. (2006). Musculoskeletal disorders and their after-effects among health professionals in Beijing *Occupational Ergonomics*, 6, 25-34.

Spear, S. J. (2005). Fixing health care from the inside, today. *Harvard Business Review*, 83(9), 78-91.

Spielholz, P., Silverstein, B., Morgan, M., Checkoway, H., & Kaufman, J. (2001). Comparison of self-report, video observation and direct measurement methods for upper extremity musculoskeletal disorder physical risk factors. *Ergonomics*, 44(6), 588-613.

Spivey, S., & Connor, T. H. (2003). Determining Sources of Workplace Contamination with Antineoplastic Drugs and Comparing Conventional IV Drug Preparation with a Closed System. *Hospital Pharmacy*, 38(2), 135-139.

Stevens, R. G., & Balon, D. (1997). Detection of hazardous drug/drug interactions in a community pharmacy and subsequent intervention. *The International Journal of Pharmacy Practice*, 5(3), 142-148.

Thomassen, M. A., Sander, D., Barnes, K. A., & Nielsen, A. (2003). *Experience and results from implementing Lean construction in a large danish contracting firm*. Paper presented at the 11th Annual conference on Lean Construction, Blacksburg, VA.

Tinubu, B. M. S., Mbada, C. E., Oyeyemi, A. L., & Fabunmi, A. A. (2010). Work-Related Musculoskeletal Disorders among Nurses in Ibadan, South-west Nigeria: a cross-sectional survey. *BMC Musculoskeletal Disorders*, 20, 11-12.

US Bureau of Labor Statistics. (2009). Table 10. Number, percent, and incidence rate of nonfatal occupational injuries and illnesses involving days away from work by selected worker and case characteristics and musculoskeletal disorders All United States, private industry, 2008. <http://www.bls.gov/iif/oshwc/osh/case/ostb2211.pdf>

US Bureau of Labor Statistics. (2011a). National Census of Fatal Occupational Injuries, 2010. <http://www.bls.gov/news.release/pdf/cfoi.pdf>

US Bureau of Labor Statistics. (2011b). Nonfatal Occupational Injuries and Illnesses Requiring Days Away From Work, 2010. <http://www.bls.gov/news.release/osh2.nr0.htm>

Womack, & Jones. (2003). *Lean thinking: Banish waste and create wealth in your corporation*. London: Touchstone Books.

Wong, Y. C., Wong, K. Y., & Ali, A. (2009). A Study on Lean Manufacturing Implementation in the Malaysian Electrical and Electronics Industry. *European Journal of Scientific Research*, 38(4), 521-535.

Woodward-Hagg, H., Suskovich, D., Workman-Germann, J., Scachitti, S., Hudsonth, B., Swartz, J., & Vanni, C. (2007). Adaptation of Lean Methodologies For Healthcare Applications. *Regenstrief Center for Healthcare Engineering*.

Yassi, A., Khokhar, J., Tate, R., Cooper, J., Snow, C., & Vallentyne, S. (1995). The epidemiology of back injuries in nurses at a large Canadian tertiary care hospital implications for prevention. *Occupational Medicine*, 45(4), 215-220.

Zhuang, A., Stobbe, T. J., Hsiao, H., Collins, J. W., & Hobbs, G. R. (1999). Biomechanical evaluation of assistive devices for transferring residents *Applied Ergonomics*, 30(4), 285-294.

Zidel, T. G. (2006). A Lean Toolbox—Using Lean Principles and Techniques in Healthcare. *Journal for Healthcare Quality*, 28(1), 7-15.

APPENDIX A: CONSENT FORM

This study is performed as a part of my master's thesis research through the department of Construction Management and Industrial Engineering at Louisiana State University, Baton Rouge, LA.

The goal of this study is to evaluate the impact of one Lean tool (5S) on the health and safety of healthcare professionals. You will be provided with a questionnaire (Dutch Musculoskeletal Questionnaire) having 63 questions. You will answer each question with a Yes or No. This process will take about 15 minutes. You will have to take the questionnaire twice; both before and after the 5S event takes place. All the information obtained will be kept confidential. I appreciate you completing the study, although you may stop at any time with no penalty. Participating in this study will contribute to understanding the impact of 5S on the health and safety of professionals in healthcare industry.

By signing below you are stating that you have read and understood the purpose of this survey, and that you consent to participate in the survey. This sheet with your signature will be separated from the actual survey to protect your identity from both your employer and/or anyone other than the researcher. Please take with you the following page with the contact information. Thank you for your participation!

Signature: _____

Date: _____

APPENDIX B: DUTCH MUSCULOSKELETAL QUESTIONNAIRE

- A. Participant Number _____
- B. Job Title _____
- C. Gender _____
- D. Age _____
- E. Years of experience in current position _____
- F. Work hours/per week _____

Adapted from “**Dutch Musculoskeletal Questionnaire: description and basic qualities**”, by V. H. Hildebrandt, P. M. Bongers, F. J. H. Van Dijk, H. C. G. Kemper, and J. Dul, 2001, *Ergonomics*, 44, p. 1038-1055. Copyright 2001 by the Taylor and Francis Ltd.

Guidelines

1. Please circle your choice for each question
2. Some questions may look the same, but it is important to answer them all
3. If unsure of the answer, try to choose the one that is closest to reality
4. The word ‘often’ means multiple times during an 8hr shift

At work, do you often have to:

- | | |
|---|----------|
| 1. Lift heavy loads (more than 11 lbs or 5 kg)? | Yes / No |
| 2. Pull or push heavy loads (more than 11 lbs or 5 kg)? | Yes / No |
| 3. Carry heavy loads (more than 11 lbs or 5 kg)? | Yes / No |

At work, do you often have to lift:

- | | |
|--|----------|
| 4. In an unfavorable/uncomfortable posture? | Yes / No |
| 5. With the load far from the body? | Yes / No |
| 6. With twisted trunk? | Yes / No |
| 7. With the load above chest height? | Yes / No |
| 8. With a load that is hard to hold? | Yes / No |
| 9. With a very heavy load (more than 20 kg)? | Yes / No |
-

At work, do you often have to:

- | | |
|---------------------------------|----------|
| 10. Stand for a long time? | Yes / No |
| 11. Sit for a long time? | Yes / No |
| 12. Walk for a prolonged time? | Yes / No |
| 13. Stoop for a prolonged time? | Yes / No |

At work, do you often have to:

- | | |
|-------------------------------------|----------|
| 14. Bend slightly with your trunk? | Yes / No |
| 15. Bend heavily with your trunk? | Yes / No |
| 16. Twist slightly with your trunk? | Yes / No |
| 17. Twist heavily with your trunk? | Yes / No |
| 18. Bend and twist with your trunk? | Yes / No |

At work, do you often have to:

- | | |
|--|----------|
| 19. Work in a slightly bent posture for a long time? | Yes / No |
| 20. Work in a heavily bent posture for a long time? | Yes / No |
| 21. Work in a slightly twisted posture for a prolonged time? | Yes / No |
| 22. Work in a heavily twisted posture for a prolonged time? | Yes / No |
| 23. Work in a bent and twisted posture for a prolonged time? | Yes / No |

At work, do you often have to:

- | | |
|---|----------|
| 24. Reach with your hands and arms? | Yes / No |
| 25. Hold your arm below shoulder-level? | Yes / No |
| 26. Hold your arm at or above shoulder-level? | Yes / No |

- | | |
|--|----------|
| 27. Exert force with your hands or arms? | Yes / No |
| 28. Make small movements with hands/fingers at a high work pace? | Yes / No |

At work, do you often have to:

- | | |
|---|----------|
| 29. Bend your neck forwards? | Yes / No |
| 30. Bend your neck backward? | Yes / No |
| 31. Twist your neck? | Yes / No |
| 32. Hold your neck in a forward bent posture for a prolonged time? | Yes / No |
| 33. Hold your neck in a backward bent posture for a prolonged time? | Yes / No |
| 34. Hold your neck in a twisted posture for a prolonged time? | Yes / No |

At work, do you often have to:

- | | |
|---|----------|
| 35. Bend your wrists? | Yes / No |
| 36. Twist your wrists? | Yes / No |
| 37. Hold your wrist bent for a prolonged time? | Yes / No |
| 38. Hold your wrist twisted for a prolonged time? | Yes / No |

At work, do you often have to:

- | | |
|---|----------|
| 39. Work in uncomfortable postures? | Yes / No |
| 40. Maintain the same uncomfortable postures for a long time? | Yes / No |

At work, do you often have to:

- | | |
|--|----------|
| 41. Always make the same movements with your trunk? | Yes / No |
| 42. Always make the same movements with your arms? | Yes / No |
| 43. Always make the same movements with your wrists? | Yes / No |

44. Always make the same movements with your legs? Yes / No

At work, do you often have to:

45. Make sudden, unexpected movements? Yes / No

46. Perform short, but maximal force-exertions? Yes / No

47. Exert great force on equipment? Yes / No

At work, do you often have:

48. Not enough room around you to perform your work properly? Yes / No

49. Not enough room above you to perform your work without bending? Yes / No

At work, do you often have:

50. Difficulty exerting enough force because of uncomfortable postures? Yes / No

51. Too few facilities to lean on during work? Yes / No

52. Trouble in reaching things with your tools? Yes / No

53. Do you sometimes slip or fall during your work? Yes / No

54. Do you often have to pinch with your hands during work? Yes / No

55. Do you in work experience noticeable vibrations or shocks? Yes / No

56. Do you carry vibrating tools during your work? Yes / No

57. Do you drive vehicles during work? Yes / No

58. Is your work physically very taxing? Yes / No

59. Do you in your work experience uncomfortable drafts, wind? Yes / No

60. Do you in your work experience uncomfortable levels of coldness? Yes / No

61. Do you in your work experience uncomfortable levels of heat? Yes / No

62. Do you in your work experience changes of temperature? Yes / No

63. Do you in work experience humid air?

Yes / No

VITA

Jastinder Singh Dhindsa was born in Maharashtra, India. He attended high school at Kendriya Vidyalaya No.1 School, Pune, Maharashtra. He received the degree of Bachelor of Engineering from University of Pune in August 2009. He joined the Department of Construction Management and Industrial Engineering at Louisiana State University in January 2010. He expects to receive his Master of Science in Industrial Engineering in the summer of 2012.