AMERICAN UNIVERSITY OF BEIRUT

SEATED VS STANDING WORK POSTURES DURING SIMULATED LAPAROSCOPIC PROCEDURES IN TERMS OF MUSCLE LOADING, COMFORT, AND PERFORMANCE

by
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A thesis
submitted in partial fulfillment of the requirements
for the degree of Master of Engineering Management
to the Department of Industrial Engineering and Management
of the Maroun Semaan Faculty of Engineering and Architecture
at the American University of Beirut

Beirut, Lebanon
May 2021

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ACKNOWLEDGEMENTS

First and foremost, I would like to thank almighty God for His countless blessings, and for granting me strength and knowledge to accomplish my thesis.

I would like to express my sincere gratitude to the Department of Industrial Engineering and Management at the American University of Beirut for granting me the opportunity of being part of the graduate assistantship and fellowship program that allowed me to conduct this thesis, and to Dr. Bacel Maddah, the chairperson of the department, for his invaluable support.

I would like to also express my sincere gratitude to my thesis advisor, Dr. Saif Al-Qaisi, for his continuous help and guidance, for generously dedicating his time for meetings, for his constructive feedback and insightful comments, and for sharing his immense knowledge throughout this thesis. I would like to extend my sincere thanks to Dr. Rana Sharara and Dr. Nadine Moacdieh for being part of my thesis committee and for their insightful comments and suggestions.

I would like to offer as well special thanks to the study team, Dr. Ahmad Zaghal, Dr. Zavi Lakissian, Mr. Rida Zeineddine, Ms. Rim Banat, Mr. Abdul Sattar Raslan, and Mr. Anthonio Chocair for their efforts and contribution in this study. I would like to also thank Engineer Ahmad Mansour for helping with the modification of the ergonomic chair used in this study.

I am genuinely thankful to the Department of Surgery at American University of Beirut - Medical Center for granting us access to the simulation lab and for their support. I am extremely thankful as well for the enthusiasm of the participants who dedicated an hour of their tight schedule to participate in this study.

I am endlessly indebted to my family for their altruistic love and care, emotional support, patience, and for being by my side throughout. I am as well deeply grateful to my friends for their emotional support and motivation.

Lastly, I would like to dedicate this thesis to my beloved late grandfather who has always believed in me, encouraged me, and celebrated my successes, and who will continue to live through the love and kindness he left to this world.

ABSTRACT
OF THE THESIS OF

Ilham Samih Abousaleh for Master of Engineering Management
Major: Engineering Management

Title: Seated vs standing work postures during simulated laparoscopic procedures in terms of muscle loading, comfort, and performance

Work-related musculoskeletal disorders (MSD) have been a prevalent problem among surgeons. According to previous literature, back and shoulder muscles are the most affected body parts while performing surgeries. Poor work posture has been linked to the increase in MSDs among surgeons, and this is also prevalent in laparoscopic surgeries where surgeons tend to stand statically for long hours. Surgeries are performed mainly in standing postures and less commonly in seated postures. While the literature has investigated differences between both postures subjectively among surgeons, this paper aimed to investigate the difference using a combination of objective (muscle activity and performance) and subjective measures (the overall workload scale and localized musculoskeletal discomfort scale) during the performance of simulated laparoscopic procedures. Twenty 3rd and 4th year AUB medical students were recruited for this experiment. Four experimental tasks were examined on the LAPSIM, a laparoscopic surgery simulator, using two complexity levels (easy vs difficult) and two postures (sitting vs standing). Back (lumbar erector spinae) and shoulder (upper trapezii) muscle activities were recorded throughout the tasks using an electromyography (EMG) system. The performance of each participant from the LAPSIM output was analyzed (LAPSIM overall performance score and the time to complete tasks). Participants also subjectively assessed the experimental tasks using the overall workload scale and localized musculoskeletal discomfort scale. The collected data was analyzed using a two-factor repeated measures analysis of variance (ANOVA) to assess the effects of posture (sitting vs standing) and task condition (easy vs difficult) on EMG muscle activity, performance, and subjective ratings. The findings did not completely favor one work posture over the other. In comparison to seated, the standing posture resulted in significantly lower shoulder muscle activation in the easy and difficult tasks and lower completion times in the difficult tasks. On the other hand, based on participant feedback, sitting offered more stability, improved focus and precision, and the ability to work for longer periods; therefore, participants preferred the seated posture specifically for the difficult task. Furthermore, although differences were not statistically significant, sitting was associated with consistently lower averages in both the subjective and objective results of the low back. As so, alternating between both postures (e.g. between surgeries or within long surgeries) is recommended as it may decrease the health risks associated with each posture. Future studies may investigate other seat designs or a “hybrid” work posture, such as supported-standing, with respect to the traditional standing work posture.

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CHAPTER I

INTRODUCTION

A prevalent problem among surgeons are the frequent reports of discomfort, pain, and musculoskeletal disorders (MSD) resulting in the workplace. Catanzarite el al. (2018) found through a review of the literature that MSD rates among surgeons ranged between 66% and 94% for open surgery, 73% and 100% for conventional laparoscopy, 54% and 87% for vaginal surgery, and 23% and 80% for robotic-assisted surgery. Gutierrez-Diez et al. (2018) conducted a survey among surgeons performing minimally invasive surgeries and found that 90% of the respondents experienced work-related MSDs. The most affected body regions were the lower back (54%), neck (51%), upper back (44%), lower limbs (42%), right shoulder (29%), and right hand (28%). Soueid et al. (2010) conducted a survey on 77 surgical consultants, of which 63 reported experiencing pain from performing surgeries, mainly in the back and neck areas. Auerbach et al. (2011) found that the two most common self-reported diagnoses among 561 surgeon members of the Scoliosis Research Society were neck pain/strain/spasm (38%) and lumbar disc herniation/radiculopathy (31%). Among laparoscopic surgeons, the most common sites of MSDs were the neck, back, shoulder, elbow, and wrist (Miller et al., 2012; Esposito et al., 2013).

Poor work posture, which is common during surgeries, has been linked with increased risks of MSD development (Nadra et al., 2018; Gupta et al., 2013; Park et al., 2015). Surgeons sustain awkward, static postures, often in a standing position, for long periods of time. Soueid et al. (2010) reported that 46% of surgeons identified posture to be the main reason for their discomfort. Kant et al. (1992) further observed the specific postures sustained by surgeons and found them to include: head bent forward, back bent forward and twisted, shoulders raised, and standing on one leg. All of these postures were classified either as slightly or distinctly harmful. The authors highlighted that the most contributing factor in the work posture stress load was the high prevalence of static tasks in surgeries. Moreover, with the increasing popularity of minimally invasive surgeries – such as laparoscopy – surgeons are moving less and therefore sustaining more static postures. Although such surgeries bring more relief to patients, surgeons may experience more pain and discomfort due to longer time periods in static postures. Among different surgical specialties, Catanzarite et al. (2018) found that laparoscopic surgeons had the highest rates of MSDs.

Surgeries are often performed using two different work postures, either while standing or less commonly while seated. Although a seated posture requires more design considerations in terms of visibility and clearances, it has advantages in reducing static loads to maintain body posture, improving blood circulation and balance, and lessening fatigue development (Pulat, 1997). The type of work that is more suited for seated postures generally includes tasks that require: more hand control; no large forces to be exerted (< 4.5 kg); a high degree of body stability or equilibrium; long periods of work; and work items to be within reach (Bendix et al., 1985; Bush, 2012; Ebben et al., 2003; Pulat, 1997). These task characteristics are similar to those performed by surgeons, yet most surgeries are still carried out while standing. Also, through a review of the literature, Waters et al. (2015) showed ample evidence that prolonged standing is associated with increased reports of low back pain, physical fatigue, muscle pain, leg swelling, tiredness, and body part discomfort. Roelen et al. (2007) determined through a survey of 983 male employees in manufacturing that jobs requiring prolonged standing are positively correlated with pain in the back and legs. According to Dutch ergonomic guidelines, prolonged continuous standing > 1 hr or a total standing time > 4 hr/day are classified to have some health risks for workers (Meijsen and Knibbe, 2007). Time periods below these limits are considered as a safe zone.

CHAPTER II

LITERATURE REVIEW

The health effects of sitting relative to standing have been compared in the literature primarily for office work. Lin et al. (2017) compared sitting and standing computer workstations in terms of electromyography (EMG) activities of shoulder and forearm muscles, perceived discomfort ratings, and posture. Participants reported similar ratings of discomfort for both workstations within the first 10 minutes of work, but after 45 minutes, discomfort ratings were more than twice as high in the standing workstation. The most discomfort was reported at the low back when standing and shoulders when sitting. Moreover, EMG muscle activations were higher at the forearm muscle when standing and at the shoulder muscles when sitting. EMG activity at the low back was not measured although the user-discomfort ratings for the back showed a difference between the two workstations. Another study by Le and Marras (2016) compared spinal load and discomfort in three different postures during a typing task: sitting, standing, and perching, a posture between sitting and standing. Spinal load was highest while standing, with no significant difference between sitting and perching. As for subjective discomfort ratings, standing had highest discomfort reports in the lower back and lower extremities. Physiological discomfort (or heart rate variability) measurements showed sitting having the least discomfort, followed by perching, and then standing (Le and Marras, 2016). Bendix et al. (1985) studied posture variation and trapezius muscle load for a task resembling office work under three cases: sitting, standing, and supported-standing. As the posture varied from standing to supported-standing and then to sitting, the trunk posture became more erect and the arms were more extended. Static muscle load was highest during standing. However, sitting was disfavored by participants, possibly due to having poor leg space and a low chair relative to the table surface level. Beers et al. (2008) measured energy expenditure in three different postures: standing, sitting, and sitting on a therapy ball. They determined that users burned more calories and expended more energy when standing, in comparison to the seated postures. Sudol-Szopinska et al. (2011) compared the number of chronic venous disorders (CVD) reported by two groups of office workers, one that works while standing and the other while seated. They found that the standing group had more reports of CVDs than the seated group (83.4% and 59.4%, respectively).

In the healthcare sector, the impact of seated and standing postures has received less attention with mixed findings. Pejcic et al. (2015) measured EMG activities from shoulder, neck, and back muscles of dentists performing work while seated and standing. EMG activities were higher for all muscles during sitting, indicating that dentists were experiencing greater physical loads. They also found that the back was laterally flexed over 20^o for longer periods of time when dentists were seated, which may explain the higher EMG activities in this posture. The lateral flexion of the back may have been necessary to clearly see into the patient’s mouth. Ratzon et al. (2002) investigated the presence of MSDs among dentists that performed while sitting vs dentists that alternated between sitting and standing; standing alone was not considered. The highest reported pain that hindered dentists from doing normal work throughout the year was in the low back and neck, but only low back pain occurrence was significantly higher for dentists performing while sitting than for dentists performing while alternating between sitting and standing. Moreover, there was a positive correlation between the percentage of time spent sitting and the score of back pain; that is, more time spent in sitting was associated with higher pain. The work conditions that force dentists to bend forward and twist for long durations might explain the presence of back pain among dentists that perform while sitting. Singh et al. (2018) investigated the posture of surgeons performing vaginal surgery and their level of discomfort when standing and seated. They found that sitting was associated with more time in an awkward trunk posture, although discomfort ratings for the back were the same for both standing and seated. On the other hand, less time was spent in awkward shoulder posture when seated, but discomfort ratings were again the same between standing and seated. Overall, surgeons in a standing position reported more discomfort at the wrists, thighs, and lower legs. Gutierrez-Diez et al. (2018) determined that surgeons specialized in ophthalmology and otolaryngology, who operate while sitting, showed higher prevalence of MSDs than other minimally-invasive surgeons who operate while standing. However, this discrepancy may be due to differences in the surgical procedures and not necessarily due to posture. Irving (1992) designed a pelvic-tilt chair for surgeons and then conducted a survey to assess its impact. About 40% of the participants reported low back improvement after using the chair for operations lasting 1 hour or less, 70% reported improvement for operations lasting 1-2 hours, and 100% reported improvement for operations lasting more than 2 hours. It has been reported in literature that complexity and increasing surgery constraints had effects in increasing stress level among surgeons, leading to physical and mental health problems (Vijendren et al., 2015). More complex surgeries, the laparoscopic surgeries, had imposed higher stress levels on surgeons, and higher time in static postures thus higher MSDs (Supe et al., 2010; Arora et al., 2010).

To our knowledge, no research has yet compared seated and standing postures on surgeons using objective measures, such as surgeon performance and muscle activation levels. The focus in the literature has been more on subjective or perceived levels of discomfort experienced by surgeons. Therefore, the purpose of this research was to compare both postures during simulated surgery using objective and subjective measures. Specifically, two main objective measures were considered, which are muscle activation levels of back and shoulder muscles – the most reported sites for pain and discomfort by surgeons (Auerbach et al., 2011; Gutierrez-Diez et al., 2018; Esposito et al., 2013; Miller et al., 2012) – and performance, including the time to complete a surgical task and the LAPSIM overall performance score. Past studies have not considered the effects on surgeons' performance; rather, the focus was more on surgeons' health and comfort. However, performance is an important factor to consider not only for assessing surgeons' quality of work but also for the safety of patients. In addition, subjective data was collected for both postures using two standard surveys that inquire about discomfort levels at different body regions (localized musculoskeletal discomfort scale) and the perceived overall workload level (overall workload scale). Using a more comprehensive approach, this research analyzed the direct impact of seated and standing postures on surgeons' muscle activations, comfort, and performance. While surgery has different levels of complications, this research also investigated how surgery complexity levels affect the measured outcomes.

CHAPTER III

METHODOLOGY

A. Study Design

The study followed a randomized cross-over design where two factors were considered, including the surgical work posture (standing vs sitting) and task complexity level (easy vs difficult). All combinations of both factors were examined and presented to participants in a random order. The total experiment duration was approximately one hour. Experiments were conducted in the simulation lab at the Department of Surgery in the American University of Beirut – Medical Center (AUB-MC). The study underwent a full board review by the Institutional Review Board (IRB) of AUB. Twenty 3rd and 4th- year medical students from AUB-MC were recruited. Sample size was determined using G*power tool for statistical power analysis (Faul et al., 2007). At 80% power, 5% significance level, and effect size derived from previous EMG studies, paired t- test results showed that having seventeen participants is sufficient to detect significant difference in outcomes between the groups under study. IRB-approved informed consent forms were presented to participants, and their signatures were obtained prior to the experiments. In addition, the Physical Activity Readiness Questionnaire (PAR-Q, British Colombia Ministry of Health) was used to screen the participants for any cardiac or other health issues, such as heart trouble, chest pain, or dizziness (Hafen and Hoeger, 1994). Any participant who answered “yes” on one of the questions was excluded from the study, as well as any participant with an acute or chronic muscle disease.

The experimental tasks were randomized for each participant using a series of William's standard balanced Latin squares and the non-restricted sequential counterbalancing method. Given that 20 participants were recruited and that there were four experimental tasks, an array of 20 × 4 was developed using a series of five William's 4 × 4 balanced Latin squares (Table 1; Appendix A); experimental trials are denoted with letters, where A = easy, sitting, B = easy, standing, C = difficult, sitting, and D = difficult, standing. This form of randomization controls the carryover effect in cross-over designs by ensuring that: each letter (or experimental task) is presented an equal number of times in both the columns and rows; and each letter is preceded by each of the other letters an equal number of times (Alferez, 2012). The 20 random sequences from the William's Latin squares were randomly assigned to each participant using a random number table (Appendix B). Table 1 shows the generated random sequence to be followed by each participant.

Table 1 Randomized task sequences for each participant (A = Easy, Sitting, B = Easy, Standing, C = Difficult, sitting, D = Difficult, standing).

Participant	Sequence
1	D C B A
2	A D B C
3	A C B D
4	B A C D
5	B D A C
6	B C A D
7	C D A B
8	C A B D
9	D B A C
10	D C A B
11	A B D C
12	B C D A
13	C A D B
14	D B C A
15	B A D C
16	A D C B
17	C B D A

18	A B C D
19	C D B A
20	D A C B

Furthermore, an interview following a survey – as shown in Appendix C – was conducted before the experiments to collect information about the participants. The survey was constructed by selecting questions from different questionnaires and interviews in the literature (Esser et al., 2007; Singh et al., 2018; Gutierrez-Diez et al., 2018; Beers et al., 2008; and Keirklo et al., 2011). Furthermore, the survey was iteratively revised and edited by the authors during multiple meetings to obtain the final version. The resulting survey consisted of two parts - a section for demographic information and another for personal and study conditions. The demographic information section asked about the participant's age, gender, height, weight, and BMI. The personal and study conditions section inquired about the participant's dominant hand, smoking habits, exercise habits, chronic diseases, personal preferences while studying, and among other questions.

B. Equipment

This study used a Tringo wireless EMG system (Delsys Inc., Boston, MA, USA) to measure muscle activation over the low back and shoulder (Figure 1). The EMG system consisted of four rectangular (37mm x 26mm x 15mm, 14g) Ag/AgCL sensors that were attached to the right and left upper trapezii and lumbar erector spinae muscles. The Trigno electrodes had a band-pass filter of 20–450 Hz and a common mode rejection ratio of 80 dB. EMG data was collected at a sampling rate of 2000 Hz and processed using the root mean square (RMS) method with a time window of 0.125 s and an overlap of 0.0625 s (De Luca, 1997; Konrad, 2005). To process and analyze the data, the EMGworks software (Delsys Inc., Boston, MA, USA) was used.

Figure 1 Trigno wireless EMG system and EMGworks software (Delsys Inc., Boston, MA, USA).

Also, a LAPSIM (Surgical science, Gothenburg, Sweden) was used, which is a simulator consisting of laparoscopic tools and a monitor to mimic tasks performed in laparoscopic surgery (Figure 2). This simulator includes a module on the fundamentals of laparoscopic surgery (FLS), which teaches medical students the required technical skills to perform laparoscopic surgery. The students learned by performing simulated surgical tasks or games that require precision at different levels of complexity. At the end of each task, the simulator outputs an overall performance score along with other detailed performance measures.

Figure 2 LAPSIM (Surgical science, Gothenburg, Sweden)

C. Data Collection and Procedures

An orientation was presented to the participants, in order to familiarize them with the experiment’s purpose, the data collection procedures, the experimental tasks, and the equipment to be used. During the orientation, participants were trained on the LAPSIM and were allowed to practice on the experimental tasks until they felt comfortable. Then participants went through an interview, collecting information about their personal characteristics and study preferences. After the interview, participants were prepared for EMG data collection by cleaning the skin with alcohol and shaving any hair over the muscle sites. Then EMG sensors were attached on the right and left upper trapezii (RUT and LUT) and right and left lumbar erector spinae muscles (RES and LES) at the following locations:

- Upper Trapezius: the electrode was placed 2 cm lateral to the midpoint between the C7 spinous process and the posterolateral border of the acromion (Cram et al., 1998; Mathiassen et al., 1995; McLean et al., 2003).
- Lumbar Erector Spinae: the electrode was placed 2 cm lateral to the L3 spinous process parallel to the muscle fibers (Cram et al., 1998).

To enable EMG comparisons between and within participants, EMG data was normalized to each participant's maximum voluntary contractions (MVC). MVCs were performed for each individual muscle against manual resistance from the experimenter. The maximum EMG amplitudes were used for normalizing EMG data; hence, the data was reported as a percentage of each muscle's MVC (%MVC). According to Ekstrom et al. (2005), the MVC for the upper trapezii muscles can be reached by shoulder abduction to 90 degrees with the neck laterally flexed to the same side, rotated to the opposite side, and then extended. At the same time, the experimenter was applying manual resistance at the participant's shoulder and head against further shoulder abduction and neck extension. As for the lumbar erector spinae, its MVC can be reached by first having the participant stand restrained facing the wall and extend his trunk against manual resistance from the experimenter at the shoulders (Al-Qaisi et al., 2020). The participants were instructed to perform the MVCs by gradually exerting up to their maximal force in 3 to 5 s, maintaining it for 3 s, and gradually decreasing their force in 3 s (Konrad, 2005). There was a 2 min break between the MVC exercises of the upper trapezius and lumbar erector spinae muscles (Konrad, 2005).

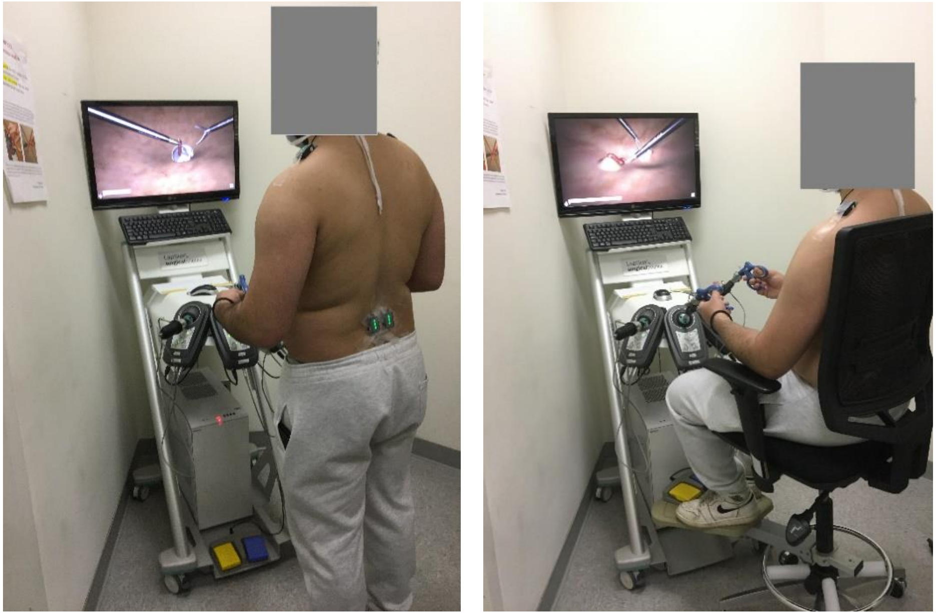


Figure 3 Participant maintaining a standing posture (left) and sitting posture (right).

Figure 4 Modified chair with platform attached, serving as a footrest and providing space to place pedals.

Then participants performed simulated surgical tasks on the LAPSIM simulator using two work postures (standing vs sitting) and two complexity levels (easy vs difficult). The two different postures are seen in figure 3. A total of four experimental tasks were performed in random order (2 postures × 2 complexity levels). The easy task required the use of only one laparoscopic tool in order to grasp, remove, and place vessels in a small disposable bag. The difficult task required the use of multiple laparoscopic tools simultaneously. Specifically, it required the participant to grasp a vessel at its end with one laparoscopic tool, grasp it with a second tool at a highlighted area, cut that area using a foot pedal, and finally place the cut end in a small disposable bag. The chair used for the seated trials (KCOM Office Solutions, Beirut, Lebanon) has an adjustable elbow rest and footrest, a back rest with lumbar support, and an adjustable seat height of up to 85 cm. An extra platform has been attached to the chair to provide space for the placement of the pedals, as presented in Figure 4. During the seated trials, an ergonomic posture was maintained by ensuring that the participant's elbow height was at the same level of the laparoscopic tools (Berquer et al.,2002) and that the pedals were placed near the feet (Sánchez-Margallo and Sánchez-Margallo, 2017). Using the elbow rest was kept as a personal preference for every participant as the tasks require continuous arm movements and in various directions, thus having the elbow rest might obstruct arm mobility. Since the LAPSIM height is fixed, the chair was adjusted during seated trials according to each participant's anthropometry, and a backrest and a footrest was provided. The footrest was set at a height such that the knee angle was approximately flexed 90^o. Participants were instructed to use both the backrest and footrest throughout the tasks. Muscle activation throughout the experimental trials was recorded using the EMG system. The average and integrated EMG activities were obtained and analyzed using EMGworks analysis software (Delsys Inc., Boston, MA, USA). For each participant, the overall performance score–which can be obtained from the LAPSIM output – and the time to complete each task was analyzed as performance measures; there was no time limit for each experimental task. The overall performance score is a measure of both accuracy and time. The accuracy component accounts for left instrument misses, right instrument misses, tissue damage, maximum stretch damage, maximum damage, rip failure, and drop failure. The time component accounts for left instrument time, right instrument time, and total time. Also, after each task, participants were asked to assess their overall subjective workload using the overall workload (OW) scale (Figure 5). It is a workload assessment tool for participants to subjectively evaluate the task on a unidimensional scale. The scale ranges from 0 (very low) to 100 (very high) with increments of 5 (Vidulich and Tsang, 1987). In addition, participants were asked to rate their perceived level of localized musculoskeletal discomfort (LMD) on a body map, specifically for the neck, shoulders, and lower back regions, labelled as 1, 2, and 7 (Van der Grinten and Smitt, 1992; Corlett and Bishop, 1976; Figure 6). The LMD method uses ratings of discomfort ranging between 0 and 10, where 0 means "no discomfort at all" and 10 means "extreme discomfort, almost maximum." Finally, at the completion of the experiment, a brief exit interview was conducted, asking about their preferred work posture in the easy and difficult tasks. Both the OW scale and LMD scale along with the exit interview questions were placed in a data collection sheet (Appendix D), which was presented to the participants.

Figure 5 Overall Workload Scale

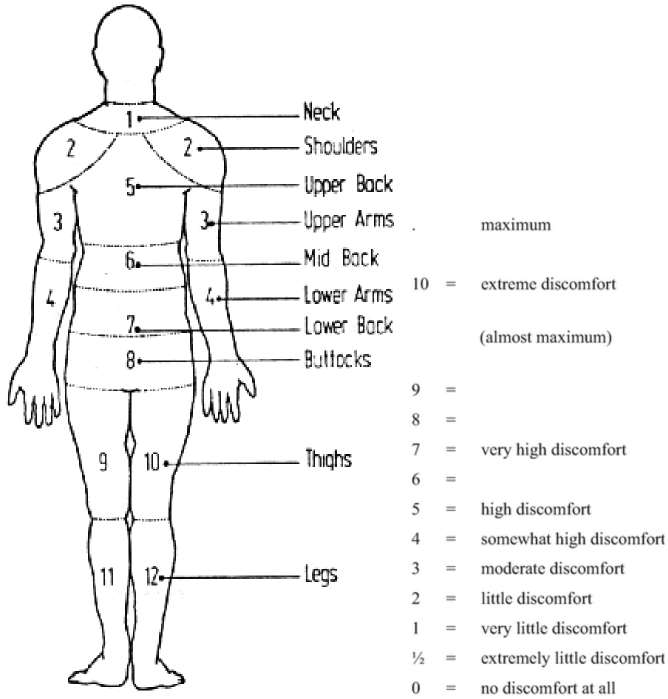


Figure 6 Discomfort Body Map (Corlett and Bishop,1976; Van der Grinten and Smitt, 1992).

D. Statistical Analysis

A two-factor repeated measures analysis of variance (ANOVA) was used to assess the effects of posture (sitting vs standing) and task complexity (easy vs difficult) on participants' muscle activity, performance, overall workload ratings, and discomfort ratings. The experiment was replicated 20 times. The replicates served as blocks within which experimental conditions were randomized. For all significant effects, post hoc analyses in the form of Tukey tests were performed to determine the source(s) of the significant effect(s). The significance level (α) will be set at 5%. Prior to the ANOVA analysis, pre-hoc Anderson-Darling tests were performed to check the normality of the data residuals of the dependent variables. Non-normal data was transformed to normal data by applying Box-Cox transformations. Integrated and average EMG data for the left and right upper trapezius muscles were transformed using the square root Box-Cox transformation. Integrated and average EMG data for the left and right lumbar erector spinae muscles, as well as the total time to complete the task, were all transformed using the natural log Box-Cox transformation. All other dependent variables followed a normal distribution.

CHAPTER IV

RISKS, BENEFITS, AND CONFIDENTIALITY

There were no to minimal risk in this study. EMG sensors imposed no risk on the participants, and the MVC exercises had minimal risk similar to that of normal stretching exercises. To minimize any potential risks, participants were requested to perform the exercises with a gradual force increase to avoid straining a muscle. Also, rest breaks were provided between exercises. Participants were requested to inform the experimenter if they feel any pain or discomfort and would like to stop.

The findings of this study may determine whether seated or standing is better during laparoscopic surgery, in terms of surgeon's performance and well-being. The subjects represent a sample of medical students. Considering that some medical students may become future laparoscopic surgeons, some of them will benefit from the findings/recommendations of this study regarding the most suitable work posture for improving performance and well-being. The benefits of the experiment outweigh the risks. The findings of this study may lead the way for future studies. It is the first study, to our knowledge, that compares sitting and standing work postures among surgeons objectively, using EMG and performance measures. The findings of this study might induce surgeons to change their posture during surgery in a way that minimizes MSD risks and improves performance.

The participants' identity remained confidential, and their data was stored on excel sheets on a password-protected computer that no one can access except for the PI and the co-investigators. All data will be destroyed responsibly after the required retention period (after three years). The participants' identity will not be revealed in any report or publication resulting from this study.

CHAPTER V

RESULTS

A. Participants' Demographics and Characteristics

20 fourth- and third-year medical students were recruited. 60% of the participants were males and 40 % of the participants were females with an average age of 24. 20% of the population were smokers and 60% of the participants consider themselves having an active lifestyle. The average height and weight of participants was 174 cm and 74.5 kg, respectively. The mean BMI of participants was 24.5 indicating healthy participants on average. 75% of the participants preferred standing during stressful situations, while all the participants preferred sitting while studying. 90% of the participants had no LAPSIM experience and 10% had minimal experience. The table below shows the characteristics of the pool of participants.

Table 2 Participants' characteristics. Data are reported in Mean (SD) and percentages.

Age		24 (0.8)
Height (cm)		174 (9.38)
Weight (kg)		74.5 (15.5)
% Males		60%
Males Characteristics	Age	24 (0.91)
	Height	179.5 (5.8)
	Weight	82.9 (3.9)
% Females		40%
Females Characteristics	Age	24.13 (0.6)
	Height	165.87 (7.62)
	Weight	61.87 (11.76)
BMI		24.5 (4.3)
% Smokers		20%
% Active participants		60%
Preferred posture during stressful situations	Standing	75%
	Sitting	35%

Hours of sleep per night	7.01 (1.03)	
Hours of sleep a night before the experiment	6.9 (1.4)	
Dominant Hand	Right	95%
	Left	5%
Hours of study per week	37.7 (25.27)	
Studying posture preference	Sitting	100%
	Standing	0%
LAPSIM experience	None	90%
	≤1 hr	5%
	≤2 hrs	5%

B. Muscle Activity

Prior to applying ANOVA statistical test, average and integrated EMG data for the four muscles were transformed to normal data by applying Box Cox transformation. Statistical analysis was performed on the transformed data. ANOVA results of the average EMG (%MVC) indicated no significant posture*complexity interaction effects for any of the four studied muscles. Thus, individual main effects were only examined. Table 3 presents the p-values from the ANOVA results for the main and interaction effects for each of the four muscles.

Table 3 p-values of the main & interaction effects. Values with asterisks (*) indicate significant p-values ($p < 0.05$).

	Avg. EMG LUT	**Avg. EMG RUT**	**Avg. EMG LES**	**Avg. EMG RES**
Posture	<0.01*	<0.01*	0.482	0.770
Complexity	0.238	0.101	0.021*	0.085*
Interaction	0.326	0.187	0.192	0.177

Posture had a significant effect only on the left and right upper trapezius muscles. Table 4 & figure 7 present the means of the average EMG (%MVC) for each muscle for the sitting and standing postures. Tukey letter groupings within each muscle are placed in superscript; means that do not share a letter are significantly different ($p < 0.05$). The means of the average EMG were significantly higher while sitting for the left and right upper trapezius muscles. Although the means of the average EMG for the left and right lumbar erector spinae muscles were higher while standing, no prove of significance was provided by ANOVA.

Table 4 Means (SE) of the average EMG (%MVC) for the posture main effect for every muscle. Means that do not share a letter are significantly different.

Posture	**Avg. EMG LUT**	**Avg. EMG RUT**	**Avg. EMG LES**	**Avg. EMG RES**
Sitting	7.182 (0.712) [a]	9.24 (1.16) [a]	15.39 (1.7) [a]	11.19 (1.17) [a]
Standing	4.947 (0.621) [b]	5.741 (0.679) [b]	17.76 (3.36) [a]	11.59 (1.99) [a]

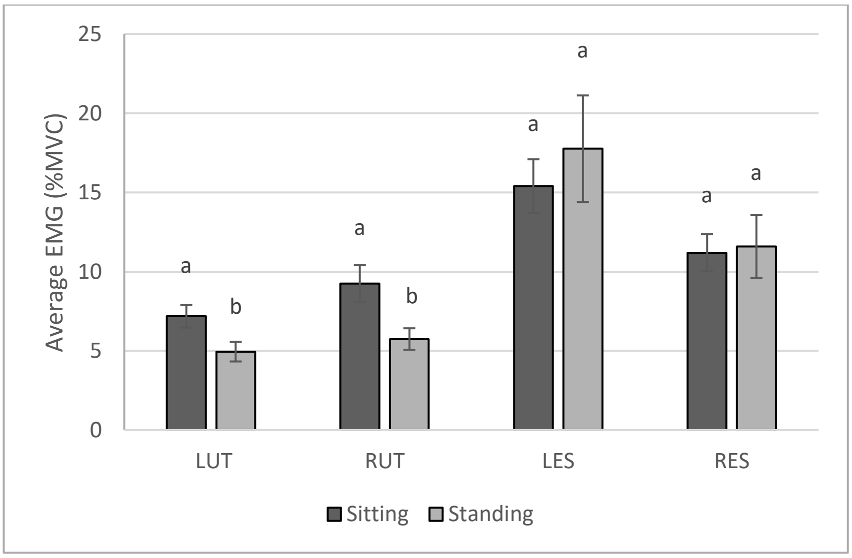


Figure 7 Histogram showing the means (SE) of the average EMG (%MVC) for the posture main effect for each of the four studied muscles. Means that do not share a letter are significantly different.

Complexity had a significant effect only on the mean of the average EMG of left lumbar erector spinae muscle. Table 5 & figure 8 present the means of the average EMG (%MVC) for each muscle for the easy vs the difficult tasks. The mean of the average EMG was significantly higher for the difficult task only for the left lumber erector spinae muscle.

Table 5 Means (SE) of the average EMG (%MVC) for the complexity effect for every muscle. Same letters within each muscle indicate insignificant effects.

Complexity	Avg. EMG LUT	Avg. EMG RUT	Avg. EMG LES	Avg. EMG RES
Easy	5.728 (0.601) [a]	7.066 (0.981) [a]	14.36 (2.19) [a]	9.97 (1.10) [a]
Difficult	6.401 (0.768) [a]	7.92 (1) [a]	18.79 (3.03) [b]	12.81 (2.01) [a]

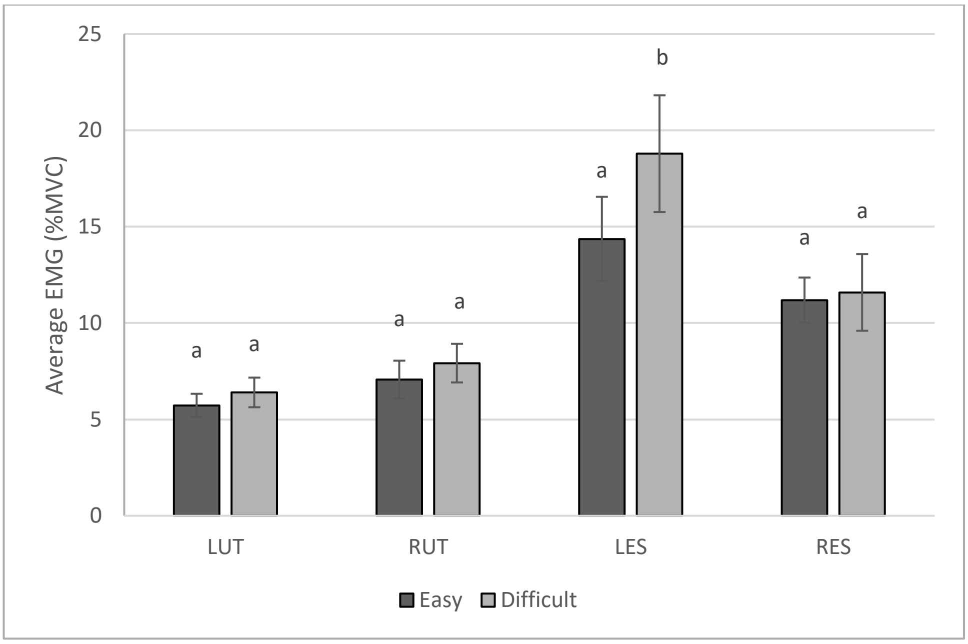


Figure 8 Histogram showing the means (SE) of the average EMG (%MVC) for the complexity main effect for each of the four studied muscles. Means that do not share a letter are significantly different.

ANOVA results of the integrated EMG (%MVC.s) indicated no significant posture*complexity interaction effects for any of the four studied muscles. Thus, individual main effects were only examined. Table 6 presents the p-values from the ANOVA results for the main and interaction effects for each of the four muscles.

Table 6 p-values of the main & interaction effects. Values with asterisks (*) indicate significant p-values (p < 0.05).

	iLUT	**iRUT**	**iLES**	**iRES**
Posture	<0.01*	<0.01*	0.813	0.969
Complexity	<0.01*	<0.01*	<0.01*	<0.01*
Posture*Complexity	0.151	0.156	0.127	0.225

Posture had a significant effect on the left and right upper trapezius muscles only. Table 7 presents the means (SE) of the integrated EMG (%MVC.s) for the posture effect for each of the four studies muscles. Tukey letter groupings within each muscle are placed in superscript; means that do not share a letter are significantly different (p< 0.05). Figure 9 shows the histogram with standard error bars of the means of the integrated EMG (%MVC.s) for participants performing the LAPSIM tasks while sitting in comparison to those performing while standing. Tukey letter groupings are also presented on the top of the bars. The means of integrated EMG significantly increased while sitting for both the left and right upper trapezius muscles. While the means of integrated EMG for the left and right lumbar erector spinae muscles increased while standing, the increase was not proven to be statistically significant.

Table 7 Means (SE) of the Integrated EMG (%MVC. s) for the posture effect for every muscle. Means that do not share a letter are significantly different.

Posture	**iLUT**	**iRUT**	**iLES**	**iRES**
Sitting	1079 (159) ^{a}	1413 (259) ^{a}	2086 (252) ^{a}	1479 (233) ^{a}
Standing	656 (103) ^{b}	829 (128) ^{b}	2880 (786) ^{a}	1718 (394) ^{a}

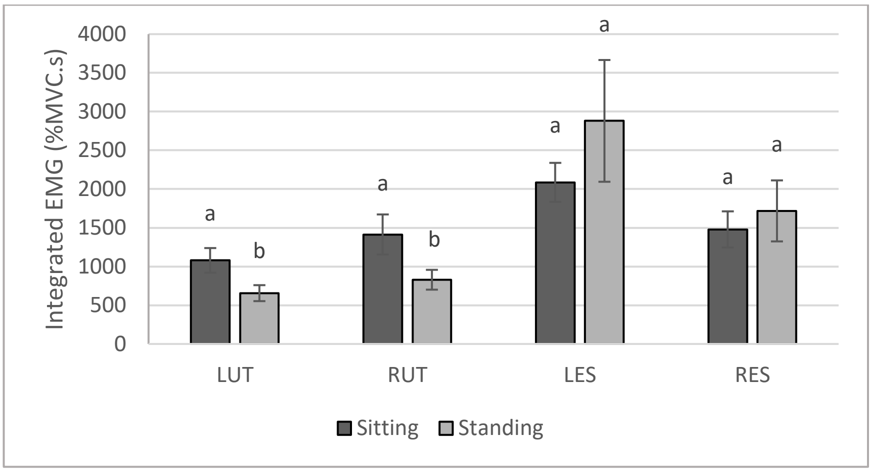


Figure 9 Histogram showing the means (SE) of the integrated EMG (%MVC.s) for the posture main effect for each of the four studied muscles. Means that do not share a letter are significantly different.

Complexity had significant effect on all the four studied muscles. Table 8 presents the means (SE) of the integrated EMG (%MVC.s) for the complexity effect for each of the four studies muscles. Figure 10 shows the histogram with standard error bars of the means of the integrated EMG (%MVC.s) for participants performing the LAPSIM easy tasks vs difficult tasks. Tukey letter groupings are also presented on the top of the bars. The means of integrated EMG significantly increased while performing the difficult tasks for each of the four muscles.

Table 8 Means (SE) of the Integrated EMG (%MVC. s) for the complexity effect for every muscle. Means that do not share a letter are significantly different.

Complexity	**iLUT**	**iRUT**	**iLES**	**iRES**
Easy	618.7 (94.9) [a]	764 (142) [a]	1529 (286) [a]	1021 (131) [a]
Difficult	1116 (162) [b]	1477 (247) [b]	3437 (750) [b]	2176 (420) [b]

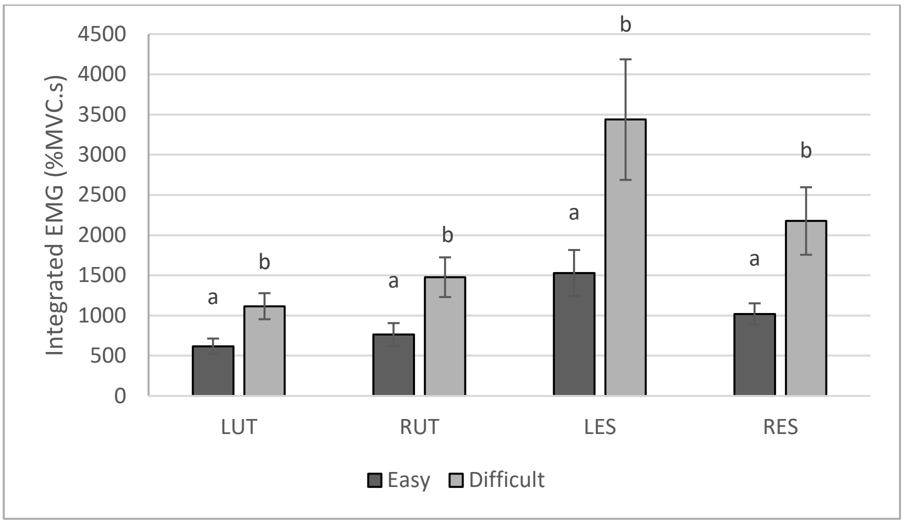


Figure 10 Histogram showing the means (SE) of the integrated EMG (%MVC.s) for the complexity main effect for each of the four studied muscles. Common letters within each muscle indicate insignificant difference.

C. Performance Measures

Prior to applying ANOVA statistical test, overall performance scores and total time data were checked for normality. Total time data was transformed to normal data by applying Box Cox transformation while overall performance scores followed a normal distribution. Statistical analysis was performed on the transformed data. ANOVA statistical test was applied for the LAPSIM overall performance scores and the total time taken to complete the task (s). Table 9 presents the p-values for the main and interaction effects. Posture*complexity interaction effect was found to be significant for the total time only ($p < 0.05$). Thus, the interaction was examined for the total time variable, and the main effects were examined for the overall performance score.

Table 9 p-values of the main & interaction effects. Values with asterisks (*) indicate significant p-values ($p < 0.05$).

	Overall performance score	**Total Time**
Posture	0.967	0.055
Complexity	<0.01*	0.526
Interaction	0.127	0.046*

Table 10 and figure 11 presents the mean (SE) of the overall performance score for each of the main effects individually. Tukey letter groupings are superscripted and placed at the top of the bars; means that do not share a letter are significantly different. The posture main effect was not found to be statistically significant, and descriptive statistics revealed the means being almost equal for both sitting and standing tasks. However, complexity main effect was found to be significant; the mean scores were significantly higher for the easy tasks.

Table 10 Mean (SE) of the overall performance score for every level of the main effects. Means within each main effect that do not share a letter are significantly different.

	Posture		**Complexity**	
	Sitting	**Standing**	**Easy**	**Difficult**
Overall Performance Score	68.99 (3.51) [a]	68.85 (3.32) [a]	78.45 (2.58)[a]	59.39 (3.47) [b]

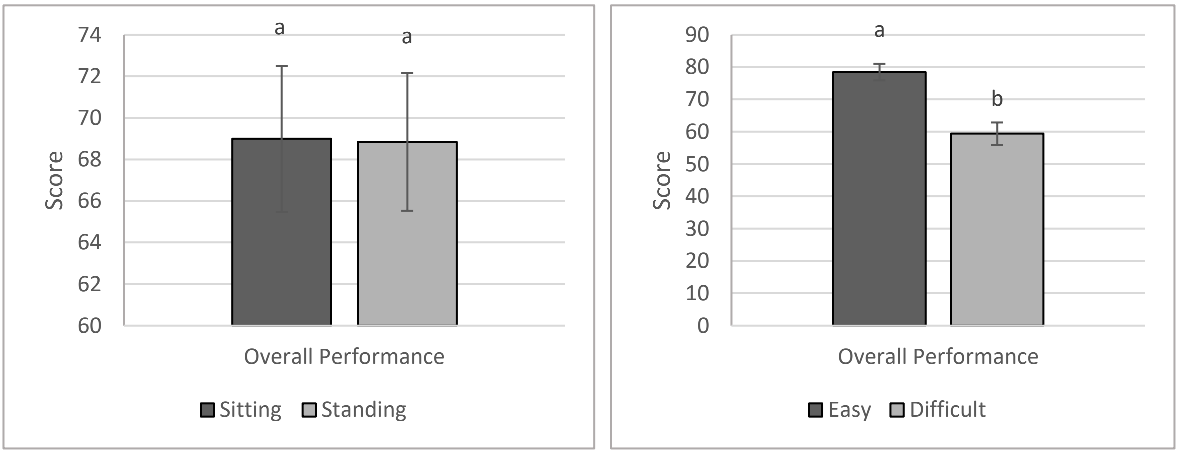


Figure 11 Histograms showing the means (SE) of the overall performance score for the posture and complexity main effect individually. Means within each main effect that do not share a letter are significantly different.

Table 11 presents the means of the posture*complexity interaction effects with tukey letters superscripted. Means that do not share a letter were significantly different. The interaction plot is presented in figure 12. As so, the total time taken to perform the task significantly increased while sitting for the difficult task only. However, for the easy task, the total time was approximately equal.

*Table 11 Mean (SE) of the Total time(s) for the Posture*Complexity interaction effects. Means that do not share a letter are significantly different.*

Total Time	Sitting	Standing
Easy	138.6 (15.7) [ab]	138.2 (13.1) [ab]
Difficult	152.8 (14.7) [a]	114 (12.9) [b]

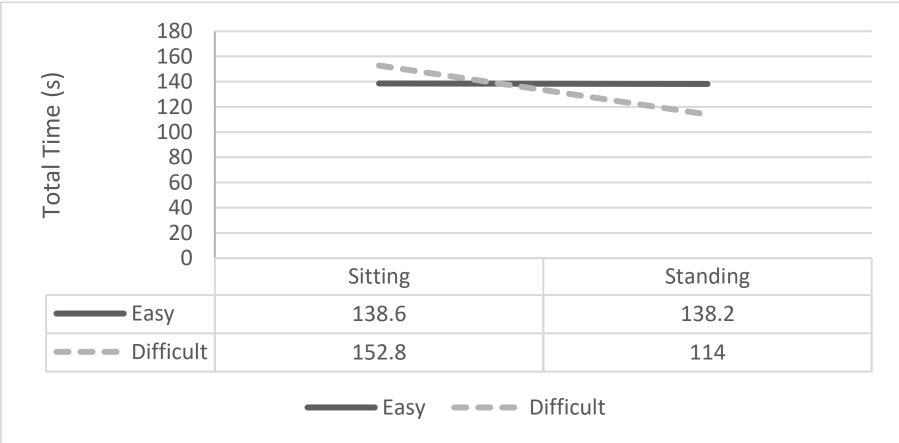


*Figure 12 Posture*complexity interaction plot for the total time means (s).*

D. Subjective Assessment

All subjective assessment data followed a normal distribution. P- values from the ANOVA results for the overall workload rating and localized musculoskeletal discomfort rating at the neck, back and shoulders are presented in table 12. No significant posture*complexity effect was detected so individual main effects were examined for all the ratings.

Table 12 P-values of the main & interaction effects. Values with asterisks (*) indicate significant p-values ($p < 0.05$).

	Overall workload rating	LMD neck	LMD shoulder	LMD back
Posture	0.584	0.496	0.06	0.172

Complexity	<0.01*	0.002*	0.002*	0.257
Interaction	0.974	0.852	0.545	0.906

The means of each of the subjective ratings for the posture main effect is presented in table 13. Tukey letter groupings are superscripted; means that do not share a letter are significantly different. Figure 13 provides the histograms of the means of the various subjective ratings for the posture main effect. Descriptive statistics revealed slightly higher mean of the overall workload rating for tasks performed while sitting. The mean of the localized LMD rating for the neck and back was higher for tasks performed while standing, while the mean of the LMD rating for the shoulder was higher for tasks performed while sitting. However, none of the latter results were proven to be statistically significant.

Table 13 Mean (SE) for the posture effect for every subjective assessment rating. Means that do not share a letter are significantly different.

Posture	Overall workload rating	LMD neck	LMD shoulder	LMD back
Sitting	49.25 (4.06) [a]	1.475 (0.241) [a]	2.175 (0.329) [a]	1.837 (0.297) [a]
Standing	47.13 (4.47) [a]	1.613 (0.217) [a]	1.663 (0.233) [a]	2.275 (0.332) [a]

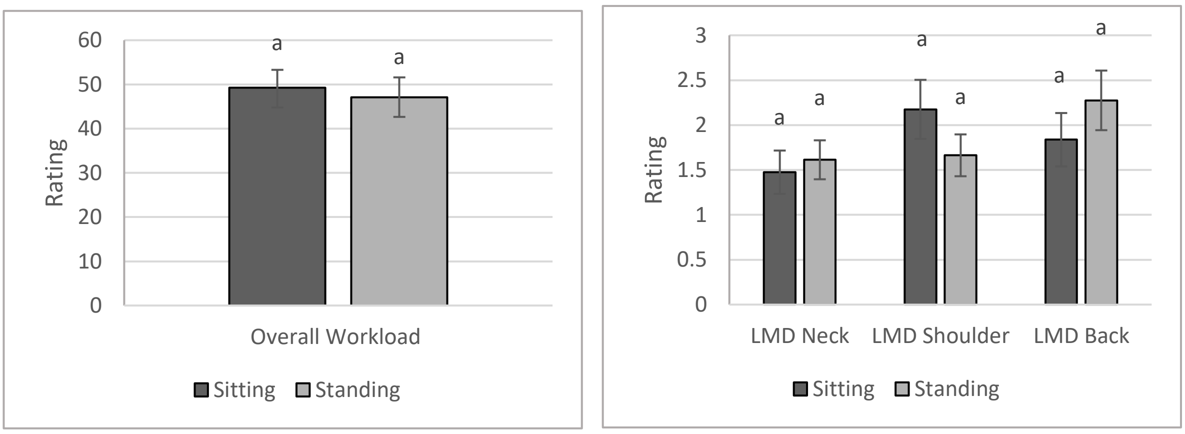


Figure 13 Histograms showing the means (SE) of the overall performance score for the posture main effect individually. Means that do not share a letter are significantly different.

Investigating the complexity main effect alone, the mean of the overall workload rating was significantly higher for the difficult task. The mean of the LMD rating of the neck and shoulder was significantly higher for the difficult task; the mean of the LMD rating of the back was higher for the difficult task but with no prove of significance. Table 14 presents the means of the subjective ratings for the complexity main effect with tukey letters superscripted. Figure 14 provides the histograms of the means of the various subjective ratings for the complexity main effect.

Table 14 Mean (SE) for the complexity effect for every subjective assessment rating. Same letters within each column indicate insignificant effects.

Complexity	**Overall workload rating**	**LMD neck**	**LMD shoulder**	**LMD back**
Easy	33.50 (2.64) [a]	1.212 (0.190) [a]	1.475 (0.269) [a]	1.875 (0.312) [a]
Difficult	62.88 (4.30) [b]	1.875 (0.253) [b]	2.362 (0.289) [b]	2.237 (0.319) [a]

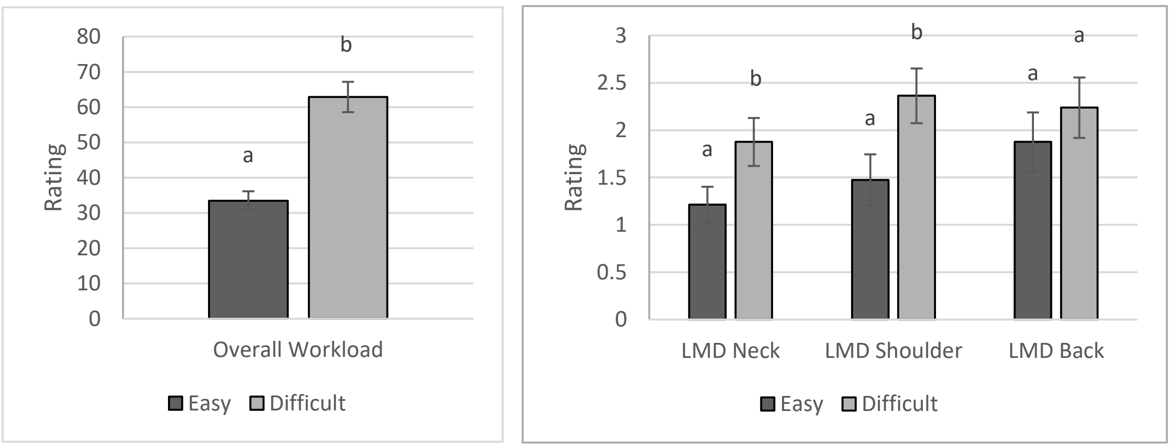


Figure 14 Histograms showing the means (SE) of the overall performance score for the posture main effect individually. Means that do not share a letter are significantly different.

E. Exit Interview Questions

Figure 15 presents the participants posture preference for each of the easy and difficult tasks. For the Easy task, 60 % of the participants preferred standing. Reasons provided by the participants varied from being less restricted and having more range of motion, feeling more comfortable, and having less neck and shoulder discomfort. Table 15 presents participants responses for the reasons they chose the preferred postures for the easy task. For the difficult task, 60% of the participants preferred sitting. Reasons provided by the participants varied from easy maneuvering of the peddle, less back discomfort and more back stability, ability to work with more focus and precision, being more in control, feeling more comfortable, and sustaining for longer times. Table 16 presents participants responses for the reasons they chose the preferred postures for the difficult task.

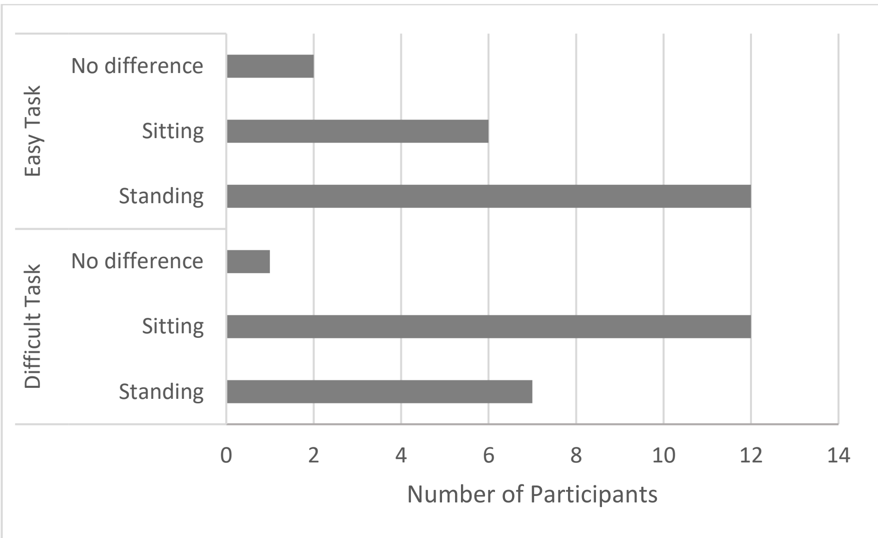


Figure 15 Participant Posture Preferences for the Easy and Difficult tasks.

Table 15 Participant responses for the question:" For the Easy task, did you prefer sitting or standing and why?". The number of participants having similar responses is found between parentheses.

Reasons Sitting was preferred	Reasons Standing was preferred
(4) More balanced body posture; back was more stable. (4) Less discomfort at the back. (3) Overall more comfortable. (3) Better maneuvering; more in control.	(5) Better maneuvering; more in control. (4) Less discomfort at the shoulders. (4) Less restricted and more range of motion. (1) Overall more comfortable. (1) Felt more engaged and responsive. (1) Personal preference. (1) Less discomfort at the neck.

Table 16 Participant responses for the question:" For the Difficult task, did you prefer sitting or standing and why?".

Reasons Sitting was preferred	Reasons Standing was preferred
(5) Easy use and reach of peddle. (4) Less discomfort at the back. (4) Better maneuvering; more in control. (3) Overall more comfortable. (2) More balanced body posture; back was more stable. (2) More focused. (2) Preferred it for longer tasks. (1) More relaxed.	(5) Less restricted and more range of motion. (2) Less discomfort at the shoulders. (1) Better maneuvering; more in control. (1) Less discomfort at the neck. (1) More focused.

CHAPTER VI

DISCUSSION

The study aimed to compare two specific work postures (sitting vs standing) in terms of muscle activity, performance, and subjective feedback while considering two complexity levels (easy vs difficult). The study investigated the average and integrated EMG activities for the left and right upper trapezius muscles and left and right lumbar erector spinae muscles. Both variables followed the same trend: The average and integrated EMG activities were significantly higher at the shoulders while sitting. Although not significantly different, the average and integrated EMG activities where higher at the lower back while standing. Such findings are in agreement with Lin et al. (2017) and Le and Marras (2016) findings. Lin at al. (2017) reported higher EMG activity at the shoulders while sitting in a computer workstation task. Le and Marras (2016) reported highest spinal load in a standing office workstation. In terms of EMG activity, standing was favored as it induced significantly lower shoulder muscle activity. Sitting resulted in more pressure on the shoulders as the participant was forced to frequently raise his shoulders upwards creating higher muscle activity. Moreover, the tasks required the participant to constantly move the tools inwards, outwards, and in several directions creating more tension on the shoulders. However, working on enhancing upper extremity posture during sitting by placing the instruments slight below elbow level – to mimic the upper extremity posture while standing – could have decreased the muscle activity at the shoulders. Also, we can notice that the percentage increase for the average EMG activity at the right and left shoulder was only 2.3% and 3.5% respectively when the posture was switched from standing to sitting. The muscle was only utilizing around 3% more of its maximum voluntary contraction than when the participant was seated. While we did not detect significant difference for the lower back muscle activity between sitting and standing, we can still report generally higher EMG activity for the lower back muscles with respect to the shoulder muscles regardless of the posture. Thus, the lower back is generally bearing higher muscle activity than that of the shoulder, utilizing up to 18% of the lower back maximum voluntary contraction. In terms of complexity, the more difficult task was accompanied with higher EMG activities. As so, once the task got more difficult, the participant experienced higher muscle activity at the lower back and shoulders.

The overall performance of the participant was not affected by the posture; participants were performing the same on average while sitting and while standing. Participants were performing better in the easy tasks. The time spent to complete the task was longer while sitting for the difficult tasks only. In terms of performance, standing was favored as it required less time to have similar performance for the difficult task done while standing as that done while sitting.

The feedback obtained from participants in terms of overall workload and localized musculoskeletal discomfort at the neck, shoulder, and back did not significantly vary between sitting and standing. This could be due to the fact that the tasks were short in resembling the time taken in a real surgery, which is 130.45 minutes on average as reported by Costa Jr (2017). The time spent in performing the tasks may have not been long enough for the participants to detect a difference in discomfort between the two postures. In terms of subjective assessment results, we could not reach a conclusion regarding a preferred posture. Similarly, Singh et al (2018) did not detect significant differences in discomfort ratings for the shoulders and trunk for actual surgeons performing real surgery either seated or standing. However, his study additionally investigated the discomfort of thighs, lower legs, and wrists, which was higher while standing and thus disfavored this posture. Had our study considered those body muscles, in addition to the shoulder and lower back, a conclusion for the preferred posture in terms of discomfort ratings might have been reached. Considering the raw averages, the LMD at the low back was higher while standing, and the LMD at the shoulders was higher while sitting. Similar trends were also noticed in the EMG activity results discussed earlier. Sitting was accompanied with higher shoulder EMG activity and higher shoulder discomfort while standing was accompanied with higher low back EMG activity and higher low back discomfort, although not always significant. In terms of complexity, it was expected to see almost all ratings significantly higher for the difficult tasks, which required more skills and focus and was thus more demanding.

In terms of participants responses, sitting was favored for the difficult tasks and standing was favored for the easy tasks. According to the participants, each posture had its benefits and drawbacks. Sitting was better for the back stability and comfort and allowed the participant to work with more focus and precision, but participants working while sitting had shoulder discomfort. Standing was better for the shoulders, allowed participants to move freely, but participants were enduring high lower back discomfort. Most of the participants preferred standing for the easy tasks although it resulted in lower back discomfort. The task was not demanding, it was possible to finish it in a short period of time, it did not require any focus and precision, so body stability was not a concern. However, once the task was more demanding, the majority of the participants preferred sitting although it resulted in shoulder discomfort. The sitting posture gave the participants the feeling of being stable and thus they were more confident in working with precision and focus and had the ability to sustain longer. Such findings are in contrary to the findings of Bendix et al. (1985) where most of the participants disfavored the sitting posture. However, the chair used for the sitting posture in the latter study was low, no leg space was present, and the back rest was not firm enough. Such discrepancies in the sitting conditions between the two studies explain the difference in the subjective feedback of the participants. Also, as mentioned earlier, the muscle activity was always generally higher for the lower back (11.2 - 17.8 %MVC) than the shoulders (4.9 – 9.2 %MVC); therefore, the overall preferred work posture may have been influenced more by differences in the low back than in the shoulders. This may explain why participants preferred the seated posture even though it induced higher shoulder muscle activation than standing.

While we do see that there are going to be compromises in case one posture is favored over the other, this gives us a window for suggesting a third posture combing both studied postures. A hybrid posture that combines both sitting and standing by either alternating between the two postures or having supported standing posture might be an optimal posture that will minimize both shoulder and lower back discomfort present in each of the postures individually maintained. Fifty percent of the surgeons participating in a study by Matern and Koneczny (2007) preferred alternating between sitting, standing, and leaning on a support. Pejcic et al. (2015) had similar recommendation for his study on dentists' posture. Alternating between sitting and standing was recommended as it minimized the fatigue and MSDs encountered while working with a single posture. Ratzon et al. (2000) reported lower discomfort ratings among dentists performing while alternating between sitting and standing and thus had similar recommendations as well. The results reported by Vink et al. (2009) supports our recommendation. In his study, two office work environments were examined: in the first work environment, only sitting and standing was possible; and in the second work environment, half-sitting posture was additionally possible, which is a posture in between sitting and standing. Participants were alternating between the three different postures in the second environment. Results showed significant decrease in discomfort ratings of the back, neck, and shoulders for participants working in the second work environment that allowed both half-sitting and alternating between postures. A systematic literature review by Ayad et al. (2005) investigated a preferred work posture for endoscopic sinus surgery, where endoscopic surgery is a general term for laparoscopic surgery. The study, in contrary to our recommendation, recommended sitting. However, the review was not based on studies that compared sitting and standing postures, but rather on studies that evaluated the health risks accompanied with standing. The study shed light on the lower extremities' injuries, neglecting the upper extremity muscle injuries. Laparoscopic surgeries require greater upper extremity muscle effort than open surgeries as reported by Berquer et al. (2003) and, thus, have the surgeon prone to higher upper extremity muscle injuries.

CHAPTER VII

LIMITATIONS AND FURURE RESEARCH

We can recognize several limitations in this study. First, the recruited participants were medical students and not surgeons. They had minimal or no surgical experience. Also, there exists an age discrepancy between the medical students and surgeons which directly affects the muscle activity. Thus, caution needs to be used while extrapolating the results from medical students to surgeons. Second, surgeons, especially more experienced ones, might be biased towards one posture over the other based on their training and experience. However, results will still be valuable for novice surgeons and medical students, who might incorporate the preferred work posture in their future training. Future studies can apply this study on a larger population of medical students or on experienced surgeons. Third, the experimental tasks were simulated laparoscopic procedures, which may fall short in replicating the environment and stress experienced in real surgeries. Fourth, the tasks fell short in replicating the actual time real surgeries take, which is 130.45 minutes on average (Costa Jr, 2017). The experimental tasks, on the other hand, were only 1.6 to 3 min on average (depending on the work posture and task complexity), underestimating the true physical workload experienced by surgeons. As so, caution should be employed when interpreting or generalizing the results to real surgeries. Future studies, however, can develop this study further by applying it in a real operating room setting. Fifth, the participants might vary in their experience with the LAPSIM simulator possibly acting as a confounding variable; however, only two participants were found to have past experience with the LAPSIM (not more than 2 hrs.). All other participants had no prior experience with the LAPSIM. Furthermore, this variable was controlled by allowing participants to practice and train on the LAPSIM until they felt comfortable with its usage. Sixth, the EMG activity results might be affected by the % fat variability between participants. Future studies can investigate the correlations between height, weight, and BMI with the EMG activity.

CHAPTER VIII

CONCLUSION

The study did not completely favor one posture over the other. Standing posture resulted in lower shoulder muscle activity and less time to complete the difficult task. However, although not statistically significant, standing was associated with consistently higher averages in both the subjective and objective results of the low back. Moreover, stability and focus were a major concern for the difficult task which the participants lacked while standing. Sitting was favored by most of the participants for the difficult tasks as it provided the stability and focus, and less discomfort at the lower back. However, sitting resulted in statistically higher shoulder EMG activity. Since no one posture was favored overall, we recommend alternating between both postures (e.g. between surgeries or within long surgeries) as it may decrease the health risks associated with each posture. Future studies may investigate other seat designs or a "hybrid" work posture – such as supported-standing or alternating between sitting and standing – to determine an optimal design that minimizes muscle activity, preserves performance, and ensures comfort.

APPENDIX A

Williams's Designs: Standard Forms of Balanced Latin Squares (2 × 2 to 12 × 12) for the First-Order Carryover Effects in Cross-Over Designs

Even-sided squares — Single carryover designs

2 × 2	4 × 4	6 × 6	8 × 8	10 × 10	12 × 12
AB	ABCD	ABCDEF	ABCDEFGH	ABCDEFGHIJ	ABCDEFGHIJKL
BA	BDAC	BDAFCE	BDAFCHEG	BDAFCHEJGI	BDAFCHEJGLIK
	CADB	CAEBFD	CAEBGDHF	CAEBGDIFJH	CAEBGDIFKHLJ
	DCBA	DFBEAC	DFBHAGCE	DFBHAJCIEG	DFBHAJCLEKGI
		ECFADB	ECGAHBFD	ECGAIBJDHF	ECGAIBKDLFJH
		FEDCBA	FHDGBEAC	FHDJBIAGCE	FHDJBLAKCIEG
			GEHCFADB	GEICJAHBFD	GEICKALBJDHF
			HGFEDCBA	HJFIDGBEAC	HJFLDKBIAGCE
				IGJEHCFADB	IGKELCJAHBFD
				JIHGFEDCBA	JLHKFIDGBEAC
					KILGJEHCFADB
					LKJIHGFEDCBA

Odd-sided squares — Double carryover designs

3 × 3	5 × 5	7 × 7	9 × 9	11 × 11
ABC	ABCDE	ABCDEFG	ABCDEFGHI	ABCDEFGHIJK
BCA	BDAEC	BDAFCGE	BDAFCHEIG	BDAFCHEJGKI
CAB	CAEBD	CAEBGDF	CAEBGDIFH	CAEBGDIFKHJ
ACB	DEBCA	DFBGAEC	DFBHAICGE	DFBHAJCKEIG
BAC	ECDAB	ECGAFBD	ECGAIBHDF	ECGAIBKDJFH
CBA	ACBED	FGDEBCA	FHDIBGAEC	FHDJBKAICGE
	BADCE	GEFCDAB	GEICHAFBD	GEICKAJBHDF
	CEADB	ACBEDGF	HIFGDEBCA	HJFKDIBGAEC
	DBEAC	BADCFEG	IGHEFCDAB	IGKEJCHAFBD
	EDCBA	CEAGBFD	ACBEDGFIH	JKHIFGDEBCA
		DBFAGCE	BADCFEHGI	KIJGHEFCDAB
		EGCFADB	CEAGBIDHF	ACBEDGFIHKJ
		FDGBEAC	DBFAHCIEG	BADCFEHGJIK
		GFEDCBA	EGCIAHBFD	CEAGBIDKFJH
			FDHBIAGCE	DBFAHCJEKGI
			GIEHCFADB	EGCIAKBJDHF
			HFIDGBEAC	FDHBJAKCIEG
			IHGFEDCBA	GIEKCJAHBFD
				HFJDKBIAGCE
				IKGJEHCFADB
				JHKFIDGBEAC
				KJIHGFEDCBA

APPENDIX B

Random Numbers

RC	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	28-30	31-33	34-36	37-39	40-42	43-45
1	450	587	446	424	639	335	518	736	573	283	979	053	034	876	961
2	980	644	218	034	981	288	307	822	754	736	105	783	149	894	013
3	414	101	674	186	494	244	078	005	485	326	666	529	668	207	364
4	744	951	067	393	254	288	538	781	187	594	565	155	509	960	069
5	730	336	204	281	982	758	607	183	076	395	027	582	569	065	138
6	666	486	328	408	974	560	760	929	396	976	075	877	470	361	227
7	853	816	678	133	715	316	288	721	369	081	052	846	510	201	094
8	355	072	133	307	153	723	149	234	514	939	240	073	039	585	628
9	296	381	210	857	149	563	762	474	056	175	261	774	559	822	341
10	668	447	484	697	274	517	520	258	116	203	742	545	878	632	150
11	622	788	820	399	351	505	959	223	284	420	119	153	930	408	682
12	688	796	739	353	239	388	097	099	545	518	615	398	561	540	718
13	782	893	207	590	670	662	534	522	097	471	827	034	323	260	739
14	643	885	000	514	737	467	951	353	247	232	178	336	174	655	872
15	361	178	396	326	188	378	929	387	358	726	568	408	262	277	926
16	755	153	278	171	220	686	587	102	880	566	773	999	374	570	337
17	888	159	762	552	881	900	592	013	986	325	797	520	320	971	148
18	463	982	732	802	129	226	953	125	000	596	180	315	372	732	393
19	406	517	671	031	937	700	929	381	655	509	507	586	303	343	318
20	580	934	770	541	518	343	839	667	723	257	042	625	376	721	069
21	058	120	455	806	484	419	256	130	312	123	544	944	566	334	928
22	776	494	666	715	032	844	506	867	528	365	668	834	144	831	105
23	214	522	425	700	517	629	884	900	182	811	282	944	502	361	378
24	150	245	532	814	879	693	856	749	639	567	130	336	325	455	466
25	860	280	912	507	102	199	565	878	609	011	729	732	948	379	244
26	479	072	311	457	197	800	628	602	502	372	166	658	040	422	655
27	309	766	042	499	621	195	538	271	485	758	448	761	163	551	502
28	860	014	490	659	388	298	783	002	239	314	075	033	411	946	850
29	582	221	520	822	546	390	578	385	789	174	212	563	884	719	755
30	546	877	963	857	205	146	798	545	305	618	906	481	251	414	814
31	975	773	401	840	641	971	111	500	049	256	483	091	911	923	633
32	014	243	679	319	616	194	421	550	704	273	932	555	455	664	424
33	115	801	761	627	721	718	590	389	958	087	374	567	960	352	681
34	466	710	233	463	048	613	256	972	638	383	704	852	398	894	300
35	794	059	269	499	973	910	666	802	552	502	483	472	707	042	861
36	556	062	467	156	833	476	296	144	487	731	385	806	497	273	786
37	936	067	019	132	469	796	445	428	360	748	689	224	096	084	307
38	825	361	837	131	334	410	591	435	372	677	010	787	266	543	210
39	440	857	063	893	245	320	432	824	814	804	158	028	373	733	084
40	068	011	968	583	852	758	033	523	738	406	433	106	605	197	901
41	294	282	248	778	494	239	196	099	939	177	942	111	336	274	497
42	023	792	160	391	764	866	521	146	324	901	251	290	077	001	458
43	996	411	136	421	199	974	788	846	036	322	690	327	013	796	108
44	082	470	462	937	037	864	142	024	252	747	628	069	908	829	572
45	580	859	676	066	911	795	036	980	852	388	696	702	669	403	329
46	089	837	888	515	143	478	122	064	439	879	405	193	500	201	962
47	309	356	890	939	282	389	129	994	320	439	268	472	121	661	916
48	444	059	922	061	147	162	979	651	436	186	816	124	609	240	347
49	231	613	553	361	720	901	764	736	166	233	614	280	207	495	134
50	336	182	014	458	882	897	321	720	514	691	472	208	614	146	217

APPENDIX C

Interview for Medical Students

I. Demographic Information

1. Age: ________

2. Gender
    a. Male
    b. Female

3. Height (cm/m): ________

4. Weight (kg): ________

5. BMI
    a. <18.5 Underweight
    b. 18.5-25.9 Healthy
    c. 25-29-9 Overweight
    d. 30-39.9 Obese

II. Personal and Study Conditions

6. Do you smoke?
    a. Yes
    b. No

7. If yes:
    a. How much do you smoke per day? _________________
    b. How long have you been smoking? _________________

8. Do you exercise or play any sports?
    a. Yes
    b. No

9. If yes, how many hours per week do you exercise or play sports? _________________

10. Do you consider yourself having an active or a sedentary lifestyle?
    a. Active
    b. Sedentary

11. Do you tend to sit or stand during stressful situations?
    a. Sit
    b. Stand

12. How many hours do you sleep per night? ________

13. How many hours did you sleep last night? ________

14. Do you have any chronic diseases?
    a. Yes, I have ________________________________
    b. No

15. Are you currently taking any medications?
    a. Yes, I take ________________________________
    b. No

16. Years of study: ________

17. Dominant hand
    a. Right
    b. Left
    c. Ambidextrous

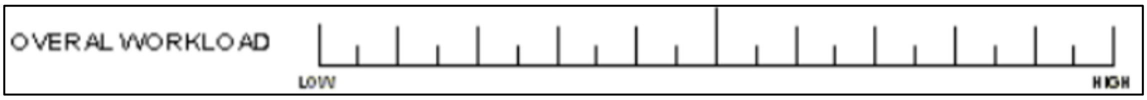
18. How many hours do you study per week? ________

19. Do you prefer sitting or standing while studying?
    a. Sitting
    b. Standing

APPENDIX D

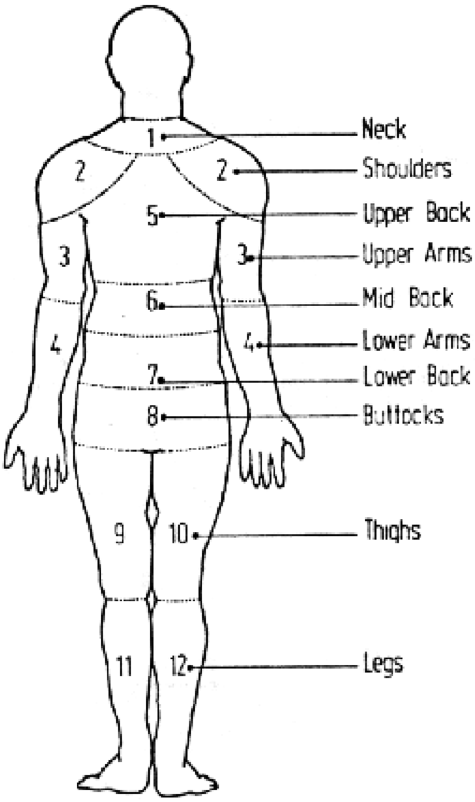
Data Collection Sheet

Overall Workload (OW) Scale Instructions:
Mark your rating on the below scale directly after each experimental task. Provide a rating that represents your perception of the overall workload of the task, which can be any value between 0 (very low) and 100 (very high). Note that each scale is divided in increments of 5. To mark your rating, draw a vertical line that crosses the scale at your corresponding rating. Base your rating solely on how you personally perceived the task to be, without considering the thoughts of others.



Order of Trials	Experimental Tasks	Overall Workload Rating
	Sitting, Easy	
	Standing, Easy	
	Sitting, Difficult	
	Standing, Difficult	

Localized Discomfort Scale (LMD) Instructions:
Rate your perceived discomfort at body regions numbered 1 (neck), 2 (shoulders), and 7 (lower back) on the diagram below directly after each experimental task. Use the scale next to the diagram to determine your rating, which may be any value between 0 (no discomfort at all) and 10 (extreme discomfort, almost maximum). You are free to choose any intermediate number using decimals. Add your rating in the table provided below the diagram. Base your ratings solely on how you personally perceived the tasks to be, without considering the thoughts of others.



.		maximum
10	=	extreme discomfort
		(almost maximum)
9	=	
8	=	
7	=	very high discomfort
6	=	
5	=	high discomfort
4	=	somewhat high discomfort
3	=	moderate discomfort
2	=	little discomfort
1	=	very little discomfort
½	=	extremely little discomfort
0	=	no discomfort at all

		Body Part No.		
Order of Trials	Experimental Tasks	1	2	7
	Sitting, Easy			
	Standing, Easy			
	Sitting, Difficult			
	Standing, Difficult			

Exit Interview:

1. For the easy task, did you favor the seated or standing work posture? Please explain why.

2. For the difficult task, did you favor the seated or standing work posture? Please explain why.

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