Biomechanical Investigation of the Colonoscopy Procedure: Is Practitioner Injury Risk Greater with Patients in the Right or Left Lateral Decubitus Position?

By © Andrew James Wilkie

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Abstract

Background: A colonoscopy is a medical procedure that uses an endoscope to assess the colon for abnormalities. It has been established in the literature that performing this procedure frequently is associated with operator musculoskeletal injury of the distal upper extremity. However, it is less understood whether this procedure contributes to pain and injury of the low back, an exceedingly common workplace injury that often results in time off.

Objectives: To investigate the effects of patient posture (left lateral decubitus [LL, right lateral decubitus [RL], and supine) on biomechanical and psychological outcome measures (muscle activity, perceived pain, exertion, and posture) in endoscopists during a simulated colonoscopy.

Methods: Eighteen practicing endoscopists performed three 10-minute trials of a simulated colonoscopy with varying patient positions: LL, RL, and supine. Surface electromyography (sEMG) sensors recorded muscle activity, and an ergonomic assessment tool assessed posture and injury risk. Perceived exertion and discomfort were measured before and after each trial using the BORG-CR10 and Visual Analog Scales. Descriptive statistics, Shapiro-Wilk tests, and one-way repeated measures ANOVA were used to analyze normally distributed data. Non-parametric data were assessed using the Wilcoxon signed-rank test. Tukey's post hoc tests were used where necessary, and Pearson correlations examined trends in height, weight, and BMI. Significance was accepted at $p < 0.05$.

Results: This study found that patient position did not result in significant differences in muscle activity, perceived discomfort, or perceived exertion during a short exposure to simulated colonoscopy. Specifically, average muscle activity levels across positions were low and not significantly different ($F(2, 32) = 3.415$, $p = 0.068$, $\eta^2 = 0.176$). Perceived discomfort and exertion showed similar patterns with no significant differences observed (discomfort: $F(2, 32) = 2.686$, $p = 0.110$, $\eta^2 = 0.144$; exertion: $F(2, 34) = 1.045$, $p = 0.342$). However, Rapid Upper Limb Assessment scores indicated a significantly lower ergonomic risk in LL position compared to the RL and supine positions (LL vs. RL: median 4 vs. 6.5, $p < 0.03$; LL vs. supine: median 4 vs. 6, $p < 0.03$). While no significant differences were found in muscle activity or perceived discomfort, ergonomic assessment scores suggest that all positions have elevated injury risk, particularly if exposures would be prolonged. Future research should examine longer durations and real-world scenarios to better understand the impact of patient positioning on injury risk.

Limitations: This study faced several limitations. The sample size was small, with only 18 participants who were predominantly right-handed, healthy, and of Caucasian ethnicity, limiting generalizability. The study used a high-fidelity simulation with a dummy patient, which may have reduced the procedural challenge and variability. Additionally, participant bias could have influenced subjective reports of strain, as more experienced endoscopists may have perceived the procedure differently. Future research should involve larger, more diverse samples and real-world settings inclusive of full workloads to address these limitations and provide more comprehensive insights into the impact of patient position on musculoskeletal demands.

Conclusion: In conclusion, this study finds that patient position does not significantly affect muscle activity or perceived pain and exertion scores during a short exposure to simulated colonoscopy. As such, endoscopists may not need to adjust patient positioning to mitigate musculoskeletal strain in brief procedures. Future research should investigate the impact of longer procedure durations and real-world settings to further explore factors that may influence injury risk.

Keywords: Colonoscopy, endoscope, musculoskeletal injury, low back pain, biomechanics, motion capture, electromyography.

General Summary:

This study explored how various patient positions during simulated colonoscopy procedures could impact the physical strain and comfort levels doctors experience when performing the procedure. Endoscopists performed colonoscopy procedures on a simulator placed in three patient positions: lying on the left side, right side, and on the back. The results did not find a difference in the amount of effort the doctors' muscles had to exert or how uncomfortable they felt between the short simulations in each of the three patient positions.

However, a tool that assesses ergonomic risk by estimating injury risk of certain postures, found that all three positions showed potential for causing injury to the doctors. This highlights the need for more research to better understand these risks and find ways to protect healthcare providers during colonoscopies. Future studies should focus on longer durations and real-world settings to get a more comprehensive understanding of the challenges doctors face and how to mitigate them effectively.

Land Acknowledgement

In gathering on this land, we humbly acknowledge it as the ancestral homelands of the Beothuk. We also pay respect to the island of Newfoundland, recognizing it as the ancestral territory of both the Mi'kmaq and Beothuk peoples. Moreover, we honor the Inuit communities of Nunatsiavut and NunatuKavut, as well as the Innu of Nitassinan, and their forebears, as the original inhabitants of Labrador. With deep reverence for this shared heritage, we aspire to nurture respectful relationships with all the peoples of this province. In our pursuit of collective healing and genuine reconciliation, we stand together in admiration for the sacredness of this land.

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List of Abbreviations

Analysis of Variance: ANOVA

BMI: Body Mass Index

CTD: Cumulative Trauma Disorder

LBP: Low back pain

LL: Left Lateral Decubitus

LLS: Left Erector Spinae

L1: First Lumbar Vertebrae

MSI: Musculoskeletal Injury

MSK: Musculoskeletal

MVC: Maximal Voluntary Contraction

RLS: Right Erector Spinae

RL: Right Lateral Decubitus

sEMG: Surface Electromyography

VAS: Visual Analog Scale

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Chapter 1: Introduction

1.0 General Introduction

1.1 Colonoscopies and Colorectal Cancer

A colonoscopy is a routine medical procedure that involves the use of an endoscope by a trained practitioner to assess the colon for abnormalities, such as colorectal cancer, polyps, and inflammation, it is also considered the gold standard for identifying colorectal cancer (Rastogi & Wani, 2017). Colorectal cancer is ranked third in terms of incidence and second in terms of mortality among all cancers globally, accounting for about 1 in 10 cancer cases and deaths and unfortunately, this number is expected to increase in the future (Sung et al., 2021). Consequently, it is expected that procedural volume and complexity of colonoscopies only stand to similarly increase, placing higher burden on the endoscopists that perform them. Currently, the average number of colonoscopies a clinician performs per year is n=159 (Josey et al., 2019).

1.2 Injury Risk and the Distal Upper Extremity

Biomechanical analyses previously done in the field have shown that colonoscopies require the endoscopist to adopt and sustain uncomfortable postures of the arms, with levels of grip pressure production and forearm muscle activity that exceed tolerance thresholds (10N and >30% MVC respectively) and are done for extended periods of time (Shergill, Asundi, et al., 2009; Shergill et al., 2021). This is largely due to the endoscope design itself, its associated weight, and resistance of the control mechanism. Despite this, there have been no recent improvements in endoscope design as it relates to the unique ergonomic performance required for the clinician. Workplace environments that involve awkward postures and sustained forces such as these have been found to increase musculoskeletal injury (MSI) risk for the distal upper extremity (Rempel, 1992); therefore this is a concern for the medical professionals that perform these tasks in their practice

1.3 The Importance of Posture

The classic adage says, "the best posture is the next posture", meaning that even the best posture held for too long will cause problems. This statement contains a lot of truth as it relates to workplace injury and posture variation throughout the day. However, despite knowing the importance of minimizing static and repetitive tasks in the workplace, many occupations are still faced with these challenges (Callaghan & McGill, 2001; Pope et al., 2002). In the medical field, specialists by nature end up focusing on a small number of specific tasks, resulting in a higher risk of injury and pain due to repetition. For example, surgical endoscopists and gastroenterologists are well documented to experience a high number of injuries resulting from performing high volumes of colonoscopy procedures. A recent systematic review found that 39-89% of endoscopists experienced some form of pain or injury related to their practice, and the associated risk factors were greater procedural volume and the number of years performing colonoscopy (Yung et al., 2017). Yung et. al found that common locations of injury for endoscopists include the back (15-57%), neck (9-46%), shoulders (9-19%), elbows (8-15%), and hands/fingers (14-82%) with carpal tunnel syndrome being the most common injury. A variable that is worth consideration, and could relate to physician injury risk, are static postures, with or without trunk flexion, adopted during the procedure. Prolonged standing involves extension of the lumbar and lumbopelvic joints, effectively loading the posterior structures. Prolonged exposure to standing has been associated with low back pain in a proportion of individuals (Nelson-Wong and Callaghan, 2014). Standing posture can be directly affected, and therefore controlled, by factors related to the set-up of the colonoscopy suite and equipment such as: monitor height, monitor position, and bed height (Shergill & McQuaid, 2019). However, other factors are less easy to control. For instance, to complete a colonoscopy, physicians need to move the patient into different positions as they navigate the scope through the colon. Specifically, during the procedure patients are often turned between three positions (left lateral decubitus, right lateral decubitus, and supine) as the physician maneuvers the endoscope through the colon to the cecum. Thus, patient size, shape, and position have great potential to indirectly influence clinician posture. Patient position has already been shown to influence colonoscopy performance-based outcomes including time to cecum and patient comfort (Vergis et al., 2015). Some of these patient positions require the physician to lean further over the patient than others. Most of the work that has been done in the area of colonoscopy biomechanics has centered on the forces and postures of the physician's hand and wrist. It has been shown that when force production of the hand and wrist consistently exceed 10 newtons, it can increase injury risk to these body parts (Shergill, Asundi, et al., 2009; Shergill et al., 2021).

However, up to this point, little research has been conducted on the neck and low back, or the effect of patient position and its potential effects on clinician posture and MSI risk. A recent field study completed by our group investigated patient positioning and its impacts on clinician posture as identified by the Rapid Upper Limb Assessment (RULA) tool (Landry et al., 2023). This validated ergonomic assessment tool is used to evaluate the risk of workplace injury based on postures and motions of the upper body. It analyzes the body in different sections looking at factors such as posture (back, neck, and limb angles), force, and duration (McAtamney & Nigel Corlett, 1993). The tool involves multiple sub-sections that are scored to give an overall RULA score that has been shown to relate to musculoskeletal injury risk and indicates if further ergonomic investigation and intervention are warranted for that work task.

This assessment can be useful to estimate potential injury risk in the workplace and identify where changes need to be made but, more definitive outcome measures are needed to truly elucidate this issue. Thus, the purpose of this thesis is to quantify the musculoskeletal (MSK) demand on the low back of the endoscopist when completing a simulated colonoscopy between three patient positions:

left lateral decubitus (LL), right lateral decubitus (RL), and supine. The results of this work will contribute to the literature by addressing gaps in our understanding of endoscopist related ergonomic risk during these procedures, ultimately leading to the development of ergonomic prevention interventions to help decrease MSI risk.

1.4 Layout of Thesis Document

The following dissertation has been organized into five chapters. The first chapter involves a general introduction, investigative purpose, and primary research questions. The second chapter contains the literature review. The third chapter is the manuscript, formatted in accordance with the author guidelines of Journal of Gastrointestinal Endoscopy, and titled "The effect of patient position on the musculoskeletal demand and perceived pain and exertion of the endoscopist." The fourth chapter revolves around a discussion about the outcomes and potential implications of this research. And lastly, the fifth chapter is the conclusion.

1.5 Purpose:

The primary purpose of this thesis is to investigate the effects of patient position (RL, LL, and supine) adopted by the endoscopist during a simulated colonoscopy on perceived pain, perceived exertion, and low back muscular demand.

1.6 Research Question:

General: Do different patient positions adopted during a simulated colonoscopy elicit different demands on the perceived pain, perceived exertion, and low back muscular activity of the endoscopist performing the procedure?

Specific Goals:

(1) To characterize the muscle activity, exertion, and discomfort experienced by the endoscopist during a simulated colonoscopy procedure.

(2) To identify if any of the commonly used patient positions (RL, LL, and supine) pose a greater MSK risk for the practicing endoscopist.

1.7 Hypotheses:

(1) Null Hypothesis ($H_0 = 0$): There are no significant differences in outcome measures among the three tested patient positions (RL, LL, supine) found in practicing endoscopists during simulated colonoscopy.

(2) Alternative Hypothesis ($H_0 \neq 0$): There are significant differences in outcome measures among the three tested patient positions (RL, LL, supine) found in practicing endoscopists during simulated colonoscopy.

Chapter 2: Literature Review

2.0 General Literature Review

2.1 Introduction

A colonoscopy is a crucial procedure for identifying colorectal abnormalities, and as global colorectal cancer rates rise, the frequency and complexity of these procedures are expected to increase (Torre et al., 2015; Kaminski et al., 2017). This growing demand places significant strain on endoscopists, potentially leading to musculoskeletal injuries (MSIs) from sustained postures, repetitive tasks, and high procedural volumes (Pope et al., 2002; Harrison et al., 1992). While advancements in patient care have been well-documented, the ergonomic challenges faced by endoscopists have received less attention. This review explores how colonoscopy impacts the endoscopists performing the procedure, focusing on the risk of MSIs in the upper extremities and lower back, and considers ergonomic strategies that might alleviate these issues.

2.1 Colonoscopies

A colonoscopy is a commonly performed medical procedure that involves the use of an endoscope by a medical specialist to assess the colon for abnormalities, such as colorectal polyps that could potentially be cancerous (Torre et al., 2015). Unfortunately, worldwide cancer rates are expected to rise in the future due to population factors such as growth and aging, and lifestyle factors such as sedentary behaviour, poor diet, and smoking (Torre et al., 2015). Since colorectal cancer prevalence is expected to increase, it can also be assumed that the colonoscopy procedures to identify them will similarly increase not only in frequency, but also in duration and complexity (Kaminski et al., 2017). This will lead to an increased burden on the endoscopists performing these medical procedures.

2.2 Workplace Injury and Ergonomics

It has been identified in the literature that any static posture held for an extended period can lead to prolonged loading of soft tissues and subsequent discomfort or injury (Pope et al., 2002). Other important variables to consider in terms of injury generation identified by Pope (2002) are: repetition of tasks, volume of work, and duration of static positions. With respect to repetitive tasks and volume of work completed, it has been previously identified that workers can develop soft tissue trauma related disorders of the upper extremity with this loading pattern (Harrison et al., 1992).

Cumulative trauma disorders (CTDs) such as these can arise from overuse of any aspect of the distal upper extremity particularly with the repetition of flexion, extension, and gripping actions of the wrist in the workplace. This can result in musculoskeletal injuries (MSIs) such as soft tissue microtears and subsequent synovial disorders, ligamentous disorders, degenerative joint disease, bursitis, or nerve entrapment (Harrison et al., 1992). When patterns of CTDs emerge in certain occupations, it is important to study these professions and identify potential risk factors so that they can be attenuated or eliminated through ergonomic intervention. Awareness of the risk of CTDs has led to the adoption of improved ergonomics (interaction between worker and their environment) and the implementation of criteria for safe working conditions. An excellent example of ergonomic intervention in the workplace being the NIOSH lifting equation and the associated recommended weight limit and lifting index (LI) which essentially evaluates the physical demands of two-handed lifting tasks (Harrison et al., 1999). Due to the complexity of certain professions and work tasks, not all ergonomically friendly thresholds and guidelines are so easily defined or adhered to. For example, various medical procedures prioritize clinical goals and patient safety and considerations for practitioner injury prevention are not at the forefront. The medical procedure this thesis will focus on is the colonoscopy examination.

2.3 Colonoscopy and Injury Risk for The Endoscopist

A colonoscopy is a procedure used to examine the interior of the colon and rectum using a flexible, tube-like device with a camera. While standing upright in front of the table, the endoscopist inserts the colonoscope through the rectum, this gives them a view of the colon's lining to identify and evaluate abnormalities such as polyps, cancer, or inflammation. This procedure is especially important for early detection of colorectal cancer. Effective preparation of the bowel is essential for a clear view of the colon (Rastogi & Wani, 2017).

Many studies have sought to find ways to protect the patient during a colonoscopy (Çelebi et al., 2020; Evans et al., 2022; Rogers et al., 2020). However, significantly less time has been devoted to identifying ways to protect the endoscopist. Protecting our medical practitioners is of equal importance since a recent international survey of endoscopists found that out of 368 participants, 73% of them had experienced MSI due to or likely due to performing colonoscopies (Al-Rifaie et al., 2021). This is an alarmingly high proportion of practitioners reporting injury and could be artificially low since it has been shown that endoscopists do not seem overly comfortable with discussing work related injury (Pransky et al., 1999). For instance, a study has found that practitioners are concerned about the effects discussing a previous work-related injury may have on their reputation, lifestyle, and/or livelihood (Shergill & McQuaid, 2019).

It has been reported that endoscopists experience a variety of injuries, For example, one survey found that the most frequent sites of injury were the hands and fingers (42%), neck (11%), and back (8.5%) (Liberman et al., 2005). Comparing data from these studies, Al-Rifaie et al. reported that approximately 73% of endoscopists experienced MSI, while Liberman et al. found a lower prevalence of injury at specific sites. It is noteworthy that these studies used different methods and populations. However, both studies highlight the significant issue of MSI among endoscopists.

2.4 Endoscopists and the Distal Upper Extremity

There are several types of MSIs endoscopists can experience and the distal upper extremity is the most common site of injury which is inclusive of the forearm, wrist, and hand. The survey by Liberman et. al found that out of 608 endoscopists, 257 experienced injuries of the hands and fingers (42%). Injuries to this location of the body can result in pain to the thumb, hand, wrist, or elbow, hand numbness, and carpal tunnel syndrome (Shergill et al., 2021).

There are a couple mechanisms for injury of the distal upper extremity that have been reported. A pilot study found that the mean peak grip pressure or amount of pressure exerted by a squeezing thumb, can exceed 10N of force during the procedure and this threshold, when repeatedly exceeded, has been associated with an increased risk of MSI (Shergill, Asundi, et al., 2009). Shergill and colleagues (2021) found strong evidence that muscle exertions of the hand and forearm (extensor carpi radialis, and flexor digitorum superficialis) exceeded both grip pressure thresholds (10N) and the percent of time spent sustaining these contractions for any colonoscopy subtasks completed.

Another common mechanism of injury is repetitive motion without sufficient rest time/recovery. One study found, when assessing endoscopists performing a simulated colonoscopy, that they spend similar amounts of time with their wrists and radio-ulnar joint engaging in three different types of motion: abduction/adduction, flexion/extension, and supination/pronation. This study also found that endoscopists spend 30% of procedure time at the extreme ranges of these motions which has the potential to strain the relevant tissues (muscles, tendons, and joints of the wrist) when done in a repetitive fashion (Mohankumar et al., 2014).

2.5 Addressing Ergonomic Challenges in Colonoscopy

There have been a handful of studies that have assessed whether there are ways to make colonoscopies more ergonomically friendly. Some researchers have even suggested in their paper's title that an "ergonomic endoscopy is an oxymoron like that of jumbo shrimp" (Shergill & McQuaid, 2019). This alludes to the possibility that these terms cannot coexist. This same paper proceeds to highlight the endoscope itself as one of the main barriers to achieving an ergonomic colonoscopy.

Unfortunately, endoscope design has changed very little since the 1980s and the companies that create this device still use a "one-size fits-all" approach. This can make it very challenging for individuals with a hand size of less than 6.5 inches, mostly women, leading to suboptimal grip and poor force production (Shergill & McQuaid, 2019). Changing the endoscope would be considered an elimination and/or substitution control which is highlighted in the hierarchy of controls laid out by the Occupational Health and Safety Administration (NIOSH, 2015).

Another way to optimize the procedure would be through a comprehensive ergonomic assessment and consequent modification of risk factors. A study by Markwell and colleagues aimed to create a personalized wellness program tailored for practicing endoscopists. This program included individualized exercises, posture re-education, procedure setup adjustments, pain management education, and follow-up sessions with a physiotherapist (Markwell et al., 2021). The researchers found that the program was well-received and significantly reduced musculoskeletal complaints among the participating endoscopists. The study implemented modifications based on engineering, administrative practices, and personal protective equipment from the hierarchy of controls. Additionally, a multicenter prospective cohort study explored a broader rehabilitation approach by leveraging physiotherapists' expertise to develop a generalized program for endoscopists. Most study participants surveyed complained of MSK symptoms at baseline (94%) and several hospital activities were associated with these symptoms. However, following the rehabilitation program, only a few hospital activities were associated with MSK pain, and most participants were satisfied (67%) with the program after the study was completed (Nam et al., 2023). This shows that even a simple and generalized rehabilitation program can have a positive effect on endoscopists in the workplace.

Overall, the current literature shows simple substitution, engineering, administrative, and PPE control changes can have a positive impact on the ergonomics of a practicing gastroenterologist. However, a useful adjustment to the practice of colonoscopies would likely be to eliminate the "one size fits-all" approach utilized by the makers of this equipment and to adopt a more tailored approach for the individual using the instrument. This would be especially helpful for those with smaller hand sizes, particularly females.

2.6 Colonoscopies and Low Back Pain

Low back pain (LBP) can be defined as pain that arises between the lower edge of the ribs and the buttock (Dionne et al., 2008). A 3-part series, published in the *Lancet*, helps elucidate this issue. The first article from this series aimed at defining LBP and why it matters. It highlighted that LBP is experienced by people of all ages and all socioeconomics statuses worldwide and is the number one cause of disability globally (Hartvigsen et al., 2018). Hartvigsen et al. (2018) also found a primary concern is that identifying a specific cause of pain is often impossible, with approximately 95% of cases classified as non-specific LBP, excluding pain caused by conditions such as tumors, infections, or inflammatory arthritis. The second article discussed the best evidence-based prevention and treatment for LBP. With respect to prevention, the research indicates that exercise in conjunction with education can be effective (Foster et al., 2018).. For treatment, Foster et al. (2018) also noted greater emphasis has recently been placed on self-management, physical and psychological therapies, and some forms of complementary medicine. The final paper discusses the importance of taking the growing burden of LBP seriously, and highlights that this recognition is essential to stimulate new, more effective strategies of prevention and care (Buchbinder et al., 2018).

As mentioned previously, MSI of the distal upper extremity is exceedingly common amongst endoscopists that perform high volumes of colonoscopies (Shergill et al., 2021). The research thus far has found that sustained grip pressure and repetitive wrist motions are likely to blame for distal upper extremity injury risk (Shergill et al., 2009, 2021). We know that there are elevated rates of LBP as well. Liberman et. al found among 608 endoscopists, that 42% experience injuries of the hands and fingers, while 12% experience LBP. What is less understood, however, are the mechanisms that lead to LBP when performing high volumes of colonoscopies. Moreover, could these mechanisms be modulated by adjusting other variables such as patient position throughout the procedure.

2.7 Does Patient Position Modulate Injury Risk?

During a colonoscopy, there are several variables that can be modified to make it a more ergonomically friendly procedure for the physician. Options include adjusting table height and monitor height (reducing awkward postures of the clinician), or even mixing in microbreaks (reducing exposure and duration) during the procedure. Ideally in the future, re-design of the endoscope will be made possible to help minimize strain of the forearm, hand, and wrist. Outside of these variables, the clinician and attending nurses also can adjust the patient position during the procedure.

There have already been some studies examining patient position and its effect on procedure time and comfort for the patient. During a colonoscopy there are 4 possible patient positions that can be utilized; left and right lateral decubitus (RL and LL), and prone or supine. A recent randomized controlled trial compared RL versus LL positions and found that RL was favourable with regards to efficiency of procedure (Vergis et al., 2015). With RL positioning, there were large improvements in time to cecum (3 minutes and 33 seconds) and improvements in patient comfort (Vergis et al., 2015). Time to cecum is a valuable measure of colonoscopy efficiency, however, adenoma detection rate is the standard for measuring the quality of colonoscopies. It has been found that adenoma detection rate can be improved through dynamic position change. More specifically, bringing the segment of the colon being examined to the highest position will improve luminal distension and visualization (Nutalapati et al., 2020). The authors of this meta-analysis concluded that, when assessing different parts of the colon, one should use different patient positions (LL for the right colon, supine for the transverse, and RL for the left side of the colon) throughout the withdrawal phase. One might assume that improvements in time to cecum or adenoma detection rate should lead to better outcomes for the endoscopist as well by reducing the overall duration of the procedure, but without analyzing each patient position and its subsequent effect on the practitioner's biomechanics directly, this is unknown.

Only one small field study, conducted by our research group, has assessed the effects of patient position on the endoscopists MSI risk. This pilot study assessed 19 endoscopists throughout a series of four-hour endoscopy clinics and estimated the injury risk for the first and last procedures of the shift using the Rapid Upper Limb Assessment tool. This study found that both the LL and RL decubitus patient positions were associated with an elevated risk of MSI for the physician, with the RL position posing a greater risk. Additionally, participant physicians generally rated that they preferred the LL position (89% (n=17)) (Landry et al., 2023). These findings point to the LL position being subjectively and objectively more ergonomically friendly for the practicing endoscopist when compared to the RL position. Subjectively, the LL position was rated favourably by most participants indicating that it felt more comfortable and was less likely to lead to strain.

Objectively, the LL position was associated with a lower estimated risk of MSI compared to the RL position based on the ergonomic evaluation tool.

This outcome is counter to many previous studies that found RL or dynamic position change strategies have more positive patient-centered outcomes regarding ADR, time to cecum, and patient comfort. However, more concrete biomechanical evidence is needed to help confirm the results of this small field study.

2.8 Colonoscopy Suite Setup and Movements Required by the Endoscopist

The setup of the colonoscopy suite and associated equipment (endoscope, endoscopy tower, monitor, and examination table) as well as the patient positioning are integral in ensuring endoscopist and patient comfort throughout the procedure. The examination table and monitor are always adjusted at the beginning of the procedure so that they are at optimal heights for the practicing endoscopist as illustrated in Figure 1. The monitor is used by the clinician to visualize and navigate through the colon. The endoscopy tower should be positioned so that it is adjacent to the operator and allows for ideal scope manipulation and access, especially if any issues with the tower arise (Lambour & Billmeier, 2020). The practicing physician is best positioned behind the patient with the monitor immediately in front of them. The patient is usually positioned in the LL or the supine positions to start a procedure for easy access to the anus.

The endoscope has a handle and two wheels that are meant to be held in the left hand to control the dials and the suction/irrigation buttons. The right hand is used to rotate the scope and change its direction (withdrawing versus advancing) (Stauffer & Pfeifer, 2024). Learning to use an endoscope and subsequently perform a colonoscopy requires time, patience, practice, and skill. There are many components to the colonoscope; manipulation of these elements requires inputs that accomplish different movements such as, up, down, right, left, clockwise, and counterclockwise rotation. With a combination of these movements, the endoscope can be navigated through the colon to the ileum. During a colonoscopy, commonly used movements include adjusting tip angulation, torquing the scope with the right hand, manipulating the wheels with the left hand, and advancing or retreating the scope (Harvin, 2014).

Figure 1: Colonoscopy suite simulation set up at the Spine Lab

2.9 Summary of Endoscopic Skills Enhancement and Ergonomic Strategies: The SEE Program and Optimizing Comfort

This section covers The Skills Enhancement for Endoscopy Program's courses which aim to improve endoscopic techniques and training. It addresses topics such as optimization of the endoscopist's environment and positioning. Additionally, it looks at strategies to enhance comfort and efficiency during a colonoscopy procedure, this includes variables such as ergonomic suite setup and endoscope design. It also discusses more practical adjustments such as proper footwear and posture breaks, aiming to reduce injury risk.

The Skills Enhancement for Endoscopy encompasses three separate types of accredited courses. The first course is colonoscopy skills improvement which focuses on colonoscopy technique, room setup, and position of the endoscopist and patient. The second course is train-the-endoscopy-trainer which is inclusive of endoscopy theory and techniques. The final course, the endoscopic polypectomy improvement course, is designed to teach colonoscopic polypectomy. The component of the skills enhancement program that is most relevant to this thesis is the skills improvement course and its focus on endoscopist environment and patient and clinician positioning.

Strategies to improve comfort and efficiency for the endoscopist during a colonoscopy predominantly lie with human engineering. Improving how the operator interacts with their workstation, tools, and tasks is of paramount importance to reduce overuse injury. This requires proper setup of the colonoscopy suite as outlined in the previous section, and a more ergonomic endoscope. Unfortunately, the basic design on the scope has not changed in the last 20 years (Shergill, McQuaid, et al., 2009). Moreover, the endoscopist having sufficient help from either a nurse or medical assistant during the procedure can make for a streamlined colonoscopy. Outside of these controls proper footwear and posture breaks can be useful strategies to help decrease injury risk as well (Markwell et al., 2021).

In conclusion, while the current literature suggests varying advantages of different patient positions during colonoscopy, further investigations into their specific influence on endoscopist ergonomics is of paramount importance. Such insights will contribute to refining clinical practice and potentially equipment design with hopes of promoting a safer and more sustainable working environment for these healthcare professionals.

2.10 Literature Search Strategy

The search strategy for this literature review was formulated with the help of a health services librarian and utilized the MEDLINE database and was limited to the English language only due to time constraints. The final search query used was: compar* AND ((((("Electromyography"[Mesh]) OR "Physical Exertion"[Mesh]) OR "Posture"[Mesh]) OR "Ergonomics"[Mesh] OR posture[tiab] OR ergonomics[tiab] OR "physical exertion"[tiab] OR "force plates"[tiab])) AND (((("Surgeons"[Mesh:NoExp]) OR "Endocrinologists"[Mesh]) OR "Gastroenterologists"[Mesh]) OR "Internship and Residency" [Mesh] OR resident*[tiab] OR surgeon*[tiab] OR gastroenterologist*[tiab] OR physician*[tiab])) AND (("Colonoscopy"[Mesh]) OR "Endoscopy"[Mesh:NoExp] OR colonoscop*[tiab] OR endoscop*[tiab]). This recovered a total of 199 results, these papers were skimmed for relevance to the current study design as well as those similar articles that included outcome measures of interest. The final search query used is shown in Table 1.

Table 1: Search query

(colonoscopy or endoscopy or endoscopic procedures) AND ("Patient Positioning"[Mesh] or right lateral or left lateral or position* or decubitus or supine) AND (endoscopist* or physician OR doctor OR surgeon or resident) AND (ergonomic* or posture OR pain OR discomfort or msk or muskuloskeletal)
(colonoscopy or endoscopy or endoscopic procedures) AND ("Patient Positioning"[Mesh] or right lateral or left lateral or position* or decubitus or supine) AND (endoscopist* or physician

OR doctor OR surgeon or resident) AND (ergonomic* or posture OR pain OR discomfort or msk or muskuloskeletal)
(colonoscopy or endoscopy) AND ("Patient Positioning"[Mesh] or right lateral or left lateral or position* or decubitus or supine) AND (endoscopist* or physician OR doctor OR surgeon or resident) AND (ergonomic* or posture OR pain OR discomfort or msk or muskuloskeletal)
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Co-Authorship Statement

The conceptualization, study design, and funding for this study were generated by Diana De Carvalho, Mark Borgaonkar, David Pace, and Kim Cullen. Andrew Wilkie led the data collection with support from Sarah Mackey and Ava McGrath. Mona Frey authored and refined the custom data processing routines in MatLab. Andrew Wilkie completed the data processing aided by Mona Frey and statistical analysis aided by Nicholas Fairbridge. Andrew Wilkie led the interpretation of the results and authored the manuscript which was subsequently reviewed by all authors.

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The effect of patient position on the musculoskeletal demand and perceived pain and exertion of the endoscopist

Andrew Wilkie[1], Mark Borgaonkar[1], Kim Cullen[1,2], Sarah Mackey[1], Ava Mcgrath[1], Mona Frey[1], David Pace[1], Nicholas Fairbridge[1], Diana De Carvalho[1]

[1]Faculty of Medicine, Memorial University of Newfoundland, St. John's, NL, Canada

[2]School of Human Kinetics and Recreation, Memorial University of Newfoundland, St. John's, NL, Canada

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Corresponding Author
Diana De Carvalho
Faculty of Medicine
Memorial University of Newfoundland and Labrador
ddecarvalho@mun.ca
p. 709-864-3856

3.0 **Introduction**

Colonoscopies, usually performed by surgeons or gastroenterologists, are commonly performed medical operations that are used to screen the colon for abnormalities such as colorectal cancer. The volume and complexity of colonoscopies are expected to rise due to the increasing global incidence of colorectal cancer (Sung et al., 2021; Torre et al., 2015). This is not only an issue for the global population, but also practicing physicians who perform these procedures. A systematic review reported that 39-89% of endoscopists (n=2265) experienced pain or injuries related to their occupation (Yung et al., 2017). Another survey found that MSI risk was associated with higher procedural volume and more years in the job (Ridtitid et al., 2015). In the past, a large quantity of research has been devoted to protecting patients during these crucial medical procedures, however, significantly less effort has been directed towards physician safety.

There are two common mechanisms for injury among practicing endoscopists with high procedural volume. The first pertains to the design of the endoscope itself and factors such as dial resistance and scope weight. Overuse injuries are common with this procedure given its ergonomically unfriendly design (Rempel, 1992; Shergill et al., 2009, 2021). The second mechanism of injury is due to posture. Awkward and sustained postures can lead to back and neck pain which can often be attributed to factors such as incorrect bed height and spatial limitations that lead to a suboptimal monitor location (Al-Rifaie et al., 2021). Regardless of the ergonomic struggles faced by endoscopists, a recent literature review revealed that ergonomics are still largely excluded from endoscopic training and practice (Ofori et al., 2018; Sussman M et al., 2020). One such ergonomic variable that needs to be explored further is the impact of patient position during colonoscopies on clinician posture.

Patient position has a strong influence on many patient-centered outcomes in colonoscopy. For instance, it has been found that dynamic position change during the colonoscope withdrawal phase can increase adenoma detection rate. This is a very important quality metric, as a higher detection rate correlates with a decreased incidence of colorectal cancer (Nutalapati et al., 2020). A randomized controlled trial also investigated whether there was a difference between right lateral decubitus and left lateral (RL and LL) decubitus positions as they relate to patient comfort and time to reach cecum. RL and LL indicate the side of their body that the patient receiving a colonoscopy is lying on.

This study found that RL decreased time to cecum by up to 30% and improved patient comfort when compared to LL (Vergis et al., 2015). However, patient size and posture can be expected to impact the posture and muscular demand of the endoscopist as they are required to bend over the patient. To our knowledge little work has been done to study the impact of patient positioning on procedural ergonomics.

Minimal research has explored ways to protect endoscopists from MSI risk, with most work focused on the upper extremity (Harvin, 2014; Markwell et al., 2021; Nam et al., 2023; Ridtitid et al., 2015; Shergill, Asundi, et al., 2009; Shergill et al., 2021; Shergill & McQuaid, 2019). Further, only one small field study has examined the difference between RL and LL patient positions and their effects on clinician posture and MSI risk. That study, using the rapid upper limb assessment tool, which is used to reveal postures that may lead to increased ergonomic risk, identified that the RL position was associated with significantly higher risk than the LL position, and that clinicians generally preferred the LL patient position (89%). Both patient positions were associated with an increased MSI risk (Landry et al., 2023). Therefore, the purpose of this study is to explore the effect of patient posture on low back muscular demand and perceived pain and exertion in a controlled laboratory setting using a simulated colonoscopy procedure. It is hypothesized that there is a significant difference in outcome measures among the three tested patient positions (RL, LL, supine) found in practicing endoscopists during simulated colonoscopy.

Considering the ergonomic challenges faced by endoscopists, this study aims to explore how different patient positions: right lateral decubitus (RL), left lateral decubitus (LL), and supine affect low back muscular demand and perceived pain and exertion during a simulated colonoscopy. We hypothesize that there will be significant differences in these outcomes among the three patient positions. Specifically, the null hypothesis (H_0) suggests no difference in outcome measures between the tested positions, whereas the alternative hypothesis (H_1) indicates that significant differences do exist. A secondary objective examined the correlation between clinician characteristics and the outcome measures of perceived pain and exertion.

3.1 Methods

Participants

A convenience sample of 18 participants were recruited from two hospitals in St. John's, Newfoundland and Labrador, Canada. Recruitment strategies included email notice (distributed through the Faculty of Medicine and Endoscopy Units), by posters (advertised in the endoscopy clinics), and word of mouth from the research team (practicing endoscopists). Inclusion criteria were experienced endoscopists (including senior surgical residents) that had been taught basic colonoscopy technique by the Canadian Association of Gastroenterology sponsored Skills Enhancement for Endoscopy™ program, and who were available to come to the lab for data collection. The study period ran from September 2022 to August 2023. This project received ethics approval from the Health Research Ethics Board of Newfoundland and Labrador (#20222784). All participants read the information letter, had an opportunity to ask questions about the experimental protocol, and gave written consent prior to data collection.

Instrumentation

Muscle Activity

Surface electromyography (sEMG) data were collected from the right and left lumbar erector spinae (RLES/LLES) at the first lumbar vertebral level (L1). Surface palpation was used to identify the first lumbar (L1) spinous process using previously established landmarking techniques (Snider et al., 2011). Areas of skin approximately 50mm lateral to either side of the L1 spinous process, designated for RLES and LLES sEMG recordings, were gently shaved and cleaned with rubbing alcohol prior to electrode application. Pairs of disposable electrodes (Ag-AgCl, Blue Sensor, Medicotest Inc., Ølstykke, Denmark) were then positioned with a 20mm interelectrode distance, aligned parallel to the muscle fibers, over the RLES and LLES respectively. Raw sEMG data were differentially amplified (Desktop DTS, Noraxon, Pheonix, AZ, USA: CMRR > 100 dB, input impedance > 100 MΩ), bandpass filtered 10-500Hz, and digitally sampled at a rate of 1500 Hz (Optotrack Data Acquisition Unit, Northen Digital Inc., Waterloo, Ontario).

Visual Analog Scale

Participants rated their perceived discomfort at the beginning (baseline) of the experiment and end of each trial using a 100mm Visual Analog Scale (VAS) (Martin Nguyen et al., 2021) with anchors of "0" corresponding to "no discomfort" for the associated area, while "100" represents the "worst possible discomfort" for several body regions: hands/forearms, shoulders, elbow, neck, upper and lower back (Figure 1). The participant indicated their level of discomfort by drawing a vertical line along the 100mm line corresponding to their perceived rating for that immediate point in time. This led to a total of 4 VAS ratings per participant.

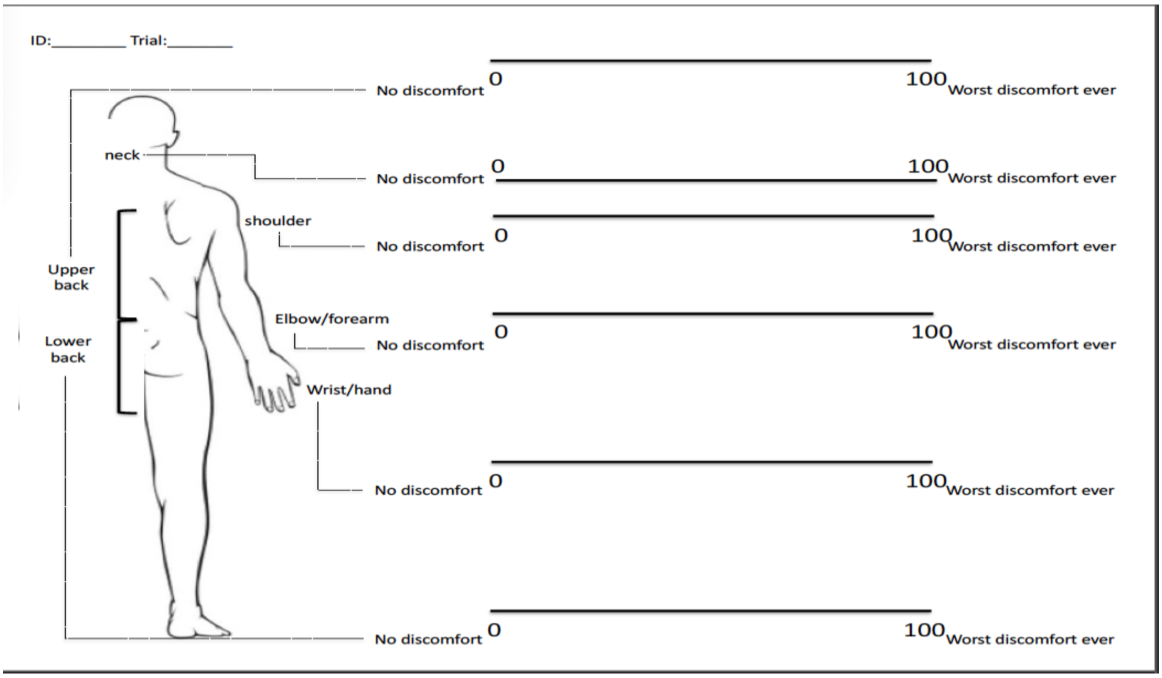

Figure 2: The visual analog scale used in this study.

BORG CR-10 Scale

Participants rated their perceived exertion levels (McGorry et al., 2010) at the beginning (baseline) of the experiment and end of each trial using the BORG CR-10 scale for the wrist/hand, elbow/forearms, shoulders, neck and back (upper and lower) (Figure 2). The participant indicated their perceived level of exertion using the 0-10 rating scale on figure 2 where “0” corresponds to “no exertion at all” and “10” corresponds to “an extremely strong exertion (almost maximal).” This led to a total of 4 BORG ratings.

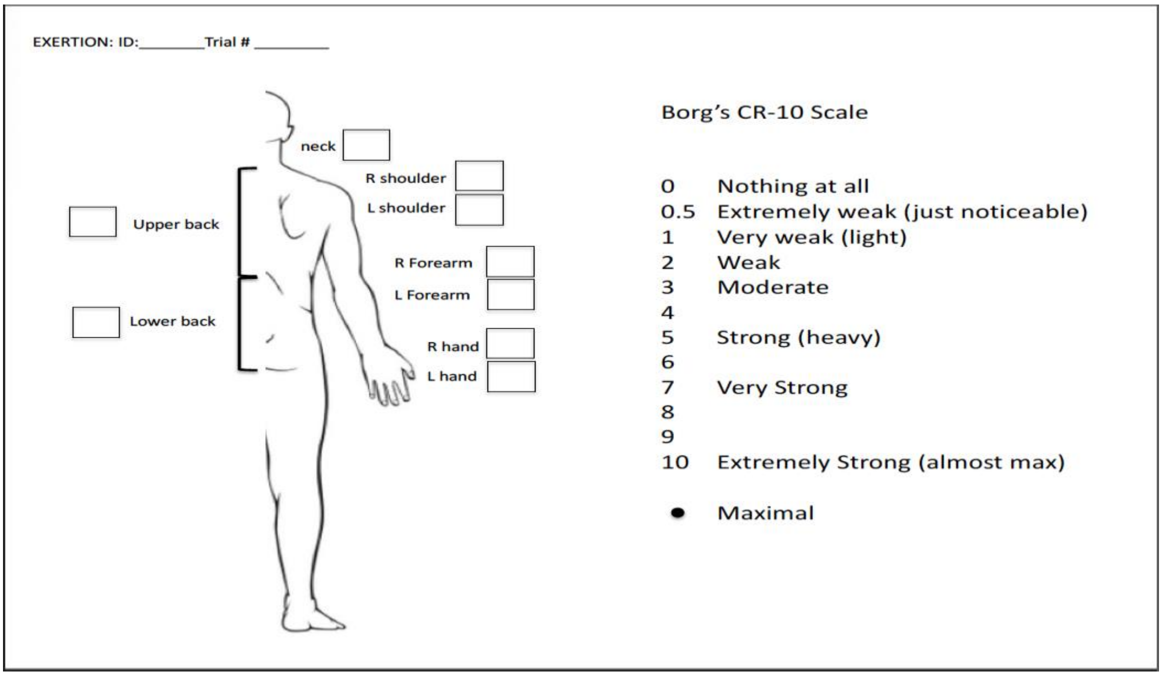

Figure 3: The BORG CR-10 Rating of perceived exertion used in this study.

Rapid Upper Limb Assessment (RULA)

The Rapid Upper Limb Assessment (RULA) tool was scored on a subset of participants in this study. This validated tool is used to assess musculoskeletal injury risk in occupational settings with the primary goal of identifying problematic work tasks requiring more in-depth ergonomic analysis and intervention (McAtamney & Nigel Corlett, 1993) (Figure 4). A trained rater completed the RULA assessment standing perpendicular to the right side of the participant at the beginning of each of the three patient posture trials in the experiment. Due to personnel constraints, this ergonomic assessment was only scored on a subset (10/18) of the study population.

Study Procedure

Following completion of informed consent participants were familiarized with the setup, instrumentation, requirements of the participant, and duration of the study. Participants provided relevant demographic information (height, weight, gender, handedness, previous MSK injury) which was recorded on the collection form.

Two pairs of electromyography electrodes were placed on the right and left low back to record muscle activity data. To normalize sEMG data, quiet and maximum voluntary contractions (MVC) trials were collected. Specifically, a 5-second resting trial was conducted while the participant lay prone and relaxed on a manual therapy plinth. For MVC trials participants were positioned prone at the end of the therapy table, aligning their anterior superior iliac spines with the edge. Ratchet straps with foam coverings were then used to secure the participant's hips and calves to the plinth, providing lower body support. Resisting in extension against the applied force of a research assistant, the participant performed three 10-second MVC trials with a minimum of 2 minutes of rest in between.

Once fully instrumented, participants were introduced to the colonoscopy simulation set-up and the exam table and video monitors were adjusted first to the participant's height and then refined to their personal preference. Just as for real colonoscopy procedures, the endoscopist was instructed to remain on the same side of the therapy plinth, facing the monitor, for the entirety of all trials. To standardize the colonoscopy procedure, a colonoscopy trainer (KK-M40, Kyoto Kagaku Co. Ltd., Kyoto, Japan) was used. This is a torso model that includes an anus and flexible colon and would be familiar to many participants from their training, thus beyond a basic introduction to the unit, no formal training or practice time was required. The trainer was oriented in the left/right decubitus or supine position during experimental trials according to the randomization scheme. Once the participant was ready, baseline VAS and BORG CR-10 ratings were completed, and the experimental trials commenced. Participants completed three scoping trials where the patient position was block randomized between the three varying patient positions (LL, RL, and supine). Each trial was 10 minutes long, and sEMG data were collected continuously throughout.

Participants were given the instruction that the objective for each trial was to perform a colonoscopy procedure, starting at the anus and advancing the scope to the furthest point possible (cecum). When this point was reached, they would promptly return to the beginning of the rectum and start navigating to the end point once again. This was done as many times as it took to complete the 10-minute trial. Immediately at the end of each trial the participant repeated the perceived pain and exertion scales. Once the three trials were completed, the participant was de-instrumented, thanked for their time and allowed to leave.

Data Processing and Analysis

sEMG Signal Processing

Customized MatLab code was used to process all sEMG data. sEMG data underwent direct current bias removal, a 4^{th} order high pass Butterworth filter with a cut-off frequency of 30Hz to remove electrocardiogram artefact, full wave rectification, then a linear enveloped was created with a 4^{th} order Butterworth filter at a cut-off frequency of 2.5Hz. Signals were then normalized by subtracting the quiet EMG trial and then dividing by the maximum EMG activity (highest of the 3 MVC trials) for each muscle channel and multiplying by 100 to give a percentage of maximum voluntary contraction (%MVC). The right and left muscle channels were averaged. The outcome measures of average and peak back muscle activity (%MVC) were calculated for the representative muscle activity for each trial and used in the analysis.

Perceived Discomfort

Perceived discomfort was extracted from relative scales and organized in an excel spreadsheet based on patient position (baseline, LL, RL, and supine) and anatomical location. Baseline scores were collected before the experiment. A ruler was used to measure the horizontal distance along the 100mm VAS line from 0mm, and this value represented the participant's level of discomfort for that time point. Baseline ratings were subtracted from each of the following trials to obtain change from baseline scores.

Perceived Exertion

Perceived exertion using the BORG-CR 10 scale was extracted from the relevant worksheets and organized in an excel spreadsheet based on patient position (baseline, LL, RL, and supine) and anatomical location. The participant used the numbered scale as indicated on the worksheet to identify the exertion for each corresponding body part following simulated trials. Baseline scores were collected before the experiment began and subsequently subtracted from each of the following trials to obtain change from baseline scores.

Rapid Upper Limb Assessment (RULA) Score and Posture

RULA scores were calculated according to the tool rubric (McAtamney & Nigel Corlett, 1993). Posture sub-scores were extracted to provide an idea of posture neutrality, deviation from neutral was qualitatively assessed for the arms, wrist, neck, and trunk. These were visualized using a heat map as follows: good (green) < 20 degrees from neutral and/or supported, moderate (yellow) 20-45 degrees from neutral, poor (red) > 45 degrees from neutral and/or twisted, bent, extended, or deviated). The total RULA score was extracted as the outcome measure for each patient position (LL, RL, supine).

Statistics

Descriptive statistics and the Shapiro-Wilk test for normality were calculated for all outcome variables. Differences in average muscle activity, injury risk (total RULA score), exertion (change in Borg-CR10 rating), and discomfort (change in VAS rating) between the patient posture conditions (RL, LL, and supine) was tested with either a one-way repeated measures analysis of variance (ANOVA) (for parametric data) or the Wilcoxon signed-rank test (for non-parametric data). Significance was considered at the $p < 0.05$ level, and Tukey's post hoc tests (Tukey, 1949) were applied when necessary. Effect sizes (as partial eta squared) were also calculated to evaluate the magnitude of differences between patient positions. Additionally, secondary outcomes of participant characteristics (height, weight, body mass index, and experience) were examined for potential trends in the dataset univariately using a Pearson Correlation, also with significance accepted at the $p < 0.05$ level. All statistics were conducted with SPSS (IBM Corp., 2023, *IBM SPSS Statistics*, Version 29).

3.2 Results

Participants

Eighteen (8 males, 10 females) participants were collected for this study, with an average age, height, and mass of 39.44 ± 11.54 years, 1.75 ± 0.07 m, and 77.02 ± 9.19 kg. Participants had on average 10.11 years of experience with the torque steering technique for colonoscopy (+/- 10.94 years), 16 were right-handed (89%), and 8 out of the 18 (44%) participants were currently experiencing or previously had issues with MSK pain or injury.

Muscle Activity

For all three positions (RL, LL, supine), average muscle activity levels for the lumbar erector spinae at L1 were generally low, with most participants activating their muscles at 8-10% MVC ±10%. There was no significant difference in average muscle activity among the patient positions ($F(2, 32) = 3.415$, $p = 0.068$, $\eta^2 = 0.176$). The effect size indicates that patient position accounted for approximately 17.6% of the variance in EMG activity.

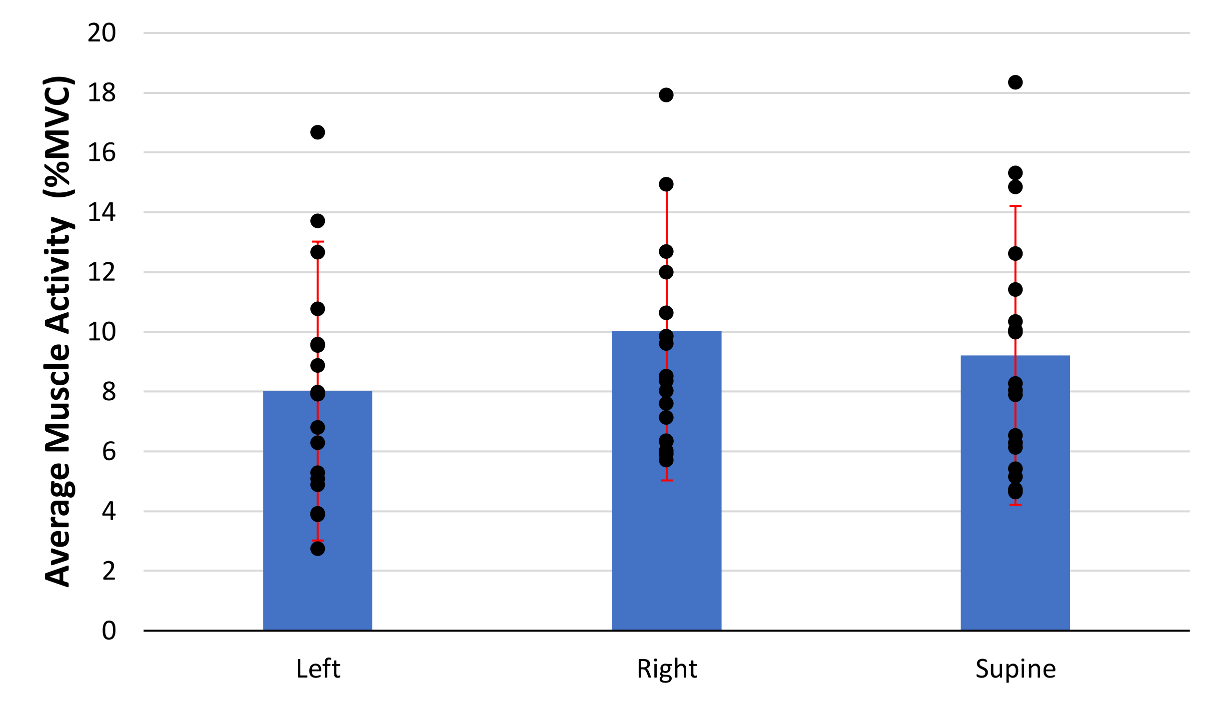

Figure 4: Solid bars are mean muscle activity of the lumbar erector spinae muscles between the three patient positions: Left = LL decubitus, Right = RL decubitus, and supine (black dots are individual participant data points, error bars are standard deviation).

Perceived Discomfort

Generally, mean changes in perceived discomfort from baseline were low (less than 10mm on average +/- 10) reported for all body regions across the three patient positions except for the wrist/hand (right, and supine) and low back (right) (Figure 4). There was no significant effect of patient position on perceived discomfort development (F (2, 32) = 2.686, p=0.110, $\eta^2 = 0.144$). The effect size suggests that approximately 14.4% of the variance in perceived discomfort was accounted for by patient position. This is a moderate magnitude and indicates that patient position only accounts for a small amount of the variance in perceived discomfort. While patient position influences discomfort to some degree, other factors not accounted for in this investigation may also play a role.

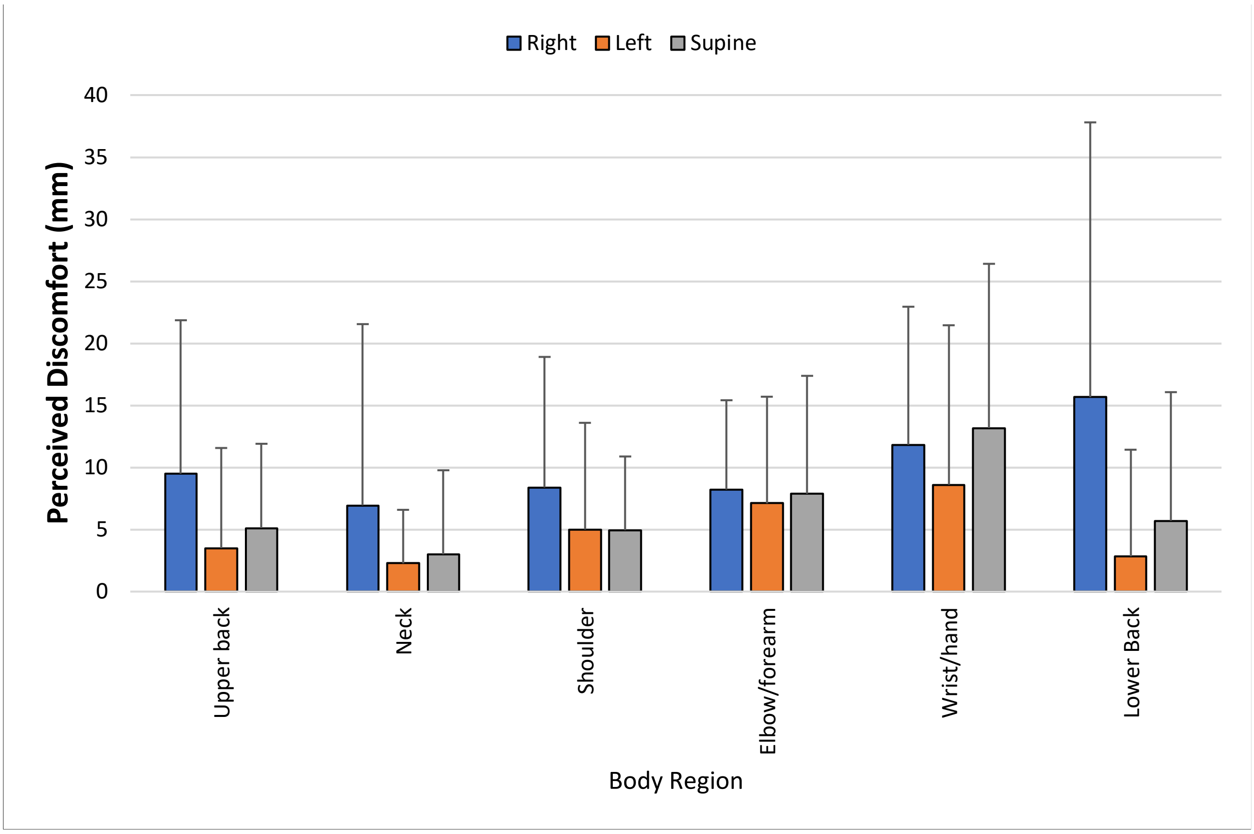

Figure 5: Mean perceived discomfort change from baseline for each patient position condition for six body regions (error bars are standard deviation).

Perceived Exertion

Generally, there were low mean changes in perceived exertion from baseline reported for all body regions across the three patient positions with all ratings under 4, corresponding to "somewhat hard"). However, a substantial amount of variability was observed. There were no significant effects of patient position on perceived exertion (F (2, 34) = 1.045, p= 0.342) (Figure 5). The F-statistic (F=1.045) and its corresponding p-value of 0.342 indicate that observed differences in perceived exertion as they relate to patient position can be attributed to random variability as opposed to the effects of patient position (Sureiman & Mangera, 2020).

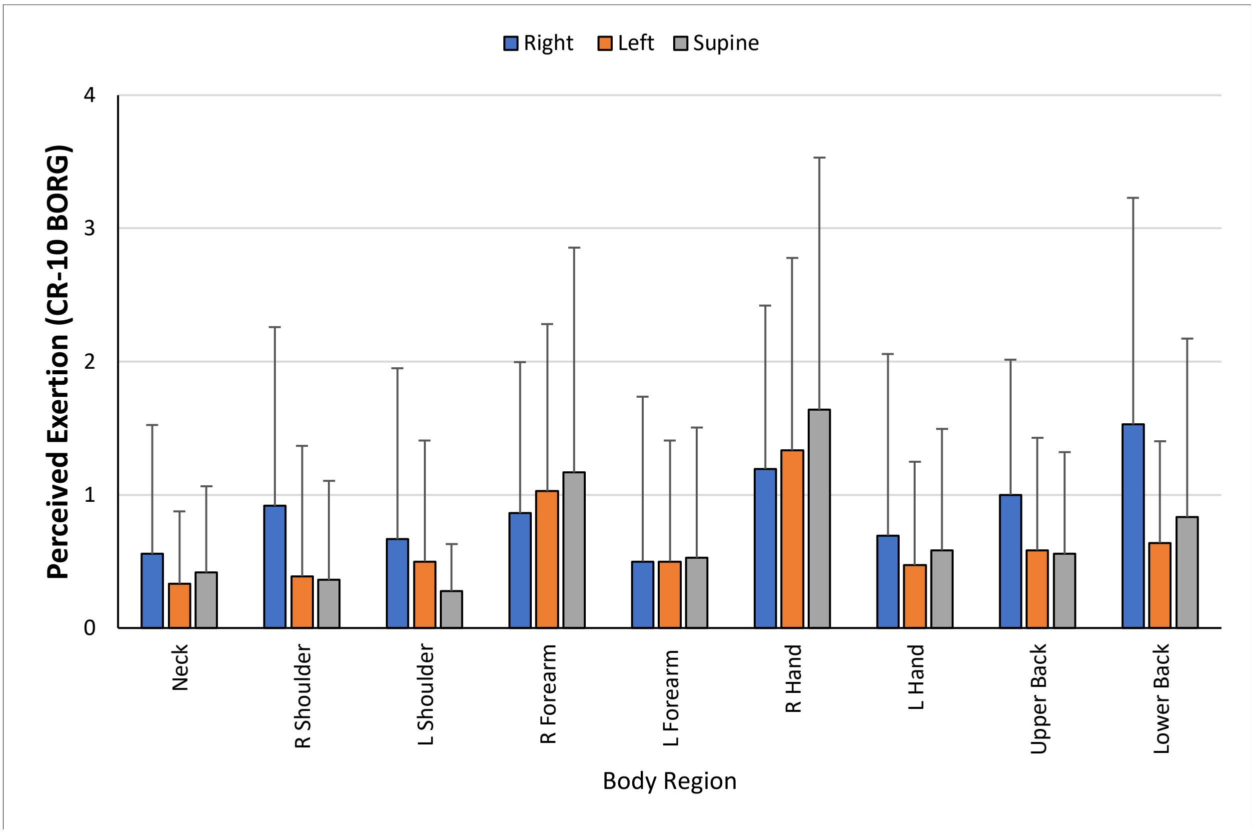

Figure 6: Mean perceived exertion change from baseline for each patient position as measured by the BORG CR-10 Scale (error bars are standard deviation).

Rapid Upper Limb Assessment

Posture

A heat map shows the degree of neutrality adopted by each participant by body region in each patient position (Figure 6). Across the three patient positions, the area of the endoscopists' body with the most non-neutral postures was the wrist. In both the supine and RL positions upper arm and lower arm were also in less neutral positions. Of potential concern would be the neck in both the supine and RL positions with some participants adopting non-neutral postures (namely in extension, potentially in relation to looking up at the monitor during the procedure). The trunk was mainly in neutral ranges (0-20 degrees) for most of the patient postures, with four participants adopting non-neutral trunk flexion in the RL patient position.

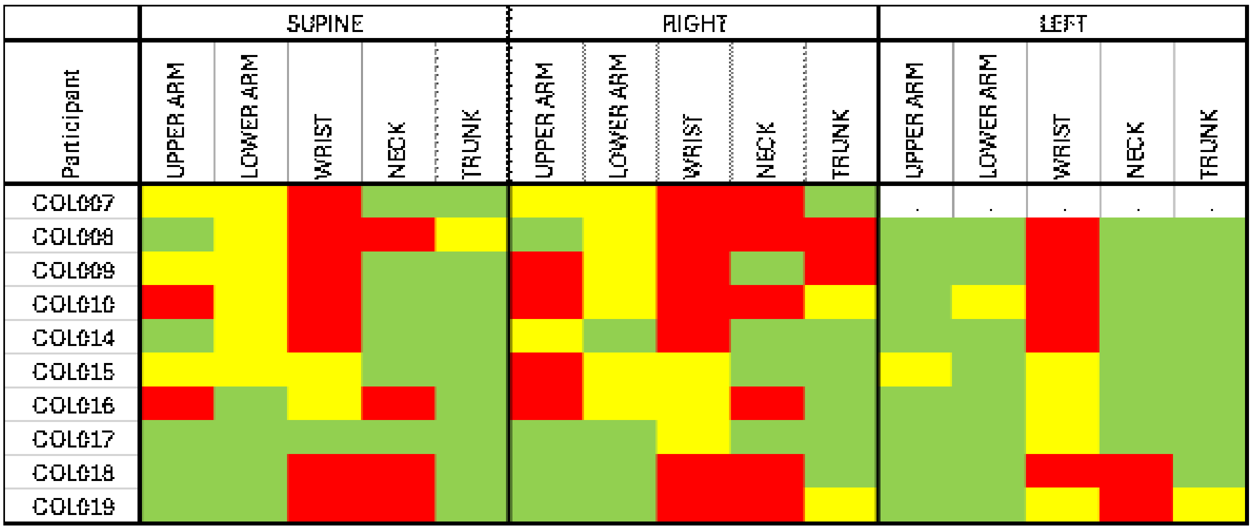

Figure 7: Heat map of posture for the upper arm, lower, arm, wrist, neck, and trunk. Green = neutral posture, yellow = moderate posture, red = non-neutral posture.

Total RULA Scores

The LL patient position was found to have significantly lower total RULA scores compared to the RL position (median 4 vs. 6.5, $p<0.03$, $z= -2.132$, Wilcoxon signed-rank test). Additionally, the LL position showed significantly lower RULA scores than those found in the supine patient position (median 4 vs. 6, $p<0.03$, $z= -2.226$). This is evident in Figure 7, that shows the mean RULA score for each patient position. The mean RULA score for each patient position was 5.9 +/- 1.45 (RL), 4.1 +/- 1.45 (LL), 5.5 +/- 1.65 (supine) respectively which corresponds to “further investigation required, change soon” for the RL and Supine, and “further investigation required, change may be needed” according to the RULA score interpretation rubric.

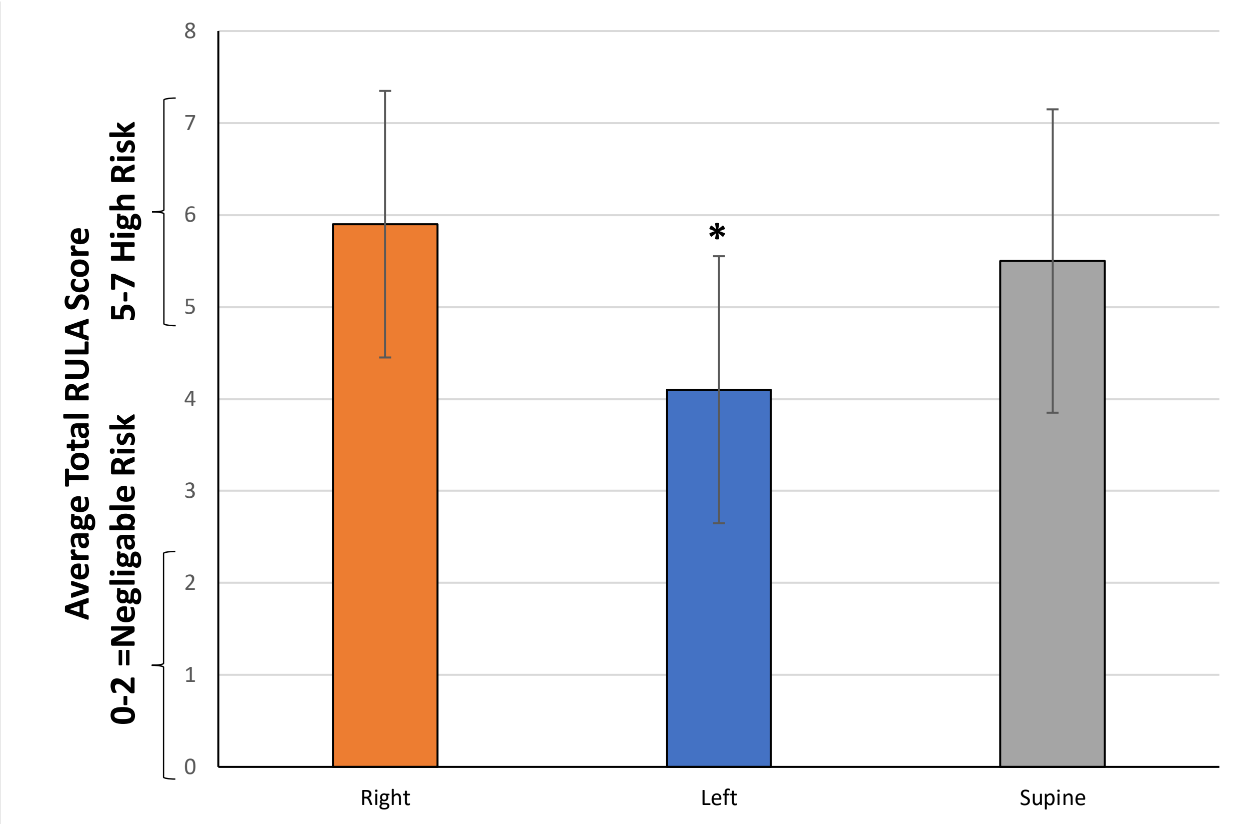

Figure 8: Average Rapid Upper Limb Assessment (RULA) score for the three patient positions. The score for the left position is significantly lower compared to both the right and supine positions.

Participant Characteristics

Two participant characteristics exhibited significant interactions with our outcome variables, these were height and BMI. Pearson correlation coefficients showed significant relationships for these variables with sEMG activity: height ($r = -0.584$, $p = 0.001$) and BMI ($r = 0.521$, $p = 0.001$) shown in table 2.

Table 2: Participant Characteristics

Correlations

		EMG_Average	EMG_Max	VAS_Total	BORG_Total	Height (cm)	Weight (kg)	Experience (Inc Residency)	BMI
EMG_Average	Pearson Correlation	1	.513**	-.225	-.219	-.584**	.115	-.076	.521**
	Sig. (2-tailed)		<.001	.112	.122	<.001	.421	.597	<.001
	N	51	51	51	51	51	51	51	51
EMG_Max	Pearson Correlation	.513**	1	.082	.028	-.282*	.196	.115	.386**
	Sig. (2-tailed)	<.001		.567	.843	.045	.168	.423	.005
	N	51	51	51	51	51	51	51	51
VAS_Total	Pearson Correlation	-.225	.082	1	.620**	.274*	.019	-.084	-.163
	Sig. (2-tailed)	.112	.567		<.001	.047	.893	.552	.243
	N	51	51	53	53	53	53	53	53
BORG_Total	Pearson Correlation	-.219	.028	.620**	1	-.017	-.039	.028	-.031
	Sig. (2-tailed)	.122	.843	<.001		.904	.781	.843	.823
	N	51	51	53	54	54	54	54	54
Height (cm)	Pearson Correlation	-.584**	-.282*	.274*	-.017	1	.313*	.285*	-.388**
	Sig. (2-tailed)	<.001	.045	.047	.904		.021	.037	.004
	N	51	51	53	54	54	54	54	54
Weight (kg)	Pearson Correlation	.115	.196	.019	-.039	.313*	1	.672**	.753**
	Sig. (2-tailed)	.421	.168	.893	.781	.021		<.001	<.001
	N	51	51	53	54	54	54	54	54
Experience (Inc Residency)	Pearson Correlation	-.076	.115	-.084	.028	.285*	.672**	1	.444**

	Sig. (2-tailed)	.597	.423	.552	.843	.037	<.001		<.001
	N	51	51	53	54	54	54	54	54
BMI	Pearson Correlation	.521**	.386**	-.163	-.031	-.388**	.753**	.444**	1
	Sig. (2-tailed)	<.001	.005	.243	.823	.004	<.001	<.001	
	N	51	51	53	54	54	54	54	54

3.3 Discussion

This study aimed to identify whether the different patient positions used during a simulated colonoscopy elicit different MSK demands on the endoscopist. We found that LL was associated with significantly lower RULA scores compared to the RL and supine, but no significant differences were found for measures of perceived pain, exertion, or muscular activity between the three patient positions.

Muscle Activity

The study showed that muscle activity varied widely among participants and positions. For instance, one participant had an unusually high muscle activity spike (130% MVC), which might be due to measurement error. Generally, the erector spinae muscle activity was low for most participants, staying under 20% MVC.

Statistical analysis indicated that patient position did not significantly affect average muscle activity levels ($p > 0.05$, $F(2, 32) = 3.415$, $p = 0.068$, $\eta^2 = 0.176$). This means that patient position explained only about 17.6% of the differences in muscle activity, suggesting that position has only a small impact on muscle strain.

Overall, the low levels of muscle activation and the minimal impact of patient position suggest that variations in muscle activity are more likely due to individual differences rather than the specific positions used. In other words, the different patient positions in this study did not lead to significant changes in muscle strain.

Previous anecdotal evidence found by our group revealed our local clinicians preferred the LL position. The RL position and its associated ergonomic challenge is attributed to the anus being further away from the endoscopist, which requires the practitioner to change their torso angle by leaning forward and subsequently adjust their neck position into more extension so that they can see the monitor properly. This theoretically could increase the demand on the lower back and neck. However, neither of these anecdotes were confirmed by our statistical analysis.

Examining the average EMG for both erectors and their associated activity for each of the three patient positions, we find LL, RL, and supine with percentages of 8.02%MVC +/- 3.77, 10.03%MVC +/- 4.72, and 9.21%MVC +/- 4.12 respectively. While the RL position shows higher average EMG activity compared to LL and supine, this difference was not statistically significant.

A larger sample size would improve the statistical power of the study, making it easier to detect differences among patient positions and their associated effects on MSK demands. With more participants, the analysis would better account for individual variability and provide more reliable results. Additionally, increasing the volume of scoping could offer a more comprehensive view of MSK demands over time, potentially revealing differences that short-duration trials might miss. The lack of significant findings could be due to the small sample size, which may have limited the study's ability to detect meaningful differences. A more detailed analysis of muscle activity, including how it changes over time or during different phases of the procedure (e.g., insertion versus withdrawal), might reveal insights that average and peak values alone do not capture. Given that static postures can lead to fatigue, as highlighted by previous research (Pope et al., 2002), future studies should consider examining a full day of colonoscopies to better identify when these issues become significant.

Perceived Discomfort

The study did not find a statistically significant effect of patient position on the mean change in perceived discomfort compared to baseline measures. Interestingly, some participants initially reported higher discomfort levels at baseline than during subsequent trials, thus suggesting a potential adaptation effect as participants engaged in the simulation. One study that examined healthcare workers in Northern Saudi Arabia using the Nordic Musculoskeletal Questionnaire found that a major factor that contributes to MSI is insufficient movement during work tasks (Alruwaili et al., 2023). This finding highlights the importance of movement and task-related ergonomics in the development of MSI.

This observation prompts consideration of the variability related to discomfort perception and calls for further exploration. Overall, while this study did not detect a significant impact of patient position on perceived discomfort, the variability observed in baseline discomfort ratings highlights the complexity of individual perception (Figure 4). These findings emphasize the need for future research to dive deeper into the factors influencing perceived discomfort in clinical settings.

Perceived Exertion

The endoscopists' exertion during the procedure primarily involves maintaining a static standing posture and manipulating the scope with the right arm. This is evident from the data, which show a general increase in perceived exertion on the right side (shoulder, forearm, and hand) throughout the trials (see Figure 5). Laparoscopy, like colonoscopy, is a minimally invasive procedure used for diagnosis and treatment. A recent study by Kromberg et al. (2020) investigated the impact of microbreaks on musculoskeletal fatigue among laparoscopic surgeons performing appendectomies. This study involved 12 surgeons, and used the BORG CR-10 scale to measure perceived exertion and well-being as well as the Visual Analog Scale. Their findings revealed that ratings of perceived exertion increased gradually over the duration of the procedures, paralleling the increase observed in our cohort of endoscopists. However, neither study found statistically significant results. Kromberg et al. used a blinded randomized crossover design where there were two groups, one incorporating microbreaks and one without. While our study employed a cross-sectional study design that assessed our clinicians during 10-minute scoping simulations with the "patient" in each of the three varying positions.

Risk of Injury

As far as we are aware, our laboratory's small-scale study remains the only examination of MSK risk encountered by endoscopists during colonoscopies with respect to patient positioning, employing the ergonomic assessment tool (Landry et al., 2023). In that study, which included 19 participants, we found that the RL position was associated with significantly higher risk of injury scores compared to the LL position. Additionally, 89% of endoscopists preferred the LL position, despite both positions indicating an increased risk of MSI.

Similarly, in this study, which assessed 18 endoscopists using the same ergonomic assessment tool, we observed a related trend. Both RL and supine positions were associated with higher risk of injury, suggesting that endoscopists face a worse ergonomic position when the patient is in these positions. This is supported by our findings which indicated RL and Supine positions fell into the category of "further investigation required, change soon" (mean scores around 5.5 to 5.9), while the LL position fell into the category of "further investigation required, change may be needed" (mean score of 4.1), indicating a relatively lower risk compared to RL and Supine positions.

Another study investigated laparoscopic surgery and associated ergonomic risk factors using the ergonomic assessment tool (Alamoudi et. al, 2020). Laparoscopic surgery and its required postures mimics those of colonoscopy very closely. This study found scores of 2-3 for the upper arm and 3-4 for the wrist position due to excessive flexion, extension, and twisting. Comparatively, for the upper arm we found average scores of 1.5-2.8, and for the wrist position scores of 4.3-5.4. In addition to these findings, in our study we also saw trunk postures that stayed predominantly at 20 degrees of flexion or less throughout all postures. This gives us a good indication as to why we had consistently low levels of sEMG activity among our participants. Less flexion points to a decreased moment arm on the low back and subsequently less required muscle activity of the erectors to maintain an upright posture during the trials.

However, we also observed greater neck extension among our cohort of clinicians (see Figure 6), likely because they positioned their monitors based on their neutral standing posture before commencing the trials. This presents a challenge as clinicians adjust their postures during the trials, requiring them to readjust their neck position to maintain proper monitor visibility. This is one avenue that practitioners bothered by neck pain could explore in the future. These findings validate assessing the MSK demands on endoscopists during the varied patient positions.

In general, all three patient positions and their associated assessment of ergonomic risk were a 3 or higher for all participants which indicates that further investigation is required, and change may be needed. Even though our analysis did not reveal any statistically significant differences, this may be attributable to our limited sample size. The observed levels of injury risk, as measured by the ergonomic assessment tool, suggests that there could be meaningful changes in MSK demands that garners further exploration. Thus, our results underscore the need for future research to explore the impact of patient position on ergonomic risk that may not be obvious with our current sample size.

Clinician Characteristics

Two clinician characteristics: height and BMI had significant effects on our outcome variables of sEMG activity and perceived exertion. Our results indicated that height had a protective effect on sEMG activity, with taller individuals exhibiting lower levels of sEMG activity. This suggests that taller clinicians may benefit ergonomically during procedures, as they can more easily align their bodies and maintain a comfortable posture, potentially reducing the need for awkward adjustments and excessive muscular effort when leaning over patients on the table (Landry et al., 2023). Conversely, a higher BMI was associated with increased effort during tasks. A systematic review by Rezaei et al. (2021) found that higher BMI is a risk factor for low back pain among healthcare providers, as excess weight can contribute to increased strain and discomfort. In our study, participants with higher BMI demonstrated higher levels of sEMG activity, suggesting that greater muscular effort is required to perform tasks. This finding supports the idea that increased body mass can lead to greater physical demands and potential discomfort during procedural activities. Our findings align with those of Landry et al. (2023), which reported that increased height facilitates movement and ease during procedures, while higher weight adds additional challenges. All other participant characteristics did not show significant interactions with our outcome variables.

Overall Interpretation

Overall, there were no significant differences for the outcome variables tested among the three patient positions; however, this does not imply that these postures are without risk. It is possible that LL, RL, and supine patient positions could increase the risk of injury for endoscopists, particularly when procedures are performed at high volumes and for extended durations. This potential risk is likely attributed to static contraction of the erector spinae muscles, increased perceived exertion in the right-side upper extremity, and elevated ergonomic assessment scores indicating that further investigation is warranted.

Although statistical tests did not show significant differences, descriptive statistics reveal that perceived exertion scores were generally higher for the right side (shoulder, forearm, and hand). This finding is consistent with existing literature on repetitive strain in the right arm, as this side of the clinician is primarily used for torque and advancement of the colonoscope (Shergill et al., 2009, 2021). The increased exertion on this side aligns with the expectation that the right extremity faces more strain due to its role in guiding the scope.

In conclusion, while no significant differences were observed in the outcome variables across the three patient positions, caution is warranted regarding their ergonomic impact. The risk of injury scores highlight that all positions require further investigation and potential changes. Despite similar muscle activation levels, consistent engagement of the erector spinae muscles indicates a risk of injury for endoscopists during lengthy procedures. Increased perceived exertion, particularly on the right side due to scope manipulation, highlights the risk of repetitive strain.

Strengths and Limitations

This study employed a high-fidelity simulation of a colonoscopy procedure that was informed by practicing clinicians in the field, and the conditions were tightly controlled throughout the entirety of the study. The study included a representative sample of endoscopists and surgical residents from our institution. To decrease variability in discomfort and exertion scores, we used change from baseline scores. For muscle activity measures, we normalized the data to each participant's maximum voluntary muscle effort.

However, there are several limitations of this study. Notably, despite covering approximately 82% of the eligible physician population, this study's small sample size may limit how generalizable the findings are. A limited number of participants can restrict the ability to notice small differences or variability among the patient positions. With a small sample, there is a higher chance that individual differences and outliers can heavily influence the results, making it challenging to identify patterns or significant effects. Additionally, the lack of kinematic data, the use of a colonoscopy trainer rather than real patients, and the lab setting may affect the generalizability of the results to actual clinical environments. The 10-minute trials provided only a brief snapshot of the colonoscopy procedure, and longer exposure to the static postures required for each patient position might reveal more pronounced MSK demands. Endoscopists typically perform many procedures each week, so extended durations, like a full workday, could potentially elicit more significant changes in MSK strain. Therefore, the short duration of the trials may not fully capture the differences from baseline scores over longer periods.

In conclusion, our study investigated the MSK demands placed on endoscopists across different patient positions during a simulated colonoscopy. We found that the LL position demonstrated comparatively lower RULA scores, thus indicating better ergonomics than RL and supine positions in a subset of the population. However, none of the positions showed significant differences in perceived pain, exertion, or muscular activity. These findings suggest that while LL may offer some ergonomic advantages, all positions warrant further investigation due to elevated RULA scores and consistent activation of the erector spinae muscle group. These findings highlight the importance of ongoing research into the ergonomic practices of endoscopy, in hopes of helping mitigate or at least attenuate injury risk stemming from high procedural volumes among our valued clinicians.

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Chapter 4: Summary and Future Directions

4.1 Summary

This thesis endeavoured to answer the question of whether varying patient position during a simulated colonoscopy could modulate MSK demand on the practicing endoscopist, an occupation with an exceedingly high MSI rate (Al-Rifaie et al., 2021; Ofori et al., 2018). It was hypothesized that there would be a significant difference in outcome measures among the three varied patient positions (RL, LL, supine) found in practicing endoscopists during simulated colonoscopy. It was theorized that LL would be the most ergonomically friendly position due to previous anecdotal evidence, and that in LL the anus is closer to the endoscopist. Any deviation from this position (RL, or supine) would place the anus further from the clinician and require postural adjustment that must then be sustained. It was determined that there were no significant differences among the three varying patient positions. However, this was a relatively small cohort of endoscopists from the Health Sciences Center (n=18), and a modest volume of scoping in each position at a duration of 10 minutes.

Although ANOVA results for muscle activity and perceived discomfort were not statistically significant, effect sizes were calculated to better understand how well we were able to test for these differences. With an η^2 of 0.176 for muscle activity, patient position accounted for 17.6% of variability, indicating there are likely other factors at play. This suggests that while patient position might influence MSK demands, our study's limited sample size and short simulation duration may have restricted our ability to detect more substantial differences.

To better highlight the role of patient positioning, future research should involve larger sample sizes to improve statistical power and account for individual variability. Additionally, increasing the volume of scoping could provide a more comprehensive view of MSK demands over time, this could reveal differences that short-duration trials might miss. Thus, future studies with expanded samples and extended scoping periods are crucial to accurately assess the effects of patient positioning on endoscopists' MSK demands.

4.2 Limitations and Future Directions

While every attempt was made to mitigate the constraints of this thesis, it was inevitable that some factors may have impacted the outcomes. The first major limitation was the sample size and associated cohort of participants. We collected a convenience sample of 18 endoscopists and residents from our local hospitals, a relatively small sample. Participants in this investigation were predominantly right-handed, healthy, and of Caucasian ethnicity. Every effort was made to recruit all available clinicians through such means as social media, email, and word of mouth, however, the full population of clinicians to recruit from was limited to 20-22 potential participants. Future research in this area should examine whether a larger sample size taken from more hospitals, clinics, and geographic locations could reveal a significant difference among the three varied patient positions and their associated MSK demand on the practicing endoscopist. Another limitation of this study is that it is only a simulation of a colonoscopy. Irrespective of the fact that this was a high-fidelity simulation of a colonoscopy, it was still a simulation. A dummy patient was used instead of a person, this likely made adjustment of the "patient" much easier and allowed for less variability when the clinician was navigating through the colon. Variables such as these could contribute to a less strenuous procedure overall. Follow-up studies could be conducted on endoscopists during their workday using wireless sEMG and hourly check-ins of discomfort or exertion ratings. Lastly, participant bias may have influenced our results. Endoscopists in our study, with an average of 10.11 ± 10.94 years of experience, may have perceived certain aspects of the procedure as more challenging, which could increase their subjective sense of strain. Despite this, our results did not show higher levels of effort or strain with greater experience. This discrepancy could be attributed to experienced practitioners using effective coping strategies or adjusting their techniques to minimize discomfort. To address this, future research could include a greater range of experience levels, such as less experienced practitioners, to better understand how experience impacts perceived strain and effort. Psychological factors like these have been shown to influence outcomes such as pain, discomfort, and exertion related to low back pain (Pincus & McCracken, 2013). Such factors have the potential to significantly affect subjective outcome measures such as ratings of perceived exertion and discomfort. Mitigating participant bias would be challenging; however, selecting a cohort consisting solely of residents with minimal experience might help minimize participant bias.

This thesis endeavoured to investigate whether varying patient positions (LL, RL, and supine) affect MSK demand on practicing endoscopists during a simulated colonoscopy. The findings suggest that there were no significant differences in MSK demand observed among the three patient positions. This could be attributed to participants' familiarity with the procedure and their prior adaptation to its demands. Future research should explore the inclusion of a broader range of gastroenterologist residents to mitigate potential biases related to patient position, as well as greater volumes of scoping to better mimic in-clinic experiences.

Chapter 5: Conclusion

MSI or pain is frequently reported by practicing endoscopists, especially as it pertains to the distal upper extremity (Al-Rifaie et al., 2021). This is largely attributed to the repetitive movements of the wrist and hand required to traverse the colon during a colonoscopy procedure. However, it is less understood why endoscopists also complain of low back and neck pain (Al-Rifaie et al., 2021; Liberman et al., 2005). Many ergonomic variables have been explored as they relate to workplace injury such as, standing, or seated posture, and distance from workspace supplies. However, in the unique context of an endoscopist, monitor height and distance, and therapy plinth height and distance are controlled for. So, the question arises as to whether some other facet of this procedure could be associated with MSI of the back and neck. Consequently, the purpose of this investigation was to determine whether patient position modulated muscular demand of the endoscopist while performing a simulated colonoscopy. This thesis found that of the three commonly used patient positions (LL, RL, and supine), none were associated with significant changes in muscular demand during a 10-minute simulation of each.

Our findings highlight that patient position may not play a large role in endoscopist muscular demand during a simulated colonoscopy, especially with a duration of 10 minutes of scoping or less. As a product of this work, endoscopists may not need to concern themselves with patient position as it pertains to their individual injury risk during a 10-minute simulation of a colonoscopy procedure. It may only be necessary to consider patient position in relation to patient-related outcomes and colonoscopy performance measures. Future studies should analyze whether an increase in the duration of scoping leads to significant differences among the three varied patient positions and their associated effect on endoscopist muscular demand. Thus, ensuring that we are taking every step we can to better protect our clinicians from harm.

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Appendix A: Ethics Approval

Research Ethics Office
Suite 200, Eastern Trust Building 95
Bonaventure Avenue
St. John's, NL A1B
2X5

April 01, 2022

230 Elizabeth Ave
Health Sciences Centre, Room 5315 St.
John's, NL
A1B 3X9

Dear Dr De Carvalho:

Researcher Portal File # 20222784
Reference # 2022.059

RE: Biomechanics investigation of the colonoscopy procedure: is practitioner injury risk greater with patients in the right or left lateral decubitus position?

Your application was reviewed by a subcommittee under the direction of the HREB and the following decision was rendered:

X	Approval
	Approval subject to changes
	Rejection

Ethics approval is granted for one year effective April 1, 2022. This ethics approval will be reported to the board at the next scheduled HREB meeting.

This is to confirm that the HREB reviewed and approved or acknowledged the following documents (as indicated):

- Application, approved
- Research proposal, approved
- Revised information and consent form, approved
- Data Collection Form, approved
- email recruitment text, approved
- Recruitment poster, approved
- Budget, approved

- Questionnaires (perceived pain, perceived exertion), approved Please

note the following:

- This ethics approval will lapse on April 1, 2023. It is your responsibility to ensure that the Ethics Renewal form is submitted prior to the renewal date.
- This is your ethics approval only. Organizational approval may also be required. It is your responsibility to seek the necessary organizational approvals.
- Modifications of the study are not permitted without prior approval from the HREB. Request for modification to the study must be outlined on the relevant Event Form available on the Researcher Portal website.
- Though this research has received HREB approval, you are responsible for the ethical conduct of this research.
- If you have any questions please contact info@hrea.ca or 709 777 6974.

The HREB operates according to the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS2), ICH Guidance E6: Good Clinical Practice Guidelines (GCP), the Health Research Ethics Authority Act (HREA Act) and applicable laws and regulations.

We wish you every success with your study.

Sincerely,

Dr Fern Brunger, Chair Non-Clinical Trials Committee Health Research Ethics Board