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# Ergonomic Challenges Encountered by Laparoscopic Surgeons, Surgical First Assistants, and Operating Room Nurses Involved in Minimally Invasive Surgeries by Using RULA Method

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## Abstract

**Background:** Following the widespread approval of laparoscopic procedures, which impose certain restrictions on surgeons' movements and access to information, extensive research has been conducted on improving ergonomic conditions in this field. Ergonomic studies have indicated high levels of physical workload among laparoscopic surgeons.
**Objectives:** The purpose of this study was to clarify the major ergonomic challenges faced by laparoscopic surgeon, their first assistants, and operating room nurses.
**Methods:** This cross-sectional study recruited 62 volunteers with different levels of experience in minimally invasive surgeries between October 2014 and June 2015. Demographic data and the musculoskeletal disorder were collected by demographic questionnaire and the nordic musculoskeletal questionnaire (NMQ). Laparoscopic cholecystectomy procedures and surgical team members' position were recorded by camera then evaluated via the rapid upper limb assessment (RULA) method by ErgoIntelligence – UEA software. The data were analyzed using T-test, ANOVA Test, pearson and Kendall correlation coefficient by using Spss 16 software.
**Results:** 60%of participates are male and 40%are female. The Mean age of male and female participates are 43.94 and37.62, respectively. There is a significant relationship between weight, height and work experience with musculoskeletal disorders and jobs and RULA score. The surgeons had the highest score in Rulla method. Pearson correlation coefficient also showed a significant relationship between age and RULA score.
**Conclusions:** The majority of the participants complained of pain and discomfort after laparoscopy, therefore it is imperative to consider ergonomic issues during such procedures.

*Keywords:* Ergonomic, Rulla, Surgeon, First Assistant, Operating Room Nurses

## 1. Background

Ergonomics is a field of scientific discipline dealing with the interactions between humans and their working environment. It generally aims not only to ensure occupational health and safety, but also to maximize the efficiency and productivity of the whole system (e.g. medical devices). It hence seeks to design equipment and living and working environments based on the characteristics, needs, and behaviors of their users (1). Most employee including surgical team members face ergonomic challenges. Moreover, many different ergonomic problems exist in operating rooms. Lack of efficient guidelines to provide the surgical team with knowledge about the importance of ergonomics is a major issue in operating rooms (2). Ergonomics is in fact responsible to assess such issues and recommend guidelines to promote safety and comfort without sacrificing effectiveness and efficiency in various work environments (3). Despite the numerous advantages of laparoscopic surgery, e.g. decreased recovery time and improved outcome for patients, surgeon's position during such surgeries might cause ergonomic and subsequent musculoskeletal problems. Therefore, surgeons' posture has received increasing attention as a major ergonomic challenge during surgical procedures. It has

been well documented that improving ergonomic conditions, muscle endurance, and posture during laparoscopic surgeries would decrease the level of fatigue and the incidence of repetitive stress injuries among the surgeons (4). While open surgery required the surgeon to utilize conventional surgical tools and operate directly on the patient, minimally invasive surgeries necessitate the use of a variety of techniques and technologies over longer periods of time (3). Therefore, following meticulous quantitative and systematic evaluations, experts in ergonomics have identified the existing issues in laparoscopic surgery and provided recommendations to enhance surgeons' safety (5). Ergonomic studies have in fact indicated high levels of physical workload among laparoscopic surgeons and highlighted the need for a combination of ergonomic interventions and applications for their resolution (6). The reduction of occupational injury after laparoscopic procedures requires awareness, knowledge, and compliance with ergonomic guidelines (7). In spite of the high frequency of musculoskeletal pains during and after minimally invasive surgeries, most of the surgeons are unaware of ergonomic guidelines (8). Three common postural mistakes in laparoscopic surgeries are pelvic girdle asymmetry, improper shoulder elevation, and forward head position. While correct ergonomic behavior needs learning and practicing, appropriate operating room arrangement, correct posture, and repositioning during surgery can substantially reduce the painful experiences in surgeons (9). The arrangement of laparoscopic equipment (e.g. monitors, insufflators, lights, and image capturing and electrocautery devices) on a single trolley (or sometime multiple trolleys), along with the development of various surgical and visualization techniques, has resulted in significant ergonomic challenges for the surgical team and possible threats to patient and occupational safety (5). Lack of ergonomic considerations for laparoscopic procedures increases physical tension particularly on the upper extremities of the surgeons. According to a recent study published by Sari et al., neck, lower back, and shoulder pains are the most common physical complaints during or after laparoscopic procedures. They also found poor monitor positioning, inadequate table height adjustment, and suboptimal design of instrument handles among the most important reasons of the reported discomforts (10). Appropriate positioning of the monitor plays a major role in desirable ergonomic conditions during laparoscopic surgeries. Placing the monitor at or just below the eye level and at a moderately inclined viewing angle would not only reduce musculoskeletal strain on the neck and shoulders, neck pain, and degenerative spine conditions, but also curtail eye fatigue caused by near work (11). The distance between the monitor and the surgeon's eye should also be set at 80 - 120 cm to ensure both safety and comfort (5). Although ergonomic conditions in the operating room can be simply improved by setting the screen at a height lower than body height, the fixed position of the monitor on top of the trolley generally prevents its ideal adjustment (12). Moreover, the transferred force from instrument handles to the surgeon's hand can cause nerve lesions. While ergonomic products have been shown effective in alleviating chronic pain caused by constant occupational pressure on surgeons, laparoscopic instruments (e.g. trocars) commonly have a range of motion with five degrees of freedom, which is far below the range of motion provided in open surgery (13). An ideal posture for laparoscopic surgeons can thus be achieved by considering an optimal height of operation tables, proper monitor positions, and using appropriate man-machine interfaces (14). Following the widespread approval of laparoscopic procedures, which impose certain restrictions on surgeons' movements and access to information, extensive research has been conducted on improving ergonomic conditions in this field (15). Several biomechanical methods have also been adopted to measure physical workload during various laparoscopic tasks (16). It is thus essential for all experienced and novice laparoscopic surgeons to acquire adequate knowledge about the applications of ergonomics in laparoscopic procedures (17). Every job has its own dangers and health problems, and operating room staff and surgeons are no exception. Musculoskeletal disorders are one of the most common diseases that can be seen in the medical staff. These disorders are more likely to be static in surgeons and operating room staff who have been practicing laparoscopic surgery for hours.

## 2. Objectives

Since there is not two monitors and assistance of surgeons in surgery rooms therefore the work load on the surgeons and operating room nurses are high. On the other hand, musculoskeletal disorders have not been studied in this group of people in Iran so far. This study has been reviewed by The Rulla software to analyze the posture of surgeons and the operating room staff during laparoscopy surgery. We examined the work status and the prevalence of musculoskeletal disorders based on the scores obtained from the Rulla software and the Nordic questionnaire. Therefore, the current study sought to clarify the ergonomic challenges faced by laparoscopic surgeons, their first assistants, and operating room nurses by using Rulla method.

## 3. Methods

This cross-sectional study recruited in hospitals with Laparoscopic surgical room. Only 62 people worked in hospitals that were equipped with laparoscopic surgery. Then 62 people with different levels of experience in minimally invasive surgery participated in this study. The study was performed between October 2014 and June 2015 in some hospitals in Tehran and Karaj (Emam Khomeini, alborz and Rasol Akram). Laparoscopic cholecystectomy procedures and surgical team members' position were recorded by camera then evaluated via the rapid upper limb assessment (RULA) method by ErgoIntelligence – UEA software. Musculoskeletal problems were calculated; divided organs in frequency percentage for everyone. Institutional review board approval was granted for the sample collection and evaluation of patient demographics by the medical ethics committee of Tehran University of medical sciences, also the study was carried out according to the Helsinki declaration (As revised in Tokyo 2004). Verbal Informed consent was obtained from all patients' before data collection and inclusion in the study. The participants were surgeons, first assistants, or operating room nurses. A demographic questionnaire (containing gender, age, body mass index (BMI), and experience in laparoscopic surgery) and the Nordic standard Musculoskeletal Questionnaire (NMQ) (18) were used to collect data. The rapid upper limb assessment (RULA) method was applied to determine the risk of problems in the participants. The NMQ is a two-part questionnaire introduced by the nordic council of ministers. The first part of the NMQ comprises 40 forced-choice items trying to determine areas of the body (i.e. neck, shoulders, upper back, elbows, low back, wrists, hands, hips, thighs, knees, ankles, and feet) causing musculoskeletal problems. The respondents are required to mention any musculoskeletal problems preventing them from performing their routine tasks over the past seven days and 12 months. The second section of the NMQ poses supplementary questions to extract additional information about problems in the neck, shoulders, and lower back. In addition, 25 forced-choice items are included to identify any accidents affecting the mentioned areas and their functions, duration and diagnosis of the problem, and musculoskeletal problems during the past seven days. RULA focuses on posture to determine the risk of work-related upper limb disorders in workers. It evaluates the upper limbs in two separate groups, namely upper arms, lower arms, and wrists (group A) and legs, trunk, and neck (group B). In order to calculate the scores of each group, different angles of the body are measured and scored based on the relevant tables. The global scores of the two groups are then modified based on the type of muscular activity and the applied forces. A combination of these modified global scores is then used to calculate the grand score (the general postural score) which determines the possible risk of work-related upper limb disorders during a task. Higher scores of RULA suggest a greater risk of developing musculoskeletal disorders. After completing the demographic questionnaire and NMQ , the participants performed a planned laparoscopic cholecystectomy procedure and the whole process was filmed (the focus was on the surgical team's position). After recording the kinematic and static status of the subjects, the movies were evaluated and RULA was conducted by a qualified examiner. Repetitive movements and the longest held and the worst adopted posture(s) were selected and documented. Following the application of RULA, the posture scores of each body part were calculated using a software package and compared with standard scores. The final scores ranged between one and seven. While scores one-two indicates acceptable posture, scores three-four imply the necessity of modifications in the task and further analysis. Redesigning the task or the applied method would be warranted with scores five-six. Finally, scores of seven suggest the need for urgent modifications in the performed task or the work environment. All statistical tests were performed with SPSS 16 for Windows (SPSS Inc., IL, USA). The normality of the data was determined using Kolmogorov-Smirnov test. The data were analyzed using T-test, ANOVA Test, Pearson and Kendall's correlation coefficient.

## 4. Results

A total of 62 subjects (60% male and 40% female) were recruited. The Mean age of male and female participates are 43.94 and37.62, respectively. Most of the participants (45.53%) were operating room nurses and the majority of these nurses were female. Moreover, 37.11% of the participants were surgeons and 19.35% were first assistants. The latter group had the highest mean age. Nearly half of the subjects had more than 20 years work experience. Furthermore, 70% of the participants used two monitors and 30% used just one. Muscleskeletal disorders caused by static posture during laparoscopic surgery was reported by the majority of the participants. Likewise, varying levels of discomfort, particularly in the neck, shoulder, back, elbow, forearm, thumb, upper leg, knee, lower leg, and ankle, were indicated by most subjects. The prevalence of musculoskeletal disorders is expressed in different organ of the body in Table 1. of people experienced at least one musculoskeletal disorder during the last year. Most of these disorders are related to the neck and waist (upper and lower part). Among the group, the most complaints were related

to operating room nurses and then surgeons and first assistances. Also, musculoskeletal problems in the last seven days are expressed in Table 2. Severe levels of Neck pain and backache were indicated by about half of the participants. Although pain in this area had the lowest frequency among first assistances. Operating rooms and surgeons suffered maximum severity of pain (66.7% - 56.5%). Moreover, while 70.4% of operating room nurses, 66.7% of first assistants and 30.4% of surgeons had lower back pain, the highest severity of pain was reported by operating rooms. Wrist pain was experienced by 47.7% of surgeons, 51.8% of operating room nurses and 33.3% of first assistants. However, first assistants suffered from less severe pains in the wrist. The mean age and work experience (42.17 and 30) in peoples with the disorder were higher than those who did not report the disorders (41.23 and 15.33). Likewise, people with a disorder had a mean weight and height (176.43 and 79.43) higher than those without a disorder (168.29 and 70.75). T-test analysis showed a significant relationship between weight (P = 0.002), height (P = 0.011) and work experience (P = 0.046) with musculoskeletal disorders, but there isn't any significant relationship between age and musculoskeletal disorders (P = 0.76). RULA scores of seven, five-six, three-four, and one-two were acquired by 12.9%, 24.2%, 58.1%, and 4.8% of the participants, respectively. Finally, in comparative analysis based on RULA scoring, 16.7% of first assistants, 11.1% of operating room nurses, and 13% of surgeons were at immediate risk of developing injuries caused by improper posture (Table 3). The ANOVA test showed a significant relationship between jobs and RULA score (P = 0.004). The surgeons had the highest score in RULA method. Pearson correlation coefficient also showed a significant relationship between age and RULA score (P = 0.002). However, there was no significant relationship between weight and height and work experience with RULA score. Kendall's correlation coefficient did not show a significant relationship between jobs and musculoskeletal disorders.

## 5. Discussion

Based on the NMQ, 58.1% of our participants had experienced neck pain during the 12 months prior to the study. Most complaints in this regard were reported by operating room nurses (66.7%). Furthermore, back pain was experienced by 56.5% of the subjects. Again, the highest frequency of complaints was seen in operating room nurses (59.3%). Nearly half of the subjects had suffered from lower back pain. Of these, 70.4% were operating room nurses. In a study by Tijam et al., 86.0% of the participants had experienced musculoskeletal complaints over the 12 months before the study. More than half (62.1%) of these complaints were believed to be related to work. Moreover, neck, back, and shoulders were areas with the most reported complaints (19). Wauben et al. (2), Mirmohammadi et al. (7), published similar findings. The majority of our participants believed that their static posture during laparoscopic surgery was responsible for a level of muscle fatigue they experienced. They also reported levels of discomfort, especially in their neck, shoulders, and back. Szeto et al. compared surgeons' postures and identified significant differences in neck posture and left shoulder abduction between surgeons performing open and laparoscopic surgeries. In addition, while a static neck posture was held for a longer time during laparoscopic surgeries, movements had higher frequency during open procedures (17). In total, 67.8% of the subjects experienced shoulder pain in the present study. The complaint was more common among first assistances (75%). Moreover, severe levels of pain were reported in about half of cases of shoulder pain. The highest severity of neck pain was observed among operating rooms. The operating rooms and surgeons had maximum neck pain by high severity (66.7% and 56.5%). A large study estimated the frequency of discomfort in the neck, shoulders, and back among thoracic surgeons in European countries at 81.9%, 76.3%, and 83.2%, respectively (1). According to Miller, Wauben et al. Liang et al. and others study, More than half of surgical team members participating in the current research experienced low back pain. This problem had the greatest severity among surgeons (30% vs. 22.2% in operating room nurses and 0% in first assistances). Holding a static posture for a long time results in the production of lactic acid and toxins by muscles and tendons. Therefore, static postures are believed to cause more severe musculoskeletal damage in comparison to dynamic postures. According to Miller et al., 100% of surgeons experienced neck stiffness, as well as back stiffness and pain, during laparoscopic procedures (20). According to Wauben et al. and other studies. In the present study, wrist pain was reported by 47.7% of surgeons, 51.8% of operating room nurses, and 33.35% of first assistants. While the severity of wrist pain was almost similar among surgeons and operating room nurses, first assistants suffered from lower levels of pain. Shergill et al. great numbers of endoscopists (37% - 89%) complained about musculoskeletal disorders, particularly in their left thumb, right wrist, neck, and back (21). The findings of Mirmohammadi et al. (7), Wauben et al. (2), have also confirmed these results. We detected a significant relationship between weight, high and work experience with musculoskeletal disorders.This subject show that the increasing work experience causes increased the musculoskeletal disorders. On the other hand, height and weight are also effective in a person's posture and consequently, in the devel-

**Table 1.** Musculoskeletal Problems in the Last 12 Months (%(n))

| | Groups | Operating Room Nurses (27) | First Assistances (12) | Surgeons (23) | All (62) |
|---|---|---|---|---|---|
| **Neck** | | 66.7 (18) | 41.7 (5) | 56.5 (13) | 58.1 (36) |
| **Shoulders** | Right | 14.8 (4) | 50 (6) | 21.7 (5) | 24.2 (15) |
| | Left | 18.5 (5) | 8.3 (1) | 30.4 (7) | 21 (13) |
| | Both | 33.3 (9) | 16.7 (2) | 13 (3) | 22.6 (14) |
| **Elbows** | Right | 3.7 (1) | 0 (0) | 8.7 (2) | 4.8 (3) |
| | Left | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| | Both | 14.8 (4) | 0 (0) | 0 (0) | 6.5 (4) |
| **Wrists/hands** | Right | 14.8 (4) | 25 (3) | 13 (3) | 16.1 (10) |
| | Left | 3.7 (1) | 8.3 (1) | 21.7 (5) | 11.3 (7) |
| | Both | 33.3 (9) | 0 | 13 (3) | 19.4 (12) |
| **Upper back** | | 59.3 (16) | 50 (6) | 56.5 (13) | 56.5 (35) |
| **Lower back** | | 70.4 (19) | 66.7 (8) | 30.4 (7) | 54.8 (34) |
| **Hips/thighs** | | 25.9 (7) | 0 (0) | 13 (3) | 16.1 (10) |
| **Knees** | | 59.3 (16) | 33.3 (4) | 26.1 (6) | 41.9 (26) |
| **Ankles/feet** | | 44.4 (12) | 8.3 (1) | 21.7 (5) | 29 (18) |

**Table 2.** Musculoskeletal Problems in the Last 7 Days (%(n))

| | Groups | Operating Room Nurses (27) | First Assistances (12) | Surgeons (23) | All (62) |
|---|---|---|---|---|---|
| **Neck** | | 55.6 (15) | 16.7 (2) | 34.8 (8) | 41 (25) |
| **Shoulders** | Right | 0 (0) | 25 (3) | 13 (3) | 9.7 (6) |
| | Left | 22.2 (6) | 0 (0) | 30.4 (7) | 21 (13) |
| | Both | 22.2 (6) | 16.7 (2) | 13 (3) | 17.7 (11) |
| **Elbows** | Right | 3.7 (1) | 0 (0) | 0 (0) | 1.6 (1) |
| | Left | 0 (0) | 8.3 (1) | 0 (0) | 1.6 (1) |
| | Both | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| **Wrists/hands** | Right | 25.9 (7) | 0 (0) | 4.3 (1) | 12.9 (8) |
| | Left | 0 (0) | 8.3 (1) | 0 (0) | 1.6 (1) |
| | Both | 7.4 (2) | 0 (0) | 13 (3) | 8.1 (5) |
| **Upper back** | | 55.6 (15) | 41.7 (5) | 52.2 (12) | 51.6 (32) |
| **Lower back** | | 51.9 (14) | 41.7 (5) | 26.1 (6) | 40.3 (25) |
| **Hips/thighs** | | 14.8 (4) | 0 (0) | 17.4 (4) | 12.9 (8) |
| **Knees** | | 29.6 (8) | 16.7 (2) | 17.4 (4) | 22.6 (14) |
| **Ankles/feet** | | 29.6 (8) | 8.3 (1) | 13 (3) | 19.4 (12) |

opment of disorders. Attarchi et al. concluded that shift work and longer shifts could multiply the prevalence of lower back disorders among nurses (22). In a large survey in North America, Park et al. reported that almost 87% of surgeons involved in minimally invasive surgeries suffered from physical symptoms. The symptoms were mostly reported by fellowship trainers who had a high caseload, i.e. higher caseloads were associated with higher rates of neck, hand, and lower extremity symptoms (23). Some surgeons complained about foot pain due to uncomfortable pedal not only in the questionnaires, but also during the laparoscopic procedure. According to ergonomic

**Table 3.** Comparing Rapid Upper Limb Assessment (RULA) Scores Between Surgical Team Members

| Groups | % (No.) | Score | Percent in Each Level (n) | Interpretation |
|---|---|---|---|---|
| **Operating room nurses** | 43.54 (27) | 1 - 2 | 3.7 (1) | Acceptable posture but not to be held or repeated for a long time. |
| | | 3 - 4 | 70.4 (19) | Further investigation required. |
| | | 5 - 6 | 14.8 (4) | Further investigation and Modifications are required soon. |
| | | 7 | 11.1 (3) | Further investigation and modifications are immediately required to prevent injuries. |
| **Surgeons** | 37.11 (23) | 3-4 | 47.8 (11) | Further investigation required. |
| | | 5-6 | 39.1 (9) | Further investigation and modifications are required soon. |
| | | 7 | 13 (3) | Further investigation and modifications are immediately required to prevent injuries. |
| **First assistances** | 19.35 (12) | 1 - 2 | 16.7 (2) | Acceptable posture but not to be held or repeated for a long time. |
| | | 3 - 4 | 49.9 (6) | Further investigation required. |
| | | 5 - 6 | 16.7 (2) | Further investigation and modifications are required soon. |
| | | 7 | 16.7 (2) | Further investigation and modifications are immediately required to prevent injuries. |
| **Total** | 100 (62) | 1-2 | 4.8 (3) | Acceptable posture but not to be held or repeated for a long time. |
| | | 3 - 4 | 36 (58.1) | Further investigation required. |
| | | 5 - 6 | 15 (24.2) | Further investigation and modifications are required soon. |
| | | 7 | 8 (12.9) | Further investigation and modifications are immediately required to prevent injuries. |

guidelines, the best position for the pedal is in front of the main foot. Moreover, since the flexion of the foot increases the loading of body weight and leads to numbness, neck pain and stiffness, and shoulder, back, and leg pain in surgeons (24), the foot should not be flexed above the pedal. Based on some studies, more than half of the surgeons prefer to use manual control instead of the pedal because of its discomfort and consequences. Monitor's position is another major ergonomic factor leading to improper use of the pedal (1, 25). Unfortunately, as some operating rooms in this study had only one monitor, first assistants and operating room nurses had to turn the monitor to have a good view. This position led to an incorrect use of the foot pedal. Likewise, in a study on surgical team members involved in thoracoscopy, Wauben et al. found discomfort, particualrly in the neck, shoulders, and back, in 80% of their participants (2). Franasiak et al. evaluated physical strain among gynecologic oncologists who performed laparoscopic surgeries. They detected discomfort in 88% of the surgeons. Persistent pain was also reported by more than half (52%) of the mentioned group. Furthermore, only 29% of the surgeons had received treatment to reduce their pain (26). Since RULA scores of seven, five-six, three-four, and one-two were acheived by respectively 12.9%, 24.2%, 58.1%, and 4.8% of our participants, nearly 95% of the subjects had ergonomic problems and 37.1% of them were in high-risk conditions. And due to the relationship between RULLA score and job and according to our findings, investigation and modification are immediately required to prevent injuries. Then surgeons held the worst postures and required urgent efforts to change their posture and prevent injuries. In Iran, operating room nurses or surgical technologists work as surgical first assistants. They hence work with different surgeons in minimally invasive surgery rooms for long hours each day. They might thus be at increased risk of injury based on their previous

history. Roberta et al. suggested demographic properties as important determinants of the prevalence of musculoskeletal symptoms (27). On the other hand, considering the inappropriate equipment and setting of the operating rooms in Iran (e.g. there is sometimes only one monitor), operating room nurses are expected to be at higher risk of pain and work-related injuries. Due to the high prevalence of musculoskeletal problems among the studied surgical team members, the reduction of occupational injury after laparoscopic procedures requires awareness, knowledge, and commitment to ergonomic guidelines. Katrin et al. reported that almost all their participants (94.4%) were unaware of the existing guidelines about table height and monitor and instrument positioning during endoscopic surgeries (1). Similar findings were also highlighted by Gofrit et al. (24).

### 5.1. Conclusions

It is necessary to consider ergonomic principals in both instrument design and surgical members' postures in laparoscopic operating rooms.

### 5.2. Limitations

Because of the little opportunity, The Nordic Questionnaire may be filled with some errors. There is no limit to the postures analysis.

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