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ORIGINAL ARTICLE

# Minimally Invasive Surgery: Are We Doing It Right?

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## Abstract

Ergonomics is essential in surgical practice and especially in minimally invasive surgery (MIS) due to concerns with dexterity, loss of 3D view, fulcrum effect and longer duration. This paper aims to audit the ergonomic practice amongst minimally invasive surgeons in Bangalore, India. In this audit, personal assessments of surgeons were done while they were performing surgery based on accepted ergonomic practice guidelines, after taking their consent. The assessment data included demographics, surgeon's posture and operating room configurations. Of the 51 surgeons who were assessed, 17 (33%) of them reported history of musculoskeletal problems. Majority (more than 75%) of surgeons followed proper ergonomics when keeping themselves in line with target organ and monitor, maintaining proper angles at the elbow joint and forearm. More than 80% of operating rooms had appropriately functioning tables and instruments. Less than 50% of surgeons maintained proper head and neck posture. Monitor height was more than the operating MIS surgeon's height in 43% of operating rooms. Although many surgeons showed good ergonomic practice overall, it was found that there were a few areas for improvement with respect to the ideal posture. Our recommendations include adjusting height of the monitor with respect to the surgeon's height by use of foot stools or by updating operating rooms with ceiling suspended monitors, height adjustments of the operating table to facilitate maintenance of pelvic girdle symmetry with equal weight distribution while standing. Surgeons must also be advised to be aware of the prolonged and extreme degrees of joint movements and correct them accordingly.

**Keywords** Ergonomics · Ergonomic challenges · Musculoskeletal disorders · Musculoskeletal strain · Minimally invasive surgery · Laparoscopy · Occupational health

**Key Points** • Minimally invasive surgery requires a high degree of physical inputs from the operating surgeons who are generally used to open surgery.
• Proper ergonomic practice helps to avoid musculoskeletal problems.
• But knowledge of and compliance to proper ergonomic practice is lower amongst the minimally invasive surgeons because of which musculoskeletal problems are on rise with the growing number of procedures.

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## Introduction

Ergonomics is the science which strives to fit the worker to his working conditions [1]. In the era of minimally invasive surgery (MIS), the interaction of the surgeon to his surgical environment has brought about a paradigm shift in surgical ergonomics.

The role of ergonomics is to analyse problems brought forth in the operating room and subsequently frame guidelines for creating a work environment that promotes safety and comfort for its operators, at the same time ensuring effectiveness and efficiency of the procedure being performed [2]. The term "Ergonomics" was formally defined in 1949 [1, 3].

Minimally invasive surgery has ushered in new technological applications that have brought about new physical challenges [4].

An important aspect of minimally invasive surgery is the surgeon's non-neutral posture [5] during these procedures. Contrary to the traditional open surgeries, the posture of the surgeon is affected by the hand-held instruments, the monitor

placement, height of the operating table and foot pedals [5]. The instruments enter the abdomen at one point and movements occur about this fixed point (the fulcrum). Also, surgeons perform repetitive and precise movements while overcoming the limited degrees of freedom of movement with laparoscopic instruments [6].

Hence, it is very important to maintain properly functioning instruments and table and maintain the proper monitor height in the operating room to avoid musculoskeletal problems [7, 8].

There are some questionnaire-based studies from India which aimed to assess musculoskeletal problems [1, 9]. But there is a lack observational studies that document the compliance of surgeons towards ergonomic practice in MIS surgery.

This study aims to assess the awareness of the surgeons and their compliance to the ergonomic guidelines for minimally invasive surgeries carried out in the operating room through an audit.

## Aim and Objective

To audit the ergonomic practices of minimally invasive surgeons in Bangalore, India is the aim and objective.

## Materials and Methods

The surgeons were assessed while performing minimally invasive surgery with respect to the established ergonomic principles. The operating room where the surgery was taking place was also simultaneously assessed. Observations were made by two observers, the first two authors. These observations were recorded for multiple surgeons at their usual place of practice. Approval from the institution and consent from the operating surgeons were obtained for the purpose of the study. Ethical committee clearance was not required as no patients were involved in the study.

The assessment was done as per the proforma. This was prepared on the basis of current ergonomic guidelines [3, 8, 10, 11]. Demographic details of the surgeons were recorded along with the monthly frequency of MIS procedures they performed and years of experience of the surgeon. History of the previous or present musculoskeletal problems was also recorded. All surgeons were assessed for their head and neck posture, shoulder position, upper arm position, forearm movements, elbow and wrist angles. The ease of an instrument rotation, monitor position with relation to the target organ and the operating surgeon, height of the monitor and its type (ceiling suspended vs table mounted), the position of the foot pedal with relation to the operating surgeon were also observed and noted [3, 4, 10]. Consistency of the observations was ensured by limiting the number of observers to two, training them in advance about what to look for and the use of a structured proforma.

The operating room and the surgeon were assessed from the start of the procedure for a minimum of 30 min. Procedures where there was a conversion to open procedure within the first 30 min or when the primary surgeon changed during the principal operative procedure were excluded from the study.

Based on the average number of laparoscopic surgeries performed in a month (less than 15, 15–30, and more than 30 surgeries), three groups were made for analysing the data and to determine any statistically significant difference in their ergonomic practice and musculoskeletal problems. Chi-square test, Fisher's exact test and independent $t$ tests were used to identify differences, if any ($p$ value of $< 0.05$ was considered statistically significant).

## Results

Fifty-one surgeons were observed; 44 male and 7 female surgeons aged between 28 and 70 years of age formed the cohort. Forty-four of the surgeons were aged 50 years and below in the study. These surgeons were from different surgical specialties including general, laparoscopic, thoracic, gynaecology, urology and paediatric surgery. The surgical procedures were commonly undertaken by the surgeons in their respective fields of expertise.

The overall surgical experience ranged from 2 to 35 years, with 35 (68.62%) of the surgeons having had more than 10 years of overall surgical experience.

Thirty-two (63%) surgeons were noted to operate with their head protruded forward or the posture of forward translation of the cervical vertebrae (Table 1). Twenty-nine (57%) of the surgeons showed extension of the neck beyond 30°. Eleven of these surgeons were operating with the monitor of height more than 160 cm (Fig. 1a, b).

Fourteen (27%) surgeons had abnormal wrist flexion or extension; 6 of them showed extension beyond 20° and 8 of them showed flexion more than 40°. Thirty-eight (75%) surgeons maintained their upper arm perpendicular to the floor. Twenty-nine (57%) of the surgeons were seen to operate with their shoulder abducted less than 30°. This was considered ergonomically favourable. Shoulder position while operating was observed, and 30 (59%) surgeons managed to operate with the shoulders dropped or in a neutral position (Fig. 1c, d).

Except one, all (98%) of the surgeons showed normal dorsiflexion (less than 25°) of the foot while controlling the foot switch. All the surgeons used the right foot for the usage of diathermy. During the shifting of the leg to control the foot pedal, uneven weight bearing is expected and the body weight shifts to the contralateral leg. However, observations were

**Table 1** Surgeon-related ergonomic observations

| Parameter observed | Yes | No |
|---|---|---|
| Is the monitor, operating surgeon and target organ in the same line? | 84% (43/51) | 16% |
| Is the head in the normal position? | 37% (19/51) | 63% |
| Is the neck if in line with the spine (between 0- and 30-degree flexion)? | 43% (22/51) | 57% |
| Is the shoulder abduction less than 30°? | 57% (29/51)) | 43% |
| Are the shoulders in neutral position? | 59% (30/51) | 41% |
| Is the wrist movement within normal range (from 20-degree extension to 40-degree flexion)? | 73% (37/51) | 27% |
| Is the upper arm remaining perpendicular to floor? | 75% (38/51) | 25% |
| Are the elbows held between 90- and 120-degree flexion? | 78% (40/51) | 22% |
| Is the forearm in neutral position between supination and pronation? | 92% (47/51) | 8% |
| Has the body weight been equally distributed between both the feet? | 55% (28/51) | 45% |
| Is there normal dorsal flexion at the foot while controlling foot switch? | 98% (50/51) | 2% |

done while the surgeons were not using the foot pedal. Twenty-three (45%) surgeons did not stand with equal weight distribution between both the feet, affecting the pelvic symmetry, with 12 of the 23 showing preference for standing on the left feet. Figure 2 shows the instrument-related ergonomic observation.

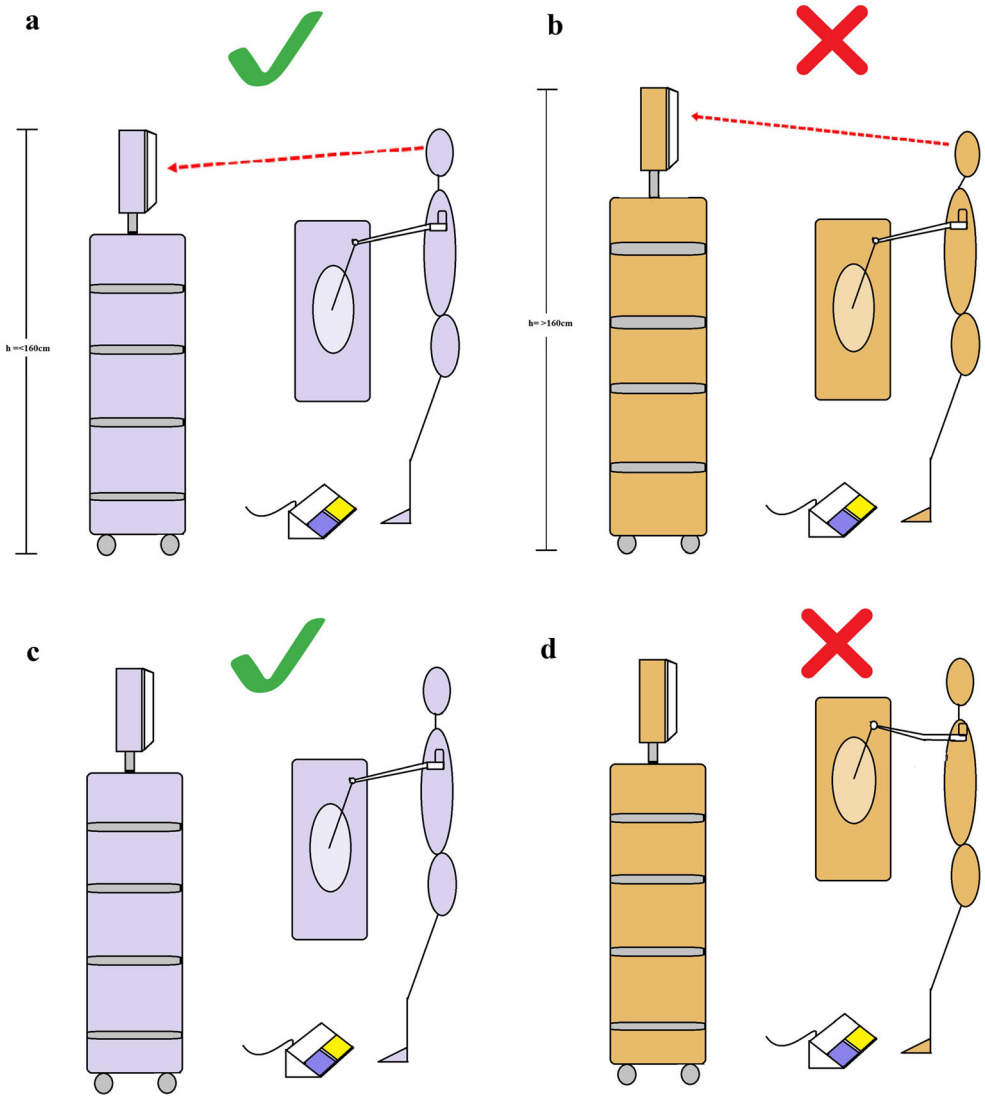


**Fig. 1** **a** Monitor height should be less than or equal to the height of the surgeon which aids ideal neck position. **b** Increased height of the monitor may cause ergonomically unacceptable neck extension. **c** Ideal forearm and shoulder position. **d** Incorrect shoulder elevation

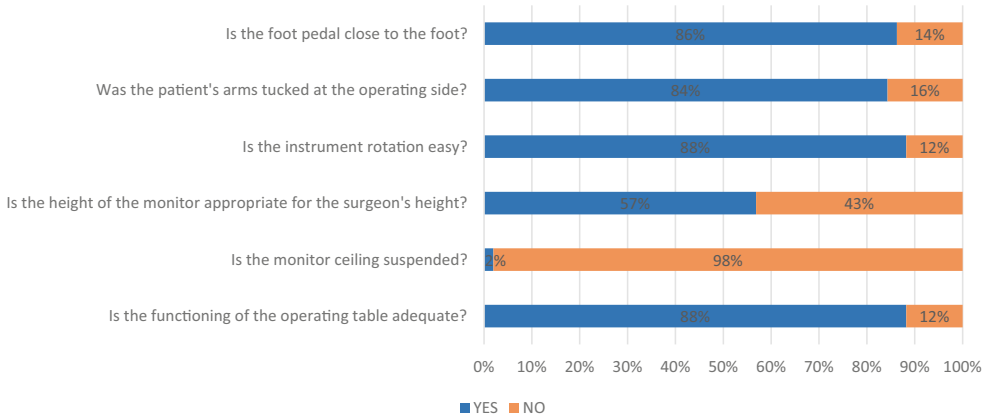


**Fig. 2** Instrument-related ergonomic observation

Figure 3 shows the result of observations of the surgeons having divided them into three groups based on the average number of minimally invasive procedures per month. Twenty-one (41.17%) performed less than 15 procedures in a month. Fifteen (29.41%) surgeons operated between 15 and 30 minimally invasive procedures in a month, and the remaining 15 (29.41%) had more than an average of 30 procedures in a month.

Among surgeons who performed more than 15 minimally invasive procedures in a month, ideal ergonomically acceptable postures of 80% and above was seen in half of the observed postures. These included placing the target organ, monitor and themselves in a straight line, upper arm being perpendicular to the floor, elbow positioning, neutral forearm positioning, wrist movements and foot dorsiflexion while controlling foot switch.

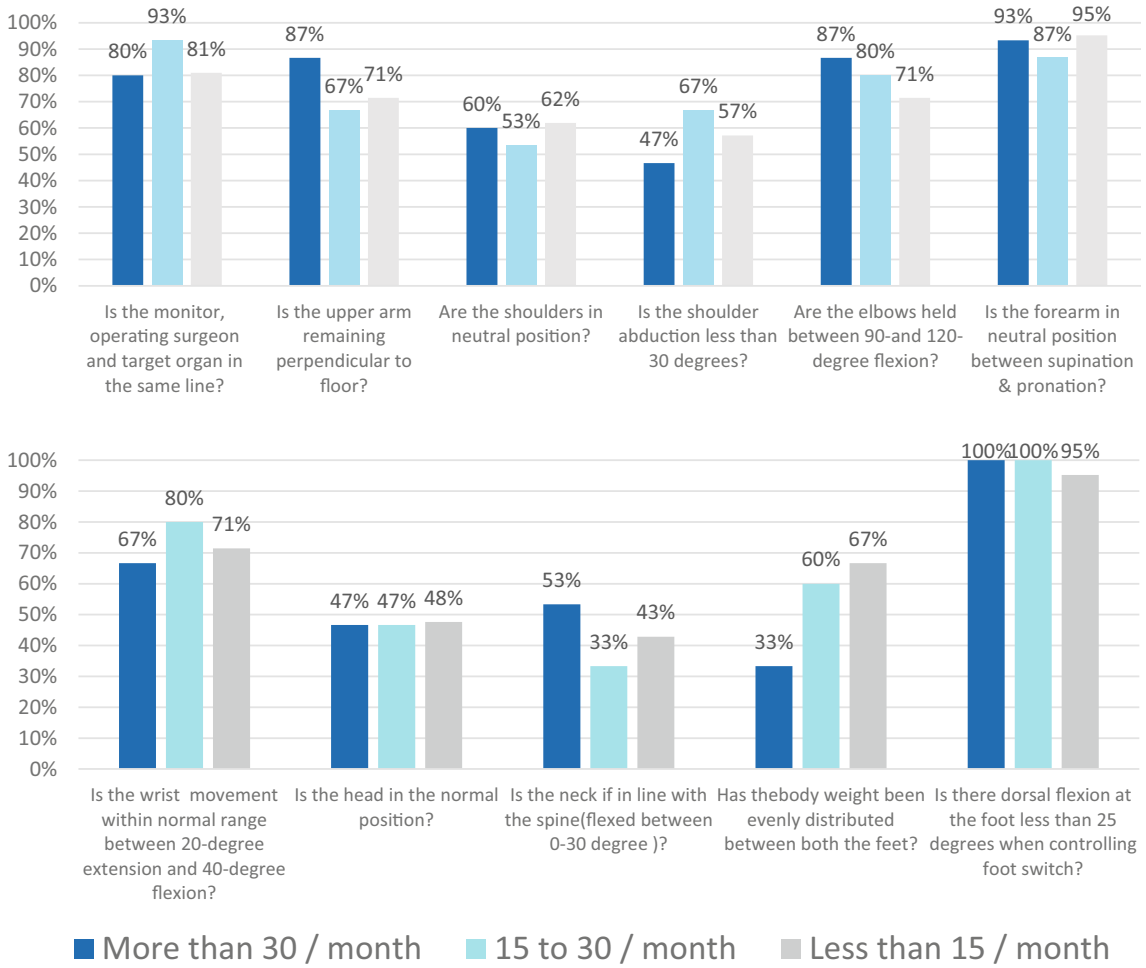


**Fig. 3** Surgeon posture–related ergonomic observations—based on number of laparoscopic surgeries performed per month. Not statistically different

Surgeons performing more than 30 minimally invasive procedures in a month showed higher shoulder abduction and uneven weight distribution when compared with the other two groups.

Surgeons performing minimally invasive procedures less than 15 times a month followed ergonomic practices of 80% and above in only 3 of the 11 observed postures. They also had the lowest percentage of ideal head and neck postures at 48% and 43% respectively. However, there was no statistically significant difference among these three groups with respect to ergonomic practice ($p$ value − 0.628, Pearson Chi-square test value − 0.235).

Thirty-four (66.66%) of 51 surgeons did not report any musculoskeletal symptoms or disorders. Figure 4 shows the distribution of the musculoskeletal disorders amongst the three groups based on the average number of procedures performed per month. There was no statistically significant difference between average number of procedures and prevalence of musculoskeletal disorders. ($p$ value − 0.081, Fisher's exact test).

When comparing these three groups on basis of their age and years of experience, it was observed that there was no statistically significant difference in their compliance towards ergonomics (independent $t$ test and $p$ value, 0.13 and 0.29 respectively) and musculoskeletal problems (independent $t$ test and $p$ value, 0.24 and 0.17 respectively).

## Discussion

This study is a first of its kind where surgeons were observed while performing a minimally invasive procedure in their place of practice. Surgeons were observed from the start of the procedure when they were relatively energetic and unaffected by the duration of the surgery.

In this study, from the assessments of 51 minimally invasive surgeons, 37% (19 of 51) of the surgeons followed good ergonomic practice. A good ergonomic practice was considered when the surgeon was seen to follow the ideal ergonomic practice as per guidelines in at least 80% (9 out of 11) of the parameters studied in the proforma.

A comparison of axial skeletal motions of surgeons during MIS vs. open surgery shows that although surgeons maintain a more erect posture with respect to their head, neck and axial spine during MIS, they are more limited in movements [11]. In addition, their centre of gravity favours a forward shift. Therefore, surgeons are more prone to short-term musculoskeletal strain with the risk of injuries over a prolonged period of MIS practice [12]. In a meta-analysis by Stucky et al., it was observed that MIS surgeons are significantly more likely to experience musculoskeletal symptoms than surgeons performing open surgery [13].

Wauben et al. [8] performed a study on 284 surgeons which was a questionnaire-based survey held on an email basis. The study identified a lack of ergonomic practice amongst the surgeons leading to the musculoskeletal problems with 64% of subjects having neck-related issues and 77% of them had shoulder problems. A similar study by Liang et al. with 241 urologists participating in the nationwide questionnaire survey, noticed 54% of urologists had neck-related problems and 34% of them had shoulder-related problems [14]. A questionnaire-based Indian study by Modi et al. concluded a lack of awareness about ergonomics in minimally invasive surgeons of India [15].

In a video assessment–based study by Atchinson et al. [16] assessments of 150 video recordings of 18 surgeons was captured by fixed camera positions during live gynaecological laparoscopic surgery. The study observed inappropriate ergonomic practice in 4 areas (1) extended periods of neck rotation; (2) asymmetrical loading between the dominant and non-dominant shoulders; (3) power morcellation and frequent insertions/removals of laparoscopic instruments resulting in repetitions of the most extreme shoulder positions; and (4) a negative correlation between height and percentage time spent in more extreme positions [16].

Majority (57%) of operating rooms had monitor height more than 160 cm. This height was more than the height of the operating surgeon, thereby causing higher chances of acquiring a head up and/or extended neck posture to visualise

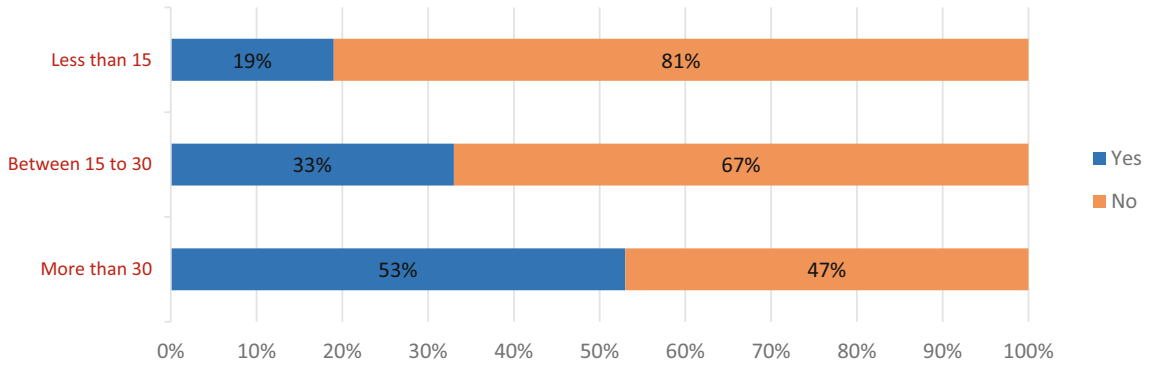


**Fig. 4** Musculoskeletal disorders reported by the groups based on average number of minimally invasive surgeries performed. Not statistically different

the monitor. Wauben et al. [8] in their study found that 94% of the respondents (74% somewhat to fully and 23% fully) agreed with the proposition that an unfavourable monitor position causes discomfort in the neck. In this study, the shortcomings of the head and neck posture may have been avoided either with the use of the foot stools to adjust with the height of the monitor, or by using ceiling suspended monitors in the operating rooms.

Ergonomically incorrect upper limb postures such as shrugging of shoulders and over abduction of shoulders beyond 30° angles can be attributed to the inappropriately adjusted operation table height. In the study by Wauben et al. [8], majority of the respondents agreed to the fact that extremes of the table height indeed caused neck and shoulder complaints. In the present study, although the majority (88%) of the operating room had adequately functioning height adjustable operating tables, they may not have been used fully to the surgeon's advantage.

Owing to stiffly rotating or fixed instruments, surgeons are forced to operate with hyper-pronation or supination either at the forearms or at the wrist joint. These repetitive abnormal movements put these joints at a risk of hastened wear and tear [11]. In this study, it was observed that in the majority of instrument-related observations (88%), instruments showed ease of rotation. The surgeons too adequately followed correct forearm posture and wrist movements.

Nearly half of the surgeons were operating with body weight distribution on a unilateral leg which is deemed ergonomically incorrect. This inequality and pelvic asymmetry may lead to musculoskeletal problems of lower extremities. This uneven posture appeared to be habitual in a majority of the surgeons, while in small numbers (14%) it was attributed to the distal placement of the diathermy pedal from the operating surgeon's foot. If the diathermy pedal is placed too close to the foot, it may lead to accidental or unnecessary activation of the diathermy thereby increasing risk of cautery burns to the patient [8].

In this study, age and experience (in years) of the surgeon and their MIS practice (number of surgeries per month) did not significantly affect the ergonomics followed by the surgeon, or the prevalence of musculoskeletal problems. However, in a questionnaire-based study by Stomberg et al. [17], it was observed that longer work experience and the increasing age of the surgeon were associated with significantly increased musculoskeletal problems. [17]. The lack of difference among the three groups in our study is likely to be due to the fact that a formal training in ergonomics or even attention to ergonomics by individual surgeons is generally lacking. It would be interesting to see if compulsory formal training in a skills laboratory with formal training in ergonomics would help overcome this attitudinal issue among laparoscopic surgeons.

It was observed that 17 (37%) surgeons had a history of single or multiple musculoskeletal problems. The musculoskeletal problems which were pre-existing before the surgeon started surgical practice were excluded. However, this study does not detail the musculoskeletal disorders with reference to the joint so as to correlate with the posture. This is one of the limitations of the study.

It should be noted that we have not factored in the effect of gender, glove size, design of instruments and haptic feedback, duration of surgery, etc. in the evaluation process. The focus in this study was to evaluate the general awareness and practice of ergonomics among laparoscopic surgeons.

One of the other limitations of this study was the possible interference from the Hawthorne effect [1, 3]. There could have been an alteration of the behaviour by the operating surgeon (subject) due to his/her awareness of being observed.

In future, studies on ergonomics may include the factors listed above to get more detailed information on the subject.

## Conclusion

Although most surgeons showed good ergonomic practice overall, a few areas of concern were found where-in surgeons could improve ergonomic practices and implement it in their day-to-day practice to reduce the risk of harm from musculoskeletal problems like (1) adjusting height of the monitor with respect to the surgeon by either using footstool by the surgeon or updating operating rooms with ceiling suspended monitors, (2) table height adjustments as per the convenience of the operating surgeon and (3) to maintain pelvic girdle symmetry with equal weight distribution between legs.

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### Compliance with Ethical Standards

**Conflict of Interest** The authors declare that they have no conflict of interest.

**Informed Consent** Informed consent was obtained from all surgeons included in the study.

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