International Surgery Journal
Shankar KCM et al. Int Surg J. 2017 Dec;4(12):3907-3914
http://www.ijsurgery.com
pISSN 2349-3305 | eISSN 2349-2902

DOI: http://dx.doi.org/10.18203/2349-2902.isj20175151

Original Research Article

Ergonomics in laparoscopy: a questionnaire survey of physical discomfort and symptoms in surgeons following laparoscopic surgery

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Received: 21 October 2017
Accepted: 14 November 2017

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ABSTRACT

Background: The prolonged and frequent use of laparoscopic equipment raises ergonomic risks that may cause physical distress for surgeons. We aimed to assess the prevalence of laparoscopic surgeons' physical distress associated with ergonomic problems in the operating room (OR) and their awareness of the ergonomic guidelines in laparoscopy.
Methods: A sample of 150 laparoscopic surgeons was assessed using a questionnaire on demographic information, ergonomic issues in the OR, musculoskeletal symptoms, and awareness of the ergonomic guidelines for the OR.
Results: There were 112 survey respondents (74.3%) with valid questionnaires. Among the respondents 50% had completed laparoscopic training programs while 39.2% had no laparoscopic training. 61.5% respondents placed the operating table at umbilicus height during the actual operation. The majority of the respondents used only one monitor during the procedure. Only 4.3% placed the monitor below the eye level. 3% of the respondents attributed pain due to foot pedal design. The respondents experienced discomfort in the following regions in descending order: right shoulder (87.2%), left shoulder (78.3%), neck (67.4%), back (46.8%), hand (30.3%), leg (21.6%), and wrist (15.8%). The respondents with more than 5yrs of experience complained less discomfort than those with less than 5yrs. Only 54.6% of respondents were aware of the ergonomic guidelines. However, almost all of the respondents (100%) regarded the ergonomic guidelines to be important in the OR.
Conclusions: Most of the laparoscopic surgeons were not aware of the ergonomic guidelines for the laproscopic OR; especially, junior laparoscopic surgeons and surgeons with <5 years of laparoscopic surgical experience were more affected. They have been suffering from varying degrees of physical discomfort caused by ergonomic issues. There is an urgent need for education regarding ergonomic guidelines in the OR for laparoscopic surgeons.

Keywords: Ergonomics, Laparoscopy, Physical discomforts

INTRODUCTION

Although laparoscopic procedures significantly benefit patients in terms of decreased recovery times and improved outcomes, they contribute to mental fatigue and musculoskeletal problems among surgeons. A variety of ergonomic interventions and applications are implemented by surgeons to reduce health problems. Currently, there is a gap in knowledge regarding a surgeon's individual assessment of the operating room, an assessment that, in turn, would prompt the implementation of these interventions.[1]

Following of ergonomic principles are required for better work results in fields which demand productivity. The word "ERGONOMIC" originates from Greek word ergon (labor) and nomog (natural law) that reveal knowledge concerning the law of human labour.[2] Ergonomics is the

study of optimal designs to ensure appropriate psychological and physical interactions among the worker, product and environment.[3]

The ergonomic problems of the surgeons are mainly associated with the following five issues in the operating room (OR): a) the design of the hand-held instrument, b) the height of the operating table, c) the number and placement of monitors, d) foot pedal use and e) body support to relieve the static posture.[4]

Sensorial ergonomics, manipulation and visualization improve precision, dexterity and confidence while physical support provides comfort for surgeons. Together these two elements of ergonomics improve safety, have better outcome and reduce the stress.[5] The ergonomic guidelines for these issues have been stated in the literature to reduce the risk factors of musculoskeletal distress.[6]

However, few of the guidelines in the literature have been adopted in routine practice. To investigate the current application of these ergonomic guidelines and the awareness of surgeons regarding the guidelines in the OR, we initiated an integrated cross-sectional study to identify probable ergonomic factors that might result in the physical complaints of laparoscopic surgeon while performing the procedures. "HAWTHORNE EFFECT"- Any individual performs a skill better and with more caution whenever he has the knowledge that he is under observation and assessment.

This effect which has been found applicable to most scientific assessment of human function and hence an integral knowledge of this aspect is essential for ergonomic purposes.[7] Suboptimal following of ergonomic principles expose surgeons to physical discomfort during and after laparoscopic surgery.[8] Multiple reports of shoulder pain, backache, carpal tunnel syndrome, tenosynovitis, eyestrain, cervical spondylosis and stress exhaustion.

Aim of this study was conducted to investigate the prevalence of symptoms in laparoscopic surgeons, evaluate associations between symptoms and operating room ergonomics and awareness of ergonomic guidelines and its application.

- Physical discomfort and symptoms in surgeons following laparoscopic surgery
- Relation between physical complaints and equipment used
- Awareness and application of ergonomic guidelines among laparoscopic surgeons.

METHODS

A questionnaire designed to assess the frequency and degree of physical discomfort practicing surgeons experienced and their awareness of the responsible factors was distributed to approximately 150 general surgeons, practicing in Bangalore, India through email, whatsapp and hard copies.

Table 1: Questionnaire.

Demographics (10)	
Age (in yrs)	
Height (in cms)	
Gender	Male
	Female
Dominant hand	Right
	Left
	Ambidextrous
Completed a laparoscopic training program/fellowship	Yes
	No
	In training
Years of practicing laparoscopic surgery	
Number of laparoscopic cases performed in a week	
Laparoscopic cases performed in a day (mention in hours/mean time)	
Type of laparoscopic surgeries performed (multiple selections can be made)	Basic
	Advanced
	Robotic
Performed laparoscopic surgeries in rural areas	Yes
	No
Physical symptoms (8)	
Any physical discomfort or symptoms attributed to laparoscopic operating	Yes
	No (skip to question 19)
Area of physical condition/symptoms (please describe in detail) (multiple selections can be made)	Eyes
	Neck

	Upper back
	Lower back
	Hips
	Knee
	Ankles
	Feet
	Left shoulder
	Right shoulder
	Elbow
	Wrist
	Thumb
	Other fingers
Any other discomfort/symptoms that were not included above	
Rate the physical discomfort, from 0 (no pain) to 5 (severe pain)	
Describe any treatment received for the condition	
When do the symptoms or discomforts bother you? (multiple selections can be made)	While performing surgery
	Immediately after performing surgery
	Throughout the day, persistently
	Throughout the day, not persistently
How have you attempted to minimize these problems or conditions? (multiple selections can be made)	Changing postural position
	Changing instruments
	Taking a break
	Ignore any such problem
	Others (please specify)
Factors attributing your physical complaints (multiple selections can be made)	Instrument design
	Operating room table setup
	Display monitor location
	Type of display system
	Foot pedal
	Others (please specify)
Environment and equipment:(11)	
Level of the display monitor	At eye level
	Above eye level
	Below eye level
Size of monitor	14”
	26”
	>26”
Height of the operating table?	At umbilical level
	Above umbilical level
	Below umbilical level
Laparoscopic instrument handles are	Too big
	Just right
	Too small
If available, would you utilize laparoscopic instruments in more lengths?	Yes
	No
Are commonly used foot pedals comfortable?	Yes
	No
Describe any complication experienced during port insertion	
Technique used for port insertion	Open
	Closed
Type of electrocautery used	Hook
	Bipolar
	Harmonic
	Vessel Seal
	Others
Does trained assistant matter in laparoscopic surgery?	Yes
	No
Ergonomics:(4)	
How aware are you of the recommendations made by the field of surgical ergonomics, its studies and research?	Not aware
	Slightly

	Somewhat
	Aware
	Very aware
Where did you acquire this information?	Literature
	Surgical training
	Online
	Regional Or national meetings
	Laparoscopic product
	representative
	Other
Have you applied any of this information to? your surgical practice?	Yes
	No
Do you think that the ergonomic conditions in the operating room are important?	Yes

The response sheets were analyzed. Design of the study was prospective study. The target group:

- General surgeons performing laparoscopic surgeries
- The survey was conducted by means of a questionnaire.

Hard copies of the questionnaire: Personally, handed at their respective institutes, and also e-mail, Facebook, whatsapp.

Questionnaire

- 33 questions
- Arranged in 4 chapters
    - Demographics (10)
    - Physical symptoms (8)
    - Equipment (11)
    - Awareness of ergonomics (4)

Ergonomics and laparoscopy

A questionnaire survey of physical discomfort and symptoms in surgeons following laparoscopic surgery.

Instructions

- Please answer every question as honestly as you can. This is not a test and there are no right or wrong answers!
- Your answers are completely confidential and shall be used for study/research purposes only.

Statistical analysis

Microsoft Excel format. Univariate analysis- single answers. Multivariate analysis- multiple answers. Correlation analysis.

RESULTS

The study was conducted among the general surgeons practicing laparoscopy in Bangalore, India. 150 questionnaires were sent to the laparoscopic surgeons. Among these 112 responded. Duration of practice as laparoscopic surgeon was considered. Operating room factors considered were Operating surface (Table) height, Monitor height, Monitor size often using and Monitor size comfortable with. Physical discomfort factors considered were neck pain, shoulder and finger numbness, eye strain and arm pain.

Table 2: Demographic information of the respondents.

	Results
Age in years	Mean - 43years
Height in cm	166cm
Gender	Male:107, Female:5
Dominant hand	Right:111,
	Left: 0,
	Ambidextrous:1
Years of experience	<5yrs-48.2%(54)
	5-10yrs-38.3%(43)
	>10yrs-13.3%(15)
No/ of cases performed in a day (Mean hours)	2hrs-20.5% (23)
	4hrs-58.0% (65)
	6hrs-14.2%(16)
	8hrs- 7.1%(8)
	>10hrs-0%
Types of laparoscopic surgery:	Basic -91%(102)
	Advanced -8.9%(10)
Completed a laparoscopic fellowship/ training	Yes-50%(56)
	No- 39.2%(44)
	In training-10.7%(12)

Any physical discomfort or symptoms attributed to laparoscopic operating? Rate the physical discomfort? When do the symptoms or discomforts bother you?

- While performing surgery- 100% (91)
- Immediately after performing surgery- 61.5% (56)
- Throughout the day but not persistently- 10.9% (10)

Out of 150 questionnaires sent, 112 responded. Most of the participant surgeons, with an average age of 43yrs,

(male-107, female-5). Mean height of surgeons was 166cms with most of the surgeons were right handed.

In our study individuals with less than 5ys of experience were 48.2% (54), 5-10ys experience were 38.3% (43) and more than 10yrs were 13.3% (15) .58% (65) of surgeons had 4 hours laparoscopic surgery mean time per day. Basic laparoscopy was practiced by 91% (102) while advanced laparoscopy 8.9% (10). 50% (56) had completed laparoscopic training /fellowship program and 39.2% (44) had not undergone any laparoscopic training.

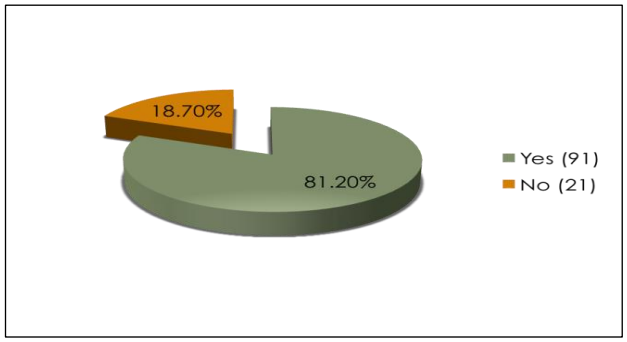

Figure 1: Physical discomfort prevalence.

All of the respondents were asked whether they experienced symptoms in the hand, wrist, shoulder, neck, leg or back. If the answers were positive, they were also required to describe the extent of the discomfort. 81.2 % (91) participating surgeons had musculoskeletal problems attributed to laparoscopic surgery while 18.7% (21) had no complaints.

Most surgeons had made note of pain/ discomfort in right Shoulder (87.2%), left shoulder (78.3%), neck (67.4%) pain between shoulders (46.8%), eye pain (33.7%) in descending order and other joint pains as depicted in Figure 2.

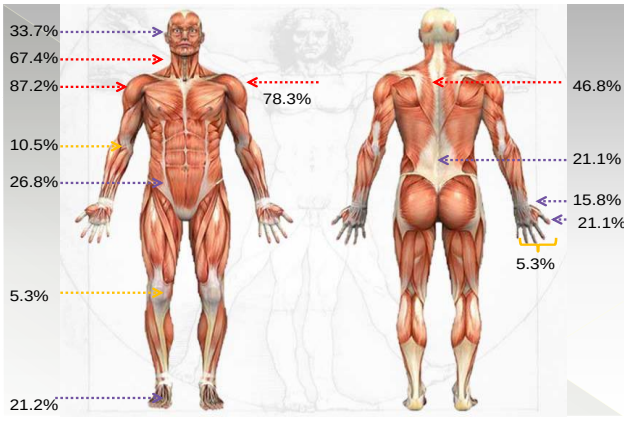

Figure 2: Depicting various sites of musculoskeletal pain in laparoscopic surgeons.

Analysis of physical discomfort on visual analogue pain scale was maximum 2 (71.4%) as shown in Figure 3.

Figure 3: Grading of physical discomfort on visual analog scale in laparoscopic surgeon.

100% (91) surgeons had physical discomfort while doing surgery and immediately after surgery. 61.5% (56) surgeons had physical discomfort immediately after surgery but not while surgery. 10.9% (10) surgeons had complained of pain throughout the day but not persistently. For the above mentioned physical discomfort surgeons has received treatment (20.8%) like massage, physiotherapy, ultrasonic stimulation, and oral analgesics as shown in table below (Table 3).

Questionnaires for measures taken by surgeons for minimizing the physical discomfort attributed to laparoscopic surgery showed 70.3% (64) opted for changing the posture while operating, taking break 8.1% (9) changing instruments 7.1%(8) and 10.9%(10) ignored to minimize the discomfort.

Table 3: Symptoms and treatments.

Symptoms	Treatment
Pain between shoulders	Massage
Pain and muscular distress, tenosynovitis, tendon thickening, knee joint pain,	Physiotherapy, ultrasonic massage
Back pain radiating to legs	Oral analgesics
Neck stiffness	Oral analgesics

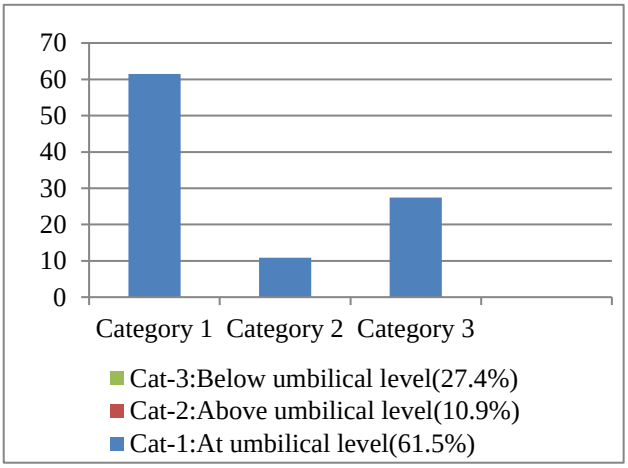

Figure 4: Height of operating table.

Height of operating table was at umbilical level in 61.5%, above umbilical level 10.9% and below umbilical level in 27.4% as shown in Figure 4. Display monitor was at eye level in 29.6%, above eye level 65.9% and below eye level in 4.3%. as shown in Figure 5.

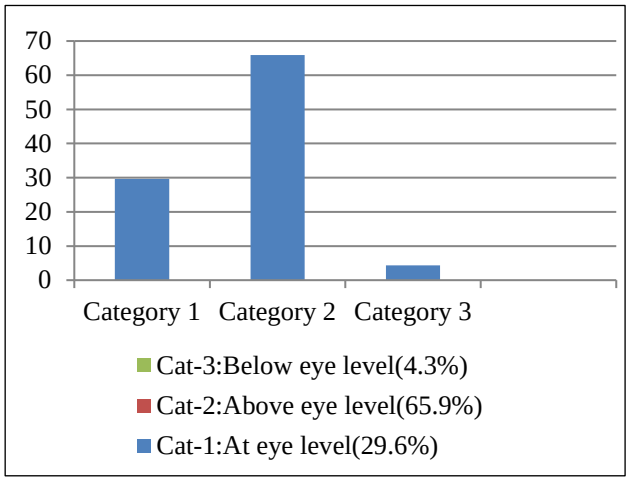

Figure 5: Level of display monitor.

Questions regarding laparoscopic handles 92.3% (84) found size of handles were appropriate, 7.6% (7) found handles too big. 30.8%(28) were happy to use long length laparoscopic instruments if available. 30.3% (28) surgeons were uncomfortable with commonly used food pedals.

All participants (100%) concluded that trained laparoscopic assistants matters in laparoscopic surgery. Of various attributing factors for physical discomfort during laparoscopic surgery, display monitor location (67%) had major contribution followed by operating room design (12%) and instrument design (12%).

In our survey 54% of participants were somewhat aware of ergonomics principles, 25% were aware, not aware were 11% and very aware were 9%. Awareness of ergonomic principles was found to be through surgical training (54%), conferences (25%), literature (18%) and online (2%) as depicted in Figure 6.

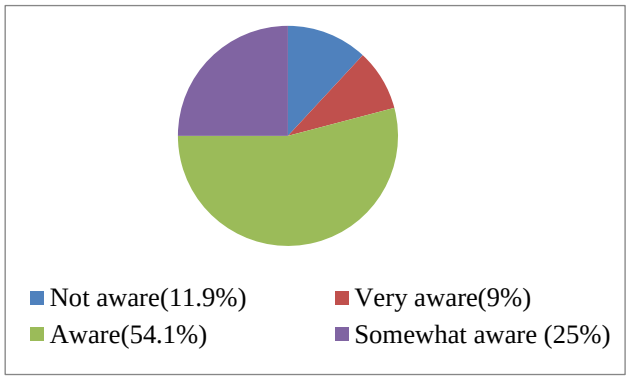

Figure 6: Awareness of ergonomics.

Ergonomic principles and guidelines was followed by 77.1% while 22.9% had not followed in their laparoscopic practice Figure 7. All surgeons (100%) stressed the importance of ergonomics and its advantages in operating room Figure 8.

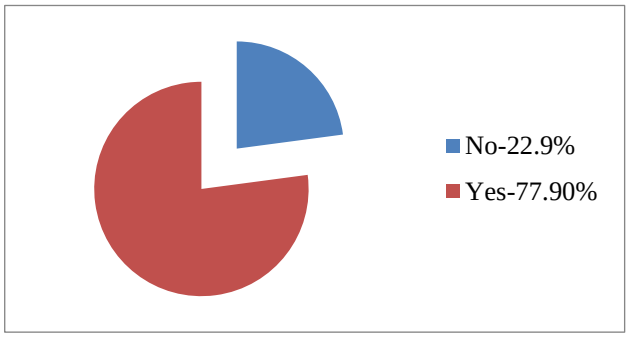

Figure 7: Application and ergonomics importance in operating room.

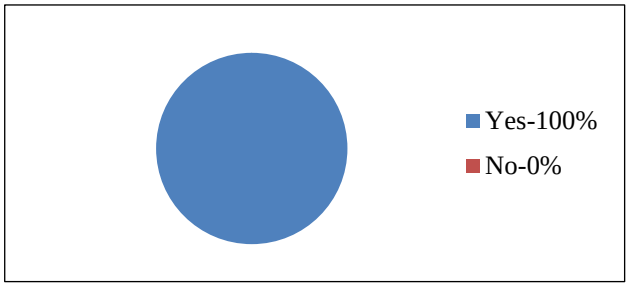

Figure 8: Importance of good ergonomic conditions in operating room.

DISCUSSION

Although laparoscopic procedures significantly benefit patients in terms of decreased recovery times and improved outcomes, they contribute to mental fatigue and musculoskeletal problems to operating surgeons. A variety of ergonomic interventions and applications are implemented by surgeons to reduce health problems. Currently, there is a gap in knowledge regarding a surgeon's individual assessment of the operating room, an assessment that, in turn, would prompt the implementation of these interventions for reducing these problems.

In 2001-2003, van VMA et al, in the faculty of industrial design engineering at Delft University of Technology, gradually developed a series of guidelines for surgeons to reduce the risk of laparoscopic injury.[4,6,9,10] Nevertheless, more and more cases of occupational injury and problems among laparoscopic surgeons have been reported. However, there is little in the literature on the ergonomic situation of the laparoscopic surgeons.

The response rate of our study is 74.3%, which is higher than those in comparable studies of minimally invasive surgeons of other studies. In our study the complaints of

the surgeons decreased with increased laparoscopic experience of more than 5years. This result of our study was consistent with the observations of Sari V et al and Hemal et al. among laparoscopic surgeons.[11,12] In these studies, surgeons with laparoscopic surgical experience of less than two years showed more discomfort. Uhrich ML et al found that less experienced surgeons have higher electromyography amplitudes than experienced surgeons, which is a sign of higher muscle tension that may result in musculoskeletal symptoms.[13] Experienced laparoscopic surgeons were better able to manipulate the tools and had a greater awareness of the risk factors in the OR; thus, they were able to avoid being injured during operations.

Placement of the monitor is one of the most important ergonomic factors in the OR. The guidelines for monitor placement suggest that the monitor be placed in front of each surgeon to avoid axial rotation of the spine in the horizontal plane and approximately 10-15° below eye level to avoid neck extension in the sagittal plane.[14] Most of our respondents did not place the monitor below the eye level; thus, neck discomfort was the most prominent problem among the surgeons, presumably due to the extended duration of posture that included bending their necks forward. The majority of the respondents (63.5%) used only one monitor, while the assistant had to rotate his neck and spine to gaze at the monitor that was placed next to him. In these conditions, the surgeon places more stress on his neck and back.

The operating table height in our study represents the height of the operating surface during the procedure. Most of the respondents performed the incision and placement of the trocars with the operating surface height at navel level, which is the ideal height for open surgery. Nonetheless, a majority of the respondents placed the operating surface at levels other than pubic level, which was suggested in the ergonomic guidelines. Van Veelen et al suggested that the optimum height for laparoscopic surgery should be located at a factor of 0.7-0.8 of the length from the floor to the elbow height of the surgeons. To eliminate the inconvenience of measuring the elbow height of every surgeon during practice, the optimum operating surface height was suggested to be pubic level.[15] At that height, the surgeon could maintain a neutral posture in which the laparoscopic instruments could be placed close to elbow level of the surgeons to minimize joint excursion and discomfort in the arms and shoulders while performing the precise actions required by the procedures.

The use of hand-held instruments influences the surgeons' alignment of the hands and wrists. In our study, most of the surgeons used the laparoscopic forceps with an angled ring handle to grasp and dissect, and needle holders with in-line positioned shank handles were most commonly used. Most of surgeons were satisfied with size of hand instruments in our study. As technology has developed, the design of these instruments has improved greatly with respect to ergonomics. However, the newly designed instruments remain unable to completely solve the ergonomic problems in the upper extremities.

Although fewer respondents complained about the foot pedal, many deficiencies in their design also exist. Van VMA et al, designed novel types of foot pedals to improve these ergonomic aspects so that the surgeon would experience less discomfort in using the foot pedal.[16]

Most of our respondents were unaware of the ergonomic guidelines and had never received any specific training or education related to them. Only 9% of the respondents were very aware of the ergonomic guidelines concerning hand-held instruments, operating table height, placement of the monitor, foot pedal use and the application of body support. Of the respondents (11%) never received any training or education on ergonomic guidelines in the OR. However, almost all of the respondents stated that ergonomic guidelines in the OR are important and should be considered. Bagrodia et al, showed in his study that 25% of the surveyed surgeons were affected by physical discomforts or complaints and would fully consider ergonomic problems when deciding on an operative approach.[17] Xiao DJ et al. found that a skills lab with surgical simulators could help surgeons to learn about the ergonomic factors in the OR through a series of lessons.[18]

Almost all of the respondents in our study realized the importance of ergonomic issues during the laparoscopic procedure and that better ergonomic conditions would lead to better performance and less discomfort. There is an urgent need to popularize relevant knowledge concerning ergonomics in the OR among laparoscopic surgeons. Directing the attention of these surgeons toward ergonomic issues in the OR through training before the actual procedure should ameliorate their musculoskeletal strain. Meanwhile, manufacturers should provide more ergonomic instruments and devices to improve the ergonomic conditions of the OR.

CONCLUSION

The increasing dependency on technology in the laparoscopy has created physical and mental ergonomic challenges. The laparoscopic surgeons commonly experience prolonged static body postures, extreme joint positions and repetitive movements. The most affected body parts are the neck, back, shoulders, and wrists/hands due to the frequent postures held while performing fine hand movement for surgery or technical work. The common sources in the OR contributing to the ergonomic problems include operating table, foot control pedals, footstools, various hand tools, surgical monitors, surgical trays and carts.

With the ever-growing variety of technology, laparoscopy ergonomics research is lagging behind the pace of new OR surgical procedure development.

Ergonomic researchers' input should be incorporated in the development of surgical instruments and their manufactures. More attention is warranted to promote better ergonomics in laparoscopy by encouraging the industry to provide multidisciplinary human-centered design approach for the improvement of ergonomics, comfort, and usability for the broad range of OR medical team. On the other hand, there is urgent need to popularize the principles of ergonomics and to simulate operational training using these ergonomic guidelines among surgeons.

ACKNOWLEDGEMENTS

Authors would like to thank acknowledge all of the kind responders who participated in the survey and completed the questionnaire.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

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Cite this article as: Shankar KCM, Manjunath K, Krishnappa R. Ergonomics in laparoscopy: a questionnaire survey of physical discomfort and symptoms in surgeons following laparoscopic surgery. Int Surg J 2017;4:3907-14.