INTRODUCTION
Gynecological laparoscopy surgery is a quantum leap due to several patient benefits such as shorter hospital stay, reduced morbidity, enhanced postoperative recovery and external cosmetic results. However, health impacts on the laparoscopic surgeon are often overlooked and under-reported.

According to 2010 data of the largest North American Survey, 87% of surgeons who regularly perform minimal invasive surgeries suffer from musculoskeletal injuries which is in contrast to previously reported number of 23%.

The term Ergonomics is derived from the Greek words “ergon” meaning work and “nomos” meaning natural laws or arrangements. Ergonomics is the scientific study of people at work, in terms of equipment design, workplace layout, working environment, safety, productivity and training.

Over the last decade, there have been five million lost working days from self-reported work-related injuries and illnesses in the health and social care sector within the UK. Furthermore, an estimated 100,000 new cases of work-related ill health have been reported which is significantly above the average in comparison to other industries.

This review article looks into various ergonomic issues faced by the gynecology laparoscopic surgeons and various coping strategies.

ERGONOMIC CHALLENGES FACED BY LAPAROSCOPIC SURGEONS
Laparoscopic surgery is physically and mentally more complex and demanding than open surgery. There are several contributory factors such as monitor and port positions, static postures, repetitive motions, inappropriate equipment and poorly adapted environments.

Surgeon-related factors include posture, footwear, gender, duration of surgery and workload on surgeon.

SURGEON-RELATED ISSUES
Great concentration and skill is required for performing complex laparoscopic surgeries consequently the operating surgeon assumes a more static posture which is more disabling and harmful than dynamic postures as muscles and tendons build up lactic acid and toxins.

Also, static state of upper extremities lead to excessive abduction to allow working with long laparoscopic instruments. This poses additional musculoskeletal stress on laparoscopic surgeons.

Shifting position during surgery can reduce musculoskeletal distress according to one study. Other studies mention that surgeons had to take breaks in between surgeries and 40% choose to ignore their symptoms. Although sitting position has been described to be more comfortable, laparoscopic surgeons have
not adopted it despite the introduction of especially designed laparoscopic chairs since 1999 (Fig. 1). Surgeons commonly complain of foot ache during surgery. There is paucity of data to recommend appropriate footwear. Traditionally, surgeons wear crocs during surgery which are devoid of flexibility.

Haramis G et al. evaluated in their study and concluded that the gel pads not only decrease musculoskeletal injuries but also fatigue and hence reduction in errors.7 Park et al. reported that musculoskeletal injuries are directly proportional to the workload the surgeon is exposed to and not the age of the surgeon.

Laparoscopic surgeries are tedious compared to open surgeries. This can add to musculoskeletal distress to the surgeons.8 Szeto et al.9 found that 35.6% of respondents reported almost always “working through pain so that the quality of their work would not suffer.” Sari et al.10 found that no respondents reported any surgical complications due to their own fatigue or physical complaints; however, this could have been influenced by surgeons’ reluctance to admit to such occurrences.

There is conflicting data of surgeons’ gender having musculoskeletal health impact due to laparoscopic surgeries. Dolan and Martin11 reported that backache occurred more commonly in male (75.6%) than female (62.1%) gynecologists. Stomberg12 on the contrary found that female laparoscopic surgeons and gynecologists were more likely to experience musculoskeletal disorders than males despite being younger and having worked fewer years than their male counterparts. Although Park et al. found no differences in the prevalence of musculoskeletal symptoms between the sexes, they noted that male laparoscopic surgeons were more likely to suffer symptoms of the lower limbs while female surgeons reported more symptoms in the upper limbs.

Due to sustaining musculoskeletal injuries, surgeons resort to various measures to cope with the pain-like analgesics, physiotherapy and taking off sick.13 All these have a negative impact on surgeon’s life.

CONCEPTS OF ERGONOMICS IN OPERATING THEATER

Working environment in operating theater should be ergonomically viable so that the laparoscopic surgeon can perform complex surgeries with minimal fatigue and surrounding distractions. This can be addressed by looking into various factors such as height of operating table, monitor position, trocar placements, manipulation angles for instruments and instrument-related challenges.

Height of Operating Table

Height of operating table is of great significance during open and laparoscopic surgery. This can be a challenge as often there is height discrepancy between the surgeon and the assisting surgeon. In most cases, the height of the operating table is adjusted to suit the surgeon. In addition to this, the tables used in the operation theater are still those that were designed for open surgeries.

Study by Berguer and Smith suggests that the optimum table height for laparoscopic surgery should position the laparoscopic instrument handles close to surgeons’ elbow level. This will minimize discomfort and workload on upper arm and shoulders. This corresponds to an approximate table height of 64–77 cm above floor level.14 Van Veelen et al.15 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. It is inconvenient to measure this height for every surgeon during the case, hence the optimum operating surface height was suggested to be at pubic level. This height allows the surgeon to maintain a neutral posture in which the laparoscopic instruments could be placed close to elbow level and thus perform precise actions while minimizing discomfort to arms and shoulders.

Monitor Position

Optimal position and height of the monitor is very important in minimal access surgeries. The aim is to minimize eye strain and stress on neck muscles so the surgeon and the team can continue performing prolonged complex laparoscopic surgeries with minimal long-term health impact. Based on several studies, the monitor should be in horizontal plain between 15 and 40° below the eye level. A surgeon’s eyes should be positioned 1 meter (m) distant and no more than 15° below the top of an operating monitor.16 Van Det et al.17 has developed guidelines for ergonomically optimal height and position of the monitor. They have suggested that the optimal
downward viewing direction is 15° and optimal distance is between 80 and 120 cm to minimize eye strain. El Shallaly and Cuschieri concluded that the minimum and maximum monitor distance is variable for most surgeons. However, the surgeon should never be farther than 3 m (10 ft) or less than 0.9 m (3 ft) from the monitor. The maximal view distance increases with increasing monitor size but the limit for close-up distance is 0.9 m, irrespective of monitor size.

**Trocar Placements**

Placement of trocars is crucial to smooth operating experience. Most surgeons like to customize port placement. Incorrect port placement can not only result in imprecise movements leading to prolonged operating time, but also increased risk of musculoskeletal injuries. Some surgeons prefer to place the trocars in a triangulation pattern while others in a sectorization fashion.

The aim is to allow smooth manipulation of instruments and adequate laparoscopic visualization.

Triangulation port placement involves that the target organ be 15–20 cm from the center port for placing the optical trocar. Generally, the two remaining trocars are placed in the same 15–20 cm arc at 5–7 cm on either side of the optical trocars. This allows the instruments to work at a 60–90° angle. This pattern of port placement avoids problems of long handle too far or too near placement of ports and problem of abdominal wall interference. If necessary, two more retracting ports can be placed in the same arc but more laterally so that instruments do not clash (Fig. 2A).

Another type of port placement is sectorization where the ports are placed on the same side or ipsilateral port placement (Fig. 2B).

The introduction of Gel Port laparoscopic system allows surgeons to rapidly alternate between hand access, straight laparoscopic and open surgical technique to optimize procedural efficiency and clinical outcomes. The Gel Seal cap offers unparalleled access for rapid dissection and mobilization of tissue.

Gupta and Bhartia in their study concluded that hand-assisted laparoscopic surgery strikes a perfect balance between an extended open laparotomy incision and an excessively tedious laparoscopic exercise.

**Manipulation Angles of Instruments during Laparoscopy**

The ease of performance of laparoscopic procedures and its execution time is determined by the manipulation, elevation and azimuth angles which in-turn are determined by location of the port sites. The manipulation angle is the angle between the two instruments (active and assisting). The azimuth angle is the angle between the instrument and the optical axis of the endoscope. The elevation angle is the angle between the instrument and the horizontal plane (Fig. 3). Optimal manipulation, elevation and azimuth angles are required for maximal laparoscopic task performance.
Manipulation angles play a key role in task efficiency and performance quality. Manasnayakorn et al. from their animal studies have concluded that the ideal manipulation angle is between 45 and 60º which is achieved by correct port placement.22

Azimuth and manipulation angles should be same for optimal performance.

**INSTRUMENT RELATED CHALLENGES**

Laparoscopic instruments are not ergonomically friendly. Most instruments have either axial or pistol-like handles. Pistol-like handles use finger and thumb rings for control. This with time results in neuropathic damage particularly of the thumb.23 Also, pistol-like handles require radial deviation of the wrist to align instrument in line with the axis of the forearm.24 Use of axial type instruments require ulnar deviation of the wrist and shoulder abduction.24 Hand size is another factor which determines the difficulty in using laparoscopic instruments. Berguer et al.25 from the large questionnaire survey concluded that surgeons with glove size 6.5 or less encountered significant difficulty in using the laparoscopic instruments. Another significant factor affecting the outcome, is the length of laparoscopic instruments. Use of short shaft length instruments (250 mm) compared to standard shafted instruments (330 mm) resulted in shorter task execution time and lesser muscle workload on the dominant arm.26

Laparoscopic instruments have limited freedom of movement compared to open surgeries. There are only 4 degrees of movement (in and out, left and right, rotation, up and down) compared to full 360º hand movement. In addition to this, two-dimensional vision, lack of tactile feedback from tissues and dependency on assistants to hold camera and provide instruments takes longer to perform the task. A survey concluded that articulation at the tip enhances tool’s degrees of freedom. This in turn will provide a more comfortable mechanism for the surgeon thus increasing patient safety by reducing surgeon’s fatigue and decreasing the need for complex cognitive planning.27

Foot pedal position and mechanism is vital to laparoscopic surgeons. Most foot pedals require the surgeon to maintain the foot in dorsiflexion to maneuver quickly between monopolar cutting and bipolar coagulation. This affects the surgeon’s stability and often results in anterior leg compartment pain. Van veelan et al.28 designed a foot pedal which worked with right/left rotation of the foot with the surgeon’s foot staying flat to minimize the discomfort.

**CONCLUSION**

**What Already Exists?**

Applications of laparoscopy surgery will continue to rise. Also, statistically, the age of retirement is increasing. This means the surgeons are exposed to the physical hazards of operating for a much longer duration.
What We Can Incorporate?

• Emphasizing on physical fitness program for laparoscopic surgeons. Tse et al.29 reported that a trunk endurance training program reduced both discomfort and error rate during a simulated laparoscopic task.

• A especially designed ergonomic body support is an effective way to minimize muscle activity which in-turn may reduce physical problems and discomfort for the operating surgeon in open and laparoscopic surgery.30

• To evaluate the ergonomic integration and suitability of the laparoscopic operating theater environment to address the issues of efficiency, safety, and comfort for the operating team.

• The manufacturers to pay special attention to the ergonomics to make them more user friendly to the laparoscopic surgeons. This approach is particularly important in the design of laparoscopic surgical instruments.31

• Several studies mention the use of arm, elbow and wrist support to increase accuracy of laparoscopic manipulations. Jafri et al.32 concluded from the minimal access simulation studies that arm rests not only decrease surgeon fatigue by decreasing energy consumption but also cut-down error rates from 42.3% to 35%.

— So far surgical patient safety problems with training and communication33 have been addressed. However, it is high time now to incorporate engineering solutions (working with safety scientists, including Human Factors/Ergonomics Practitioners) in training curriculum of postgraduate candidates.

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REFERENCES