Human Factors Evaluation of Surgeons' working positions for Gynaecological Minimal Access Surgery

Sue HIGNETT*[1] PhD, Diane GYI[1] PhD, Lisa CALKINS[1] MSc, Laura JONES[1] MSc, Esther MOSS[2] PhD

[1]Loughborough Design School, Loughborough University, Loughborough, UK

[2]University Hospitals of Leicester NHS Trust, Leicester, UK

*Prof. Sue Hignett PhD
Loughborough Design School
Loughborough University,
Loughborough, Leics.UK.
LE11 3TU
Tel: +44 (0)1509 223003
Email: S.M.Hignett@lboro.ac.uk

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Précis: Musculoskeletal discomfort was explored using survey and observational data. Ergonomic solutions are needed to support MAS with a work place and equipment which fit the task, surgeon and patient.

Abstract.

Study Objective: To investigate work-related musculoskeletal disorders (WRMSD) in gynaecological minimal access surgery (MAS), including bariatric (plus size) patients

Design: Mixed methods

Design classification: Level III (descriptive and qualitative)

Setting: UK Teaching Hospital

Patients: Not applicable

Interventions: Not applicable

Measurements: Survey, observations (anthropometry, postural analysis) and interviews.

Results: WRMSD were present in 63% of survey respondents (n=67). The pilot study (n=11) identified contributory factors including workplace layout, equipment design and preference of port use (relative to patient size). Statistically significant differences for WRMSD-related posture risks were found within groups (average size mannequin and plus size mannequin) but not between patient size groups suggesting that port preference may be driven by surgeon preference (and experience) rather than patient size.

Conclusion; Some of the challenges identified in this project need new engineering solutions to allow flexibility to support surgeon choice of operating approach (open, laparoscopic or robotic) with a work place which supports adaptation to the task, surgeon and patient.

Keywords. Gynaecology, musculoskeletal disorders, surgery, postural analysis, bariatric

1. Introduction

The application of laparoscopic surgery (minimal access surgery; MAS) has been rising since the 1980s with patient benefits of reduced morbidity, recovery time and inpatient stay as well as enhanced cosmetic external results (1). For surgeons, MAS is reported to be more physically complex and mentally demanding than traditional open surgery (2,3), and despite early warnings that physical Ergonomics (Human Factors) should be considered in MAS workplace design (4), surgeon injury report rates have increased to 87%, far higher than traditional open surgery (5).

Physical demands have been reported with respect to table height, monitor and port positions, static postures (reduced visual field), repetitive motions, inappropriate equipment and poorly adapted environments (5, 6, 7, 8, 9). Two recent surveys have reported physical discomfort (work-related musculoskeletal disorders; WRMSD) in 61% and 88% of gynecological surgeons (10, 11) with higher rates reported for robotic surgery (10). It has been suggested that female surgeons may be at greater risk of injury due to shorter stature and reach distance, and weaker upper body strength (2, 11, 12; 13).

The majority of the UK adult population (61%) is now either overweight or obese (14) and a link between obesity and gynaeocologic symptoms has been reported (15, 16) leading to an increased presentation in this clinical specialty. It has also been suggested that this population is suitable for MAS in preference to open surgery as it is likely to be less painful and leads to quicker recovery with fewer complications (15).

This research aimed to investigate Human Factors issues related to WRMSD in surgeons working in gynaecological MAS, including bariatric (plus size) patients.

2. Methods

Data were collected using an online survey, observation (anthropometry and postural analysis) and interviews.

Anthropometry is the study of human body sizes and physical abilities (17) with physical anthropometric dimensions available as internationally published standards (18). Body measurements include stature, arm and leg segments in different functional positions and activities. Determining critical design criteria requires both knowledge of task activities and the user population (different body sizes and abilities). For example, elbow height (vertical distance from the floor to the radiale of the elbow) is an important datum for determining the optimum working (operating) height of a surgeon and the range of adjustability recommended for an operating table. Generally, the range should accommodate both a smaller (1st/5th percentile female for specified age range and culture), and larger users (95th /99th % percentile male). Stature and elbow height were measured in this study.

Postural analysis data were collected with the Rapid Entire Body Assessment (REBA; 19). REBA was developed specifically for use in the healthcare industry and has high face validity from extensive international applications. Data are collected as snapshots about the body posture, forces used, types of movement or action, repetition and coupling. The data are combined and processed through a series of data tables to generate a final risk score (20) with an action (urgency) recommendation on a five-point action category scale (0-4) from no risk (0: no action needed) to high risk (4: necessary now).

Survey

An online survey was used to investigate the prevalence of WRMSDs. The survey was distributed via the Royal College of Obstetrics and Gynaecology (O&G) and the

Midlands O&G Trainees' Research Collaborative personal networks (MTReC) from February to June 2016.

An 18 question survey (Figure 1) was developed using previous research (10, 11) to collect data about exposure to MAS-associated risks, WRMSD symptoms, contributory factors (e.g. availability of equipment and assistance, time pressures, type and complexity of surgery, patient shape and size) and coping strategies.

1. Consent to participate in survey
2. How many years have you been working in the field of obstetrics/gynaecology? (including training years)
3. How would you describe your current post?
4. What type of post do you hold?
5. If you undertake elective gynaecology surgery, how many theatre sessions do you have on average every month? (1 session = 4 hours)
6. How would you describe the role minimal access surgery (MAS) takes in the procedures you perform?
7. What type of MAS do you perform?
8. What is the typical duration of procedures you perform with MAS?
9. In your opinion has the proportion of elective gynaecological cases that you are performing by MAS changed in the last 3 years?
10. How old are you?
11. Are you male/female?
12. How tall are you?
13. Have you experienced work-related musculoskeletal symptoms (ache, pain, discomfort) in the...[body part]?
14. Are there any factors that have contributed to your work-related musculoskeletal symptoms?
15. Have you taken time off work because of work-related musculoskeletal symptoms?
16. Have you ever had (or are you having) treatment for work-related musculoskeletal symptoms?
17. Have you ever changes your work because of musculoskeletal symptoms?
18. Have you ever had formal training on optimising your operative technique in order to reduce the risk of work-related musculoskeletal symptoms?

<Figure 1: Survey questions>

Pilot Study: Surgeons' interaction with their working environment

Eleven surgeons were recruited from different hospitals across England by purposive and snowball sampling to analyse physical behavior (simulated working postures) and explore coping strategies (interviews). Demographic data were collected about age, experience and body size (anthropometric measurements) for stature and elbow height.

Data were collected about physical behaviours and working postures during MAS (proposed scenario: total laparoscopic hysterectomy for a normal size uterus with no ovarian/tubal pathology and no previous pelvic surgery). Two abdominal mannequins were used to represent the patient:

1) Surgical mannequin with sagittal abdominal depth (SAD) approximately the size of an average sized (or 50th percentile) female (225 mm SAD (18) + 60 mm (estimated average insufflation height (21)) = 285 mm

2) Surgical mannequin (plus padding) to represent a plus size (BMI 30 or more) or 99.99th percentile female. There are an increasing number of obese patients in gynecological MAS, but specific data was not available, SAD was estimated as 427mm (from personal communication with Moss 2016 and literature (22)).

The working height (Figure 2) was defined as the table surface height (720-1070 mm; from product technical specification), plus patient SAD including insufflation (285mm or 430 mm).

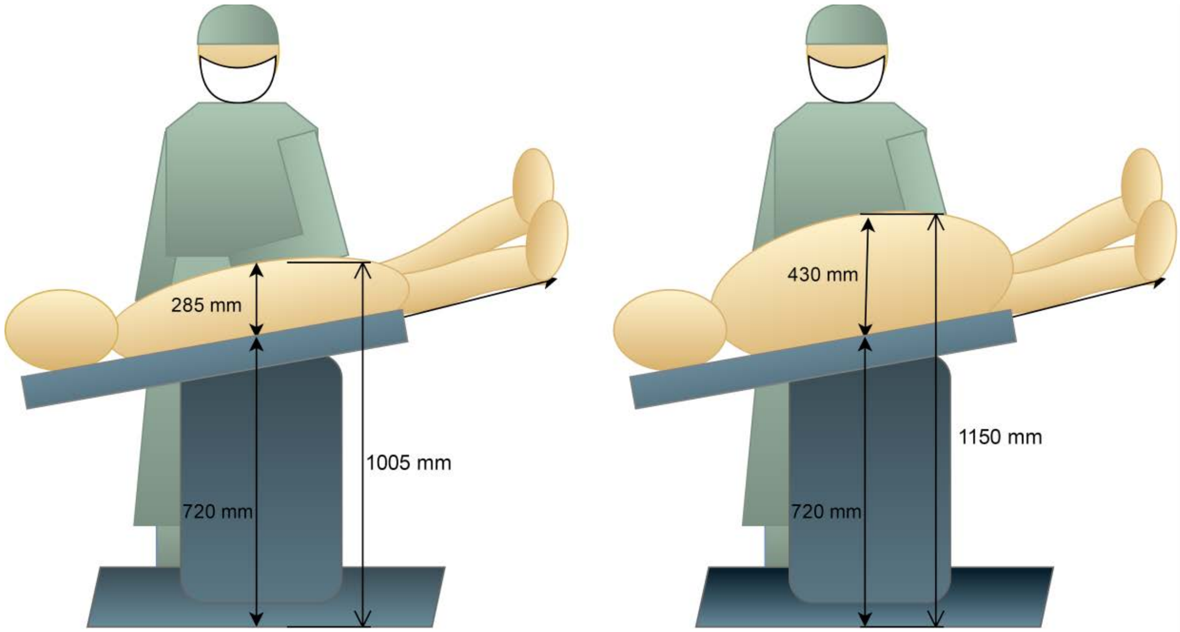


Figure 2: Working height (a) average sized female – SAD 285 mm; (b) obese female – SAD 430 mm.

The surgeons were asked to set up their preferred working layout (including optional use of steps) and position for two working ports with (1) contralateral ports , (2) ipsilateral ports, and (3) a midline port (figure 3) with both mannequins. Observational data using REBA were collected for the most extreme postures for each of the three port options and monitor position.

<Figure 3: (a) Contralateral, (b) ipsilateral, and (c) midline port placements on 50^{th}%ile mannequin>

Semi-structured interviews were used to explore monitor positions and coping strategies (adjustments) for the three port options and plus size patients. The interview data were audio-recorded and imported into NVivo 10 (23), a qualitative management software package, which supports thematic analysis (24). The data were classified into preliminary nodes (and sub-nodes). The interviews were then recoded with the revised conceptual framework as more themes emerged.

The research was assessed as an NHS Service Evaluation and was approved by Loughborough University Ethics Committee.

3. Results

Survey

Responses were received from 67 participants; 38% from males and 62% females. Over 70% were under 40 years of age with a range of experience in O&G from less than 1 year to over 40 years. 63% (n=42) of respondents reported WRMSD within the last 12 months and last 7 days, especially for the lower back, shoulders, neck and wrist/hands. Of these, 62% had sought treatment, including physiotherapy, analgesia and steroid injections, but only 6% reported taking time off work. Contributory factors for WRMSD were suggested to be patient shape and size, and the duration and complexity of surgery. Coping strategies which were reported to help manage pain and discomfort included proactively managing/reducing workload (limiting additional operating lists), increasing/decreasing the number of MAS cases, reducing the number of complex cases (including plus size patients), and stopping performing elective surgery major/minor cases and emergency surgery.

Pilot Study: Surgeons' interaction with their working environment

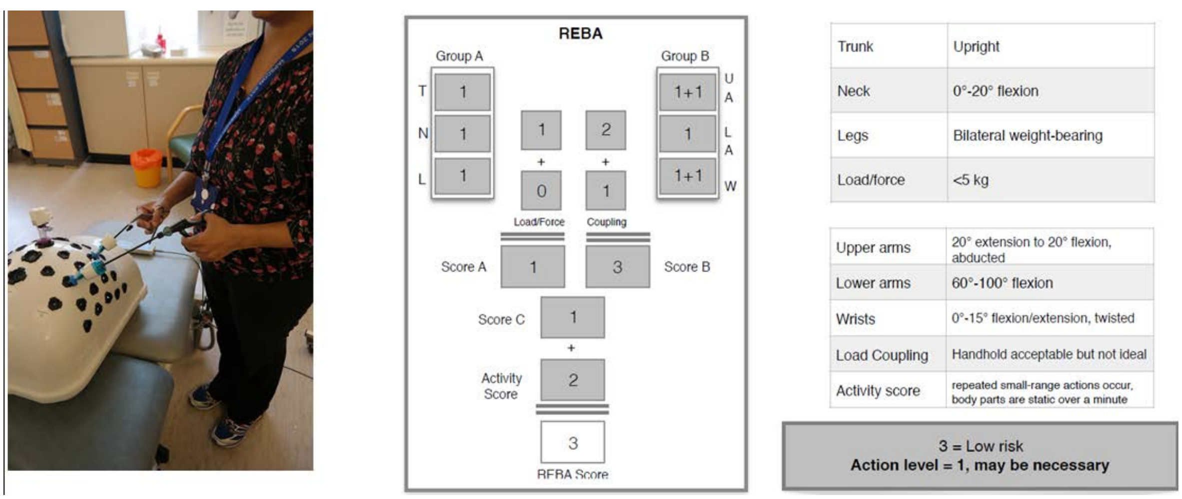
The 11 participants (4 males and 7 females) were slightly older than the survey respondents (n=4, 30-39 years; n=5, 40-49 years; n=1, 50-59 years) and had slightly less experience (n=7, less than 5 years; n=4, 5-10 years).

The stature distribution of the surgeons (with footwear; Table 1) was 1494-1674 mm for females (n=6; mean 1613, SD 66) and for males 1746-1894 mm (n=5; mean 1894, SD 70). This represents 3rd percentile female stature to 99th percentile male stature (25). As expected there was a strong positive correlation between stature and elbow height ($r=0.946$, $p\leq0.0001$).

Participant	Gender	Stature	Elbow height	70-80% elbow height
1	Male	1746 (53)	1108 (64)	776-886
2	Female	1666 (82)	1011 (55)	707-808
3	Female	1588 (36)	989 (36)	692-791
4	Female	1494 (3)	948 (11)	664-758
5	Male	1894 (99)	1157 (90)	881-926
6	Male	1764 (63)	1121 (72)	785-897
7	Female	1674 (85)	980 (29)	686-784
8	Male	1873 (97)	1189 (97)	832-951
9	Male	1763 (63)	1106 (62)	774-884
10	Female	1634 (65)	1010 (54)	707-808
11	Female	1624 (59)	995 (41)	697-796

<Table 1 Stature (with footwear), elbow height and 70-80% elbow height in mm (anthropometric percentile estimates from British adults aged 19-65; (21))>

52% of participants chose the ipsilateral port option for the plus size 99.99th%ile mannequin and 45% chose the contralateral port position for the 50th%ile mannequin. The selection of port access for the 50%ile patient included personal factors (e.g. reach), surgical assistance (availability and experience), and pathology; ‘*ports are not just dependent on the patient size, it is dependent on the pathology … if somebody has got a left side massive ovarian cyst (…) it is easier to … have one port definitely on the right side so you are coming at an angle, so if you are working from the same side that the pathology is on sometimes it is difficult to do the movements, so you are better coming at it from the opposite side*’ (P10).



<Figure 4: REBA Analysis example>

The REBA postural analysis (Figure 4) found that ipsilateral port option had the lowest level of risk exposure compared with midline, and the contralateral port postures had the highest REBA scores (Table 2).

Participant	Unilateral 99th	Unilateral 50th	Midline 99th	Midline 50th	Bilateral 99th	Bilateral 50th
1	1	1	3	2	2	2
2	2	1	4	3	4	4
3	3	3	3	3	3	4
4	2	0	3	3	3	4
5	2	1	2	2	2	2
6	1	1	2	2	2	2
7	1	1	3	2	3	2
8	2	2	2	2	3	3
9	1	1	1	2	2	1
10	1	1	1	2	2	3
11	1	1	2	2	3	3

<Table 2. REBA results (action categories 0= none necessary; 1=may be necessary; 2=necessary; 3= necessary soon; 4=necessary NOW)>

A Friedman two-way ANOVA found a statistically significant difference in the REBA Action scores for port placement (ipsilateral, midline, contralateral) within both the 50th (chi-square (2) = 16.270, p=0.000) and 99.99th (chi-square (2) = 13.034, p=0.001) percentile abdomen sizes; post hoc analysis with Wilcoxon signed-ranks test was conducted with a Bonferroni correction applied resulting in a significance level set at p<0.017. There were significantly different REBA action scores for port placement for contralateral 99.99th versus ipsilateral 99.99th (z=-2.762, p=0.006); midline 50th versus ipsilateral 50th (z=-2.807, p=0.005); and contralateral 50th versus ipsilateral 50th percentile abdomen size (z=-2.871, p=0.004). However, using Wilcoxon signed-ranks test it was found that there were no differences in the postures adopted by the surgeons between the two different abdomen sizes in any of the port positions.

In the interviews discomfort was often attributed to awkward and sustained postures '*sometimes if I'm holding an instrument out like this* [right arm over the patient], *so sometimes your grip is not strong enough while your arm is over there or your arm is not* *long enough, so then it will start aching my shoulders*' (P4). The workplace layout could contribute to awkward postures, '*the fact that you often only have one screen for all of you is, it's not great, so you're obviously having to go and look side-on so your head is looking in the other direction'* (P7).

Surgeons were aware of the possibility that their discomfort might affect the task (and patient), '*when I'm suturing, it's probably only for 5 or 10 minutes, I'm in a very difficult position. The rest of the times, I think I kind of make sure the task is not affected, but you do so reflexively that you're not aware of your positions, only after the procedure you realise - 'Oh God, what have I done to my back' – but while you are doing the procedure, I don't think as a surgeon I'm compromising the task as such'* (P2).

Coping strategies were used to reduce discomfort, for example tilting the patient head-down (Trendelenburg) to create more internal abdominal/pelvic space. Operating table design can facilitate or limit this option, '*sometimes you can't actually bring them* [table] *down as far as you want to... Some theatre tables can go almost down to the floor, but some can't, so it's also the quality of the theatre tables is also quite important'* (P1). This lead to the second coping strategy of using steps, which could introduce additional hazards including tripping and falling off the step.

4. Discussion

Discomfort from performing MAS procedures for many surgeons appears to be part of the job and the lack of purposely designed equipment can make it very difficult to work comfortably without risking their own physical health (26). The survey and interviews indicated very similar areas of discomfort, in particular for the lower back and shoulders. Upper body discomfort was often attributed to awkward postures associated with using MAS tools. Gender has previously been correlated with higher WRMSD risk (2, 5, 11), with females reporting more symptoms from MAS in particular for upper limb problems. Franasiak et al. (11) and Aitchison et al. (6) both concluded that shorter stature people will be at a greater risk of developing shoulder and back symptoms than taller stature during MAS.

van Veelen et al. (27) found that the optimum MAS working height was 70% to 80% lower than elbow height allowing joints to remain in a neutral position for the majority of the surgery. Elbow height values are shown in Table 1 for this pilot study to give an estimate of individual optimum working height as the operating table height plus the patient's abdominal depth (with insufflation). However, even if the operating table was at the minimum height (720 mm), for the 50th percentile (285 mm) and plus size (99.99th percentile) supine abdominal height (430 mm) none of the surgeons would be able to achieve this optimum working height and is likely to be the reason why the step needed to be used by the three shortest surgeons (13).

The use of the ipsilateral port option seemed to offer lower risk postures, but may not be selected due to experience; it was noted that the younger surgeons (less than 5 years' experience) tended to use the contralateral port position more frequently. Participants reported coping strategies but options could be limited due to local working circumstances, including team support (availability and experience) and equipment. These challenges are exacerbated for plus size patients (BMI 30 or more) due to the lack of inclusive design in many operating theatres (28).

The observational data may be limited by simulation of tasks resulting in more awareness of postures and lower risk positions than might occur during in real time surgeries. The surgeons were asked to adopt their most preferred working posture; this relied on awareness of postures during surgery and an ability to simulate the postures.

Further limitations included the lack of foot pedals, however it was noted that the use of steps by three surgeons would have added to the complexity of the interaction of the surgeon and foot pedal. Future research could address these limitations by, for example, exploring lower extremity MSD risks in more detail; increasing variables for workspace layout (including handedness); research into glove size to optimize the equipment operation interface; and recruiting a purposive sample of more experienced surgeons; with a high fidelity simulation.

Age and experience have previously been correlated with increased WRMSD for both older and younger surgeons (2, 6, 11). Similar conclusions could not be drawn from this survey, but it was noted that the older interviewees reported more knee and foot discomfort from extended procedures and standing. The level of WRMSD is of concern, at over 60% for both the survey and interview participants. In other clinical professions (e.g. nursing) this has been associated with psychosocial factors (including workload and error) and turnover (including leaving the profession) (29, 30). A limitation of this work is that it is a small pilot study, future studies should ensure that data are collected on contributing factors such as the surgeons previous WRMSD, injuries, training (e.g. ergonomics) and psychosocial factors (e.g. workload, stress and error). Patient habitus, prior surgery, and the impact of underlying pathology are also important to define in more detail to ensure that a range of representative work task scenarios are identified for surgical simulations.

It has been suggested that an increase in the use of robotic surgery could address the musculoskeletal risks associated with MAS (31) but recent research (10) has not supported this suggestion and more research is needed to compare the musculoskeletal risks of these surgical techniques.

This pilot study found that MAS poses many challenges but the effects of these on surgeons could be reduced by implementing interventions and adjustments to the environment and equipment as well as continuing to raise awareness through training. There has been a tendency to address surgical patient safety problems with training and communication interventions (32), however it is becoming increasingly recognized that design and engineering solutions (working with safety scientists, including Human Factors/Ergonomics practitioners) are needed (33). A Human Factors approach would apply ergonomics methodologies including task analysis, user trials, participatory ergonomics (34).

5. Conclusion

This project was initiated due to concerns raised by a female surgeon and the challenge of MAS with obese patients. The survey and observation data indicate that there is a real problem in this population, with a very high level of WRMSD. The analysis uses a traditional ergonomics approach (anthropometry, postural analysis etc.) and there will be many previously known solutions to WRMSD which can be transferred. However some of the challenges need new design and engineering solutions to allow flexibility to support surgeon choice of operating approach (open, laparscopic or robotic) with a work place which supports adaptation to the task, surgeon and patient.

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