One size does not fit all: Impact of hand size on ease of use of instruments for minimally invasive surgery

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ABSTRACT

Background: Consideration of ergonomic factors is important for the practice of safe and efficient minimally invasive surgery (MIS). Surgeons with smaller glove sizes have previously been reported to have increased difficulties with some minimally invasive instruments. We aim to investigate hand anthropometrics and their relationship to surgeon comfort when using MIS instruments.

Methods: Male and female surgeons from two centres were surveyed on their experience of handling MIS instruments and images obtained of the dorsal and palmar aspects of their dominant hand. Photographs of hands were transformed to calibrated coordinates to enable anthropometric measurements of finger length and width as well as palm width and hand span photogrammetrically. Surgeon-perceived discomfort, fatigue, pressure points and techniques to mitigate difficulty handling instruments were compared to hand measurements.

Results: Questionnaires were completed by 58 surgeons; 20 (34%) were consultants, 17 (29%) were women. Glove size ranged from 6 to 8 (median 7.5). Male participants had significantly larger hands than females in all measured dimensions. Female surgeons and those with smaller finger and hand dimensions were significantly more likely to experience difficulty or discomfort across a range of variables when using MIS instruments.

Conclusions: Surgeons with smaller hands reported increased problems handling MIS instruments. This represents an issue of equity in surgery, with women being more significantly affected than men. Hand size varies greatly between surgeons and anthropometric variability should be considered in design of MIS instruments.

Introduction

The development of laparoscopic and minimally invasive surgery (MIS) has changed the landscape of surgical practice over recent years, resulting in a reduction in patient length of stay, reduced post operative complication rates and improved cosmesis.[1] Although MIS has clear benefits for patients, the impact on surgeons has not always been positive. There have been reports of occupational injury amongst surgeons when performing MIS due to physical stress.[2] Episodes of neuropraxia when performing MIS, although mostly self-resolving, can last weeks or even months.[3] Poor ergonomics of instruments may lead to pressure areas, nerve irritation and fatigue.[1,4,5] Despite awareness of these issues, there is limited innovation and investment in these instruments and

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important ergonomic design refinements are still only considered after technical feasibility is established.[6]

Surgical instruments for MIS are seldom available in more than one handle size, with barriers including the historical assumption that "one size fits all" and the prohibitive costs of bespoke instruments.[7] Regardless of the barriers, this status quo remains unacceptable since surgeons have a variety of hand sizes, and there are multiple reports that hand size is a significant determinant of difficulty using laparoscopic surgical instruments.[1,5] Individual surgeons using glove size 6.5 or smaller experience difficulty when using common laparoscopic instruments.[8] This also represents a disparity between the sexes since female surgeons may tend to have smaller hands than their male colleagues, a fact which is evidenced in anthropometric data sets[9] and previous studies.[10] Those surgeons with smaller hands experience higher physical stress and fatigue level when performing laparoscopic surgery compared to the larger handed surgeons and may have to adopt a two-handed approach with a single-handed instrument.[5] Since these factors may influence surgical technique and fluency, they may also have an impact on patient outcomes and warrant further investigation.

It is unknown whether specific anthropometric dimensions of surgeons' hands affect their comfort with MIS, rather than simply glove size alone. The aim of the current study was to investigate the relationship between hand anthropometric measurements and subjective comfort with MIS instruments amongst a mixed sex cohort of UK surgeons. We hypothesized that smaller handed individuals would experience more discomfort with the "one size fits all" MIS instruments, and that there may be specific parameters in size that affect comfort more than others.

Methods

Study design and setting

An observational study was undertaken to investigate the relationship between anthropometric hand measurements of surgeons and their subjective comfort in using MIS instruments. Surgeons from paediatric and adult general and urological surgical specialties in two centres were invited to participate. All participants gave informed consent to take part in the study, and the study was approved by the University of Nottingham Faculty of Engineering Ethics Committee prior to data collection.

Survey design

A questionnaire was developed to explore surgeons' experiences of using MIS instruments when operating in theatre. The authors were not aware of a validated questionnaire for the assessment of pressure-points, discomfort and fatigue in using laparoscopic instruments. Therefore, a bespoke survey was designed by consensus amongst the authors to address questions that were considered reproducible within the surgical community. The survey used Likert scale subjective assessments (never, rarely, sometimes, often, very often) to address perceived difficulties with instruments, pressure points on the hands, development of fatigue, loss of strength, wrist discomfort, and whether they had developed techniques to compensate for their difficulties. Demographic details were also collected including sex, glove size, and level of experience.

Anthropometric measurements

Photographs were taken of the palmar aspect of the dominant hand of each participant against a background containing registration marks. Images were processed using a custom MATLAB 2019a[11] script. This transformed onto a calibrated coordinate system using a projective transform. In the transformed images, each pixel accounted for 0.1 mm squared. Once transformed, control points were manually added to the images at the locations shown in Fig. 1. The distance between the control points were obtained for each hand, giving measurements of finger length and width, palm width and hand span. Although laparoscopic surgery is usually performed with both hands, the dominant hand was chosen because it was considered to represent the overall anthropometric measurements for each participant without adding potentially redundant data from the other hand.

Data analysis

Data are presented as number and percentage for categorical data, and median and interquartile range for continuous data. Continuous data are compared using Mann–Whitney U tests, and categorical data are compared using Fisher's exact test. Questionnaires responses using ordinal scales (according to Likert scores) were compared to the paired anthropometric hand measurements of individuals using Spearman's rank correlation. These included scores for fatigue, wrist discomfort, loss of strength, excessive pressure points, as well as whether they had any difficulty, whether they felt the instrument was inadequate for their hand, and whether they had developed any techniques for compensating for discomfort using the instruments. A p-value of <0.05 was considered statistically significant. Responses regarding techniques used to compensate are reported *verbatim*. Thematic analysis was performed on responses to the survey question on whether instruments are considered adequate for hand size.

Results

Study participant characteristics

There were 58 surgeons included of which 17 (29%) were female. There were 20 (34%) consultants, and the remainder were trainees. The median glove size was 7.5 (IQR 6.5–7.5), with a range of 6–8. Anthropometric measurements are summarised in Table 1 and compared between male and female participants. Male participants had significantly larger dimensions in every measured variable than female participants. Females were significantly more likely to experience some difficulty using MIS instruments.

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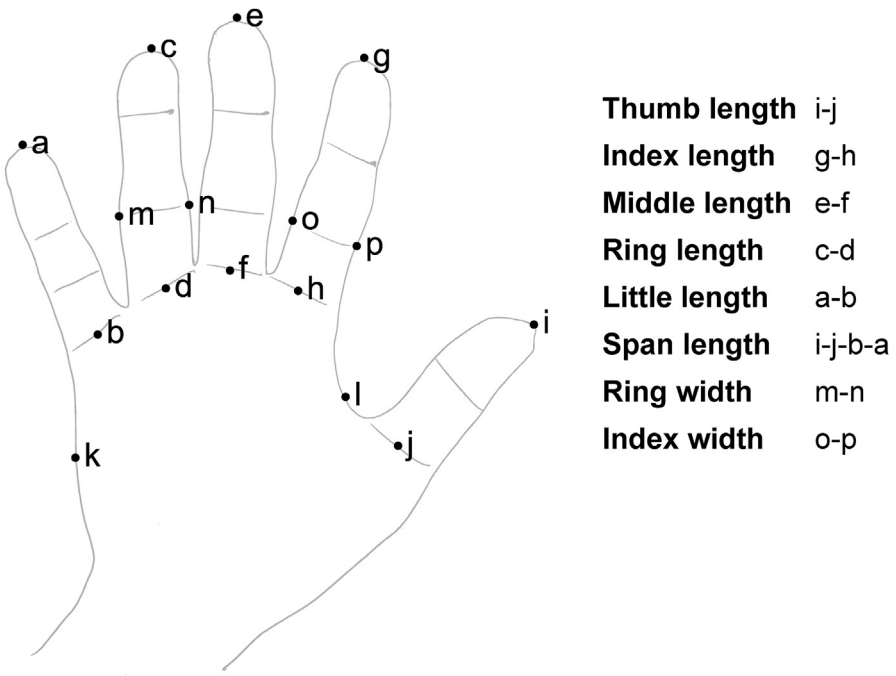

Fig. 1 – Location of control points. Anthropometric measurements were made photogrammetrically between the control points shown.

Subjective experience of instruments

All participants reported some degree of hand fatigue when performing MIS. Forty (69%) reported some level of difficulty handling the instruments, and 49 (84%) reported the experience of excess pressure points. Twenty-five participants responded that they needed to develop techniques to ameliorate difficulty to some extent, and these are summarised in Table 2.

Thematic analysis of responses to the survey question "Do you think current laparoscopic instruments are an adequate fit for your hand size?" found three key themes, summarised in Table 2. Participants reported particular difficulties with needle holders (22.2%), ratchet handled instruments (18.5%) and the pyloromyotomy spreader (14.8%).

Anthropometric measurements and subjective experience

Table 3 summarises the associations between respondents' subjective assessments and their corresponding anthropometric measurements. There was a significant association

Table 1 – Participant characteristics.

Characteristic	All (N = 58)	Male (n = 41)	Female (n = 17)	*p*-value
Grade, n (%)				
Consultant	20	16	4	0.366
Trainee	38	25	13	
Glove size, median (IQR)	7.5 (6.5–7.5)	7.5 (7.5–7.5)	6.5 (6–6.5)	<0.001[a]
Dimensions, median (IQR) mm				
Thumb length	70 (64–78)	74 (66–80)	66 (62–70)	0.003[a]
Index length	75 (72–79)	77 (73–87)	72 (69–74)	<0.001[a]
Middle length	84 (80–88)	85 (81–90)	80 (77–87)	<0.001[a]
Ring length	78 (75–83)	81 (77–84)	75 (71–76)	<0.001[a]
Little length	62 (59–66)	64 (61–68)	58 (55–60)	<0.001[a]
Span length	241 (225–253)	249 (240–258)	223 (216–226)	<0.001[a]
Ring width	20 (19–22)	21 (20–23)	19 (17–20)	<0.001[a]
Index width	22 (20–24)	22 (21–24)	19 (19–20)	<0.001[a]
Ergonomic difficulty				
Any difficulty	40 (69)	23 (56)	17 (100)	<0.001[a]
Pressure score	2 (1–2)	2 (1–3)	1 (1–2)	0.170
Fatigue score	2 (1–2)	2 (2–3)	2 (1–2)	0.092
Loss of strength score	1 (0–2)	1 (1–2)	1 (0–2)	0.327
Wrist discomfort	1 (0–1)	1 (1–1)	1 (0–1)	0.366

[a] Significant according to Mann-Whitney *U* test.

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Table 2 – Thematic analysis on adequacy of instruments for surgeons' hand size.

Theme	Example statement (taken *verbatim* from responses)
Instruments too big	'Largely designed for male hand. Size 6 hand hasn't got the spread'
	'Some instruments feel large and awkward'
	'They are too big for my normal grasp'
Difficult to use rotation or rachet	'Difficulty reaching rotating device whilst hands are in the handle. Device often too stiff for me to use single handed'
	'I often have to adjust my hands or use both hands to do simple manoeuvres such as releasing/engaging the ratchet'
	'Struggle to rotate instruments – inadequate finger strength'
	'When using the rotational wheel … it is difficult to reach it without adjusting my grip and wobbling the instruments'
Not ergonomic	' … I don't think the instruments are designed ergonomically for any surgeon'
Techniques used to improve comfort	Two handed when assisting
	Altering grip, use of ratchets, use of assistants
	Don't place fingers through the holes. Stops pressure point problems and allows me to reach twizzle bits
	Mostly palm instruments rather than place fingers through
	Occasional neuropraxia
	Palm all instruments anyway
	Palming, concentrating on not over-gripping etc.
	Palming, two handed technique
	Reposition
	Sometimes ask assistant to hold an instrument whilst I use 2 hands on the other
	Tend to palm instruments frequently
	Two hand technique
	Two hands using nurse to assist/hold

between the perception of difficulty in participants with smaller index, middle, ring and little fingers, but not the thumb. This association was also present for hand span and palm width, as well as width of ring and index fingers. There was a similar pattern for pressure symptoms and fatigue. There were no significant associations between any of the anthropometric measurements and loss of strength, wrist discomfort and the use of alternatives techniques of instrument handling (Table 3).

Discussion

The main finding from our study is that surgeons with smaller hand and finger dimensions were more likely to experience difficulties with handling MIS instruments. The length of all fingers excluding the thumb were associated with difficulty, but the magnitude of significance was greatest for the index finger length. This is unsurprising when we consider that many MIS instruments require the use of the index finger to rotate the instrument or access other functions of the instrument.

It is natural that most of the published literature about MIS has been patient-centred, with evidence of numerous benefits for patients, but there have been fewer investigations of the ergonomic effects on surgeons. Sutton et al. reported that up to 87% of surgeons who regularly perform MIS are at risk of injuries or symptoms related to performance.[1] Neuropraxia has been described in surgeons following laparoscopic procedures, with this recognised as an occupational injury.[3] Our findings of increased hand fatigue and pressure point symptoms in those with shorter finger length measurements suggest that those surgeons with smaller hands are likely to suffer disproportionately compared to their larger-handed colleagues. It is possible that discomfort and difficulty in

Table 3 – Association between subjective assessments and anthropometric measurements summarised as *p*-values using Spearman rank correlation coefficient.

Subjective assessment	Thumb length	Index length	Middle length	Ring length	Little length	Span length	Palm width	Ring width	Index width	Glove size
Any difficulty	0.223	<0.001[a]	0.004[a]	0.008[a]	0.002[a]	0.008[a]	0.011[a]	<0.001[a]	<0.001[a]	0.021[a]
Pressure	0.588	<0.001[a]	0.047[a]	0.019[a]	0.017[a]	0.421	0.296	0.177	0.591	0.224
Fatigue	0.338	0.037[a]	0.046[a]	0.047[a]	0.041[a]	0.134	0.046[a]	0.074	0.333	0.088
Loss of strength	0.413	0.082	0.851	0.602	0.253	0.759	0.382	0.142	0.348	0.635
Wrist discomfort	0.053	0.284	0.092	0.217	0.292	0.129	0.292	0.078	0.347	0.136
Developed techniques to compensate	0.182	0.101	0.239	0.056	0.069	0.246	0.227	0.339	0.988	0.082

[a] Statistically significant using Spearman rank correlation coefficient.

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using instruments during surgery may have an impact on patient outcomes, and therefore warrants attention.

Small hands have been reported to be associated with ergonomic difficulties in using MIS instruments, and this is likely to affect females more than males given the likelihood of smaller anthropometric dimensions, as found in our study and previously reported.[5] Studies of MIS instrument handle shapes and mechanisms have concluded that no handle is perfect, with all tested showing disadvantages,[4,12] despite attempts to describe criteria for development of genuinely ergonomic instrument handles.[13] These investigations used electromyography tests to measure muscle strain but did not consider the differing sizes of the participants' hands during the study. Our data showed that most study subjects found some difficulties in handling the instruments, with particular difficulties found with instruments requiring rotation or use of a ratchet, and that there were no significant differences in the development of compensatory techniques between anthropometric dimensions. We consider that this likely represents that the imperfect ergonomics of minimally invasive instruments is almost universal among surgeons, such that many have developed techniques to ameliorate difficulties whatever the size of their hands.

During the design and production of MIS instruments, a variety of sizes would likely reduce the risk of discomfort and difficulty and would cater for a more diverse surgical community. We have found that female surgeons tend to have smaller hands in all dimensions and are therefore likely to be disproportionately impacted by difficulty using MIS instruments, the impact of these potential occupational injuries may also be career limiting. Female surgeons have historically been outnumbered by their male colleagues, but this is changing over time. In 1991 only 3% of consultant surgeons were female compared to 13.2% in 2020.[14] It is therefore both important and necessary that MIS instruments are designed in a way to suit all surgeons and not just the majority. The smallest glove size included in our study was 6, but two of the authors wear a 5.5. The length of the smallest index finger is 65 mm vs the longest 87 mm. It is not at all surprising that a single "standard" handle size is a poor fit for many surgeons. The 'one size fits all' model of MIS instrument design is no longer appropriate and related work looks into how this mismatch between users anthropometric needs and the MIS tools available have an effect on surgical performance[15] and surgical training.[16]

Although the design of robotic platforms has paid particular attention to the ergonomics for the surgeon, it seems that there is still some work required for the design of laparoscopic instruments. The design and provision of MIS tools should be fit for all users and designed to support optimal surgical performance by individuals. Manufacturers of MIS instruments may wish to undertake further anthropometric testing exercises in order to reduce the risk of pressure and fatigue for all users. Recent work[17] also begins to consider the role of additive manufacturing and rapid prototyping in overcoming the issue of cost-effectiveness of producing variable sized MIS instruments, an opportunity which might eventually reach and benefit frontline surgical teams. This may not only improve surgeons' physical health but also potentially reduce operating times and technical efficiency.

Limitations

The current study was observational and based on the subjective experiences of study subjects. It is therefore at some risk of selection and recall bias, as well as lack of translatability to all surgeons. There were no objective measurements of technical tasks or skills. However, study subjects were diverse in terms of years of experience and anthropometric dimensions so that a reliable spread of measurements were sampled. Specific instruments were not individually analysed, and therefore it is difficult to make any conclusions about the specific instruments or their dimensions most at risk of causing adverse physical effects for surgeons. No assessment was made of muscle strength as a possible confounding factor, which may also influence the ability to use laparoscopic instruments. The relationship between hand dimensions, muscle strength and difficulty in using instruments warrants further investigation.

Conclusion

In our study of 58 surgeons, smaller hand and finger dimensions were associated with worse discomfort and difficulty in handling MIS instruments. The most significant of these associations was the length and width of the index finger and width of the ring finger. This has implications for MIS instruments that require the action of the first two fingers to manipulate the instrument. The historical concept of 'one size fits all' MIS instruments is not appropriate in an increasingly diverse and equitable community of surgeons. Further investigations of the relationship between comfort, technical ability and efficiency of movements of MIS instruments are warranted.

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Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.surge.2022.11.001.

REFERENCES

1. Sutton E, Irvin M, Zeigler C, Lee G, Park A. The ergonomics of women in surgery. *Surg Endosc* 2014;**28**(4):1051–5.
2. Park A, Lee G, Seagull FJ, Meenaghan N, Dexter D. Patients benefit while surgeons suffer: an impending epidemic. *J Am Coll Surg* 2010;**210**(3):306–13.

3. Horgan LF, O'Riordan DC, Doctor N. Neuropraxia following laparoscopic procedures: an occupational injury. *Minim Invasive Ther Allied Technol* 1997;**6**(1):33–5.
4. Matern U, Eichenlaub M, Waller P, Rückauer K. MIS instruments. An experimental comparison of various ergonomic handles and their design. *Surg Endosc* 1999;**13**(8):756–62.
5. Huang J, McGlothlin J. Ergonomic assessment of obstetrician-gynecologists performing laparoscopic surgery: study of hand size and surgical instruments. *J Ergon* 2017;**7**:224.
6. Human Factors Refinement of a Multimodal Laparoscopic Hand Tool. In: Garfield MR, Privitera MB, editors; 2019. 2019 Design of Medical Devices Conference V001T08A001.
7. Supe AN, Kulkarni GV, Supe PA. Ergonomics in laparoscopic surgery. *J Minimal Access Surg* 2010;**6**(2):31–6.
8. Berguer R, Hreljac A. The relationship between hand size and difficulty using surgical instruments: a survey of 726 laparoscopic surgeons. *Surg Endosc* 2004;**18**(3):508–12.
9. Pheasant S, Haslegrave CM. *Bodyspace: anthropometry, ergonomics and the design of work*. 3rd ed. Taylor & Francis; 2005.
10. Stellon MA, Seils DR, Mauro CR. Assessing the importance of surgeon hand anthropometry on the design of medical devices. *J Med Devices* 2017;**11**(4):041004.
11. MATLAB [software]. The MathWorks Inc.; 2019 [cited2022 July 18]. Available from: https://uk.mathworks.com/products/matlab.html.
12. Büchel D, Mårvik R, Hallabrin B, Matern U. Ergonomics of disposable handles for minimally invasive surgery. *Surg Endosc* 2010;**24**(5):992–1004.
13. Matern U, Waller P. Instruments for minimally invasive surgery: principles of ergonomic handles. *Surg Endosc* 1999;**13**(2):174–82.
14. RCS England. *Statistics. Number of consultant female surgeons. [Internet]Royal College of Surgeons of England London*. 2022. c2022 [cited 2022 Jul 4]. Available from https://www.rcseng.ac.uk/careers-in-surgery/women-in-surgery/statistics.
15. Sánchez-Margallo JA, González González A, García Moruno L, Gómez-Blanco JC, Pagador JB, Sánchez-Margallo FM. Comparative study of the use of different sizes of an ergonomic instrument handle for laparoscopic surgery. *Appl Sci* 2020;**10**(4):1526.
16. Weinreich HM, Babu M, Kamil R, Williams Q, Buhimschi IA. Gender-differences of proceduralists in perception of hand-held surgical instrument fit – a cross-sectional survey. *Am J Surg* 2022;**S0002–9610**(22):312–9. https://doi.org/10.1016/j.amjsurg.2022.05.011. Epub ahead of print. PMID: 35606179.
17. González AG, Salgado DR, García Moruno L, Sánchez Ríos A. An ergonomic customized-tool handle design for precision tools using additive manufacturing: a case study. *Appl Sci* 2018;**8**(7):1200.

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