REVIEW ARTICLE

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Quantifying the lumbar spine movements of surgeons during surgical lists in a teaching hospital

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Abstract

Background: Low back pain (LBP) is a common occupational musculoskeletal complaint among health professionals. No research has quantified lumbar movement patterns in the surgical workplace, identifying 'at risk' behaviours with objective measures. This project aimed to identify lumbar movement patterns and change in LBP of surgeons and surgical trainees during a surgical list.
Methods: Surgeons or surgical trainees were recruited in a tertiary metropolitan hospital. Low back movements were quantified in real time via a monitoring system. This measured three-dimensional movement, velocity, acceleration and orientation to gravity during a typical theatre session. Pre- and post-surgery LBP, or low back injury measures of functional disability were quantified using the Oswestry disability index. Mean (standard deviation) and median (interquartile range) low back movement patterns were described. A Wilcoxon signed-rank test determined differences in LBP recorded from beginning to end of recording periods.
Results: Participants (n = 28) recorded data for a mean (standard deviation) of 6.1 (2.2) h. On average, 27.7 lumbar flexion events were recorded per monitoring session, with flexion movements held for >30 s an average of 5.6 times. Many of the flexion events were considered low range (between 20° and 40°) with an average of 19.1 events per session. Orthopaedic trainees recorded the highest average of lumbar and sustained lumbar flexions per hour (4.13 times). LBP significantly increased over the work day ($z = -2.53$, $P = 0.012$).
Conclusion: This study provides a base for the understanding of low back movement patterns during surgery. This data may be useful in helping surgeons to identify their 'high risk' movements and prevent low back symptoms.

Introduction

Low back pain (LBP) is a common musculoskeletal condition affecting an estimated 70–80% of adults at some point in their lives.[1] Workplace LBP is frequent and causes not only personal pain and suffering but leads to other costs as a result of loss of productivity, workplace and family stress and an increased health care burden.[1] Musculoskeletal injuries and complaints are a common occupational hazard for all health professionals and previous studies have shown that surgeons are particularly prone to shoulder, neck and LBP. In particular, surgeons have self-reported greater frequency of LBP than any other body pain and have required a greater frequency of interventions for lumbar pain relating to disk herniation or radiculopathy, than other musculoskeletal interventions.[2–4] The overall 12-month prevalance of back pain for surgeons and interventionalists has been reported within a large systematic review.[5] Pain was self-recorded a number of ways and prevalence determined as being between 28% (189 of 671 included participants) and 60% (329 of 525 included participants).[5] Regardless of the pain measure, this prevalence was substantially higher than the mean point prevalence of LBP within the general population reported within a large systematic review as 18.3%.[6]

It has been postulated that factors contributing to the development of low back symptoms include working in ergonomically challenging postures and prolonged periods of standing and bending exposing the low back to increased mechanical stress.[3] All of these factors are relevant to surgeons in the operating theatre environment. There are limited publications on the lumbar spine movements during surgery due to the practical difficulties in undertaking observational studies.[7,8] Previous researchers have used video analysis; however, these methods were greatly hindered by viewing limitations and the impracticalities of re-watching lengthy recordings for data extraction.[7,8]

Real time measurement of lumbar spine movement with motion sensor biofeedback has been utilized to record and provide biofeedback in a randomized controlled trial for participants with chronic lower back pain.[9] This lightweight and portable equipment eliminates the need for third party observation within the operating theatre and therefore allows quantification of movement patterns and movement amounts.

The aim of this study was to undertake real time monitoring of low back motion with motion sensor equipment to quantify lumbar movements of surgeons and surgical trainees during surgical list within a teaching hospital. A secondary aim was to ascertain the prevalence of LBP within the cohort.

Methods

This study was a cohort study at Peninsula Health, Victoria, Australia. The Peninsula Health Human Research Ethics Committee approved this research (LRR16PH5). All participants gave written consent.

Participants and setting

Peninsula Health is a health care network on the Mornington Peninsula of Melbourne, Victoria. This study was undertaken within the Frankston Hospital site of the network, which is a metropolitan teaching hospital. All surgeons or surgical trainees across surgical specialties at this site were eligible to participate on a day where they were listed to be operating. This included performing or supervising surgical procedures. Participants were ineligible to participate if they had an allergy to adhesive tape, as sensors were adhered to the skin of the low back. Data were recorded between June and September 2016. Recruitment was through Directors of Research in each specialization, advertising on notice boards, personal contact and presentation at surgical meetings throughout all surgical specialties.

Measures

Demographic information collected from each participant included age, gender, handedness, surgical specialty and their role (surgeon or surgical trainee). Two scaled measures were used at the beginning of the day to collect baseline back pain data.

The Oswestry disability index (ODI)[10] was used to quantify functional disability due to LBP or injury by assessing how much the participant's LBP had affected their ability to manage everyday activities over the previous week. The questionnaire enquired about pain intensity throughout the day and fluctuation of pain, its effect and incidence when lifting, walking, sitting, undertaking personal care activities, standing, sleeping and travelling and its effect on social life. Each of the 10 sections in the ODI is scored out of five. The score is converted to a percentage where 0–20% indicates minimal disability and 81–100% is generally indicative of a person being bed bound due to pain.

The Quadruple Visual Analogue Scale[11] was used to provide a subjective evaluation of LBP levels. The respondents were asked about their level of immediate pain, typical pain over the past month, and pain at its best and worst over the past month using an 11-point Likert scale (0 no pain, 10 worst possible pain). At the end of the day, participants were asked to record their current LBP on the same Likert scale and if the day had been a standard work day or to list anything out of the ordinary that may have contributed to any unusual movements.

Real time quantitative measures of participant's lumbar movements were collected using the ViMove motion sensor system, version 5 (dorsaVi, Melbourne, Victoria, Australia). The system consists of two electromyography (EMG) sensors and two kinematic movement sensors placed on the participant's low back (Fig. 1). For the purposes of this study, the two kinematic movement sensors were used to record information. EMG sensors were used in the baseline assessment only to evaluate the flexion relaxation in the erector spinae muscles of participants during full flexion. This is purely a descriptive assessment of the EMG outputs as the flexion relaxation phenomenon has been reported to be related to objectively identify people with LBP issues.[12] These sensors were placed on the thoracic lumbar junction and in line with the superior aspects of the sacrum. The sensors measured three-dimensional positioning and the velocity of the movement of the pelvis and the low back area, with lumbar movement derived from these two measures. These movements were recorded through a wireless recording device that the participant kept in their pocket. The technology

Fig. 1. dorsaVi sensor position.

has excellent accuracy and concurrent validity against gold standards in kinematic motion analysis[13] and these measures have good inter-tester and intra-tester reliability.[14]

Following recording, the data were converted into a graphic-rich report with the equipment software. The report provided data about time spent sitting, number of occasions participants sat or stood for 10–30 min, 31–60 min and greater than 60 min, frequency and quantification of flexion and extension movements and the percentage of time spent in upright or slouched sitting. Participants wore the sensors on their back throughout the surgical list for the day of monitoring.

Procedure

Each participant completed the questionnaires in the theatre offices and were fitted with, and orientated to the ViMove system prior to their surgical schedule. Participants undertook a series of programmed movements to establish their own baseline range of lumbar movement in flexion, extension, lateral flexion and rotation. This procedure is as per the ViMove standard set up protocol within the software. Following set up, participants were free to go about their daily role. At the end of their surgical list, the participants removed the sensors from their back and completed the end of day LBP visual analogue scale (VAS) question.

Statistical analysis

Data were analysed with Stata 13 (StataCorp, College Station, TX, USA).[15] Demographic and movement data were analysed quantitatively with means (standard deviation, SD) and frequencies (%). Non-normally distributed data were presented as medians and interquartile ranges. All data exported from the ViMove system was in means only and no SDs were possible. Where there were more than five participants in a surgical specialty, subgroup analysis was undertaken. A two-sample Wilcoxon signed-rank test was used to compare the pre–post immediate pain scale data. A score difference of 3.5 was set as the minimum clinically important difference in relationship to pain change before and after surgery.[16] As this was an exploratory study, no sample sizes were calculated.

Results

There were 28 participants (15 surgeons and 13 surgical trainees), 21 were male, mean (SD) age of 39 (10.3) years, and all but one were right-handed (n = 27, 96%). No participants withdrew during the study or removed their sensors early. However, two intended participants were excluded as one was allergic to tape and another wore the sensors but due to equipment malfunction no data were obtained. No demographic data were recorded for these two.

Participants were from the surgical specialties of orthopaedic surgery (n = 10, 36%), plastic surgery (n = 6, 21%), general surgery (n = 3, 10%), obstetrics and gynaecology (n = 5, 18%), urology (n = 2, 7%), respiratory (n = 1, 4%) and vascular surgery (n = 1, 4%). There were seven (25%) participants who reported a history of back injury, three (11%) reporting previous time off work due to back pain and 13 (46%) reporting some back pain at the end of their working day during the study period (Table 1). Only one participant reported their day as differing from a typical surgical list by stating they were supervising trainees nearing the end of their training and therefore had limited involvement with the surgery. A visual inspection of the EMG traces for all participants during the baseline flexion protocol showed the presence of the flexion relaxation phenomenon in 25 of the 28 participants. The three participants who did not show relaxation of the erector spinae muscles were from different surgical specialties, were all male over the age of 45 and all started the day with a VAS pain score of 0 that progressed to a low level change in pain (0–2 was the greatest change). Due to the small number of participants who did not exhibit the flexion relaxation phenomenon, a subgroup analysis of outcomes was not possible.

Participants spent on average 1.7 h sitting, 3.3 h standing and 0.7 h moving during the total recording period. The mean (SD) recording time for all surgeons was 6.1 (2.2) h. Subgroup analysis of uninterrupted postures was undertaken for obstetrics and gynaecology (n = 5, 18%), orthopaedic surgery (n = 10, 36%) and plastic surgery (n = 6, 21%). Figure 2 displays the average occasions of short (10–30 min), medium (30–60 min) and long term (>60 min) standing and sitting postures for the total participants (Fig. 2a) and the subgroups (Fig. 2b). Plastic surgeons recorded the greatest frequency of uninterrupted short-term sitting (n = 4.4 events) and short-term standing (n = 4.6 events) while orthopaedic surgeons (n = 0.9 events) had on average more events of uninterrupted standing between 31 and 60 min.

Flexion events were recorded a number of ways, firstly through the total number of all flexions per hour and the total number of sustained flexions (>30 s) per hour. Additionally, the average amounts of short term and sustained flexion at varied degrees were recorded while wearing the sensor. The degrees of flexion were grouped into 20–40° and 40–60° of short term and sustained flexions. The equipment also recorded >60° of flexion but no participants performed at this range.

Participants recorded, on average, approximately five flexions per hour and of these, on average, one was a sustained flexion. Figure 3a reports the average number of flexion events undertaken by all 28 participants and the subgroups. There was an average of 19 flexions recorded as short term within the 20–40° range compared to an average of five sustained flexions within the same range. Figure 3b demonstrates that the orthopaedic subgroup recorded the highest

Table 1 Participant pain reports

Pain report	Median (IQR), range
Current pain at the beginning of data collection (0–10)	0 (0), 0–3
Current pain at the end of data collection (0–10)	0.5 (2), 0–7
Typical or average pain over past month (0–10)	0 (1), 0–2
Pain at its best over past month (0–10)	0 (0), 0–5
Percentage of awake hours pain is at its best (%)	99 (5), 80–100
Pain at its worst over past month (0–10)	2 (4), 0–10
Percentage of awake hours pain is at its worst (0–10)	1 (4), 0–20
Oswestry disability index (%)	0 (0), 5–48

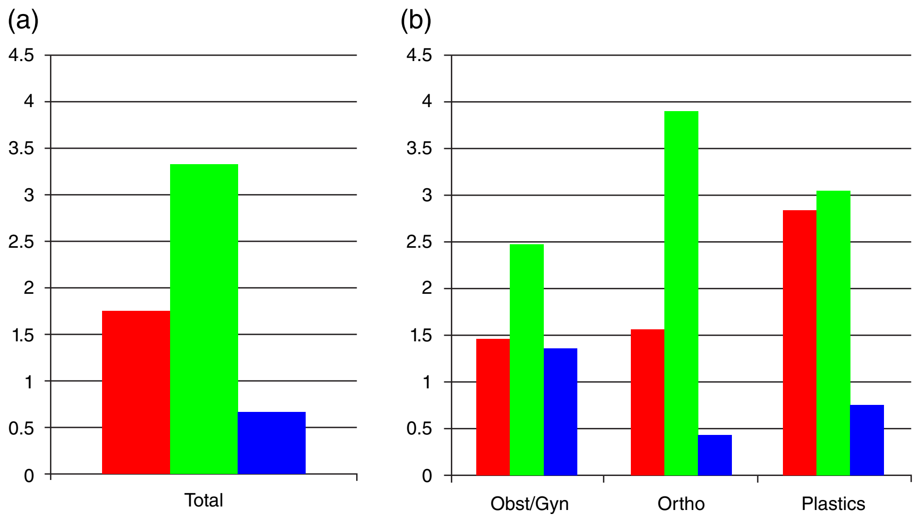

Fig. 2. Uninterrupted sitting and standing occasions of (a) total participants and (b) subgroups. (■) Average of sitting, (■) average of standing, (■) average of dynamic.

average number of short-term lumbar flexions in the 20–40° range (n = 24). Plastic surgeons recorded the highest average number of short-term flexions at the 40–60° range (n = 7). Obstetrics and gynaecology (n = 6) and plastic surgeons (n = 6) recorded the highest average number of sustained flexions in the 20–40° range, and plastics recorded the highest average of sustained flexions at 40–60° range (n = 3). Trainee data were separated from consultant data to determine if there was a trend between flexion events of each group. Orthopaedic trainees averaged a slightly larger number of flexion or sustained flexion events (n = 4.13 events per hour) compared to plastics trainees (n = 4.00 events per hour) and obstetrics and gynaecology (n = 3.38 events per hour). The numbers were too small to statistically analyse for differences but these trainee data was greater than all consultant average of flexion or sustained flexion events (orthopaedics = 2.83, plastics = 2.75 and obstetrics and gynaecology = 0.50 events per hour).

Lastly, right and left lateral flexions were explored in a similar manner to the forward flexions. On average, there were a total of 18 events of right lateral flexions compared to 35 on the left. This equated to an average of three events per hour on the right, compared to six on the left, one of these events per hour on the left were sustained. Figure 4a displays the average number of short term and sustained lateral flexions in the 10–15° and 15–20° ranges for each side.

The orthopaedic subgroup had over double the number of flexions between 10° and 15° (n = 44) to the left when compared to the right (n = 18). This trend was similar but not to the same extent in the other subgroups. Of interest, the participant who was left-handed was not in the orthopaedic subgroup.

There were only two participants with a pre–post VAS score change greater than 3.5, both participants reported a score difference of four. One participant reported a negative score difference and started the day with a VAS of two and reported zero at the end of the day. There was a significant difference in the paired scores at the beginning and end of the recording session ($z = -2.53$, $P = 0.012$). The lumbar movements were recorded over a mean (SD) of 6.1 (2.2) h, and ranged between 4 and 10 h of recording.

Discussion

This is the first study to quantify real time back motion of surgeons within the theatre setting while undertaking or supervising surgical procedures. The only other study to quantify lumbar movement only included five participants and used video. Differences were reported between laparoscopic and open operating.[7] Due to the different study designs, participants and data collection methods, limited comparisons can be made to our data. Therefore, this study has

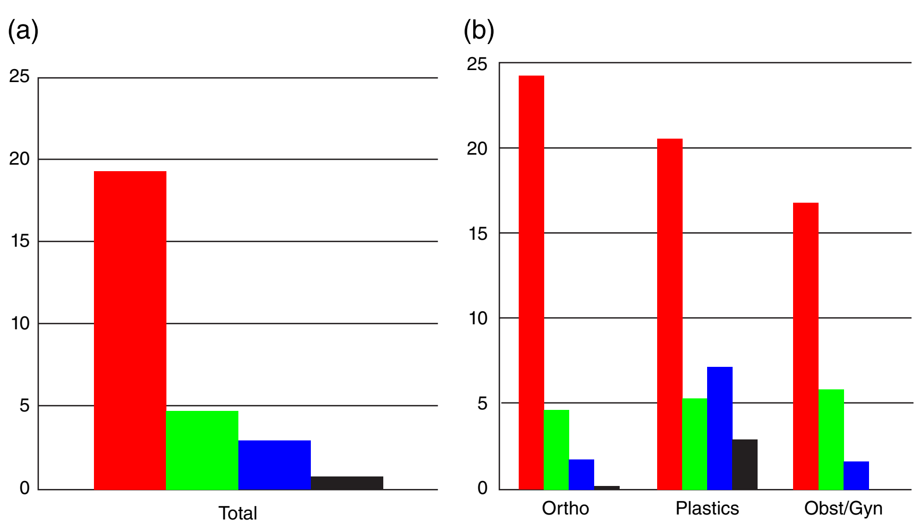

Fig. 3. Average number of short-term and sustained flexions during the recording time for (a) total participants and (b) subgroups. (■) Average of short-term flexion, 20–40°; (■) average of sustained flexion, 20–40°; (■) average of short-term flexion, 40–60°; (■) average of sustained flexion, 40–60°.

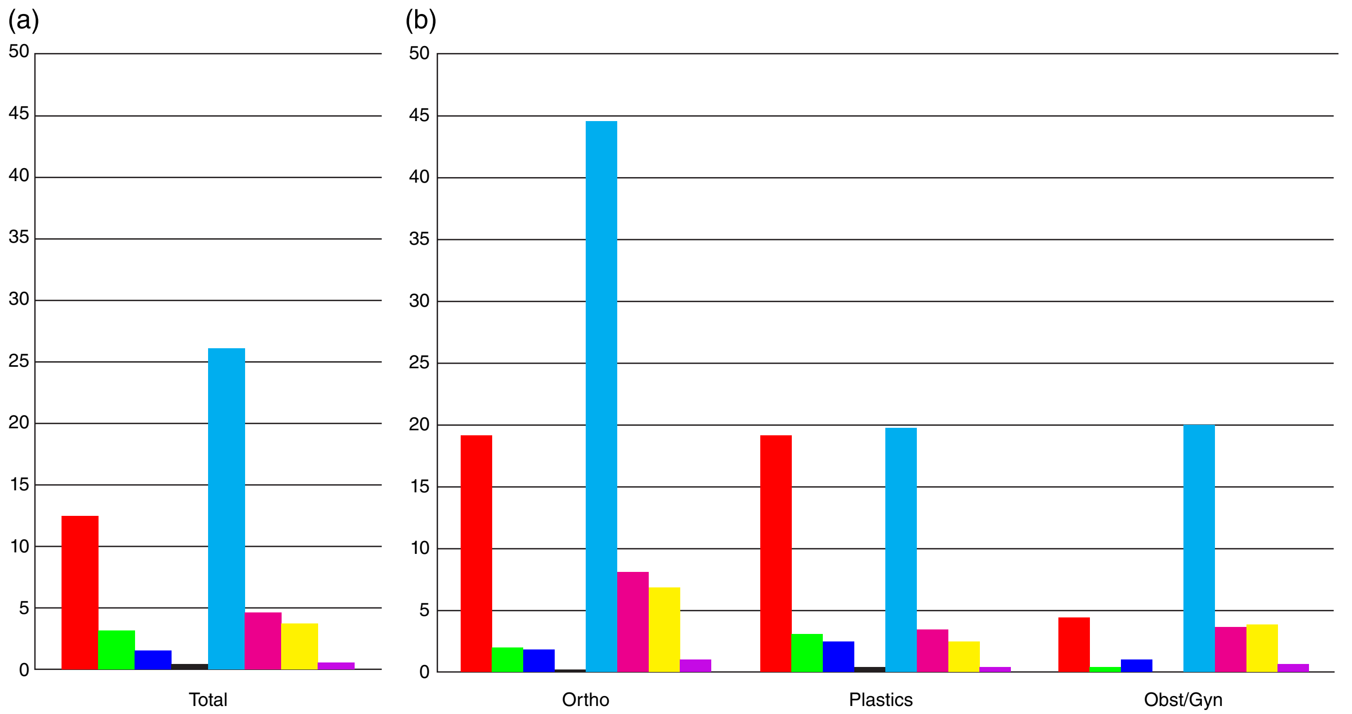

Fig. 4. Right and left short-term and sustain flexions for (a) total participants and (b) subgroups. (■) Average of short-term right lateral flexion, 10–15°; (■) average of sustained right lateral flexion, 10–15°; (■) average of short-term right lateral flexion, 15–20°; (■) average of sustained right lateral flexion, 15–20°; (■) average of short-term left lateral flexion, 10–15°; (■) average of sustained left lateral flexion, 10–15°; (■) average of short-term left lateral flexion, 15–20°; (■) average of sustained left lateral flexion, 15–20°.

successfully quantified low back movement patterns across a number of surgical specializations. With no other available comparative studies, these results can act as a foundation for future research. The data collected within the present study is unique and offers insights into the physicality required within the operating theatre.

The protocol for our data collection included full flexion movements at baseline, at which time the flexion relaxation phenomenon was identified through EMG traces. The flexion relaxation phenomenon has been identified as a transfer of tissue loading during end of range flexion.[17] Visual inspection of EMG patterns in healthy individuals should see an absence or insignificant impairment of the EMG trace for the erector spinae muscle group during full flexion. As the presence or absence of lower back pain was not a selection criterion for our research, variance in the flexion relaxation phenomenon was unlikely. Although there were a small number of participants without this relaxation phenomenon, this small number did not allow for further analysis. This is particularly because the demographic characteristics of the three participants (age, gender, handedness, surgical specialty, baseline VAS) were similar to the rest of the participants. As measures of muscle fatigue or flexibility were not a part of this study, it is difficult to determine if the absence of the flexion relaxation phenomenon was related to any other demographic differences has been reported in the literature or workload of the prior day.

Movement patterns are hard to change. It is also difficult to match movement patterns with pain as no real time movement studies and limited self-report studies exist to compare these results. One study has shown a link between sustained trunk axial twisting to the development of lower back pain.[18] Overall little is known about particular movement patterns precipitating pain. This present study suggests that different movement types and pain may be associated, but the sample size was too small to answer this question. Although it would be intuitive that certain type of movements such as asymmetrical or sustained movement would be more likely to contribute to the development of pain, we were unable to find a relationship due to the small participant numbers in this study.

The secondary aim of this study focused on quantification of LBP in this cohort. Similar to other studies, participants within this present study reported an increase in the level of pain at the end of the surgical list.[19–21] Pain at the end of the working day was significantly higher than at the commencement and again, this is consistent with what is known about this working environment.[19] However, the pain recorded by participants was considered to be low-grade pain and only one participant recorded an ODI score consistent with a severe impact on activities of daily living and as such, this pain should be further investigated by this individual in order to maintain good health during their surgical career.

Musculoskeletal pain has been reported as a major problem among other health care professions whose tasks require adoption of flexed postures including dentists[22] and podiatrists.[23] Previous studies using self-reported data[3,21] found LBP in surgeons to be far higher than what was found within these participants within this present study. Surgeons in other studies have reported pain severe enough to force a break from operating to relieve symptoms.[19] Although the task requirements,[2] surgical equipment[24] and operating theatre set up individualized to procedures[25] differs across specialties, LBP is a consistent finding across all surgical specialties.

Limitations of this study included an insufficient number of participants with minimally clinical important changes in pain to identify if there were specific lumbar movements associated with LBP. Another limitation was that there was no quantification of the level of surgeon involvement in the surgical procedure or differentiation of operating versus non-operating (or supervising) time while wearing the motion sensor equipment. Larger number of participants or repeated measures with different surgical procedures would assist in exploring these factors better. Additional recording from the surgeons or trainees for exact operating time would also be required to understand the differences in movements between actually performing surgery compared to supervision. As this study was undertaken in a training hospital, there was potential for the surgeon being monitored to either be leading the surgery, assisting with the surgery or observing the surgery. Care must be taken in interpreting the subgroup analysis due to the small numbers. It was deemed valuable to report these details as a guide for future research to consider the differences between specialties and how they move during surgery.

The study demonstrated feasibility of real time measurement of lumbar movements for surgeons and surgical trainees during their working day. Future research should consider the correlation of movement patterns with pain symptom development. This would be particularly helpful to identify high risk specialty groups within surgery. Identification of high risk movement patterns by individual surgeons in these specialty groups early in their career may lead to remediable intervention to increase the longevity of their surgical career.

Conclusion

This study has quantified lumbar movements of surgeons and surgical trainees during their surgical activities. By quantifying these low back movement patterns this research could help to reduce occupational musculoskeletal symptoms in surgeons by identifying ergonomically safe postures and movements, and inform the design of suitable work equipment and settings. In addition, this work has set a foundation from which further research can quantify the low back movement of differing surgical specialties and assist in the planning of return to work procedure for an injured surgeon.

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Conflicts of interest

None declared.

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