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ORIGINAL ARTICLE

Ergonomic assessment of robotic general surgeons: a pilot study

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Abstract

Inadequacies exist in the ergonomics of upper body positioning of robotic surgeons; these deficits in biomechanical efficacy predispose surgeons to musculoskeletal injury. Ergonomics and biomechanics may be objectively measured using the Rapid Entire Body Assessment (REBA) and the Rapid Upper Limb Assessment (RULA) to quantify ergonomic efficacy. The purpose of this study is to use validated ergonomic tools to assess the posture of robotic surgeons to examine deficiencies. Four robotic surgeons using the da Vinci model were observed for a minimum of 30 min each. An Xbox connect camera was positioned 10 feet away from the surgeon console. Kinetisense software measured position of the head, shoulders, mid-spine, hips, and knees. One image was captured every 30 s. The software measured the positions in centimeters that deviated from an ideal central postural line (plumb line). RULA and REBA were also employed to assess posture using a still image at 15 min. The average RULA score for the four surgeons was 4.75 (range 3–6). The average REBA score for the four surgeons was 7 (range 5–8). The average RULA score of 4.5/7 and the average REBA of 7/15 qualify as medium risk with the recommendation that action is needed to improve ergonomics. While this pilot study is limited in size, it demonstrates the need for further investigation. With more than half of surgeons reporting musculoskeletal pain after robotic surgery (McDonald et al. in Gynecol Oncol 134:243–247, 2014), poor posture may offer an explanation.

Keywords Ergonomics · Robotic · Human factors · Surgery

Introduction

Robotic surgery is among the latest innovations in the world of minimally invasive surgery and its application only continues to grow. While the technological advancement and software of robotic surgery continues to advance, the ergonomics of use for the surgeon has not followed suite. The ergonomics of the upper body in respect to robotic surgery contains serious deficits that predispose surgeons to musculoskeletal injury; with 61% of robotic surgeons reporting physical discomfort after cases [1]. Wang et al. [2] conducted a study where 127 surgical oncologists at MD Anderson were surveyed about occupational injury. 27.6% reported an occupational injury, 65.7% of which received some form of treatment with 17.4% of those treated requiring surgical intervention. Occupation ergonomics, especially in robotic surgery, plays a major role in the physical well-being of surgeons and can lead to lower volume of cases performed and threatens premature retirement due to potential musculoskeletal injury. This concern is magnified when we find that the American Medical Colleges forecast a deficit of 41,000 general surgeons by the year 2025, accounting for 33% of the total physician shortage [3]. This is further worsened due to a 13% decrease in US medical students matching to general surgery residency programs since 1994 [4]. Surgeons are an invaluable asset to the medical field and with the shortage becoming more prevalent, it is imperative to maximize the productivity of surgeons and lengthen their careers to provide invaluable care. One of the ways this can be accomplished is by optimizing the ergonomics of the operating room especially in regard to robotic surgery. This can be seen in other professions who have made it a priority to monitor ergonomics and biomechanics using graded tools to quantify ergonomic efficacy. Among these tools is the Rapid Entire Body Assessment (REBA) or the Rapid Upper Limb Assessment (RULA). Currently, over half of robotic surgeons report physical discomfort after cases.

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Our hypothesis is that current ergonomics for robotic surgeons are poor which leads to physical discomfort after performing these cases. The purpose of this study is to assess posture and current ergonomics or robotic surgeons using validated ergonomic tools in hope of being able to shine a light on this problem and begin the discussion on understanding the biomechanics of robotic surgeons to provide a better solution moving forward.

Methods

Participants

Four general surgeons volunteered for this study: two males and two females. All surgeons had no current history of lower back pain or had taken any sick leave due to musculoskeletal pathology in the past 12 months. Exclusion criteria include a history of scoliosis, spinal surgery, vestibular disorders, lumbosacral/musculoskeletal pathology, or neurologic diseases.

Data collection section

Four robotic surgeries using the da Vinci Xi model were observed for a minimum of 30 min each: two cholecystectomies, one partial colectomy, and one appendectomy. An Xbox connect camera positioned 10 feet away from the surgeon console was used to obtain the necessary data points. Kinetisense software was used to measure positions of the head, shoulders, mid-spine, hips, and knees to assess posture. One image was captured every 30 s during the entire 30 min that was recorded. The software measures the positions in centimeters behind or in front of a central line, also known as the plumb line (Fig. 1). The plumb line is a validated tool used to assess posture [5]. It is a midline sagittal plane that transverses the tragus of the ear, the shoulder joint, the greater trochanter, and the lateral malleolus. The software also provides normal values for each joint position. As a secondary assessment of posture, we used the Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA) to validate the data collected above. The REBA [6] and RULA [7] are validated tools that score both overall ergonomics and upper limb ergonomics through the evaluation of different joints, assessing risk and recommending changes based on the risk. Both the REBA and RULA tools are similar except for the RULA is better at measuring sitting objects. For the REBA and RULA tool, a still image from the 15-min mark of the surgery was used to obtain data points.

Fig. 1 Kinetisense image capture of robotic surgeon positions

Statistical analysis

A two-tailed t test to account for absolute value from the plumb line was used for statistical analysis. The population mean used was the value the software defines as average for each joint (x). The null hypothesis is that the surgeons head, shoulder, mid-spine, hip and knee positions are average or better. An alpha value of 0.05 was used, so that if the p value is < 0.05, this would indicate that the joint is in a poor ergonomic position. Due to software errors in the camera, values that were three standard deviations from the mean were recorded. These represented objects in the field other than the surgeon. These values are incompatible with normal anatomy, so they were, therefore, discarded and not incorporated into the analysis.

Primary posture assessment

An Xbox connect camera with the Kinetisense tool software to measure the distance in centimeters from the plumb line of different joints (as seen in Fig. 1) was used for primary assessment of posture. Every 30 s, an image was captured from the recorded video to obtain an image and the program provides measurements of head, shoulder, mid-spine, hip, and knee position.

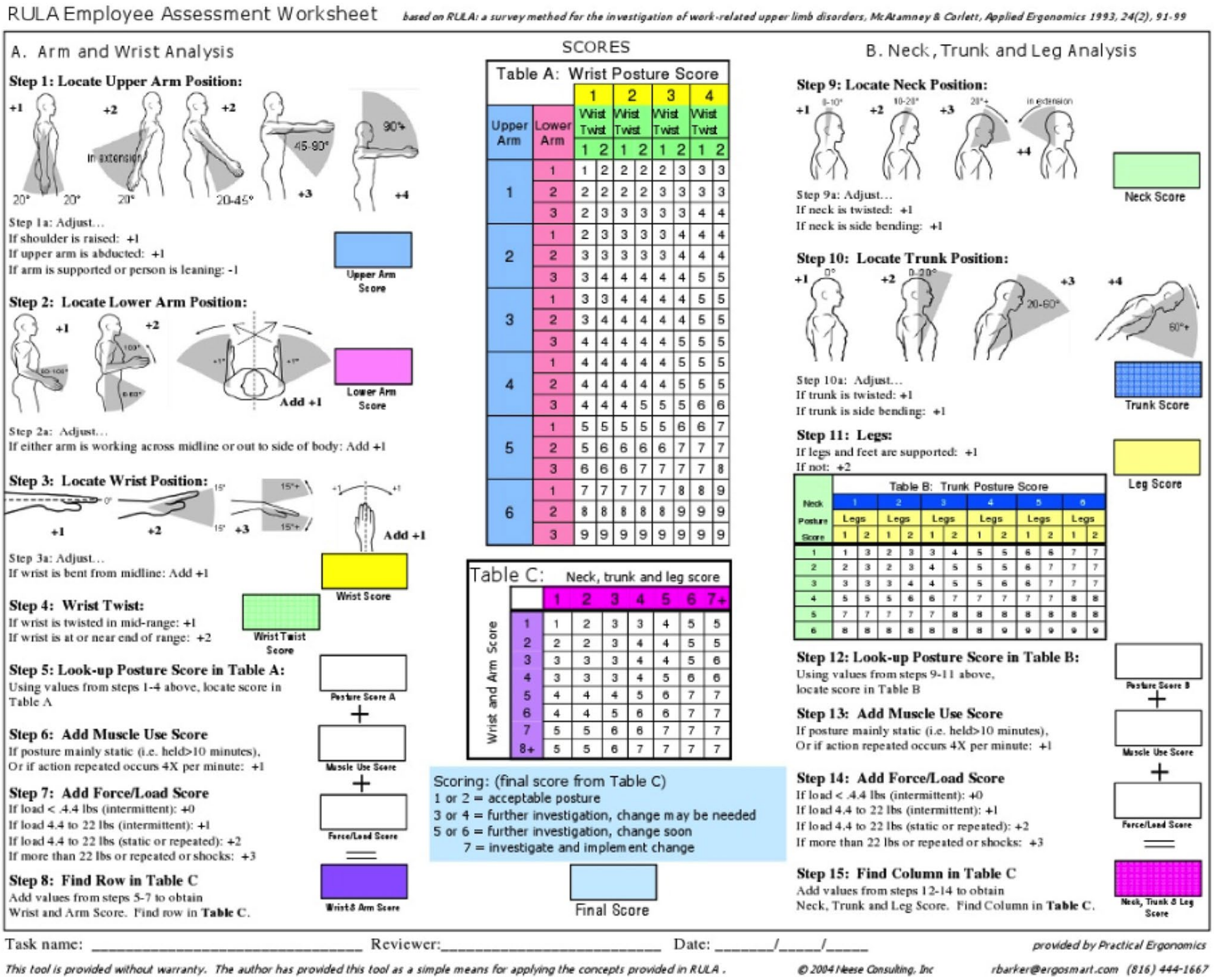

Fig. 2 Rapid Upper Limb Assessment (RULA)

Secondary posture assessment

An image from the 15-min mark from the recorded video was used to perform the Rapid Entire Body Assessment (REBA) and Rapid Upper Limb Assessment (RULA) as secondary tools to confirm our data. The RULA requires a still image for evaluation. Joint positions are scored using a series of charts. The score is used to assess the need for improvement in ergonomic efficacy (Fig. 2). The REBA (Fig. 3) is similar to the RULA but includes a lower body assessment for standing subjects. Of note, the participants are sitting when performing robotic surgery. Given the validity of both the REBA [6] and RULA [7] using both should give the Kinetisense results perspective.

Results

Kinetisense posture assessment

Normal values according to the Kinetisense tool are less than 6 cm forward (FWD) or behind (BHD) midline for the head position, less than 5 cm FWD/BHD for shoulder position, less than 5 cm FWD/BHD for mid-spine position, less than 4 cm FWD/BHD for hip position, and less than 2 cm FWD/BHD for knee position. Any value larger than these is classified as poor posture. These will statistically be used as the population mean.

Average Kinetisense postural assessment

Individually, male 1’s (DC) average head, shoulder, mid-spine, hip, and back position were -17 cm (SD = 8.23 cm; p value < 0.00001), 6 cm (SD = 7.56 cm; p value = 0.02),

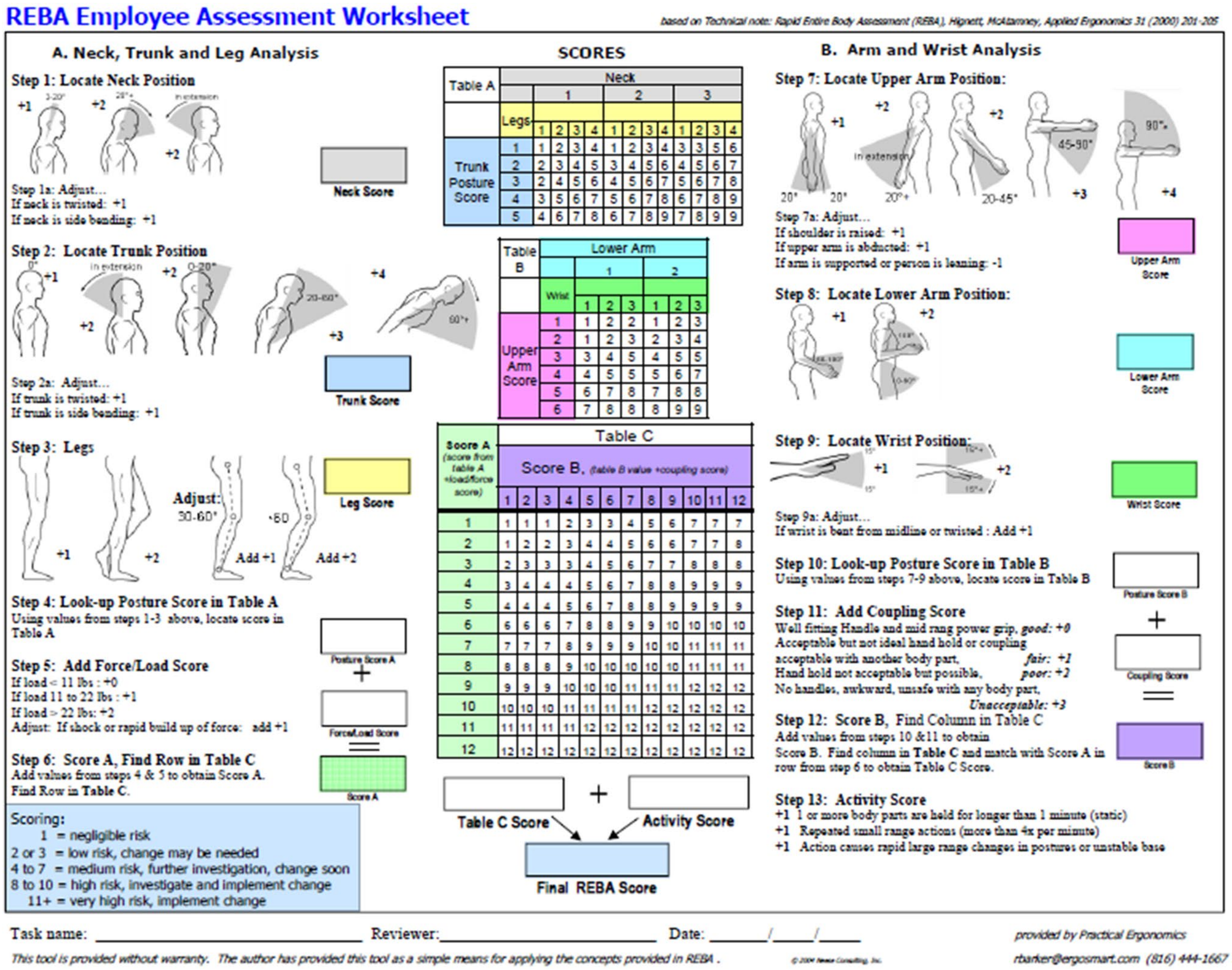

Table A	Neck	1				2				3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Table B	Lower Arm	1			2		
	Wrist	1	2	3	1	2	3
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

Table C Score A (score from table A +load/force score)	Score B, (table B value +coupling score) 1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Fig. 3 Rapid Entire Body Assessment (REBA)

− 15.5 cm (SD = 2.51 cm; p value < 0.00001), − 8.5 cm (SD = 3.54 cm; p value < 0.00001), and 7.5 cm (SD = 2.11 cm; p value < 0.00001), respectively; male 2's (SM) average head, shoulder, mid-spine, hip, and back position were − 9.5 cm (SD = 14.89 cm; p value < 0.00001), 7 cm (SD = 11.34 cm; p value = 0.65), − 5.5 cm (SD = 13.14 cm; p value < 0.00001), − 6 cm (SD = 12.22 cm; p value = 0.00007), and 16 cm (SD = 9.25 cm; p value = 0.00354). Female 1's (RD) average head, shoulder, mid-spine, hip, and back position were − 20.81 cm (SD = 3.28 cm; p value < 0.00001), − 3.53 cm (SD = 3.58 cm; p value < 0.00001), − 17.12 cm (SD = 3.46 cm; p value < 0.00001), − 11.53 cm (SD = 4.22 cm; p value < 0.00001), and 21.29 cm (SD = 6.29 cm; p value < 0.00001), respectively. Female 2's (RA) average head, shoulder, mid-spine, hip, and back position were − 4.5 cm (SD = 5.15 cm; p value < 0.00001), 10.5 cm (SD = 7.77 cm; p value < 0.00001), − 6.5 cm (SD = 5.05 cm; p value = 0.00069), − 14.5 cm (SD = 10.53 cm; p value = 0.01409), and − 7.5 cm (SD = 10.02 cm; p value = 0.007), respectively.

RULA and REBA

The average RULA score for the four surgeons was 4.75. The scores ranged between 3 and 6. According to the RULA assessment tool (Fig. 2), a score of 1–2 is acceptable posture, 3–4 requires further investigation and change may be needed, 5–6 further investigation and change soon, and 7 investigate and implement change immediately.

The average REBA score for the four surgeons was 7. The scores ranged between 5 and 8. According to the REBA assessment tool (Fig. 3), a score of 1 is negligible, 2–3 is low risk, 4–7 is moderate risk, and 8–10 is high risk. Above 10 is considered extremely high risk.

Table 1 Average Kinetisense postural assessment

Surgeon	Average head	Shoulder	Mid-spine	Hip	Back position
Male 1 (DLC)	− 17 cm SD = 8.23 cm p value < 0.00001	6 cm SD = 7.56 cm p value = 0.02	− 15.5 cm SD = 2.51 cm p value < 0.00001	− 8.5 cm SD = 3.54 cm p value < 0.00001	7.5 cm SD = 2.11 cm p value < 0.00001
Male 2 (SM)	− 9.5 cm SD = 14.89 cm p value < 0.00001	7 cm SD = 11.34 cm p value = 0.65	− 5.5 cm SD = 13.14 cm p value < 0.00001	− 6 cm SD = 12.22 cm p value = 0.00007	16 cm SD = 9.25 cm p value = 0.00354
Female 1 (RD)	− 20.81 cm SD = 3.28 cm p value < 0.00001	− 3.53 cm SD = 3.58 cm p value < 0.00001	− 17.12 cm SD = 3.46 cm p value < 0.00001	− 11.53 cm SD = 4.22 cm p value < 0.00001	21.29 cm SD = 6.29 cm p value < 0.00001
Female 2 (RA)	− 4.5 cm SD = 5.15 cm p value < 0.00001	10.5 cm SD = 7.77 cm p value < 0.00001	− 6.5 cm SD = 5.05 cm p value = 0.00069	− 14.5 cm SD = 10.53 cm p value = 0.01409	− 7.5 cm SD = 10.02 cm p value = 0.007

Discussion

This study was designed to assess the need for further investigation into the kinematics of robotic general surgery and to shine light on an issue that plagues this community. The data collected by Kinetisense confirms (Table 1) that each of the participants had poor ergonomic posturing. On average each individual surgeon had poor posture in each of the five categories according to the Kinetisense assessment tool. Individually, the surgeon's average posture was poor with only one surgeon (RA) having acceptable head posture at − 4.5 cm ($p = 0.65$). The other joint positions of all individual surgeons were extremely poor with p value < 0.05.

The Kinetisense software gives hard data on the joint position of individuals which is extremely valuable but not widely used. Therefore, the RULA [6] and REBA [7] tools which are validated and widely used were utilized as a secondary assessment and comparison to the Kinetisense tool. The RULA and REBA are scored systems that look at the angles and positions of different body parts to assess the need for ergonomic quality improvement. The RULA focuses on the upper body and is good for sitting subjects. The REBA is used to assess the entire body. The average RULA score was 4.5/7, which recommends further investigation and suggests that change may be needed. The average REBA score for the group was 7/15, which qualifies as medium risk and falls under the recommendation that action is needed to improve ergonomics. Although the total score of 15 includes the lower body assessment (i.e., knees, legs) which were made to assess a standing individual, this lower body assessment is not relevant due to the surgeons being seated and indicates that a score of 7 may actually be an underestimation of the overall score. Our surgeons were sitting, so the lower extremity portion of the REBA was given scores of zero. This assumes that the lower posture is perfect and did not contribute to the average of 7. At best, the average score is 7 which is at the higher end of medium risk. The need to improve ergonomic quality is necessary and these validated tools support the data from the Kinetisense software.

The Kinetisense tool was easy to use but had its limitations. The camera would capture objects in the field of view other than the surgeon giving some values that are outside the scope of normal human biomechanics. To account for these outliers, if any value was more than three standard deviations from the mean then they were discarded from the data set. More accurate cameras and software exist but for the funding allowed for this pilot study, this software was the best available. This may be an area of improvement in future studies with larger sample sizes. The data are still promising because the RULA and REBA are validated ergonomic assessment tools that support the findings from the Kinetisense software.

Another limitation is the size of the study. While this study is limited to four participants, the goal is to show the possibility of a need for further investigation. With more than half of surgeons reporting musculoskeletal pain after robotic surgery [1], poor posture and biomechanics may offer an explanation. There are many studies that investigate musculoskeletal disorder in dentists but with the general laparoscopic robotic surgery only being FDA approved as recently as the year 2000, there is need to assess the risk to surgeons using this technology. While the technology and the advantage that robotic surgery brings to patient care are noticeable, it lacks in proper ergonomic positioning for the surgeon. This technology is being incorporated more and more into the surgical world, making it imperative to improve the risk it poses to surgeons. The hope is that this study will open the door for innovations and improvements in ergonomics which may prolong the careers of our fellow surgeons.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. McDonald ME, Ramirez PT, Munsell MF, Greer M, Burke WM, Naumann WT, Frumovitz M (2014) Physician pain and discomfort during minimally invasive gynecologic cancer surgery. Gynecol Oncol 134(2):243–247
2. Wang DS (2017) Re: do no harm, except to ourselves? A survey of symptoms and injuries in oncologic surgeons and pilot study of an intraoperative ergonomic intervention. J Urol 198(4):721
3. Tierney J, Terhune K (2017) Expanding the National Health Service Corps Scholarship Program to general surgery: a proposal to address the national shortage of general surgeons in the United States. JAMA Surg 152(4):315–316
4. Are C, Stoddard H, Carpenter LA, O'Holleran B, Thompson JS (2017) Trends in the match rate and composition of candidates matching into categorical general surgery residency positions in the United States. Am J Surg 213(1):187–194
5. Kendall FP, McCreary EK, Provance PG, Rodgers MM, Romani WA (2005) Muscles: testing and function, with posture and pain (Kendall, muscles). Lippincott Williams & Wilkins, Philadelphia
6. Chubineh A (2004) Posture analysis methods in occupational ergonomics, vol 1383. Fanavaran Publication, Tehran, pp 2–50
7. McAtamney L, Corlett EN (1993) RULA: a survey method for the investigation of work-related upper limb disorders. Appl Ergon 24(2):91–99

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