ORIGINAL ARTICLE

Features of an Ergonomic Chair Designed for Surgeons Performing Microscopic Surgeries

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ABSTRACT

Introduction: This study aimed at ergonomic assessment of the risk of musculoskeletal disorders among microscopic surgeons , investigate the specification of ergonomic chairs and designing one for use during microscopic surgeries. **Methods:** This descriptive study was performed on 27 micro surgeons out of 4 surgeons (ear, nose and throat), eye surgery, neurosurgery and plastic surgery in Khalili, Namazi, Shahid Chamran and Shahid Faghihi hospitals in Shiraz, Iran. The study was carried out in 4 steps. Objective evaluations included posture assessment by RULA and assessment of postural angles of the body (during performing microscopic surgeries) by Digimizer software. Subjective evaluation included the assessment of pain intensity and chair comfort using a visual analogue scale. next step was to determine the necessary anthropometric dimensions of the micro-surgeons. The fourth step was 3D modeling of the initial idea using Sketch Up 2017. **Results:** The mean and standard deviation of the final RULA scores of the surgeons' postures were obtained 6.75 ± 0.5 and 6.5 ± 0.57 for the right and left sides of the body, respectively. Pain VAS scores after using normal chairs for microscopic surgeries were 5.32 (low-back pain), 4.42 (right shoulder/ arm pain) and 4.15 (left shoulder/ arm pain) which were their highest pain scores. The results of the assessment of postural angles by Digimizer software also showed a high risk of musculoskeletal disorders in the arm, forearm, wrist, neck, and trunk. **Conclusion:** In terms of ergonomics, the chair with the specifications listed may reduce physical fatigue and a potentially safer working environment for surgeons to create.

Keywords: Design, Ergonomic Chair, Surgeons, Microscopic Surgery

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INTRODUCTION

Work-related musculoskeletal disorders (WMSDs) are among the most common causes of chronic pain and disability in health care personnel (1) including surgeons due to the nature of their daily work (2). Studies have shown that physical (3-6), psychosocial / organizational (7-12, 3), individual (3, 13) and occupational factors cause these disorders (14, 15). According to NIOSH, there is strong evidence that workgroups with high-level static contractions, prolonged static loadings, or extreme working postures are at increased risk for musculoskeletal disorders of the shoulder, neck and low-back (16). Surgeons usually work with sharp instruments and sophisticated equipment which will create many opportunities for neck, finger, hand, arm or wrist injuries (17, 18). Despite their limited knowledge of ergonomics (19), they try to reduce pain during surgery. The most commonly used approach is position change; however, this approach is not effective enough due to the constraints on room and instruments (20-22). In some cases, surgeons may have to improve the symptoms by reducing workload or undergoing open surgery instead of minimally invasive surgery (23).

Today, surgeons use minimally invasive procedures. These procedures often place more physical demands on the surgeon's body than in open surgeries (24). Studies have shown that the prevalence of musculoskeletal symptoms is significantly higher in surgeons (who perform minimally invasive surgery) and endoscopists compared with that in other medical and surgical specialists (25). WMSDs of upper extremities, neck, and low-back are often called cumulative trauma disorders. Surgeons' exposure to one or multiple risk factors, such as repeated and inappropriate positioning, is very likely. This exposure is enhanced due to the amount of time spent on working with microscopes (26). Given that the seat-stand ergonomic chairs designed for surgeons (27) do not provide the ergonomic posture required for microscopic surgeries while they can prevent back pain during open surgeries (3), this study aimed to investigate the characteristics of ergonomic surgeon's chair and design it for use during microscopic surgeries. That is because, over the past two decades, new innovations have led to a significant increase in the prevalence of microscopic surgeries (28). As a result, poor posture and musculoskeletal strain can increase disability rates and decrease the surgeon's life-span (29).

MATERIALS AND METHODS

This was a cross-sectional study. The sample size was determined from census data to be 27 surgeons from 4 surgical specialties, including Ear, Nose and Throat (ENT) surgery, eye surgery, neurosurgery and plastic surgery, who performed microscopic surgeries at Khalili, Nemazee, Shahid Chamran, and Faghihi teaching hospitals. The Inclusion criterion was the surgeons' musculoskeletal health. The study population consisted of all micro-surgeons of the teaching hospitals of Shiraz University of Medical Sciences. The study was carried out in 4 steps. The first steps was reviewing the literature related to the purpose of the study and the second step included interviewing micro-surgeons, viewing and preparing their photos and films and also ergonomic assessment of the risk of musculoskeletal disorders during performing microscopic surgeries.

Ergonomic assessment

a) Posture assessment by Rapid Upper Limb Assessment (RULA): At this stage, the postures of micro-surgeons were assessed by RULA during microscopic surgeries. RULA is the most applicable ergonomic assessment tool for the ergonomic analysis of working postures of microlaryngeal surgeons since these surgeons maintain a static sitting position (for a prolonged time) similar to that in some manufacturing tasks (30).

First, the worst or the most repetitive postures of the micro-surgeons were sampled using an observational method. Then, the samples were evaluated (Group 'A' diagrams were used for the arm, forearm and wrist positions; Group 'B' diagrams were used for the neck, trunk and leg positions). The scores of repetitive tasks and force were extracted from the respective tables and were added to 'A' and 'B' scores to obtain 'C' and 'D' scores, respectively. Using Table 'C', 'C' and 'D' scores were merged together to get the final score. In this way, the priority level of corrective actions was determined. In this technique:
- Action Level 3: final scores of 5 and 6 indicate further study, ergonomic modifications and intervention are needed in the near future.
- Action Level 4: final scores of 7 and above indicate further study, ergonomic modifications and intervention are immediately required.

b) Assessment of postural angles by Digimizer software: At this stage, the postures of the surgeons were filmed for 30 minutes during each microscopic surgery. Then, 20 postures from the second ten minutes of each film (30 seconds each) were entered into Digimizer software. Then, different postural angles were measured.

c) Assessment of pain intensity and chair comfort via Visual Analogue Scale (VAS): The VAS consisted of a 10 cm line segment where the user placed a mark. At the end of the evaluation, given that each scale could be divided into ten equal intervals, a ruler was used to measure the distance from the starting point of the scale to the user's marks. Regarding pain intensity assessment, a score of 0 indicated "no pain" and a score of 10 indicated "unbearable pain" and with regard to chair comfort assessment, a score of 0 indicated the lowest degree of chair comfort and a score of 10 indicated the highest degree of chair comfort.

This evaluation was performed in a simulation environment. In simulation conditions, finding the most appropriate surgical task is crucial. To do so, microlaryngeal surgery was considered (31). This stage consisted of 7 micro-surgeons with at least 3 years of experience in microscopic surgery. The users were randomly selected. They were trained to perform simulation surgery. The height of the bed, the height of the chair and the location of the microscope and its eyepieces were manipulated for each participant to achieve optimal conditions. The task duration was 15 minutes. The participants completed the pain intensity questionnaire before and after the task. In this way, each individual was compared with himself/herself in terms of pain intensity. Moreover, the demographic questionnaire was also filled in by the users before the experiment. Additionally, at the end of the experiment, the surgeon was asked to fill out the normal chair evaluation form.

3-Dimensional (3D) modeling

The first step was to determine the necessary anthropometric dimensions of the micro-surgeons. A digital vernier caliper (ASIMETO, Germany), with the resolution ratio of 0.01 mm, was used for measuring length, height, and width dimensions. All dimensions were measured by one operator. To ensure the consistency of measurements, the intra-operator reliability was assessed using intra-class correlation coefficient (ICC). The values of ICC ranged between 0.931 and 0.992 for different dimensions. The fourth step was 3D modeling of the initial idea using Sketch Up 2017. The experienced surgeons and industrial designers were consulted before and after 3D modeling of the initial idea. The initial idea resulted from the existence of problems. Some imperfections of the existing surgical chairs include: they do not have back rests, chest support, arm rests, ergonomic seats, foot rests or foot pedals; they are not designed specifically for surgeons and ergonomic principles are not considered in their design; they are also incompatible with the type of surgery and are not user- friendly. One of the principles in designing the new chair is that the depth of anterior-posterior lumbar curve of the short backrest should be 15 to 20 mm and the optimum backrest angle should be between 100 ° and 110 ° providing a stable base of support for upper extremity movements. In addition, since microscopic surgery is a delicate and precise work, using a hand rest is recommended.

Statistical analysis
The study data were analyzed using the Statistical Package for Social Sciences 19 (SPSS Inc., Chicago, IL, USA). The quantitative variables were reported as the mean and standard deviation and the qualitative variables were reported as frequency and percentage. A p-value less than 0.05 was considered to be statistically significant.

RESULTS

Figure 1 shows the posture and chair sample used by a micro-surgeon during a microscopic surgery.

Ergonomic assessment
The mean and standard deviation of the final RULA scores of the surgeons' postures were obtained 6.75 ± 0.5 and 6.5 ± 0.57 for the right and left sides of the body, respectively. These values are close to the final score of 7 (level 4 corrective actions) which means that further study, ergonomic modifications and intervention are immediately required.

The mean time of each microscopic surgery was 1.71 hours and the average number of daily working hours (microscopic surgery) was 3.42 and 4 hours in sitting and standing positions, respectively. The average daily working hours of the micro-surgeons were 4.71, 1.28 and 1.42 hours for forward bending, upright seated and lean-back positions respectively. Therefore, it can be said that these surgeons spent most of their working hours bending forward.

Pain VAS scores after using normal chairs for microscopic surgeries were 5.32 (low-back pain), 4.42 (right shoulder/ arm pain) and 4.15 (left shoulder/ arm pain) which were their highest pain scores. Their lowest pain scores were 2.64 (right hand / wrist) and 2.51(left hand / wrist).

According to Table I, the available chairs used by micro-surgeons (given the VAS mean scores) were evaluated to be poor-quality chairs in terms of facilitating performance (2.54), improving posture (2.31), and easy adjustments during an activity (1.35). These chairs were almost ineffective for reducing physical pressures placed on the neck (0.9) and shoulder/arm (0.38) and a little bit effective for reducing physical pressures placed on the low back (1.81). These chairs were found to be effective for reducing physical pressures placed on the knee/leg (3.07).

Table 1: Chair comfort assessment (n=7)

Items	Mean	SD
Facilitating performance	2.54	2.01
Improving posture	2.31	1.69
Reducing physical pressures in:		
Neck	0.90	1.04
Shoulder-Arm	0.38	0.52
Waist	1.81	1.38
Knee-feet	3.07	1.36
easy adjustments	1.35	1.79

3-Dimensional (3D) modeling
a) Measurement of anthropometric dimensions: At this stage, 23 dimensions of the body of micro-surgeons and their residents (14 males and 10 females) were measured (Table II). Each of these dimensions can be used depending on the characteristics of the chair and considering the need, cost, etc. The mean age of the participants at this stage was 37.37 ± 6.11 years. The mean height and weight for the male participants were 174.39 ± 4.94 cm and 73.3 ± 4.68 kg, respectively. The mean height and weight for the female participants were 163.8 ± 2.97cm and 61.33 ± 5.25kg, respectively.

b) 3-D modeling of the initial idea using Sketch Up 2017: This was the final step and resulted in a chair 3-D model for microscopic surgeons (Figure 2). Table III shows the

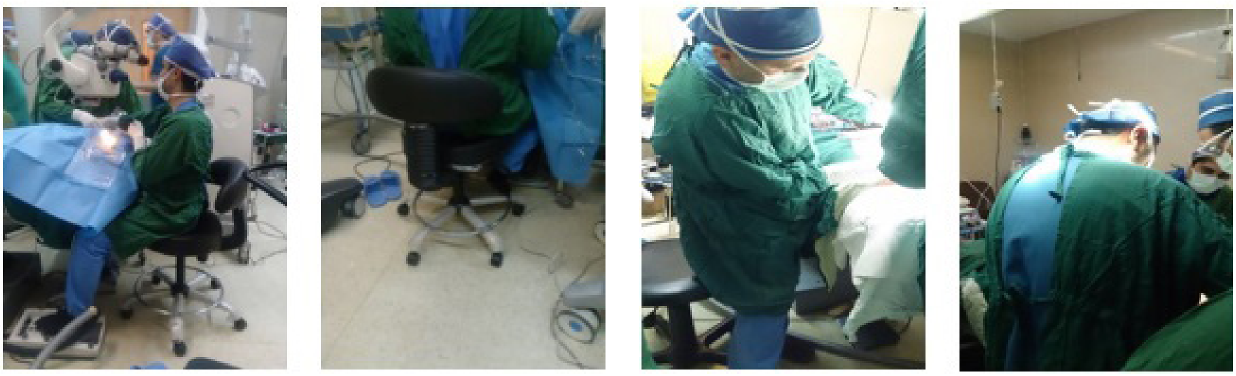

Figure 1: Posture and chair sample used by a micro-surgeon during a microscopic surgery

Table II: Anthropometric dimensions of the body of micro-surgeons (n=24)

(cm) Dimension	Percentiles							
	Males (n=14)				Females (n=10)			
	5th	50th	95th	SD	5th	50th	95th	SD
Buttock-Popliteal length	44.10	48.40	53.80	3.10	43.50	46.20	51.00	2.60
Buttock-Knee length	54.10	58.10	62.40	2.70	53.00	56.60	59.50	2.10
Waist breadth	30.10	32.70	35.80	1.70	21.50	24.30	27.00	1.70
Hip breadth	34.20	37.10	40.80	1.90	33.00	39.40	45.00	4.00
Foot length	23.50	26.00	30.90	2.50	21.50	23.30	27.00	1.70
Foot breadth	7.20	10.10	12.40	1.60	7.00	8.60	10.50	1.00
Heel breadth	6.00	7.50	8.90	0.90	5.50	7.20	8.50	0.80
Elbow-fingertip	45.20	48.20	50.90	1.70	40.00	42.20	45.00	1.50
Elbow-elbow breadth	42.10	46.60	51.80	3.40	35.00	40.10	45.50	3.80
Neck height (sitting)	68.60	72.30	75.40	2.40	60.00	63.60	67.00	2.30
Waist height (sitting)	20.10	22.60	25.40	1.60	18.00	22.00	24.50	2.10
Head length	15.60	18.40	21.90	2.00	15.50	16.80	18.50	0.90
Head breadth	14.20	16.20	17.40	0.90	13.50	15.00	16.50	0.90
Popliteal height	39.20	44.00	46.80	2.30	36.00	38.00	41.50	1.90
Knee height	48.10	52.20	55.90	2.60	45.00	48.60	53.00	2.70
Thigh thickness	14.10	16.20	18.90	1.50	14.50	17.00	18.50	1.40
Abdominal depth	26.00	28.00	32.90	2.20	25.00	27.20	29.00	1.40
Elbow height (sitting)	21.60	23.70	27.40	1.90	19.00	22.20	25.00	1.90
Eye height (sitting)	78.00	80.50	84.80	2.40	70.00	72.50	76.00	2.00
Stature	164.60	174.60	181.60	4.90	158.00	164.00	168.00	2.90

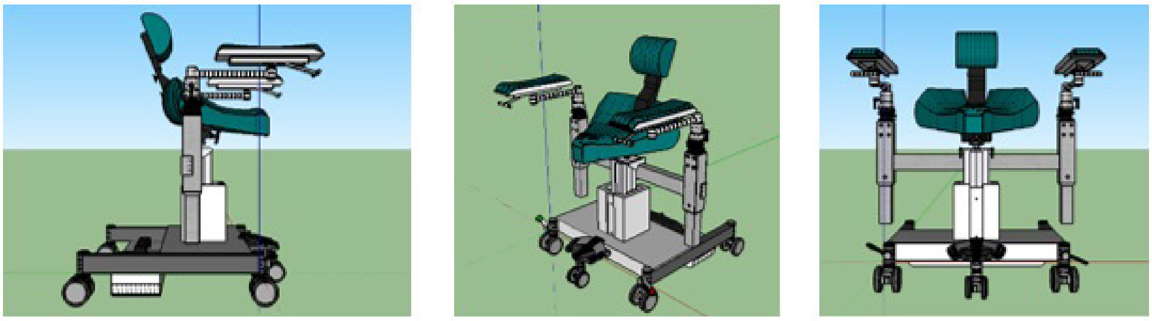

Figure 2: Final 3D design

Table III: Anthropometric measurements applications in designing the new chair

Dimensions	Application	Percentiles (cm)		
		Female 5th	Female 95th	Male 95th
Waist breadth	Backrest breadth	21.50		
Hip breadth	Seat width		45.00	
Foot length	Foot pedals			30.90
Foot breadth	Foot pedals			12.40
Heel breadth	Foot pedals			8.90
Elbow-fingertip	Forearm rest	40.00		
Buttock-Popliteal length	Seat depth	43.50		
Popliteal height	Seat height	36.00		46.80
Elbow height (sitting)	Forearm rest height	19.00		27.40

anthropometric measurements and their applications in designing the new chair. According to the table, the backrest, seat and arm rest height are adjustable. Figure 3 shows the initial chair design. Also, Figure 4 shows the initial 3D design and Figure 2 shows the final 3D design of the new chair for micro-surgeons.

DISCUSSION

According to research findings, surgeons spend most of their working hours in a forward-bending position. Various studies have shown that surgeons have exhibited frequent prolonged static head- and back-bent postures (27, 32). The results of objective evaluations also showed that micro-surgeons are at high risk for

Figure 3: Initial chair design

the development of musculoskeletal disorders of the arm, forearm, wrist, neck and trunk. Other studies have also shown that microscopic surgeons are at high risk for the development of musculoskeletal symptoms (3, 28, 33, 34). Given the results of objective assessments demonstrating that surgeons are at high risk of musculoskeletal disorders of the neck, after consultations with mechanical engineers, industrial designers and surgeons, we concluded that a head rest should be not considered as part of the chair and thus it is better to design it as part of the microscope or provide a more ergonomic alternative to traditional microscopic surgery to minimize the risk of musculoskeletal disorders in this area as in the study conducted by Mendez et al. (28) on the new technology (3D heads-up microscopic surgery). Moreover, in designing a chair based on anthropometric principles, these dimensions should be examined for further corrections. According to the surgeons' self-report on the comfort of normal chairs, these chairs had a low score on ease of seat height adjustment while performing an activity. Hence, incorporating foot pedals in the new design can increase the ease of seat height adjustment. Other studies have also identified foot pedals as one of the factors affecting surgeons' postures while performing minimally invasive surgeries (30). In addition, according to the laws and regulations of the Institute of Standards and Industrial Research of Iran (ISIRI), surgeons can use electric chairs. General requirements for the basic safety and essential performance of medical electrical equipment are considered in INSO 3368-1. Also, INSO-IEC 60601 is a series of technical standards for the safety of such equipment.

The limitations of this study include the study is cross-sectional in nature and some data collection done by self-report, the findings should be interpreted cautiously. Moreover, this study was performed among micro-surgeons in Shiraz. Therefore, the results might not be generalized to other surgeons. Furthermore, this study was conducted on a small sample size. Hence, using a larger sample size is needed to achieve more robust results in this context.

CONCLUSION

Given that surgeons are at risk for development of musculoskeletal disorders, especially in the low-back and shoulder/arm due to the nature of their work (Ocular and accurate) and given that these surgeons spend most of their working hours in a forward-bending position for microscopic surgeries, a chair was decided to be built so that the surgeon can operate in a sitting position and keep his feet flat on the floor to limit forward bending during surgeries. In the new design, the seat is almost slope less, so that the surgeon can overlook the surgical field and the patient's bed. The foot pedals are designed to increase the ease of seat height adjustment. In addition, adjustable height armrests which can be adjusted in all directions, and a short height adjustable backrest with lumbar support were considered. The backrest height supports from above the pelvic area to the shoulder blades and also allows maximum freedom of shoulder and hand movements. Also, the designed caster wheels (for ease of use) are lockable with a special mechanism.

ACKNOWLEDGMENTS

This article is based on the thesis of Shahrzad Riaei, a postgraduate student in ergonomics, School of Health, Shiraz University of Medical Sciences (grant No. 1396-01-04-15842). The authors would like to express their gratitude to the staff of Khalili, Nemazee, Shahid Chamran, and Shahid Faghihi hospitals, especially the surgeons and operating room personnel who collaborated in this research project.

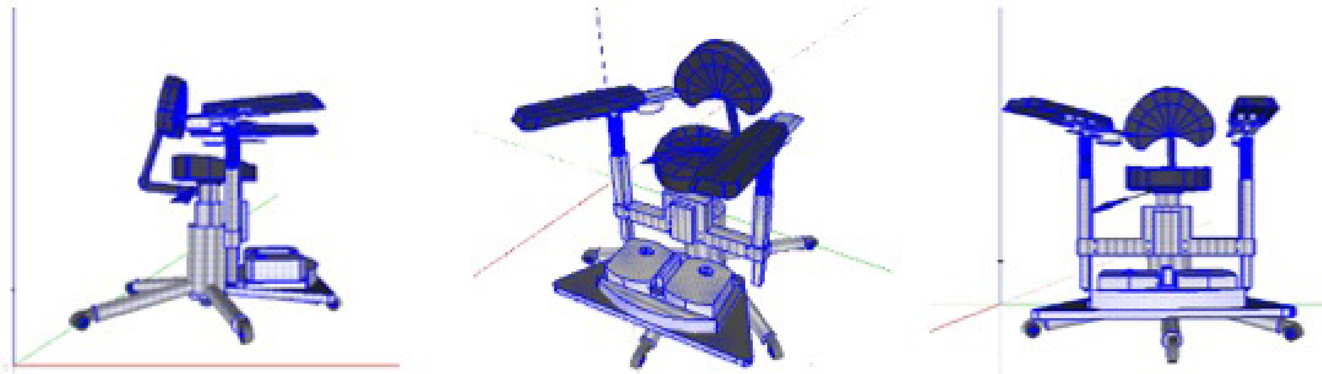

Figure 3: Initial 3D design

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