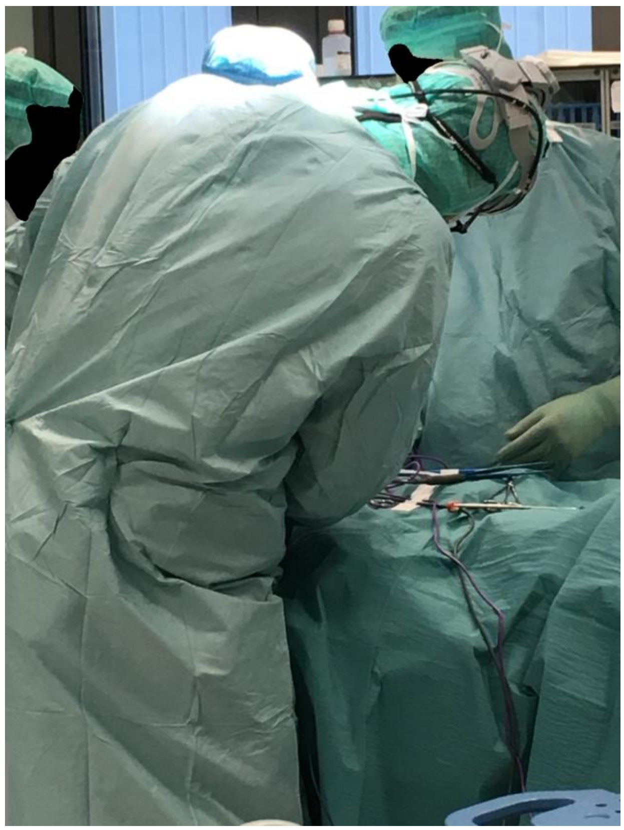
INTERNATIONAL HELLENIC UNIVERSITY

SCHOOL OF HEALTH

DEPARTMENT OF PHYSIOTHERAPY

PHYSICAL WORKLOAD OF UPPER BODY FOR OPEN NECK SURGEONS



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Abstract

Aim The following thesis is aiming to assess the workload during open neck surgeries on head, back, arms and descending trapezius part during the workday.

Methods A research took place at Karolinska University Hospital on 3 relative surgeons (subjects), who were measured during a whole workday. They performed the surgeries while wearing inertial measurement units (IMUs) that continuously track neck, shoulders, and torso motion without interfering with the sterile environment. Muscular load was recorded by electromyography (EMG). Registrations were made bilaterally by surface electrodes on the descending part of trapezius muscle. During the measuring day the surgeon was followed by a research member who kept a protocol and was marking the start and end time of the most important tasks (i.e. surgery, administrative work[1], breaks and lunch).

Once the procedure started the start and end time of the most important tasks (i.e. surgery, administrative work, breaks and lunch) was noted.

Results The results shown that during the lunch time the right descending trapezius worked on the most extreme positions and reached its peak activity, and the left trapezius reached its peak activity during the operations. In addition, breaks were described as non-demanding task, during which an extended period (29% of the time for the right arm and 25 for the left) spent for muscular rest (subjective and objective measures). Furthermore, surgery proved to be the most loading activity, among the four, for the head and the back, and lunch the one with the least variance in terms of joint movements.

Conclusion Open neck surgeries seem to be such a loading task for surgeons since they maintain a non-ergonomic posture for long periods, which is characterized of a general kyphotic position and abducted, unsupported arms (Figure 1). Even though the abduction is mild its long maintenance makes it harmful for the surgeons' physical health and well-being.

Key words open neck surgery, ergonomics, workload, electromyography, IMUs.

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[1] Computer work and meetings.

***Figure 1** Surgeon during operation with his back and neck bended and his arms in abduction.*

Introduction

Musculoskeletal disorders are one of the most causes of occupational injuries and disability in industrialized nations and developing countries. One of the greatest risk factors involved in the occurrence of the damage is the poor ergonomic posture. The disorders mainly occur in the upper extremities such as hands, wrists, arms, shoulders, neck and waist. The signs of musculoskeletal symptoms are muscle pain, discomfort, numbness down, burning, tenderness, swelling, limited range of motion, and loss of power.

Several professionals such as surgeons are at risk of these symptoms. The surgeons perform the surgery in a standing position, and the hands are generally in motion in surgery. Sometimes a fixed posture continues for hours and the pressure exerted by the musculoskeletal organs is too high. Over time, the continuous exposure to biomechanical and psychological stressors may intensify the musculoskeletal injuries in the workplace. Because surgery is often subtle, sensitive, and time-consuming, ergonomics aims at helping the surgeons to work without feeling any pain, or stress, and with less error. Nowadays, various surgical procedures are done such as open surgery. The body posture of the surgeons during open surgeries is described as a head-bent and back-bent posture. Surgeons maintain this posture for long periods, and as a result, they experience physical discomfort during and after the surgery. Due to the position and depth of the incision during open surgery, surgeons have a fixed work posture, tending to work with arms abducted and unsupported. In addition to improper posture due to ergonomics, repetitive movements of the hands and wrists, neck and shoulders, and excessive force can ultimately cause or exacerbate musculoskeletal disorders.

This study aimed to measure the load occurs on surgeon upper limbs' main joints, neck and waist during open neck surgeries and how it can be decreased and, if possible, eliminated by ergonomic principles.

Materials and methods

Participants

In this study the participants are 3 volunteer surgeons, two males and one female, who are actively performing open neck surgeries at Karolinska University Hospital provided written consent to participate in this study. All participants were asked for personal information including education and experience level, height, weight, age, sex, glove size, right/left-side domination and subjective description of their own experience about physical and/or mental workload. Each participant was given a unique ID for further data analysis, and their name was removed so that their identities cannot be traced back.

Subjective and objective measures

State-of-the-art wireless and wearable motion tracking devices were used to objectively quantify surgeon postures throughout the procedure. The Opal™ system (APDM, Inc., Portland, OR, USA) consists of six inertial measurement units (IMUs), with each sensor containing accelerometer, gyroscope, and magnetometer. These sensors have previously been validated and used for motion tracking in sports, space suits, and improving patient health. Prior to the surgical procedure, five IMUs were worn on the surgeon's head, sternum, upper arms, and pelvis (Figure 2) without interfering with surgeons' performance and the sterile field. The sixth sensor was used by a study team member to stamp the start and stop times of procedures and roles. After the sensors were donned and before each procedure were being started, sensors were calibrated using a static I-pose as described by the software vendor (NexGen Ergonomics, Montreal, Quebec). The units logged data at 64 Hz onto onboard memory cards, which were downloaded and processed after the full surgical day.

The bilateral descending trapezius muscle activity was recorded by electromyography (EMG). Registrations were made by surface five electrodes, two active for each side and one ground, symmetrically distanced from each side (Figure 3). The muscular activity was normalized to the maximal EMG activity (MVE) provoked by maximal voluntary contractions. The proportion of muscular rest (possibly for muscular recovery) was defined as the time spent below 0,5% of the MVE. Furthermore, the 10th, 50th and 90th percentiles of the amplitude distribution function were used for describing the muscular loads. This function means that all values registered are ranged in increasing order and the specific values for different proportions of time (10, 50 and 90% of time) are used as description of the results. This also accounts for positions.

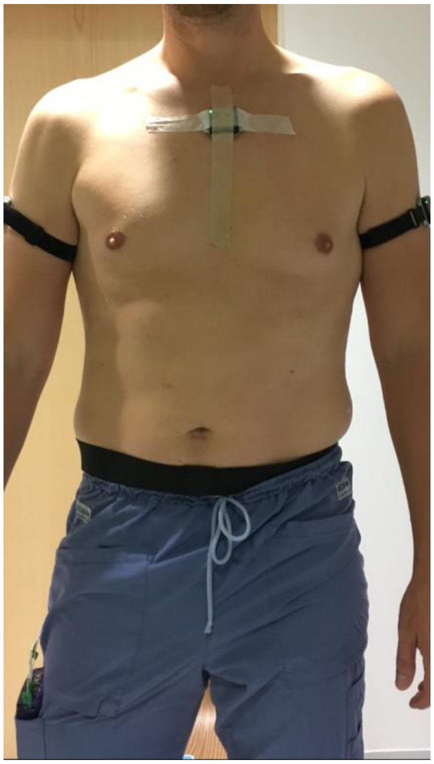
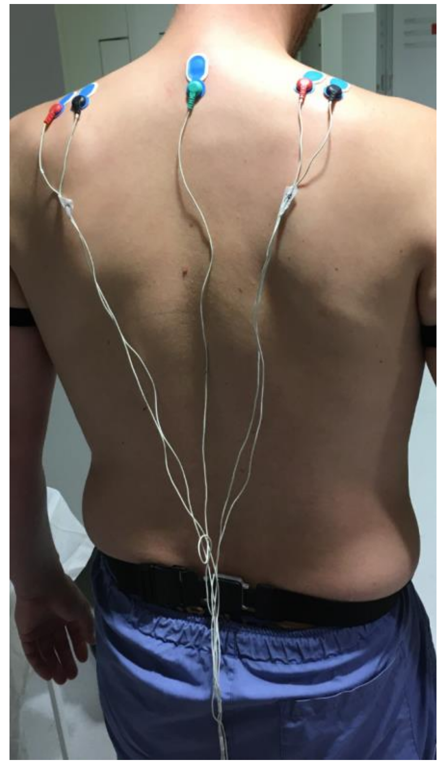


Figure 2 *(left) Wearable wireless motion tracking sensors placed on the surgeon before the surgery. Head's sensor is not depicted in this photo.*

Figure 3 *(right) Electromyography surface electrodes on the descending trapezius muscle. Green is the ground.*



Data analysis

Accelerometer, gyroscope, and magnetometer data from the IMU sensors were processed into postural angles using scripts programmed in MATLAB® (R2015b, Mathworks Inc., Natick, MA, USA). Specifically, the low-pass-filtered (fourth-order Butterworth filter set at 32 Hz) data streams were used to calculate neck flexion, torso flexion, and left/right shoulder elevation over time throughout the entire procedure with reference to the static I-pose. Neck flexion was defined as the head motion relative to the torso in the sagittal plane, torso flexion was defined relative to vertical, and shoulder elevation was defined as the upper arm motion relative to vertical. These continuous computed postures were summarized for each procedure into (1) mean posture angles, (2) range of motion, defined as the difference between 90th percentile and 10th percentile posture angles.

EMG active measuring surface electrodes were attached on the descending trapezius body bilaterally recording the muscle's activity. The ground electrode was attached on the C7 spinous process. The whole-day measured activity interpreted on a waveform for each task. Those waveforms summarized into (1) percentage of maximal voluntary effort (%MVE), (2) range among extreme, medium and mild contractions (90th, 50th and 90th percentiles respectively), and (3) percentage of rest time (subjective and objective measures).

Results

Nine open neck cases were collected in this study. Three were first case of the day, three were second, two were third, and one was fourth case of the day. Cases were performed by 3 different participants (table 1), of whom two were males and one female. Operation duration was varying because of the complexity of the case, as stated by the surgeons (49 ± 27 min).

Table 1 *Basic subjects' information.*

	Gender	Age (years)	Height (cm)	Weight (kg)	Dominant side
Subject 1	Male	39	192	98	Right
Subject 2	Male	43	166	68	Right
Subject 3	Female	62	187	82	Right

Right descending trapezius worked on a peak 13,46 ± 5,52% of the maximal voluntary contraction (%MVC) during lunch (Table 2). Second most demanding activity for this muscle was surgery, when it worked on 10,58 ± 3,45 % MVC. Break and administrative work are third and fourth respectively, without significant statistical differences. The most demanding activity for the left side was surgery, during which the descending trapezius worked on 14,08 ± 1,64% MVC. Second was lunch (12,31 ± 2,42% MVC). Third and fourth were similar to the right side. When comparing the activities, break was noticed with the highest proportion of time with a muscular activity lower than 0,5% MVE, "muscular rest", for both sides. Almost the same amount of time spent in those positions for the right trapezius during administrative work, but it was severely lower for the left hand (Table 2). However, concerning the levels of muscular activity, no worth-mentioning difference among the activities for the percentiles could be detected.

Regarding positions, the greatest posture average for all joints recorded, by far, during break (Table 3). The other three activities scored similar figures. However, the only, far-from-neutral, extension of the head met during administrative work (-21,64^o ± 44,56^o), most likely because they sometimes were discussing with colleagues from sitting position (working on computer), while their partners were standing. During breaks, they were usually lying with their buttocks on the sofa's edge. This excuses back's greatest recorded extension (-13,38^o ± 11,12^o). The arms were moving only in positive-sign postures.

Surgery implied significant workload for the head and the back while they were bended for more than 45^o ± 13^o and 25^o ± 8^o, respectively, for longer than half of the time (50th percentile or median).

Finally, the survey shown that besides lunch had the smallest, and closer to zero, range of motion, and posture mean (º), surgeons spend the longest time in rest during administrative work for all joints, except for back which has 3% of time less than total break period.

Table 2 *Physical workload for right and left descending trapezius in the workday.*

		Right Trap		Left Trap	
Activity	Parameter	Mean	S.D.[2]	Mean	S.D.
Surgery	Average in the day	10,58	3,45	14,08	1,64
	10th	3,43	1,62	3,90	2,95
	50th	8,91	4,36	11,30	2,09
	90th	15,31	6,84	21,28	2,84
	Rest (% of time)	2,14	1,38	2,98	3,38
AD	Average in the day	7,50	6,81	6,82	4,40
	10th	0,54	0,60	0,91	1,16
	50th	5,57	7,34	4,50	4,51
	90th	10,43	9,26	10,11	6,05
	Rest (% of time)	28,31	21,65	17,77	11,43
Break	Average in the day	8,47	6,10	7,85	3,36
	10th	0,25	0,18	0,25	0,14
	50th	4,00	4,06	3,55	1,82
	90th	13,15	11,04	12,02	6,01
	Rest (% of time)	28,68	13,38	24,88	9,12
Lunch	Average in the day	13,46	5,52	12,31	2,42
	10th	0,27	0,05	0,23	0,05
	50th	9,24	7,10	7,33	4,52
	90th	20,88	8,44	19,90	2,99
	Rest (% of time)	12,94	11,53	13,74	12,24

[2] Standard Deviation.

Table 3 *Posture mean (°), range of motion[3] and time in rest during different activities.*

Activity	Parameter	Head incl.	S.D.	Back incl.	S.D.	R. arm elev.	S.D.	L. arm elev.	S.D.
Surgery	Posture Mean (°)	10,90	4,08	8,01	3,20	14,01	4,10	11,30	3,34
	10th	23,00	21,63	7,98	12,09	7,98	2,23	8,09	2,07
	50th	45,36	12,91	25,60	8,11	18,15	1,70	21,77	2,51
	90th	58,59	11,77	39,80	3,57	36,16	2,01	39,87	9,09
	Rest (% of time)	3,95	4,37	17,60	9,82	29,89	3,10	25,15	5,84
AD	Posture Mean (°)	10,21	2,73	9,08	5,03	10,40	2,41	9,82	1,75
	10th	-21,64	44,56	-0,94	13,21	11,79	1,87	9,35	3,02
	50th	12,74	14,02	19,16	7,25	18,95	2,35	19,12	7,08
	90th	36,80	19,13	28,12	9,93	50,53	33,40	52,02	29,76
	Rest (% of time)	39,56	25,63	36,54	33,67	40,95	16,09	38,21	17,61
Break	Posture Mean (°)	18,70	5,13	17,39	6,26	20,27	8,80	19,24	10,66
	10th	-2,93	9,08	-13,38	11,12	8,49	2,76	8,26	4,21
	50th	12,43	16,04	5,13	9,22	23,09	3,22	25,20	10,79
	90th	37,64	25,42	31,99	10,14	41,60	3,65	48,31	22,06
	Rest (% of time)	24,19	17,00	39,52	4,61	21,56	6,84	22,97	11,66
Lunch	Posture Mean (°)	11,66	10,16	9,00	7,99	11,30	9,79	10,41	9,02
	10th	-0,03	3,94	-3,65	3,23	8,80	7,68	8,90	7,72
	50th	8,17	7,91	9,49	11,90	17,52	15,24	18,66	16,17
	90th	23,14	21,15	17,43	16,11	30,42	26,43	27,19	23,57
	Rest (% of time)	17,55	15,33	24,47	24,45	10,18	8,81	10,86	9,66

Discussion

This study shown that open neck surgeons have to deal with high physical workload. This is mainly because they maintain a non-ergonomic, head-bending and back-bending, with abducted and unsupported arms, posture during surgeries, which cover a big amount of their workday. This conclusion is also supported by Tatiana Catanzarite et al (Catanzarite T, Tan-Kim J, Whitcomb E, Manefee S., 2018) who imply that open neck surgeons experience pain in the hands, arms, neck, low back and shoulders in the range of 66% to 94% of the cases. Moreover, it was surprising to find out that trapezius activity during lunch is similar to that during surgery. However, a pleasant finding is that there are several periods during the workday for muscular rest.

[3] Difference between 10th and 90th percentile.

Limitations

Despite the strengths of this research there are some limitations.

First is the sample size. The number of participants and measuring days is very low due to the limited available time and the complexity of surgeons' scheduling. Therefore, this research cannot represent the total population.

A second limitation is the skin movement, which could move the IMUs and mix the results. Thus, we avoided body places where there is few soft tissue underneath the skin, like muscles and fat, and the bony ones were preferred instead.

The third limitation is the shift of the devices. Elastic bands, double-sided tape and regular tape helped us fix them on the desirable position. Moreover, we kept an eye on them during the whole procedure, just in case of possible movement.

The final limitation is the battery availability. We prevented any unpleasant surprise by beginning the procedure with the IMUs fully charged and EMG device with a new set of batteries.

Conclusions and aspects

This research underlines that open neck surgeons have a high prevalence of neck and lower back physical workload, especially during surgeries. Hence, future efforts must aim to develop supportive equipment and medical instruments that help surgeons work on less demanding postures, make their work conditions more acceptable and ensure the health and longevity of their careers and general well-being. However, further researches must be taken to confirm these findings.

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