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Identification of risk factors for fatigue and pain when performing surgical interventions

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ABSTRACT. **Objective***: Evaluation of fatigue and pain following surgical activities.* **Methods:** *Cross-sectional study. We distributed a self-evaluation questionnaire to 180 surgeons to investigate working postures and fatigue and/or pain following working activities.* **Results:** *100 surgeons replied (74 male), mean age 40.1 (SD 10.85; 26-65). Multivariate analysis suggests that the highest risk factor for developing muscle fatigue whilst performing surgical operations is standing compared to sitting (OR: 4.92; 95% CI: 1.32 - 18.33), followed by the ability to alternate between the two postures (OR: 3.46: 95% CI: 1.26 - 9.52). Surgeons who complain of intense fatigue when standing have 16 times the risk of developing musculoskeletal pain than surgeons who complain of light fatigue when standing (OR: 15.77; 95% CI: 1.51 - 164.37). The ability to adjust the height of the operating table before each operation reduces the risk of developing musculoskeletal pain by 83% (OR: 0.17; 95% CI: 0.03 - 0.87); 90.9% of surgeons who rest their forearms for less than half the duration of an operation reported pain.* **Conclusions:** *Fatigue and pain associated with performing surgical interventions could be managed more effectively by: controlling the working posture, being able to rest forearms, being able to regulate the height of the operating table, and possibly by applying the ergonomic guidelines.*

Key words: *fatigue, pain, posture, surgery.*

RIASSUNTO. ***Obiettivo:*** **Valutazione dell'insorgenza di fatica e dolore dopo attività chirurgica tradizionale.** ***Introduzione:*** **È stato documentato che l'attività chirurgica soprattutto se prevede posture statiche prolungate, movimenti ripetitivi e assunzione di posizioni incongrue, può condizionare l'insorgenza di disturbi muscolo-scheletrici.** ***Materiali e metodi:*** **Studio cross-sectional. È stato distribuito un questionario di autovalutazione a 180 chirurghi, operanti nei dipartimenti di Chirurgia dell'Università degli Studi di Pavia, al fine di analizzare la postura mantenuta durante il lavoro e l'eventuale insorgenza di affaticamento e/o dolore dopo l'attività lavorativa.** ***Risultati:*** **Hanno risposto 100 chirurghi, 74 maschi, di età media 40.1 (SD 10.85; range 26-65). L'analisi statistica multivariata ci indica che i fattori di rischio più importanti per l'insorgenza di affaticamento muscolare durante l'attività chirurgica sono: la posizione eretta durante gli interventi, rispetto a chi ha la possibilità di stare seduto (OR: 4.92; 95%IC: 1.32 - 18.33), seguita dalla possibilità di alternare le 2 posizioni (OR: 3.46: 95%IC: 1.26 - 9.52). Inoltre i chirurghi che riferiscono fatica intensa in posizione eretta presentano un rischio di sviluppare dolore muscolo-scheletrico di circa 16 volte maggiore rispetto a coloro che lamentano un affaticamento lieve (OR: 15.77; 95%IC: 1.51 - 164.37). La possibilità di adattare l'altezza del lettino operatorio ad ogni intervento riduce il rischio di insorgenza di dolore dell'83% (OR: 0.17; 95% IC: 0.03 - 0.87); il 90.9% di coloro che hanno la possibilità di appoggiare gli avambracci per meno della metà della durata dell'intervento chirurgico lamenta dolore.** ***Conclusioni:*** **I disturbi muscolo-scheletrici relativi all'attività chirurgica potrebbero essere meglio controllati attraverso la riduzione dei tempi di postura fissa, la possibilità di appoggio dell'avambraccio, l'altezza adattabile del tavolo operatorio, l'esecuzione di esercizi di rilasciamento muscolare e stretching, e l'applicazione delle linee guida ergonomiche.**

Parole chiave: fatica, dolore, postura, chirurghi

Introduction

It has been shown that surgical activities can lead to musculoskeletal disorders, especially if they involve prolonged static postures, repetitive movements and awkward body postures (1-13).

The first ergonomic assessments to be carried out in a surgical setting were about the handle design of surgical instruments (Patkin 1967) (14). Ergonomics is now being applied to new surgical techniques, such as laparoscopic surgery and minimally invasive surgery. Ergonomic guidelines for endoscopic surgery have been jointly compiled by The European Association for Endoscopic Surgery (EAES) and Delft University of Technology. These guidelines are based on a study on European surgeons, which considered the following factors: their posture during surgery, table height, monitor placement, monitor height, and the position of foot pedals (2).

Studies on the posture of operating teams, in particular Operating Department Practitioners (ODPs), have revealed that standing for a prolonged period of time is a risk factor for developing musculoskeletal disorders (15-16). As a result, research has been undertaken to improve working conditions in operating theatres with an aim to guaranteeing safety, efficiency and comfort to the operating team. Part of the research involves devising a new approach to planning which instruments are used in minimally invasive surgery, with a view to optimising the equipment used in operating theatres (5).

The aim of this study is to evaluate the factors that can cause fatigue and pain following surgical activities.

Methods

We conducted a survey by means of a self-evaluation questionnaire, which was sent to all employees of the surgery units affiliated to the University of Pavia. We asked respondents to refer to their previous week at work when answering the questions.

The questionnaire included the following items:

– subject's body measurements
– surgical speciality, qualifications
– working information: posture used in operating theatre, ability to alter height of operating table, ability to rest

forearms, mean time a fixed posture is held during an operation
- overall fatigue quantified according to the Borg scale (17), and pain quantified according to the visual analogue scale (VAS) in the: shoulders, elbow, hands, cervical spine, vertebral column, lumbar spine, hips, knee and feet
- recovery time after fatigue and/or pain
- awareness of the ergonomic guidelines
- sporting activities performed

Statistical analysis

The Shapiro-Wilk test was used to test the normal distribution of quantitative variables. When they were normally distributed, we used mean, SD and range (min-max) to summarise the results, otherwise we used median and interquartile range (IQR; 25° - 75° percentile). Parametric or non-parametric tests were used to compare quantitative variables (t-test for independent data for comparisons between two groups or Man-Whitney test). The chi-squared statistics or Fisher's exact test, as appropriate, were applied to compare qualitative variables. Univariate and multivariate logistic regression models were used to identify variables associated with fatigue and pain. Results are expressed as Odd Ratio (OR) with 95% Confidence Interval (CI). Variables included in the models were: subject's body measurements, working activity information, presence of fatigue and pain, sporting activities and awareness of the guidelines. Only variables that were either significant at the 0.2 level at univariate analysis, or deemed clinically important, were included in the multivariate model. The likelihood ratio (LR) test was used to assess the significance of including each variable. $P<0.05$ was considered statistically significant. All tests were two-sided. Data analysis was performed with STATA statistical package (vers: 9; Stata Corporation, College Station, 2008, Texas, USA).

Results

We sent 180 questionnaires to surgeons in April-July 2007. 100 (55,6%) surgeons replied: 74 male, mean age 40.1 (SD 10.85; range 26-65), mean height 173.84 cm (SD 7.42; range 152-188), mean weight 72.32 kg (SD 13.38; range 45-105), 94 right-handed, 6 left-handed. They represent 9 surgical specialities: General Surgery (25), Cardiac surgery (18), Vascular surgery (15), Ophthalmic surgery (14), ENT surgery (7), Gynaecological surgery (7), Urology (6), Plastic surgery (5), and Oral surgery (3). They use open surgery.

Posture

Seventy-five of the surgeons mainly work in a standing position, 17 in a sitting position and 8 alternate between the two postures. Ninety-six are able to alter the height of the operating table, 74 reported that the height of the operating table is regulated for each operation to suit the primary surgeon's needs. Fifty surgeons are unable to change their posture during an operation. Sixty-five surgeons are able to rest their forearms during an operation, whereas 34 are not, and 1 did not indicate this information on the questionnaire. Only 17 surgeons use specific arm rests during operations, whereas the other 48 rest their arms on the operating table, or on the patient.

Timing

Mean duration of daily surgical activities: 4.36 hours (SD 1.53; range 1-8). Mean time surgeons maintain the same position during an operation: 1.77 hours (SD 1.20; range 15 minutes-6 hours); 19 stay in the same position for less than an hour, 41 for 1-2 hours, 16 for 3-4 hours, and 3 for more than 4 hours; 21 did not supply this information.

Fatigue

Forty-eight surgeons reported general fatigue after performing an operation. We divided the surgeons into 2 groups on the basis of the median value of their fatigue, calculated according to the Borg scale (median 2.9 (IQR 1.7-3): less than 2.9 = no fatigue, more than 2.9 = fatigue).

Table I reports the univariate analysis of the association between fatigue and surgical activities.

The most relevant data indicate that musculoskeletal fatigue mainly occurs: in surgeons who have to maintain a fixed body posture for long periods of time (median 2 hours (IQR 1-3)), in surgeons who work in a standing position (55.4%), in surgeons who are not able to rest their forearms during operations (60.6%), and in surgeons who do not perform physical exercise during their free time (68.4%).

Table II reports univariate and multivariate logistic regression models to show the relationship between fatigue and other variables. It clearly shows that both the working posture and the inability to change position during an operation are risk factors, whereas performing regular exercise in free time is a preventative measure.

The highest risk factor for developing muscle fatigue whilst performing surgical operations is standing compared to sitting (OR: 4.92; 95% CI: 1.32 - 18.33), followed by the ability to alternate between the two positions (OR: 3.46: 95% CI: 1.26 - 9.52). Carrying out physical exercise in free time reduces the risk of developing muscle fatigue by 83% (OR: 0.17; 95% CI: 0.06 - 0.49). Albeit not statistically significant, the ability to rest forearms whilst performing an operation reduces the risk of fatigue by 53% (OR: 0.47; 95% CI: 0.17 - 1.31).

Table III illustrates the relationship between fatigue and working position: standing versus sitting and alternating between the two postures. It shows that a standing position increases overall fatigue, and influences fatigue in the vertebral column and lower limbs.

Pain

Seventy respondents reported that they feel pain after performing operations. Mean time before pain occurs: 4.29 hours of work (SD 1.79; range 1-8). Twenty-five of these 70 surgeons pinpointed the following specific postures that provoke pain: standing (13), bending vertebral column (7), twisting vertebral column (2), absence of forearm rest (1), stretching vertebral column (1), pulling with arm (1). Only 18 of these surgeons are able to alter this position during an

Table I. *Univariate analysis of the association between overall fatigue and surgical activities*

VARIABLES		FATIGUE (n=48 (48%))	NO FATIGUE (n=50 (50%))	P VALUE
Handedness	Right-handed	45 (49.5)	46 (50.5)	0.444
	Left-handed	2 (33.3)	4 (66.7)	
Sex	Female	10 (40)	15 (60)	0.357
	Male	36 (50.7)	35 (49.3)	
Age (median (IQR))		40 (30 - 50)	36 (29 - 48)	0.279
Daily working hours (mean (SD))		4.4 (0.2)	4.2 (0.3)	0,556
Length of time in fixed position per operation (median (IQR))		2 (1-3)	1.5 (0.5-2)	0.101
Working posture during surgery	Standing	**41 (55.4)**	33 (44.6)	**0.035**
	Sitting	3 (20)	**12 (80)**	
	Alternate	3 (37.5)	**5 (62.5)**	
Ability to change position during an operation	Yes	18 (39.1)	28 (60.9)	**0.031**
	No	**30 (61.2)**	19 (38.8)	
Ability to rest forearms	Yes	27 (42.9)	36 (57.1)	**0.098**
	No	**20 (60.6)**	13 (39.4)	
Thinks armrests would be useful	Yes	25 (50)	25 (50)	0.426
	No	14 (41.2)	20 (58.8)	
Fatigue in standing position	Minimum	2 (14.3)	12 (85.7)	**0.012**
	Medium	19 (52.8)	17 (47.2)	
	Maximum	**24 (60)**	16 (40)	
Thinks an exercise plan would be useful	Yes	39 (47)	44 (53)	0.645
	No	7 (53.8)	6 (46.2)	
Physical activity in free time	Yes	20 (34.5)	38 (65.5)	**0.001**
	No	**26 (68.4)**	12 (31.6)	

Table II. *Uni- and multivariate analysis of factors related to fatigue onset*

	UNIVARIATE			MULTIVARIATE		
VARIABLES	**OR**	95% **CI**	**P VALUE**	**OR**	95% **CI**	**P VALUE**
Length of time in fixed position per operation (hours)	1.28	0.86 - 1.91	0.217			
Working posture during surgery (standing/sitting and alternate)	3.52	1.25 - 9.93	**0.017**	4.92	1.32 - 18.33	**0.018**
Ability to change position during an operation (yes/no)	2.46	1.08 - 5.60	**0.033**	3.46	1.26 - 9.52	**0.016**
Ability to rest forearms (yes/no)	0.49	0.21 - 1.15	0.101	0.47	0.17 - 1.31	0.150
Physical activity in free time (yes/no)	0.24	0.10 - 0.58	**0.001**	0.17	0.06 - 0.49	**0.001**

Table III. *Relationship between fatigue and working position*

Muscular fatigue measured on the Borg scale	STANDING	SITTING/ ALTERNATE	MISSING	P VALUE
General fatigue (median (IQR))	3 (2-4.34)	1.67 (1.34-3)	3	**0.0005**
Fatigue in upper limbs (median (IQR))	3 (1-3)	2 (0-3)	22	0.2368
Fatigue in vertebral column (median (IQR))	3.67 (2.67-5)	3 (2-3.67)	7	**0.0112**
Fatigue in lower limbs (median (IQR))	3 (1-3.67)	0 (0-1)	18	**<0.001**

operation. Thirty surgeons did not pinpoint the posture that provokes pain. Sixty-two surgeons reported that their pain subsides after resting, but 13 say they sometimes need to take medication, mainly NSAIDs and myorelaxants.

Table IV shows univariate analysis of the factors associated with the onset of pain. The most relevant results are related to the side on which the surgeons work (all left-handed surgeons complain of pain), the height of the operating table (all surgeons who are unable to adjust the table, and 86.4% of those who are unable to adjust the height of the table before each operation feel pain), changing position during operations (77.5% of surgeons who are unable to do this reported pain), forearm rest (90.9% of surgeons who rest their forearms for less than half the duration of an operation reported pain).

Only 28 of the 70 surgeons who feel pain recognise their posture as a provoking factor, while only 30 reported that they are able to change position during an operation.

Table V shows the relationship between the onset of pain and various variables, using univariate and multivariate logistic regression models. The results of the multivariate analysis are as follows: the ability to adjust the height of the operating table before each operation reduces the risk of the onset of musculoskeletal pain by 83% (OR: 0.17; 95% CI: 0.03 - 0.87), surgeons who complain of maximum fatigue when standing have 16 times the risk of developing musculoskeletal pain than surgeons who complain of light fatigue when standing (OR: 15.77; 95% CI: 1.51 - 164.37), and albeit not statistically significant, maintaining the same position whilst performing an operation is strongly associated with the onset of musculoskeletal pain (OR: 5.14; 95% CI: 0.82 - 32.37). The two risk factors for the onset of musculoskeletal pain are intense fatigue in a standing position, and noticing that a particular position provokes pain; whereas being able to adjust the height of the operating table before each operation is a preventative measure.

Ergonomics, physical activity

Forty-eight of the surgeons perform relaxation exercises between operations. Eighty-seven think an exercise plan would be useful and only 13 do not. Only 34 of the 60 surgeons who play sports do so regularly.

Table IV. ***Analysis of the factors associated with the onset of pain***

VARIABLES		PAIN (n=70 (70%))	NO PAIN (n=29 (29%))	P VALUE
Handedness	Right-handed	64 (68.8)	29 (31.2)	0.104
	Left-handed	**6 (100)**	**0 (0)**	
Daily working hours (median (IQR))		5 (3.5-6)	4 (3-5)	0.123
Length of time in fixed position per operation (median (IQR))		1.75 (0.88-2.75)	1.5 (1-2)	0.861
Operating table height	Adjustable	66 (69.5)	29 (30.5)	0.254
	Non-adjustable	**3 (100)**	**0 (0)**	
Table height adjusted for each operation	Yes	47 (64.4)	26 (35.6)	**0.05**
	No	**19 (86.4)**	3 (13.6)	
Working position during surgery	Standing	53 (71.6)	21 (28.4)	0.865
	Sitting	12 (70.6)	5 (29.3)	
	Alternate	5 (62.5)	3 (37.5)	
Ability to change position during an operation	Yes	30 (62.5)	18 (37.5)	0.105
	No	**38 (77.5)**	11 (22.5)	
Ability to rest forearms	Yes	45 (70.3)	19 (29.7)	0.737
	No	25 (73.5)	9 (26.5)	
Length of time forearms are rested	100%	18 (69.2)	8 (30.8)	0.312
	50%	21 (67.7)	10 (32.3)	
	<50%	**10 (90.9)**	1 (9.1)	
General fatigue measured on the Borg scale (median (IQR))	Total	2.9 (1.9-4.3)	2.9 (1.7-3)	0.118
Fatigue in standing position	Minimum	9 (60)	6 (40)	**0.000**
	Medium	18 (50)	18 (50)	
	Maximum	**38 (97.4)**	1 (2.6)	
Specific position which provokes pain	Yes	**28 (93.3)**	2 (6.7)	**0.002**
	No	39 (61.9)	24 (38.1)	
Ability to change such position during operations	Yes	18 (62.1)	11 (37.9)	**0.006**
	No	**35 (89.7)**	4 (10.3)	

Table V. ***Uni- and multivariate analysis of factors related to pain onset***

	UNIVARIATE			MULTIVARIATE		
VARIABLES	**OR**	95% **CI**	**P VALUE**	**OR**	95% **CI**	**P VALUE**
Table height adjusted for each operation (yes/no)	0.28	0.08 - 1.06	0.060	0.17	0.03 - 0.87	**0.033**
Ability to change position during an operation (yes/no)	0.48	0.20 - 1.17	0.108	0.67	0.16 - 2.78	0.583
Fatigue in standing position ***Minimum***	1*			1*		
Medium	0.67	0.20 - 2.26	0.516	0.46	0.10 - 2.16	0.328
Maximum	25.33	2.70 - 237.53	**0.005**	15.77	1.51 - 164.37	**0.021**
Specific position which provokes pain (yes/no)	8.62	1.88 - 39.47	**0.006**	5.14	0.82 - 32.37	0.081

* reference

Only 9 of the total number of surgeons surveyed (100) say they are familiar with the ergonomic guidelines for surgery, and only 3 of these surgeons actually apply the guidelines.

Discussion and Conclusions

Most of the surgeons complain of fatigue and pain following surgical activities. Fatigue is shown to be related to: the amount of time a surgeon maintains a fixed posture (which varies from speciality to speciality), working in a standing position (75% of the surgeons reported that they mainly work in a standing position, and the mean duration of an operation is 4.36 hours), inability to change position during operations (this is the case for 50% of the study group), inability to rest forearms during operations, and lack of physical exercise in free time. The onset of pain was shown to be linked to: inability to adjust the height of the operating table to suit all surgeons involved in an operation due to the different heights of the team members, inability to change posture during operations, fatigue in a standing position, and specific body positions which provoke pain.

Previous studies have confirmed that one of the main aspects that provokes pain in surgeons is maintaining a standing position for long periods of time (12, 18-19). This is considered as a risk factor for the onset of musculoskeletal disorders, mainly in the lower limbs, the knee and the vertebral column (20-23). Many of the previous studies which analysed posture in surgery were carried out on non-medical staff. One study which was carried out on perioperative personnel in the Netherlands compiled a package of practical guidelines for working in a standing position, derived from international standards and European Commission directives (21). It was developed as a stoplight model, distinguishing between three levels of risk: green, amber and red. Green, the lowest level of risk, comprises no more than 1 hour of continuous standing and no more than 4 hours of standing in total. Amber, the medium level of risk comprises more than 1 hour of continuous standing or more than 4 hours of standing in total. Red, the highest level of risk comprises more than 1 hour of continuous standing and more than 4 hours of standing in total (15).

A survey carried out by the Society of American Gastrointestinal Endoscopic Surgeons revealed that 8-12% of 149 responding surgeons reported frequent pain or numbness in the arms, wrists, or hands following laparoscopic surgery. There were also some reports of thenar neuropathies resulting from the mishandling of instruments, and of pectoralis tendonitis resulting from the prolonged use of a bowel clamp (4).

Previous studies about posture and forearm resting have mainly been performed in the field of laparoscopic surgery, due to the fact that it involves a monitor and heavy instruments connected to the equipment which force the surgeon to maintain a fixed position and regularly move his/her head from the monitor to the operating field. These factors have frequently led to musculoskeletal disorders (4-5, 7-8, 11, 24-26).

In our study group, 65 surgeons reported that they are able to rest their forearms, but for most of them this occurs on the operating table or on the patient, only 17 of them use ergonomic armrests. Fifty-one surgeons think it would be beneficial to improve the way they rest their arms by using specific supports.

A study carried out by Galleano et al in 2006 shows that the use of adequate armrests significantly reduces fatigue in both the upper limbs and the vertebral column, and can increase the precision of laparoscopic surgical manipulation. Armrests provide the operator with forearm support which reduces physiological tremor, hence improving hand movement control and consequently laparoscopic instrument control. Armrests also prevent or delay the occurrence of fatigue and discomfort in arm, shoulder, and upper spine muscles during long procedures. All participants in the study found it considerably easier to carry out procedures using arm rests, and this did not alter individual operation times (27).

A study on surgeons' posture, by Nguyen et al, showed that surgeons involved in open surgery often complain of neck and back pain. This is usually due to the fact that they need to position themselves in such a way as to gain a better view during surgery, thus assuming less ergonomically appropriate positions. On the other hand, surgeons involved in laparoscopic surgery adopt more static positions that are awkward and uncomfortable due to the laparoscopic instruments they use. As a result, more muscle effort is required

during operations (11). Furthermore, surgeons have neck problems when they perform endoscopic surgery as it requires twisting their neck to observe the monitor, even though it doesn't involve bending, twisting or straining the neck in the same way as open surgery does (25).

Various studies have found a strong link between musculoskeletal disorders of the cervical spine and high levels of static muscle contraction, prolonged static load, and work postures involving neck and shoulder muscles (28). A surgeon's working posture usually involves prolonged static contraction of the trunk, scapulothoracic and scapulohumeral muscles, combined with repeated contractions of the wrist, hand and finger muscles during movements that require fine motor control (29-30).

We interpret the missing data in our survey as the surgeon's unawareness of the effort involved in maintaining a particular posture during surgery due to the emotional and intellectual effort required to perform a surgical operation. A surgeon's work can involve high levels of mental concentration and very precise movements, so much so that it can be classified as a moderate intensity physical activity. Surgeons are required both to be highly skilful and precise, and to take important decisions hastily in critical moments during surgical operations (9, 25).

Another study by Albayrak et al demonstrates that surgeons concentrate so hard on the operation that they tend to neglect their posture (31), in other studies surgeons attribute their lower back pain and neck stiffness to getting older and being overweight (11).

Fatigue and pain could be diminished by: reducing fixed posture even if this is only achieved through awareness, operating table height adjustment, creating specific ergonomic supports for the upper limbs, performing relaxation exercises and stretching contracted muscles at the end of the operating sessions. These measures can benefit both the surgeon's and the patient's health status.

The weak points of this study are the low number of question responses we received, and some missing data. This suggests a lack of awareness of the problem. We have discussed the results of our study with the surgeons involved, who have shown interest and asked us to provide them with both the ergonomic guidelines and suggestions for stretching exercises.

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