Surgery Open Science 16 (2023) 184–191

Contents lists available at ScienceDirect

Surgery Open Science

journal homepage: www.journals.elsevier.com/surgery-open-science

Research Paper

Surgical fatigue syndrome and EDiS3 intervention, should every surgeon need to know how to mitigate muscle skeletal discomfort?

Gerardo Chávez-Saavedra [a,*], Angélica Espinosa-Hinojosa [b], Luis Enrique Colonna-Márquez [c], Carlos Hidalgo-Valadez [a], Daniel Alberto Díaz-Martínez [e], Beatriz Verónica González-Sandoval [d]

[a] Medicine and Nutrition Department, University of Guanajuato, Av. Puente del Millenio 1001 Fracc, San Carlos León, Guanajuato 37670, Mexico
[b] Regional General Hospital "María Ignacia Gandulfo", Novena Calle Sur Oriente 11 Barrio, San Sebastián, Comitán de Domínguez, Chiapas 30029, Mexico
[c] Regional General Hospital 58, Mexican Institute of Social Security, Blvd. Juan Alonso de Torres Pte. 2125, San Miguel, 37268 León, Guanajuato, Mexico
[d] Medicine and Nutrition Department, University of Guanajuato, Av. Puente del Millenio 1001 Fracc, San Carlos León, Guanajuato 37670, Mexico
[e] Instituto de Salud Pública del Estado de Guanajuato. Tamazuca No. 4 Zona Centro, Guanajuato, Guanajuato. CP 36000

ARTICLE INFO

Keywords:
Surgical fatigue syndrome
Surgical ergonomic
Surgical performance
Work-related musculoskeletal disorders
Musculoskeletal discomfort

ABSTRACT

Background: Surgical fatigue syndrome (SFS) is a frequent, but underestimated, entity that occurs during laparoscopic surgeries. It could impair surgical outcomes, patient safety, and surgeon health. Furthermore, current surgical education lacks effective interventions to avoid it. Discomfort represents the most common manifestation and includes musculoskeletal fatigue, numbness, or frank pain. The most common affected sites are the back neck, dominant hand shoulder, and high or low back. We propose an integral intervention (surgeon posture, instruments/devices design & use and discomfort improvement) that prevents or mitigates SFS.
Methods: An experimental study was conducted on 57 general surgery residents and general surgeons. Participants in the experimental and control group executed standardized laparoscopic knots in a simulator and knowledge, body discomfort, and posture/ergonomic risk was evaluated before and after intervention application.
Results: A statistically significant decrease in discomfort intensity was found in the experimental group. Also, discomfort presentation by the anatomic site diminishes and surgical performance improves.
Conclusions: Intervention prevents or mitigates discomfort associated with muscle-skeletal component of SFS.
ACGME competency: Practice Based-Learning and Improvement.

Introduction

Surgical fatigue syndrome (SFS) is a common surgical performance entity (at least in its muscle-skeletal component) but underestimated and under-researched [1]. It is manifested by reduced psychomotor dexterity, mental exhaustion, increased irritability, and impaired surgical judgment. It is recognized generally after 4 h of continuous surgical performance during elective surgery [2], but its first and incipient manifestations (muscle-skeletal component) probably appear earlier. The most common places of pain include the back neck, dominant hand shoulder, and high or low back [3].

Surgeons report muscular symptoms in 12 % to 80 % of laparoscopic surgeries [1,4]. Despite its high prevalence, related symptoms such fatigue, numbness or frank pain are included in the term discomfort, and it represents the most common manifestation of SFS [3]. Surgeons are often unaware of recommendations or guidelines designed to improve their comfort while operating [5,6]. Most general surgery programs lack formal ergonomic education [7], especially for minimally invasive procedures and only 60 % of surgeons incorporate recommendations appropriately [8]. These lead to poor discomfort perception, inaction and SFS persistence.

In addition, minimally invasive procedures have altered the way surgeons interact with the surgical field and how the SFS manifests. Static and specific postures (for example, leaning forward increases

Abbreviations: SFS, Surgical Fatigue Syndrome; SP, Surgical performance.

* Corresponding author at: Blvd. Puente del Milenio 1001 Fraccionamiento San Carlos, 37670 León, Guanajuato, Mexico.
E-mail addresses: g.chavezsaavedra@ugto.mx (G. Chávez-Saavedra), le.colonnamarquez@ugto.mx (L.E. Colonna-Márquez), ddiazma@guanajuato.gob.mx (D.A. Díaz-Martínez), bvgonzalez@ugto.mx (B.V. González-Sandoval).
@DRCHAVEZS (G. Chávez-Saavedra)

https://doi.org/10.1016/j.sopen.2023.10.014
Received 20 June 2023; Received in revised form 3 October 2023; Accepted 24 October 2023
Available online 2 November 2023

muscle activity to balance the upper body) contribute to physical fatigue [9,10]. The surgeon's vision is restricted by an optic and camera system, and long-shafted instruments (both with limited degrees of freedom movements) causing uncomfortable excursion and loss of tactile feedback represent ergonomic deficiencies that affect body movements, compared to open surgery [11,12].

An intervention focused on preventing and mitigating musculoskeletal discomfort, integrating probed principles that modify 3 main factors that predispose to SFS during surgical performance, was designed. The intervention was called EDiS3 because includes Ergonomic principles, Discomfort perception and muscular Stretching. Surgeon optimal posture (Fig. 1) improves quality and execution time because reduces muscle work [13]; distance from monitor reduce visual stress and its consequent body position modification; operating room table height and laparoscopic instruments handle position and angle minimizes muscle work in upper arm and shoulder [14] allowing arm and wrist neutral position for a comfortable stitching and knotting execution (Fig. 1) [15].

The instruments/devices design & use, that impact muscle work and surgical performance, are included in EdiS3 (Fig. 2). Ergonomic needle holder use avoids forced ulnar deviation and reduces hand and forearm muscles work [15]; partial introduction of thumb in the handle ring while instrument manipulation reduce workload in finger's dorsum & tenar region. Both changes translate into more efficient task performance [16]. Easy foot pedal access (just in front of the dominating foot) diminishes surgeon efforts to keep comfort position while preventing foot contact loose with the pedal, preventing loading body weight on the other foot [17].

Finally, discomfort perception is improved, and stretching is applied to mitigate it (Fig. 3). The lack of musculoskeletal symptoms awareness of surgeons [1] is modified by increasing self-perception of discomfort presentation, leading to stopping surgical performance & execution of muscle stretching in 3 repetitions with a duration of 20 s [19].

The main objective of this research is to determine if EDiS3 diminishes SFS in surgeons and residents. This paper seeks to provide knowledge about SFS musculoskeletal symptoms, how to prevent or mitigate it, and measure if some surgical performance parameters (time of execution and number of knots) improve with the proposed intervention. SFS mental component, its short- and long-term consequences avoidance and patient safety impact are out of the scope of this work.

Material and methods

After institutional ethical review committee approval was obtained and the subjects gave informed consent to the work, an experimental single-blind study was conducted. An entire cohort ($N = 57$) of general surgery residents and general surgeons from two second-level and one third-level hospitals were included in the study (Table 1). None of them had formal education in SFS and ergonomics; general surgeons had basic laparoscopic training and experience. After they signed informed consent, they were randomly divided into a control group (n = 28) and an experimental group (n = 29). Both groups performed laparoscopic exercises two times and were evaluated at the end of each time. The experimental group received EDiS3 intervention, and the control group received only the theoretical component. Discomfort (auto perception time and intensity) was selected as the dependent variable as it is proposed to be diminished or prevented with EDiE3.

EDiS3 implementation includes three components: a principles theoretical session, posture measure & correction, and practical demonstrations for discomfort awareness. Although it is applied in an experimental context, all components could be translated into the operating room. The theoretical component is based on cognitive load theory to develop declarative competencies about theoretical principles of SFS avoidance [20]. The objective is to provide knowledge with a practical orientation to integrate surgical performance. It includes clear and simple explanations of SFS general aspects, ergonomic principles and stretching explanations.

The practical component is based on the practice-base learning theory [21]. It consists of facilitator demonstration and participant executions of laparoscopic knot tying applying theoretical principles. The objective is to apply the principles learned, increase discomfort perception, and develop comfortable psychomotor laparoscopic skills. Discomfort perception represents a key element for mitigation because it allows the participant to stop surgical execution, start stretching of affected muscle and restart surgical activities with a relaxed muscle.

Each component was evaluated by validated tools. The theoretical component was evaluated by an *ad hoc* developed questionnaire that

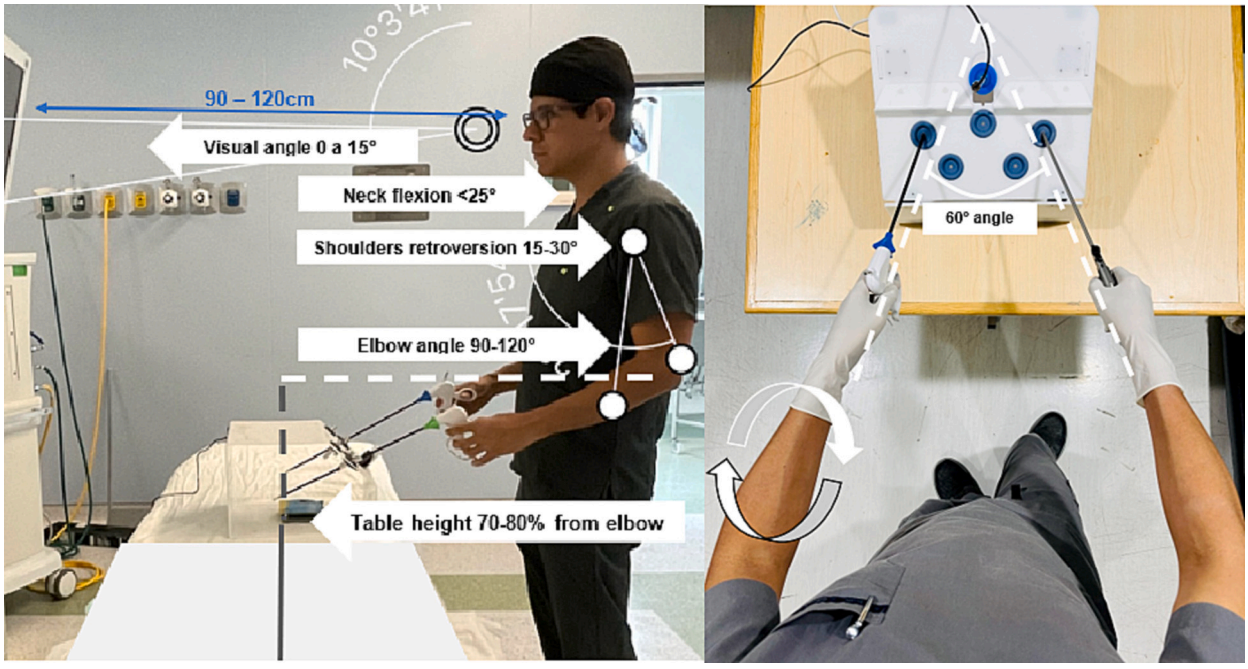

Fig. 1. Surgeon posture. Monitor and table position determined body work angles. Angle between instruments determine forearm neutral rotating posture to allow comfortable movements (curve arrows). The wrist should have a slight extension and fingers are bent slightly.

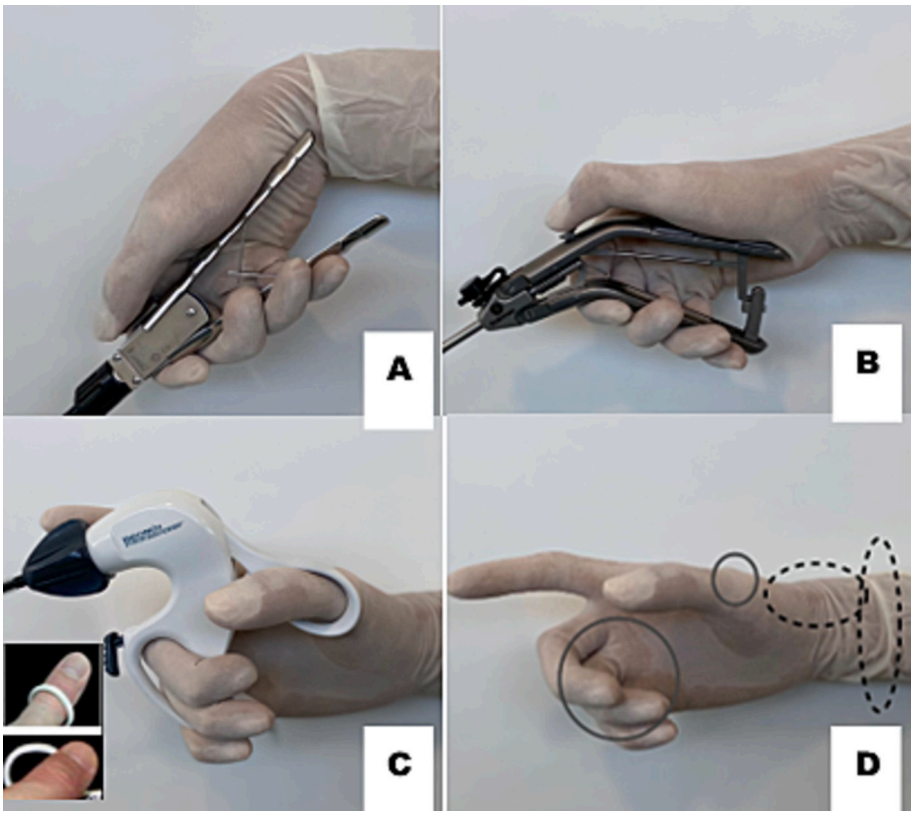

Fig. 2. Instruments use & pressure zones. A, forced ulnar deviation caused by a non-ergonomic needle holder. B, avoidance of ulnar deviation by ergonomic instrument. C, Introduction of full thumb in instrument ring increase pressure and increase risk of discomfort. Partial introduction diminishes discomfort without compromising instrument manipulation. D, Main points of pressure due to instrument use.

assess fundamental knowledge acquisition in 20 multiple choice items. It was designed by a specialist in physical medicine and rehabilitation, a Doctor of Philosophy engineer with expertise in ergonomics, and a laparoscopic surgeon with experience in competency assessment tools. A test performed in a pilot group allows its review and improvement before its application in both groups to ensure internal validation and reliability.

Participant posture measure & correction component relies on the Rapid Upper Limb Assessment (RULA) application. The objective is the acquisition and maintenance of the correct laparoscopic posture during the exercise's execution. The RULA scale, measured from participant pictures, allows neck, shoulder, and elbow angle correction [22]. This tool had been previously validated in an industrial ergonomic context to measure injury risk in workers and in ergonomic risk assessment of surgeons performing endoscopic sinus surgery [23].

Practical demonstrations for the discomfort awareness component were evaluated by the Body Discomfort Scale (BDS) Test. It assesses the site and intensity of discomfort in the body, the changes in discomfort patterns during the work period, the tool design influence on discomfort, and the effectiveness of ergonomic changes introduced to diminish discomfort. It was validated in spot welders working with machines by an engineering production evaluation of postural discomfort [24] and maxillofacial surgery [25]. This component also includes adaptation of operating room elements before surgical execution to fit ergonomic principles: height of the monitor, position and height of the operating table and foot pedal, and correct instrument use and position [16].

A first laparoscopic knot execution was performed by both groups. Participants performed knots continuously for 15 min or until they began perceiving musculoskeletal discomfort. Executions were performed under standardized conditions: same laparoscopic simulator, Maryland clamp in the right hand, grasper clamp in the left hand, table height set at 60 cm from the ground, 2–0 silk thread of 24 cm and "C" technique for knot execution with the right hand.

Then a pre-intervention evaluation was applied. It included the Questionnaire, BDS Test and RULA scale. Anthropometric and performance parameters were also evaluated: height, weight, Body Mass Index (BMI), body muscle percentage (MP), time to experience discomfort, number of knots and attempts executed. An Omron bioimpedance scale and a Mead & Johnson measuring tape were used to obtain previous data.

The experimental group received EDiS3 intervention, and a second laparoscopic knot was executed. Early recognition of musculoskeletal discomfort was encouraged to stop knot execution, start stretching and correct body posture. The control group only received a theoretical session (theoretical component). A post-intervention evaluation was performed, and all data were registered in a database.

Statistical analysis was applied using SPSS Version 26.0 (IBM, Armonk, New York) software for Windows. Inferential statistics using

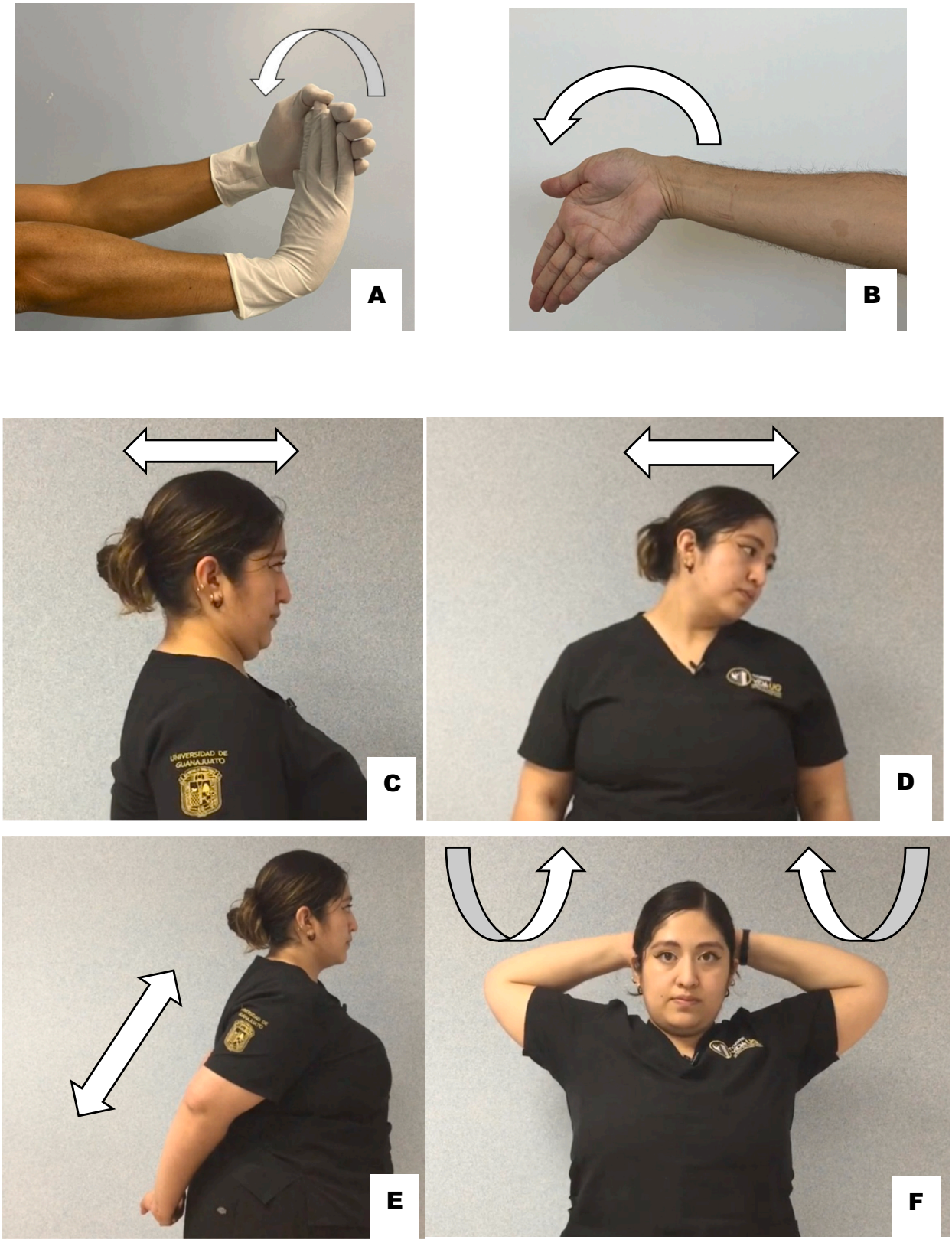

Fig. 3. Muscle exercises: A: Flexor muscles of the fingers. B: abductor/extensor longus of thumb. C: posterior cervical. D: sternocleidomastoid. E: deltoid. F: pectoralis major. Each exercise is performed for 15 s and repeated 3 times.

Table 1
Participant demographics and anthropometric data.

	Experimental group 29 (50.87) n (%) +/-SD	Control group 28 (49.12) n (%)+/-SD	*p* value
Age	28 ± 11.394	28 +/− 2.457	0.118
Gender			
Male	16 (55.17)	20 (71.42)	0.638
Female	13 (44.82)	8 (28.57)	
Residency year			
I	6 (20.68)	6 (21.42)	0.811
II	6 (20.68)	6 (21.41)	
III	6 (20.68)	6 (21.42)	
IV	6 (20.68)	6 (21.42)	
Surgeons	5 (17.24)	4 (14.28)	
Anthropometric data (media)			
Weight (kg)	71.07 ± 14.559	75.52 ± 11.184	0.919
Height (m)	1.66 ± 0.091	1.73 ± 0.081	0.041
BMI	26.04 ± 4.127	25.17 ± 2.752	0.060
Muscle (%)	32.93 ± 5.995	32.57 ± 5.206	0.790

Student's *t*-test for independent samples were used to analyze the pre- and post-test scores between the groups to determine if the EDiS3 intervention mitigates discomfort. Chi-square analysis was also used. Statistical significance was set at $p < 0.05$.

Funding was provided by the authors. A laparoscopic simulator, laparoscopic instruments tape measure and bioimpedance scale were provided by the authors.

Results

There was no significant difference between the demographic profile of the participants in the control and experimental group (Table 1). Data analysis indicated height was the unique anthropometric data with statistical significance between groups. The main effect of intervention showed a statistically significant difference in intensity (BDS Test) of discomfort perception, as the main musculoskeletal manifestation of SFS, between the two groups (Table 2). The effect was the same for both surgeons and residents from any residency year. Discomfort incidence by site also diminishes in the neck, shoulders, wrist, and hand (Fig. 4).

The number of executed knots, as a performance parameter, improve with EDiS3 (Table 2). But the time and the number of attempts didn't decrease. Declarative competencies development (knowledge) increases in both groups, but the experimental group increase was statistical significance compared with the control group.

Discussion

EDiS3 represents an attempt to improve surgeon safety in a physically demanding profession [3]. Although it was applied under experimental conditions, its implementation could be adapted to each operating room context. This means its effects may vary in an operating room during real surgery. However, the principles of ergonomics, perception of discomfort, and the application of most stretches are feasible to apply intraoperatively.

Table 2
Performance and discomfort evaluation.

Variable	Experimental group		Control group		*p**
	Pre EDiS3	Post EDiS3	Pre-Non	Post Non	
Discomfort time (media in minutes)	6.78	6.39	6.69	6.13	0.054
BDS Scale (0–7)	3	0	2	2	0.000
Questionnaire (%)	36.38	75.52	41.07	56.07	0.000
Knots (media)	2.92	3	3	3	0.027
Attempts (media)	4.08	2.8	4.46	3	0.613
Action level RULA (1–7)	3	3	3	3	0.328

* $p \leq 0.05$ intergroup pre and post intervention difference comparison.

EDiS3 ensures correct surgical ergonomics based on practiced behavior, as has been demonstrated by Rosenblatt. It prevents the three most common errors in ergonomic posture: excessive forward head position, sustained uncomfortable elevations, and asymmetry in weight-bearing [26]. Results also showed theoretical session alone didn't improve discomfort. It has been demonstrated that a redesign of equipment and techniques is needed to mitigate risks in health providers [27], and the adoption of ergonomic principles represents an easy way to deal with discomfort.

The best means to prevent work-related injuries are understanding and recognizing how a stable posture feels [28]. This argument sustains discomfort auto perception as a critical step in EDiS3 intervention. This understanding requires training to develop early recognition, correction ability, and muscle memory because many of these positions are performed subconsciously from poor habits that are adopted over time [3].

Discomfort perception is subjective and susceptible to be modified by multiple factors. Therefore, the effect of the intervention may vary significantly among surgeons and even within the same surgeon. This fact shows the importance of use specific exercises that relieve musculoskeletal pain, promote posture correction, and attenuate its subjective character to diminish its variable presentation and risk [29].

Height is statistically significant because it determines neck, elbow, and wrist angles. Short-height participants showed shoulder discomfort because the simulator and table were too close to elbow level, reducing elbow angle and limiting instrument movement. Tall height causes the neck dorsum discomfort because the neck angle is narrowed when head position adapts to a lower monitor position. Muscle percentage didn't show relevance probably because muscles involved are not specifically trained to the surgical load work and instruments point of pressure (more than muscle work) represent a more important cause of discomfort.

Declarative competencies developed (measured by the questionnaire) were statistical significantly improved in experimental group. A feasible explanation is that the practical component of intervention could trigger significant learning in the experimental group. The control group received the same knowledge content and in the same way, but lack of application in a real scenario could impair this competency acquisition. It means that interventions to mitigate SFS need a practical component to be effective.

Results show that surgical performance improved because the number of executed knots increased. Although the main objective was not the surgical performance study, less discomfort presentation during surgery may potentially enhance it. On the other hand, the number of attempts and the execution time didn't decrease maybe because both depend on individual psychomotor skills to perform knots and not in the SFS presentation. To understand how discomfort impairs surgical performance it is necessary to consider other variables such as the type of surgery and the surgeon's physical condition [30].

Adoption of the proposed intervention, among other surgeon lifestyle factors and operating room facilities improvements, could improve surgical performance. Furthermore, specific tools to evaluate SFS discomfort are needed to address better its impact on surgical performance and outcomes.

Conclusion

EDiS3 intervention mitigates discomfort associated with muscle skeletal component of SFS.

Ethical approval

INSTITUTO MEXICANO DEL SEGURO SOCIAL
DIRECCIÓN DE PRESTACIONES MÉDICAS

Dictamen de Aprobado

Comité Local de Investigación en Salud **1005.**
H GRAL ZONA -MF- NUM 21

Registro COFEPRIS **17 CI 11 020 031**
Registro CONBIOETICA **CONBIOETICA 11 CEI 004 20190709**

FECHA **Viernes, 27 de enero de 2023**

Dr. Gerardo Chávez Saavedra

P R E S E N T E

Tengo el agrado de notificarle, que el protocolo de investigación con título **Intervención en la Ergonomía del laparoscopista ¿Una posibilidad de mejorar el desempeño quirúrgico?** que sometió a consideración para evaluación de este Comité, de acuerdo con las recomendaciones de sus integrantes y de los revisores, cumple con la calidad metodológica y los requerimientos de ética y de investigación, por lo que el dictamen es **A P R O B A D O**:

Número de Registro Institucional
R-2023-1005-005

De acuerdo a la normativa vigente, deberá presentar en junio de cada año un informe de seguimiento técnico acerca del desarrollo del protocolo a su cargo. Este dictamen tiene vigencia de un año, por lo que en caso de ser necesario, requerirá solicitar la reaprobación del Comité de Ética en Investigación, al término de la vigencia del mismo.

ATENTAMENTE

M.C. Manuel Lopez Varela
Presidente del Comité Local de Investigación en Salud No. 1005

Imprimir

IMSS
SEGURIDAD Y SOLIDARIDAD SOCIAL

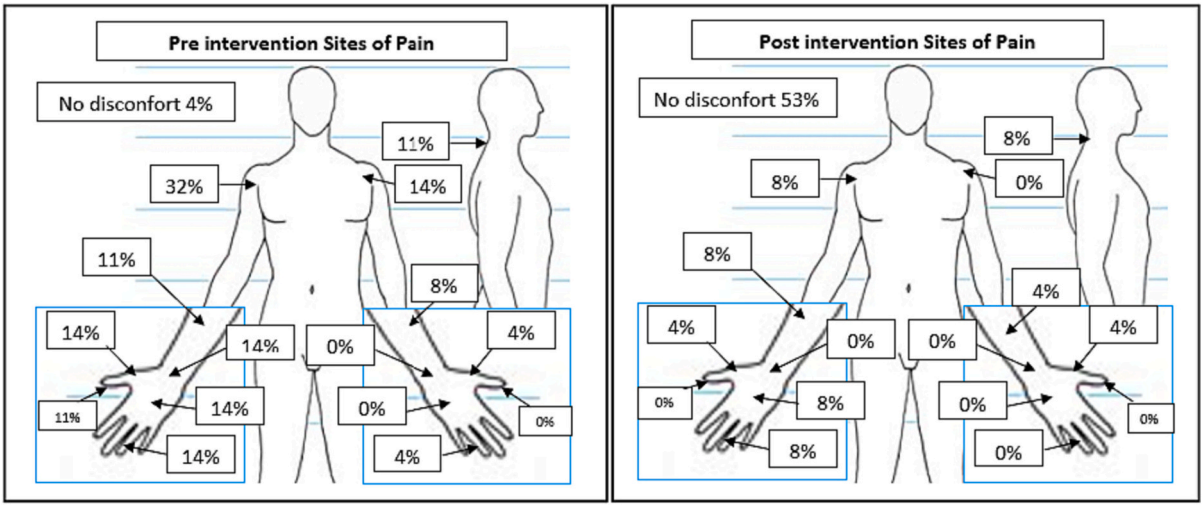

Fig. 4. Percentage of discomfort by site. Incidence of discomfort diminishes in majority of sites after experimental group received EDiS3.

Funding sources

This study was supported by the Instituto de Salud Publica del Estado de Guanajuato.

CRediT authorship contribution statement

Gerardo Chávez-Saavedra: Conceptualization, Methodology, Investigation, Writing – review & editing. **Angélica Espinosa-Hinojosa:** Investigation, Data curation, Visualization. **Luis Enrique Colonna-Márquez:** Investigation, Resources, Writing – original draft. **Carlos Hidalgo-Valadez:** Validation, Resources. **Daniel Alberto Díaz-Martínez:** Formal analysis, Supervision. **Beatriz Verónica González-Sandoval:** Investigation, Writing – original draft.

Declaration of competing interest

The authors states don't have conflict of interest.

Acknowledgements

The authors wish to thank Alejandra del Rocio Reynoso Ramírez for stretching demonstrations.

References

[1] Epstein S, Sparer EH, Tran BN, Ruan QZ, Dennerlein JT, Singhal D, et al. Prevalence of work-related musculoskeletal disorders among surgeons and interventionalists: a systematic review and meta-analysis. JAMA Surg 2018;153(2). Feb 1.
[2] Cuschieri A. Whither minimal access surgery: tribulations and expectations. Am J Surg 1995;169(1):9–19. Jan.
[3] Schlussel AT, Maykel JA. Ergonomics and musculoskeletal health of the surgeon. Clin Colon Rectal Surg 2019;32(6):424–34.
[4] Berguer R, Forkey DL, Smith WD. Ergonomic problems associated with laparoscopic surgery. Surg Endosc [Internet] 1999;13(5):466–8. May 27. Available from: http://link.springer.com/10.1007/PL00009635.
[5] Schlussel AT, Maykel JA. Ergonomics and musculoskeletal health of the surgeon. Clin Colon Rectal Surg 2019;32(06):424–34. Nov 22.
[6] Plerhoples TA, Hernandez-Boussard T, Wren SM. The aching surgeon: a survey of physical discomfort and symptoms following open, laparoscopic, and robotic surgery. J Robot Surg 2012;6(1):65–72. Mar.
[7] Epstein S, Tran BN, Capone AC, Ruan QZ, Fukudome EY, Ricci JA, et al. The current state of surgical ergonomics education in U.S. surgical training: a survey study. Ann Surg 2019;269(4):778–84. Apr 1.
[8] Park A, Lee G, Seagull FJ, Meenaghan N, Dexter D. Patients benefit while surgeons suffer: an impending epidemic. J Am Coll Surg 2010;210(3):306–13. Mar.
[9] Kant IJ, de Jong LCGM, van Rijssen-Moll M, Borm PJA. A survey of static and dynamic work postures of operating room staff. Int Arch Occup Environ Health 1992;63(6):423–8. Feb.
[10] Matern U. The laparoscopic surgeon's posture. In: Bogner MS, editor. Misadventures in health care: inside stories. Lawrence Erlbaum Associates Publishers; 2004. p. 75–88.
[11] Berguer R, Rab GT, Abu-Ghaida H, Alarcon A, Chung J. A comparison of surgeons' posture during laparoscopic and open surgical procedures. Surg Endosc 1997;11(2):139–42. Feb 1.
[12] Matern U. Ergonomic deficiencies in the operating room: examples from minimally invasive surgery. Work 2009;33(2):165–8.
[13] Emam TA, Hanna G, Cuschieri A. Ergonomic principles of task alignment, visual display, and direction of execution of laparoscopic bowel suturing. Surg Endosc Other Interv Tech 2002;16(2):267–71. Feb 30.
[14] Berquer R, Smith WD, Davis S. An ergonomic study of the optimum operating table height for laparoscopic surgery. Surg Endosc Other Interv Tech 2002;16(3):416–21. Mar 16.
[15] Matern U, Waller P. Instruments for minimally invasive surgery. Surg Endosc [Internet] 1999;13(2):174–82. Feb 20. Available from: http://link.springer.com/10.1007/s004649900934.
[16] Emam TA, Frank TG, Hanna GB, Cuschieri A. Influence of handle design on the surgeon's upper limb movements, muscle recruitment, and fatigue during endoscopic suturing. Surg Endosc 2001;15(7):667–72. Jul 9.
[17] van Veelen MA, Snijders CJ, van Leeuwen E, Goossens RHM, Kazemier G. Improvement of foot pedals used during surgery based on new ergonomic guidelines. Surg Endosc [Internet] 2003;17(7):1086–91. Jul 1. Available from: http://link.springer.com/10.1007/s00464-002-9185-z.
[19] Winters JN, Sommer NZ, Romanelli MR, Marschik C, Hulcher L, Cutler BJ. Stretching and strength training to improve postural ergonomics and endurance in the operating room. Plast Reconstr Surg Glob Open [Internet] 2020;8(5):1–9. Available from: https://journals.lww.com/10.1097/GOX.0000000000002810.
[20] van Merrienboer JJG, Kirschner PA, Kester L. Taking the load off a learner's mind: instructional design for complex learning. Educ Psychol 2003;38(1):5–13. Jan 1.
[21] Ericsson KA, Krampe RT, Tesch-Römer C. The role of deliberate practice in the acquisition of expert performance. Psychol Rev 1993;100(3):363–406. Jul.
[22] Cameron JA. Assessing work-related body-part discomfort: current strategies and a behaviorally oriented assessment tool 1. Int J Ind Ergon 1996;18.
[23] Dabholkar T, Dabholkar YG, Yardi S, Sethi J. An objective ergonomic risk assessment of surgeons in real time while performing endoscopic sinus surgery. Indian J Otolaryngol Head Neck Surg 2020;72(3):342–9. Sep 7.
[24] Corlett EN, Bishop RP. A technique for assessing postural discomfort. Ergonomics 1976;19(2):175–82.
[25] Seifert LB, Herrera-Vizcaino C, Herguth P, Sterz J, Sader R. Comparison of different feedback modalities for the training of procedural skills in Oral and maxillofacial surgery: a blinded, randomized and controlled study. BMC Med Educ 2020;20(1):330. Dec 24.

[26] Rosenblatt PL, McKinney J, Adams SR. Ergonomics in the operating room: protecting the surgeon. J Minim Invasive Gynecol 2013;20(6):744.
[27] Harris NO, Crabb LJ. Ergonomics. Reducing mental and physical fatigue in the dental operatory. Dent Clin N Am 1978;22(3):331–45. Jul.
[28] Kisner C, Colby LA. The spine: structure, function, and posture. In: Therapeutic exercise: foundations and techniques, 6e [internet]. New York, NY: McGraw-Hill Education; 2012. Available from: http://fadavispt.mhmedical.com/content.aspx?aid=1134929778.
[29] Kim D, Cho M, Park Y, Yang Y. Effect of an exercise program for posture correction on musculoskeletal pain. J Phys Ther Sci [Internet] 2015;27(6):1791–4. Available from: https://www.jstage.jst.go.jp/article/jpts/27/6/27_jpts-2015-023/_article.
[30] Whelehan DF, Connelly TM, Burke JR, Doherty EM, Ridgway PF. Self-reported surgeon health behaviours: a multicentre, cross-sectional exploration into the modifiable factors that impact surgical performance with the association of surgeons in training. Ann Med Surg 2021;65. May. Available from: https://journals.lww.com/10.1016/j.amsu.2021.102299.