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ERGONOMICS EDUCATION IN ORTHOPEDIC SURGERY

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Abstract

The motivation of research was poor quality of working conditions in orthopedic practice which results from lack of use of ergonomics principles by medical staff. Hence, the research objective was to indicate the most important determinants for creating high-quality working conditions in operating room, particularly when performing orthopedic procedures. As methodology, the observations, video-registrations and interviews with orthopedic professionals were conducted. Based on the research material, the ergonomic and workflow assessments were examined. The research outcomes confirmed a problem of low quality working conditions during orthopedic surgeries resulted from insufficient knowledge and awareness of orthopedists regarding ergonomics. There was diagnosed a need for creation of a specialized guide for orthopedists and medical decision makers of how to improve working conditions in operating room on the background of the human and technical perspectives. As a result there was proposed the comprehensive online course on ergonomics for orthopedists and all medical staff who are interested in and are responsible for safety and comfortable conditions at their workplace. Hence the future scope is formulated as the monitoring and evaluation of working conditions after implementing ergonomics course within medical staff.

Keywords

Ergonomics, Orthopedics, Operation Room, Working Condition Quality, International Online Course

1. Introduction

Surgery is one of the medical domains with high physical and mental demands and involves a series of risks for the surgeon. This is all the more important that surgery, including orthopedics, is developing and strives to change the operating techniques to minimally invasive what increases the negative impact on the health, comfort and quality of life of surgeons. The

physical and cognitive requirements during surgery pose substantial ergonomic stress (Dabholkar et al., 2015). The intraoperative surgical workplace is affected by stressing environmental factors and, additionally, surgeons have to perform high-force as well as high-precision tasks in combination with multimodal information processing. This leads to increased stress and strain, resulting in muscle overload, fatigue of surgeons and higher risk for human error (Glickson, 2012) and for inefficiencies in operations, causing that surgeons suffer from severe musculoskeletal disorders with progressing working life (Wauben, et al. 2006; Van Veelen et al., 2003; Laura Santos-Carreras et al. 2011). Another factor affecting working conditions and surgeons' effectiveness is workflow and surgical team cooperation. The survey conducted among nurses and physician indicated that the reasons of interruptions are malfunctions and organizational constraints (Elfering et al. 2015). Taking these all aspects into consideration, the recommended solution is to redesign surgical processes in order to improve efficiency, safety, and comfort for the operating team, while reducing physical strains on surgeons. Hence, in the paper we were focus on working quality development of orthopedic practice.

Among many definitions of the concept quality, two of them are especially important from quality of working conditions point of view: quality is the totality of features and characteristics of a product or service that bears on its ability to satisfy given needs (ISO 8402:1996) and quality means freedom from deficiencies (Planning for Quality, 1990). These definitions indicated two essential aspects of high-quality working conditions in such demanding environment like operating room. The first one is satisfaction of people who are staying (hospitalizing or working) at a hospital. The second one is completeness of all necessary human and technical components that condition the achievement of aforementioned satisfaction.

On the one hand the appropriate quality of working conditions is necessary to provide patients effective and safe medical services, so they influence in fact on quality of life (QoL) of patients. On the other hand working conditions influence on QoL of surgeons because of contribution of working factors to many inconveniences like mental and physical discomfort, reduced physical condition and even disorders especially within musculoskeletal system.

Taking into account the outcomes of international survey conducted in Spain, Poland and Germany by the project "Online Vocational Training course on ergonomics for orthopedic Minimally Invasive Surgery", acronym Train4OrthoMIS, one third orthopedic surgeons suffer from low back pain and neck pain. Additionally, for the most common disorders resulted from

non-ergonomic working conditions and reported by surgeons belong neck stiffness, fatigue and musculoskeletal stress, fatigue in the legs and feet and mental fatigue. The Figure 1 presents mutual relations between quality, working conditions and their impact on QoL of both internal (medical staff) and external (patients) customers of medical services.

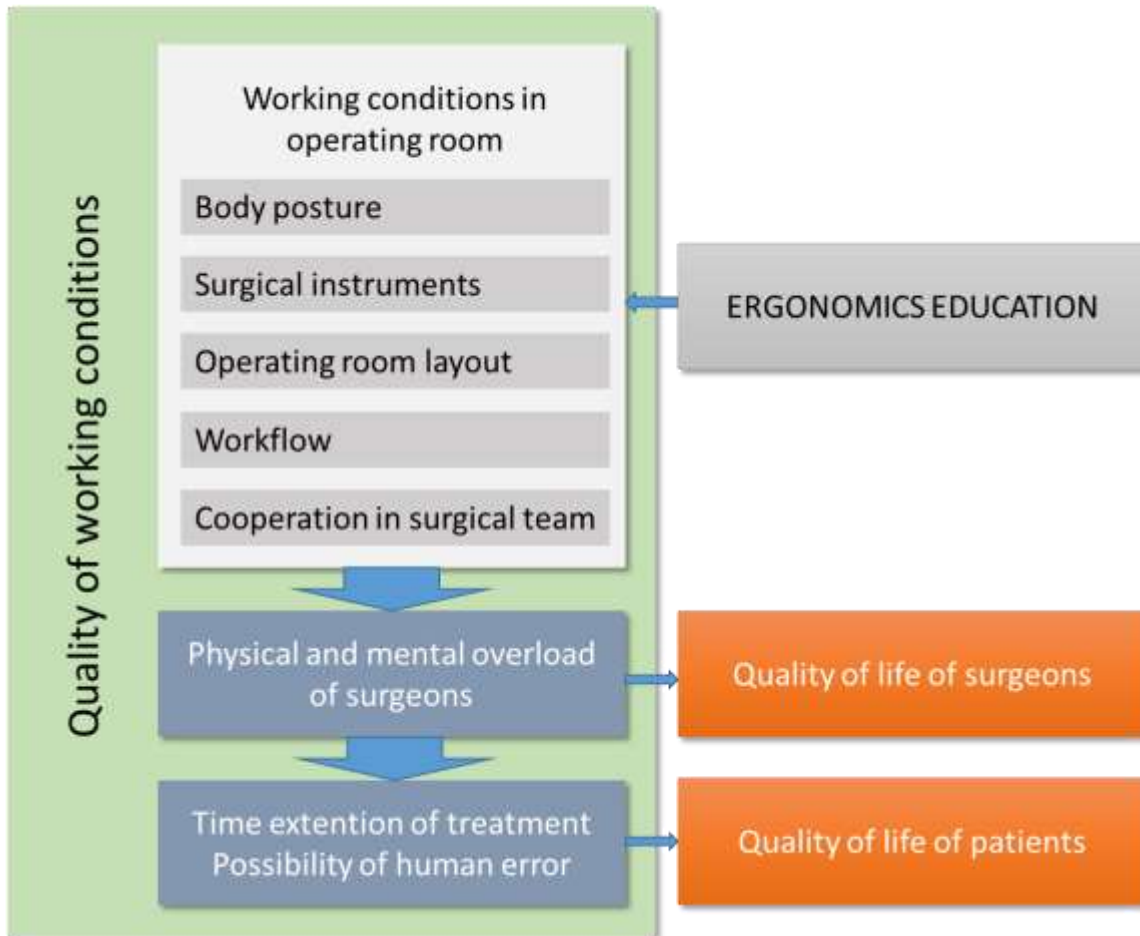


Figure 1: The relations between quality, working conditions and their impact on QoL

Based on the Fig. 1 it can be concluded that the quality of working conditions in operating room can be considered from two perspectives namely human and technical perspectives. Human perspective represents all decisions and behavior by orthopedists which affect the ergonomics factors like body posture, surgical tools design, operating room layout, surgical team cooperation and workflow. In turn, technical perspective means all technical and functional specifications that build the ergonomic quality level of technical means including surgical tools, medical equipment, medical furniture, space and shape of operating room etc. The



primary reason of physical and mental overload, resulting from ergonomic deficiencies, is lack of ergonomics education of orthopedic staff and hospital managers who are responsible for creating working conditions.

Taking into account this problem area, the research was conducted which aim was to indicate the most important determinants for creating high-quality working conditions in operating room, particularly when performing orthopedic procedures as well as to propose educational tool for quality of working conditions improvement.

2. Methodology

The interviews with experienced medical professionals from Germany, Poland and Spain including orthopedic surgeons (n=13) and doctor of occupational medicine (n=1) were conducted in order to recognition educational needs related to ergonomics in orthopedic surgery. There was used categorized questionnaire with following examined areas:

- A1. Analysis of the offers regarding trainings in the area of ergonomics dedicated to orthopedic surgeons.
- A2. The assessment of surgeons' awareness about the needs of ergonomics education.
- A3. Analysis of the areas of knowledge required for the improvement of ergonomics in orthopedic surgery.
- A4. Recognition of preferences for training. Requirements for adequate training materials on ergonomics applied to the field of orthopedic surgery.
- A5. Opinion about course online methodology.

Additionally, the observations and video-recordings (n=6) were carried out in order to assess working conditions in terms of ergonomics and workflow. The areas of examination were coincident with the presented on the Fig. 1: body posture, surgical team cooperation/communication and workflow (human perspective) surgical tools and operating room layout (technical perspective). Ergonomic assessment was based on observation methods, mainly RULA and computer aided method 3D SSPP (Three Dimensional Static Strength Prediction Program from The University of Michigan Center for Ergonomics). The workflow analysis were based on graphical representation of the work time combined with both the quantitative assessment including inter alia the execution time of specific activities or stages of the procedure as well as the frequency of critical events and the qualitative assessment indicating

the types of adverse events, the circumstances of their occurrence, etc.. These analysis were supported by CAPTIV system (TEA Technology Ergonomics Applications).

Based on the study outcomes there was indicated the determinants for creating high-quality working conditions in orthopedic surgery that should be included into training designed for medical professionals.

3. Results and discussion

3.1 Interview

In the table 2.1 there was described the results of interviews with the division on particular area of examination.

Table 1: *The interview results*

The examined area	Interview outcome
A1	According to surgeons there is little opportunity to participate in trainings on ergonomics. The main reason for it is the lack of ergonomics subjects within educational pathway, particularly in medicine schools and then provided by a hospital or health system. Occasionally, the certain ergonomics aspects are embedded into broader and specializing courses like arthroscopy, osteotomy, prosthesis or other implant.
A2	The responded experts agreed that training in ergonomics is needed for them and generally for medical professionals.
A3	The most important aspects indicated by experts that should be the subjects of the course are following: <ul style="list-style-type: none">• Comfortable body postures• Ergonomics movements• Equipment layout and setting – especially monitor, operating table etc.• How to relax, what kind of exercises should be done by orthopedists after surgery in order to compensate efforts and pains• Techniques of using surgical instruments

	<ul style="list-style-type: none"> • How to create comfortable atmosphere among surgical team members • Aspects of material work environment like temperature, humidity, walls' colors etc. • How to talk with patients • How to manage the space e.g. the problem with many kind of cables, tubes that disturb when performing surgery
A4	<p>The opinions and preferred features for online course by medical experts are as follows:</p> <ul style="list-style-type: none"> • The most appropriate duration of the course is maximum 5 months and 10 hours weekly • The course time should be flexible and allow for organizing organize the completion of the course as adjustable as possible • The training materials should be diverse and reflect useful and practical knowledge. This can be done by videos accompanied with text easy to read and interactive content. • Preferable structuring the course in small modules • The important for doctors is to receive educational points for participating in the course, also certificate or diploma is desirable
A5	<p>There were indicated advantages and disadvantages of on-line type of the course:</p> <ul style="list-style-type: none"> • The advantages are saving time, flexible organization of learning process. • The disadvantages are the lack of practical (live) exercises in operating room, little motivation to sacrifice a private (family) time.

The general recommendation for ergonomics educations is to provide opportunity to learn and preserve proper (safe) movements patterns at the beginning of educational pathway starting from primary school. The weakness of receiving knowledge being already practitioner is the problem of changing wrong habits, especially related with manual operations, e.g.

maintaining elbow above shoulder. These in turn may result in occurrence of musculoskeletal disorders.

Additionally, it was recognized the problem in the area of proper implementation of modern surgical tools and new surgical techniques like MIS in orthopedics. These are usually not known by medical personnel and the trainings provided in the beginning of using them usually does not include ergonomic aspects. This forces the need of additional trainings among medical personnel of how to use surgical instruments in a proper way and that will lead to prevent technical and occupational hazards. Simultaneously, some of negative consequences of using surgical tools do not depend on the manner of using them by surgeon but results from non-ergonomic design. Such a problem reflects the deficiencies in ergonomics education of engineers and designers.

3.2 Observations and video-recordings

3.2.1 Case study of body postures

There were recognized risk factors contributing awkward body position among surgeons when performing two examined types of orthopedic surgeries: hip replacement and spine surgeries. They are following: prolonged reaching, body parts are in deviated position from neutral, holding fixed position and repetitive movements.

Awkward postures determine static position which requires more force and increase the amount of recovery time that muscles usually need. Added force hastens the onset of fatigue and increases the likelihood of injury from overuse. Particularly the literature highlights such factors contributing awkward body position like repeated or prolonged reaching, twisting, bending, kneeling, squatting, working overhead with the hands or arms, or holding fixed positions (Jaffar 2011).

The tests performed basing on video-recordings indicated typical risk factors for all of observed surgeries. The graphical results are presented in the Fig. 2, 3, 4.



Figure 2: *Awkward body posture of surgeon while performing hip replacement – standing position*

Standing posture while performing hip replacement can force maintaining deeply bent and twisted position of trunk and neck. It results from the height of operating table and the necessity of visual accessing to operating field. Additionally surgeons can maintain twisted body position or awkward arms position when reaching for surgical instrument. This is associated to operating room layout (position of instrument table and location of scrub nurse) and workflow including team cooperation and effectiveness of communication particularly in line surgeon – scrub nurse.

In the same time the arms may be raised and abduct while using surgical tools when operating more dynamic and with repetitive movements e.g. during developing femur stem for prosthesis stem, doing bone cutters into the marrow cavity or sticking the prosthesis stem. Raised arms are the consequence of maintaining bending position of trunk.

In addition, the difficult access to operating field in combination with the maladjusted tools' design results the critical position of wrists.



Figure 3: Awkward body posture of surgeon while performing hip replacement – seated position

According to biomechanical calculations performed with the use of Three Dimensional Static Strength Prediction Programme (3D SSPP, 2011), sitting position is slightly more stressed for musculoskeletal system in back than while standing. Taking into account the neutral positions of standing and sitting there is noted the low back compression for 50 percentile male at level 474 [N] and 635 [N] respectively.

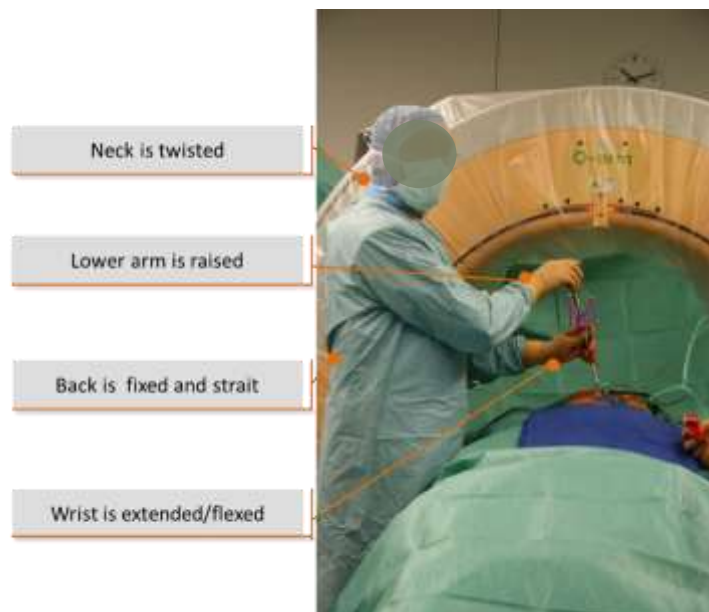


Figure 4: Awkward body posture of surgeon while performing spine surgery

This example of postural pattern highlights tendency to maintain a vertical posture, with less back mobility and weight distribution. The twisted neck results from the monitor position which is located out of the horizontal plane and straight ahead of the surgeon. Additionally the limited mobility of arms' movements causes the postural stress of upper limbs.

Summarizing all of the examples it can be concluded that the working conditions require investigation and changes immediately due to a high risk of occurrence of Work-related Musculoskeletal Disorders (WMSDs) for surgeons. According to RULA method the examined body positions receive the worst score i.e. 7 in 7-point scale. Simultaneously, the examples show that both sitting and standing position as well as upper body and lower body position are non-ergonomic and may cause postural stress.

3.2.2 Case study of surgical tools

It was examined the differences between hand anthropometric data of man and woman for 5-50-95 percentile (Fig. 5).

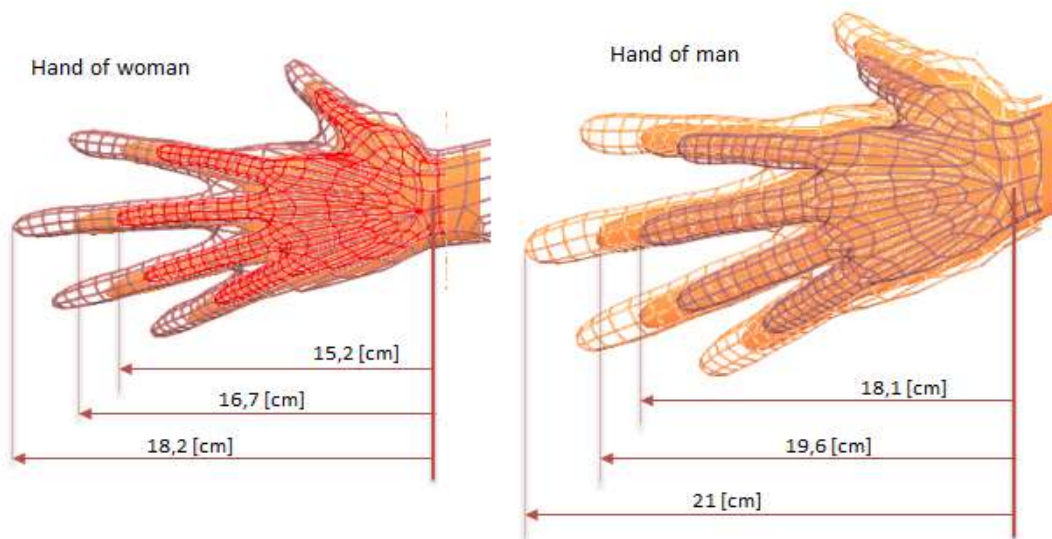


Figure 5: The differences between hand size of man and woman for 5-50-95 percentile

Comparing this anthropometric data with functionality and technical parameters of surgical tools it can be concluded that surgical instruments do not rich the ergonomic criteria in general. Indeed, on the market there are many types of tools with different combinations of handle size and shape, like ringed handle, shank handle, pistol shape of handle, axial handle. Some of the grips are equipped with grooves on the fingers and/or hook allowing relief smallest

finger and a better distribution of compressive forces. When the instruments have ringed handles, it is very important to avoid the introduction of the entire fingers so as not to cause any compressive pathology on the tendons. The rings should be large enough to be able to freely move the arms of a grip. However, there are cases when it is not possible to put a finger in the ring (see Fig. 6).

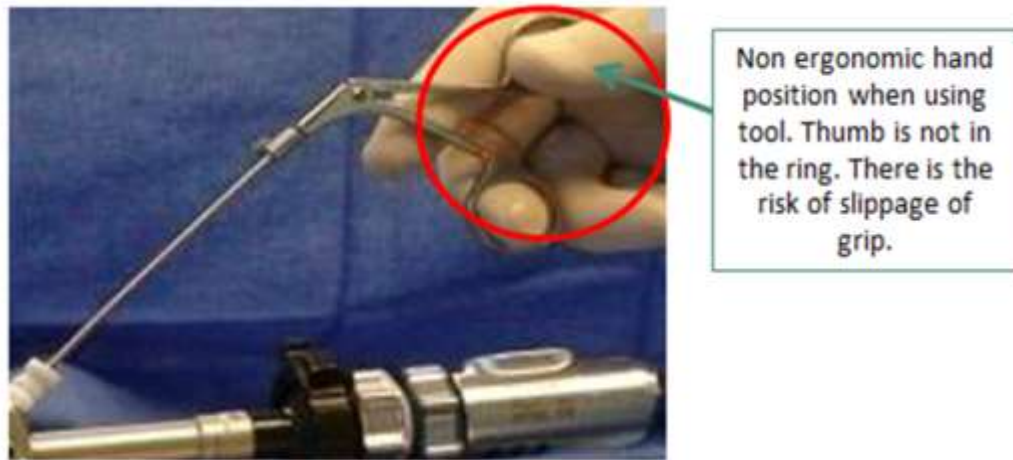


Figure 6: *Non-ergonomic hand position when using a tool*

3.2.3 Case study of operating room layout

Operating room layout represents a spatial arrangement including surgical team members, surgical tools and auxiliary equipment. There are three essential elements determining ergonomically correct working conditions while performing surgical procedures:

- location of instruments table and scrub nurse in regards to surgeon operator;
- the number and location of monitors;
- organization of auxiliary surgical equipment.

As the case study location of instruments table and scrub nurse in regards to surgeon operator was chosen. Fig. 7a,b presents the correctly and incorrectly organized space. The red circles on the pictures suggest the ranges of passing the instruments by scrub nurse.

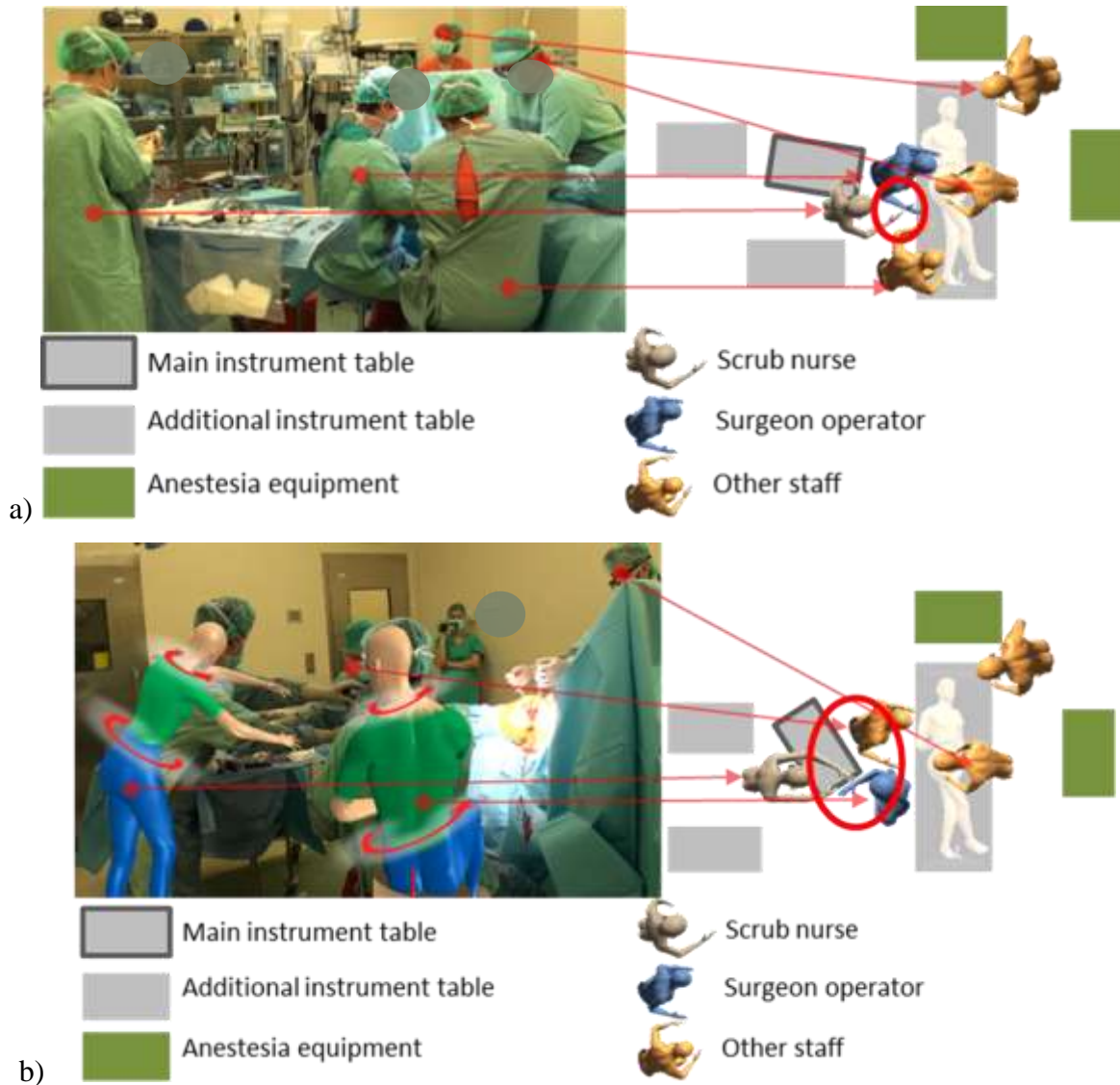


Figure 7: Correctly (a) and incorrectly (b) organized space of instruments table and scrub nurse

The first case presents the scrub nurse and the instrument table locating on the side of the dominant hand of surgeon operator. The scrub nurse is covering range: surgeon operator, surgeon assistant and main instrument table. In addition she can give or take surgical tools without excessive postural stress and effort from the musculoskeletal system.

The second case presents scrub nurse and the instrument table placing in opposite to the dominant hand of surgeon operator. The operator is reaching for the tool by right hand what determines axial rotation of his back and neck.

Because the scrub nurse has to have in range: surgeon operator, surgeon assistant and main instrument table, she handles or takes surgical tools with excessive stress of body posture and effort from the musculoskeletal system. The scrub nurse's back and neck are flexed and rotated. The red circle indicates a large range of passing the instruments by scrub nurse.

3.2.4 Case study of surgical team cooperation/communication and workflow

In general, surgical workflow is the sequence of surgical steps and actions that are accomplished to perform a treatment. Regarding the case study, the basis for modelling workflow was hip replacement treatment.

In the Fig. 8 there is presented two general sections in the graphical representation of workflow:

1. Specification of job elements, inter alia: procedure stages, tools handling, operational activities, disruptions, deficiencies.
2. The processing of job elements showed by use of charts.

All job elements are synchronized with video materials what allows for identification of problems in range of work organization and communication within surgical team as well as their causes and consequences.



Figure 8: Graphical representation of workflow while performing hip replacement

The characteristic elements describing surgical workflow and influencing ergonomics as well as effectiveness of procedure are:

- Disruptions like: improper lighting of the operative field and the need for its corrections; viability of a pump suction and flushing, which consequently can lead to replace with a new one;
- Passive action of surgeon operator results from such causes like: waiting for surgical instruments, waiting for materials etc.
- Deficiencies like: lack of materials, devices etc.
- Cases, where surgeon operator covers activities normally performed by an assistant,
- Cases, where surgeon operator must correct activities performed by an assistant.

Most of these elements are associated to misunderstanding and poor information or knowledge transfer. There is a high degree of knowledge diversity and interactions between variety staff from different units involved in surgical procedures. The problem is that particular member of surgical team does not cooperate in frame of the same team neither during surgeries in operating rooms nor working in wards.

Additionally, it is significant that surgical team consists of variety types of medical specialists who possess different kind of knowledge, motivations, personalities or abilities and that they can have different patterns of behavior as well as different educational paths.

Summarizing, the all case studies that represented only a part of research outcomes on ergonomics confirmed a problem of low-quality working conditions during orthopedic surgeries. Particularly this problem resulted from insufficient knowledge and awareness of orthopedists regarding ergonomics principles. There was diagnosed a need for creation of a specialized guide for orthopedists and medical decision makers of how to improve working conditions in operating room on the background of the human and technical perspectives.

4. Proposition of training on ergonomics for orthopedists-Train4OrthoMIS

As a response to the needs of improving ergonomics within the surgical treatments, it is proposed the comprehensive online course on ergonomics for orthopedists and all medical staff who are interested in and are responsible for safety and comfortable conditions at their workplace. The name of the course is Train4OrthoMIS.

From the obtained results of research phase, the proposal of modules and sessions of the complete online course was developed. The training content is based particularly on research outcomes described partially in previous section and on literature review. The course is divided into four modules. Each module includes work sessions which correspond to learning units and must have duration of about 2 or 3 hours. Each work session starts with a short section in which its main objectives are stated. This section is followed by the corresponding didactic unit and ends with a reinforcement activity which must be completed by the student using the online platform. This activity consists of an exercise automatically corrected by the system and the results are reported to both, the student and the course facilitator.

In the table 4.1 it is proposed following structure of the on-line course.

Table 2: *Proposed structure of the on-line course*

Structure of Module	Content of Module	
	Hip Surgery	Spine Surgery
Module I		
Introduction to the ergonomics in MIS surgery		
Session 1	<ul style="list-style-type: none"> Ergonomics: concept, fields of application in surgery and problems related with the lack of ergonomics. In this introductory session, the student is going to know the basics concepts of the ergonomics and its importance for surgeons' health, and therefore patient's safety. Furthermore, pain, illness and disorders usually suffered by surgeons who perform surgical procedures without ergonomics considerations will be showed. 	
Session 2	<ul style="list-style-type: none"> Ergonomics studies and technologies in MIS surgery. In this session, the student is going to learn different techniques and devices used to evaluate ergonomics in surgery. Then, the training models based on these studies is presented in order to integrate the learning of ergonomics in the current surgical training programs. 	



<p>Session 3</p>	<ul style="list-style-type: none"> Ergonomics guidelines for orthopedic surgery. In this session, a general overview of the most important concepts exposed in the first module is presented. This section is going to strengthen the student's knowledge related to the upper-body ergonomics, ergonomics of surgical tools, operating room layout, surgical team cooperation/communication and workflow in orthopedic surgery. 				
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; padding: 5px;">Module II</td> <td style="width: 50%; padding: 5px;">Module III</td> </tr> <tr> <td style="width: 50%; padding: 5px;">Ergonomics in hip surgery</td> <td style="width: 50%; padding: 5px;">Ergonomics in spine surgery</td> </tr> </table>		Module II	Module III	Ergonomics in hip surgery	Ergonomics in spine surgery
Module II	Module III				
Ergonomics in hip surgery	Ergonomics in spine surgery				
<p>Session 1</p>	<ul style="list-style-type: none"> Introduction to surgical procedures. In this session, basic concept about the main hip (Module II)/spine (Module III) surgeries and the different surgical approach will be presented. Besides, the student going to learn the main ergonomics problems of this type of surgery and how affect to the surgeons and patients. Finally, the pathologies and surgical treatment will be introduced. 				
<p>Session 2</p>	<ul style="list-style-type: none"> Ergonomics considerations for procedure 1. In this session, the student is going to know all ergonomic aspects related with the performance of procedure 1. In first place, a general description of the procedure 1 will be presented. After, all ergonomic consideration related with this surgical procedure will be presented: the necessary equipment, the management of the patient during the surgery, the adequate posture of the surgeons, adequate posture of the surgical team, conditions of the operating room and types of the surgical tools. 				
<p>Session 3</p>	<ul style="list-style-type: none"> Ergonomics considerations for procedure 2. In this session, the student is going to know all ergonomic aspects related with the performance of procedure 2. In first place, a general description of the procedure 2 will be presented. After, all ergonomic consideration related with this surgical procedure 				



	will be presented: the necessary equipment, the management of the patient during the surgery, the adequate posture of the surgeons, adequate posture of the surgical team, conditions of the operating room and types of the surgical tools.
Session 4	<ul style="list-style-type: none">• New surgical approaches, tools and technologies. In this session, the student is going to know innovative concepts regarding ergonomics applied to new surgical procedures. New technologies of navigation and innovative tools for surgery of hip (Module II)/spine (Module III) will be analyzed.
Module IV – Case studies	
Session 1 and 2	<ul style="list-style-type: none">• Operating room setting and environmental conditions in hip (Session 1)/spine (Session 2) surgery. In this session, the student is going to know the basics concepts of the setting and location of surgical equipment in the operating room. Specifically, we are going to present ergonomics aspects related to the operating table and surgical monitor.

When the student has finished all the sessions of the module, he or she must complete the self-evaluation test. The student must pass the tests corresponding to all the modules before doing the final examination which will be necessary for the student to get the corresponding qualifications or certificate.

In the Fig. 9 there is presented the window with implemented e-learning course into e-platform (Virtual Campus IBV <http://campus.ibv.org>).

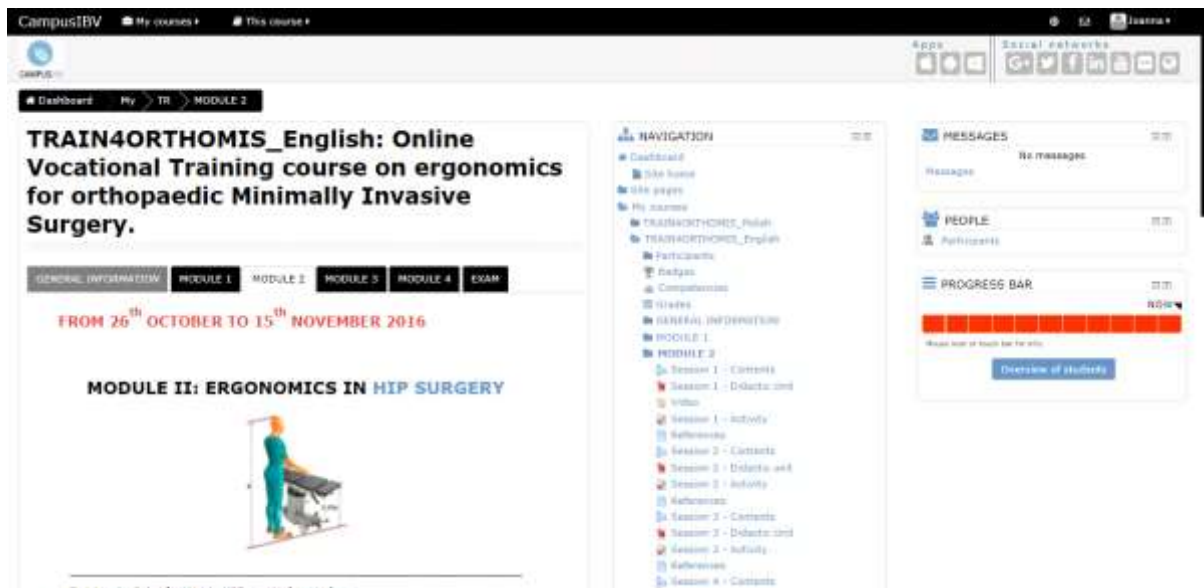


Figure 9: Train4OrthoMIS course on e-platform

The pilot e-learning course was performed in the period 1st November 2016 to 31st January 2017. A total of 76 professionals were recruited to participate in, out of which 12 finished the course fulfilled all the questionnaires in an adequate manner. The total number of questionnaires completed was 332. Particularly the aim of the questionnaires was to assess the usefulness of the training and obtain feedback needed to improve the course.

The assessment section included 6 questions (Fig. 10) which had to be answered using a five-step scale (from “strongly disagree” to “strongly agree”: 1 to 5) to evaluate each session of the 4 modules of the course.

All aspects assessed about contents for all module got good scores, with a minimum score of 4,18 out of 5 and being the best scored features the technical quality of the contents (4,38 out of 5).

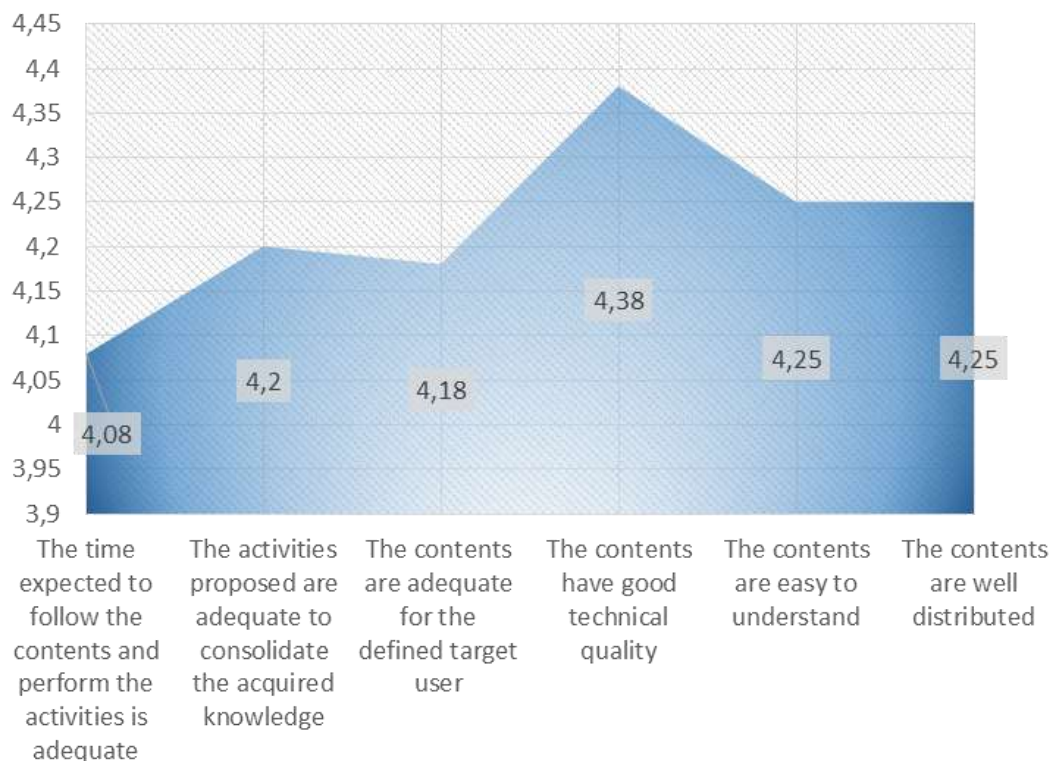


Figure 10: Assessment scores for Train4OrthoMIS course

The feedback provided by the users, compiled through a combination of quantitative information and open answers, opinions and comments, lead to a series of conclusions that should be used for the revision and improvement of the final version of Train4Orthomis course to be promoted in the within international level.

5. Conclusions

There was recognized the most important determinants for creating high-quality working conditions in operating room, particularly when performing orthopedic procedures. They are following: body posture, surgical team cooperation/communication, workflow, surgical instruments and operating room layout. Based on these determinants an international and online educational tool for improvement of working conditions in operating room was proposed named Train4OrthoMIS.

The Train4Orthomis pilot course has been conducted in three countries (Spain, Poland and Germany). According to opinions provided by the students participated in, there is possible

to improve the quality of working condition in operating room and hence QoL of surgical staff and patients by ergonomics education. The evaluation of the results of the Train4Orthomis pilot course additionally provided useful information concerning the functionality and usability of the online platform as well as the adequacy and quality of the developed materials and the pedagogical approach of the course.

Based on the pilot course feedback the future scope can be formulated as the new studies on monitoring and evaluation of working conditions after implementing ergonomics knowledge into orthopedic practice.

There were also recognized three main limitations of the research: (1) relatively small number of respondents taking part in international interview, (2) inability to use advanced research equipment, e.g. motion capture system, in the operating room during live surgeries because of sanitary restrictions, (3) a relatively small number of participants in the pilot course.

6. Acknowledgment

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