Tools and Modalities for Postural Ergonomics Research in Surgery and Neurosurgery

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Abbreviations

BPD	Body Part Discomfort
EMG	Electromyography
IMUs	Inertial measurement units
NASA-TLX	National Aeronautics and Space Administration Task Load Index
NIOSH	National Institute for Occupational Safety and Health
REBA	Rapid entire body assessment
RULA	Rapid Upper Limb Assessment
sEMG	Surface electromyography
SURG-TLX	Surgery task load index
WMSDs	Work-related musculoskeletal disorders

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1 Introduction

Ergonomics is defined by the International Ergonomics Association as 'the scientific discipline concerned with the understanding of interactions among humans and other elements of a system. It also encompasses the application of theory, principles, data, and methods to optimize human well-being and overall system performance' [1]. Ergonomics brings knowledge from anatomy and physiology, psychology, engineering and statistics to ensure that a product, workplace or system are designed to suit the user, rather than expecting people to adapt to a design that forces them to work in an uncomfortable, stressful or dangerous way.

Work-related musculoskeletal disorders (WMSDs) lead to suboptimal performance, affecting the surgeons' ability to operate and as a result patient outcome. In recent studies, up to 88% of neurosurgeons reported having experienced work-related fatigue or pain at least once in their career [2, 3]. Consequently, performing surgical ergonomics research is important to reduce the prevalence and effect of WMSDs and to establish preferable techniques and surgical tools to perform an operation [3, 4].

The aim of the current short review is to present the available tools to perform ergonomics research in the surgical specialties and, specifically, in neurosurgery. We also aim to highlight some important future considerations specific to the neurosurgical specialty.

2 Tools for Surgical Ergonomics Research

The tools and technologies available for ergonomics research in the surgical specialties can be broadly divided into subjective and objective. Figure 1 presents a summary of the available subjective and objective tools for ergonomics research.

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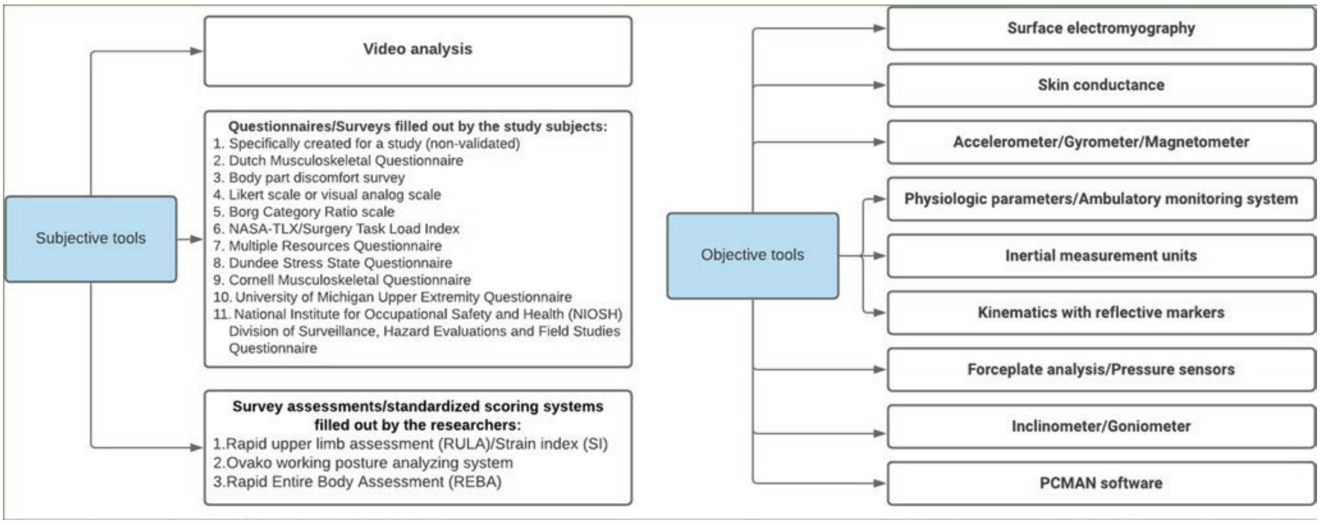

Fig. 1 Summary of the available subjective and objective tools to perform ergonomics research

2.1 Subjective Tools

The subjective tools can be further divided into three subcategories: (1) questionnaires filled out by the participants, (2) survey assessments/standardized scoring systems filled out by the researchers and (3) video analysis. Even though subjective tools are important in ergonomics research, it should be noted that their use is hindered by the presence of recall bias, and intra-rater and inter-rater variability [5].

A plethora of validated questionnaires are available [5], and some of them have been used in craniofacial and spine ergonomics studies [6]. The National Aeronautics and Space Administration Task Load Index (NASA-TLX) evaluates the physical and mental workload required for the execution of a specific task and was initially developed for use in the aeronautical industry [7]. It consists of six subscales (mental demand, physical demand, temporal demand, effort, performance, frustration levels) that are combined to provide an estimate of the required workload to perform a task. In a recent study, Ramakrishnan et al. [8] used the NASA-TLX to compare the standing and sitting positions in a cadaveric study of endoscopic sinus surgery. Notably, the surgery task load index (SURG-TLX) is a modified version of the NASA-TLX, validated for use in surgical ergonomics research [9]. Other validated questionnaires that have been previously used in surgery and neurosurgery ergonomics research include: (1) the University of Michigan Upper Extremity Questionnaire, (2) the National Institute for Occupational Safety and Health (NIOSH) Division of Surveillance, Hazard Evaluations and Field Studies Questionnaire, (3) the Body Part Discomfort (BPD) survey and (4) the Dutch Musculoskeletal Questionnaire [10–12].

It is important to note that non-validated questionnaires are often used by researchers who are investigating the prevalence of WMSDs amongst a specific population. This was also the case in two recent cross-sectional questionnaire-based ergonomics studies amongst neurosurgeons [2, 3]. Although it can be argued that, when possible, researchers should avoid using non-validated questionnaires, these studies are important because they can ask specialty-specific questions that usually cannot be found in validated questionnaires.

Video recording and analysis is another tool available for ergonomics research and posture analysis. Single or multiple-camera systems are used to record the surgeons while they perform a specific task, either in the operating theatre or in a simulation laboratory. The researchers then analyse and score the ergonomic performance of the surgeons, usually using standardized scoring systems. The most commonly used scoring system is the Rapid Upper Limb Assessment (RULA) [5]. Researchers assess upper limb, neck, trunk and leg posture alongside muscle use and force rates, leading to a total score of 1–7. Scores of 3 or higher imply possible ergonomic risk, while a score of 7 suggests high ergonomic risk necessitating change [13]. The Rapid Entire Body Assessment (REBA) is a scoring system that has been specifically developed to assess the unpredictable static-dynamic changes in the posture of healthcare workers [14]. A recent study by Aaron et al. [15] used the REBA tool to assess the ergonomic injury risk intraoperatively and reported that neurosurgeons had the highest REBA scores amongst surgeons from ten different surgical specialties. It should be pointed out that the standardized scoring systems can be either used in conjunction with video recording or as a stand-alone tool for intraoperative, real-time posture assessment, as was the case for the study by Aaron et al.

2.2 Objective Tools

Surface electromyography (sEMG) is a type of electromyography (EMG) that uses non-invasive electrodes attached to the skin of the study participant and provides information regarding the time and intensity of muscle activation [16]. It has been extensively used in ergonomics research in various fields, and it is probably the most commonly used objective tool in surgery ergonomics research [5, 16]. By using sEMG readings alongside various analysis tools, researchers can identify excessive muscle activity and fatigue [5]. In neurosurgery-related studies, sEMG has been used to assess novel ergonomic body supports for spine surgeons [17, 18] and to compare the sitting versus the standing position in endoscopic sinus surgery [8]. The use of sEMG in the operating theatre is currently complicated by the cumbersome wiring that might contaminate the sterile surgical field and could affect surgeons' performance [19]. However, in recent years, engineers have managed to create wearable sEMG acquisition systems that can be used in surgery ergonomics research [20]. Figure 2 shows an example of the set-up needed for sEMG recordings [21].

Systems for kinematic data capturing using reflective markers and cameras are also commonly used in surgery ergonomics research [22, 23]. High-speed, high-resolution motion capture systems, consisting of multiple digital cameras, are used to track the reflective markers that are attached to specific anatomical landmarks. The researchers are then able to use the data to reconstruct the movement of selected body segments in three-dimensional space. Park et al. [23, 24] used this modality to compare different operating table heights and various visualization methods while performing spine surgery, in a simulated environment. Notably, this research tool is completely wireless, thus minimizing the risk of compromising sterility. However, its limitations are associated with the application of the non-sterile markers on the sterile surgical gown [5]. Furthermore, objects or personnel in the operating theatre who cause reflections or block the direct visualization of the reflective markers from the camera can interfere with measurements [25]. Figures 3 and 4 present examples of the elaborate camera system needed for kinematic data capturing and the placement of the reflective markers, respectively [26, 27].

Inertial measurement units (IMUs) are sensors that are comprised of accelerometers, magnetometers and gyroscopes creating a wearable device that can be used for motion tracking [28]. They have the advantage of being entirely wireless and they can be placed underneath the surgical gown, thus avoiding interference with the surgical sterile field. They are also lightweight and small, ensuring minimal effect on a surgeon's ability to operate. Yang et al. [29] used IMUs in the operating theatres to evaluate the impact of procedure type, operation duration and adjunctive equipment on intraoperative discomfort, across surgical specialties including neurosurgery. Figure 5a, b presents the IMUs used in the study. Another study used IMUs to assess neck postures and cervical spine loading in microsurgeons using loupes and a headlamp [30]. In the future, wearable technology might be used to enable the adjustment of a surgeon's

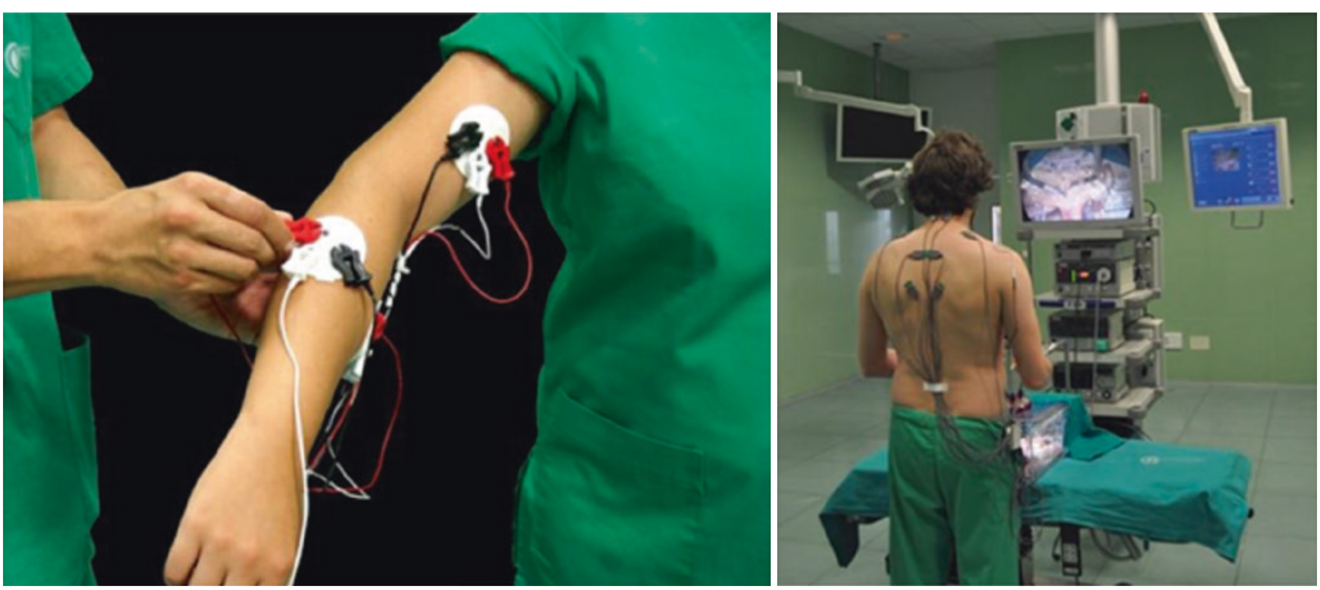

Fig. 2 The set-up and wiring during an ergonomic study using surface electromyography [Reproduced from [21] (License: Creative Commons Attribution 3.0 License)]

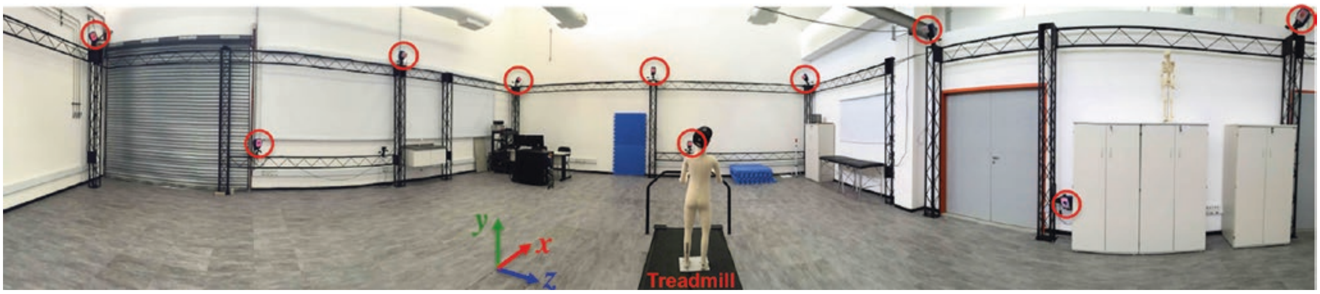

Fig. 3 The elaborate camera system needed to perform kinetic data capturing [Reproduced from [27] (License: Creative Commons Attribution License)]

Fig. 4 (**a–c**) The reflective markers used during kinetic data capturing [Reproduced from [26] (License: Creative Commons Attribution License)]

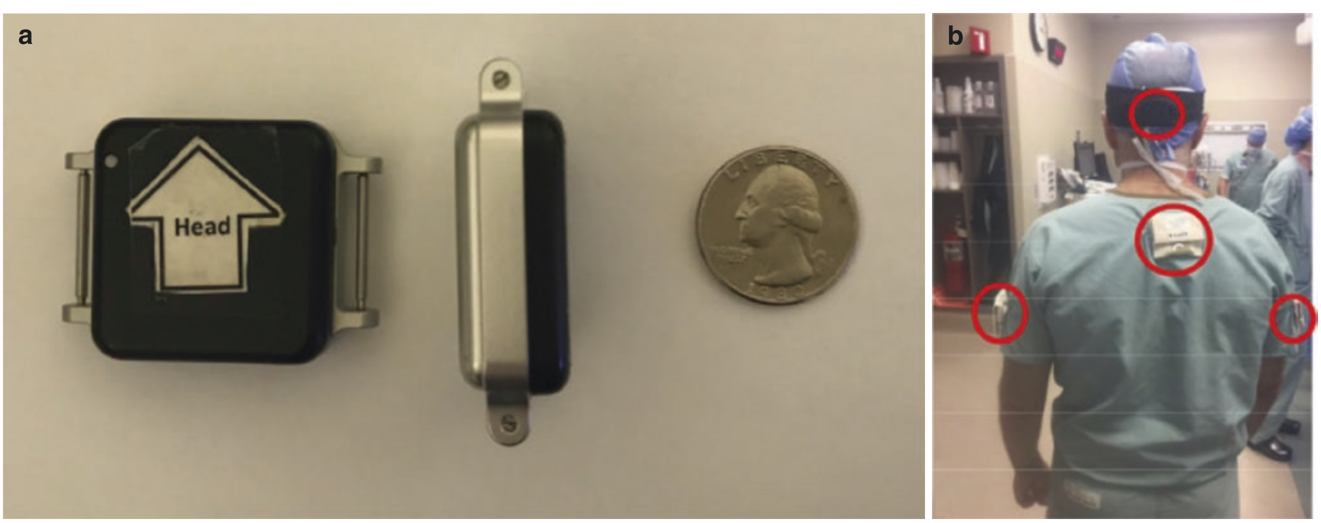

Fig. 5 The (**a**) size and (**b**) placement of inertial measurement units (Reproduced from [29] [License: Creative Commons Attribution—NonCommercial—NoDerivs (CC BY-NC-ND 4.0)])

posture by broadcasting real time data on a screen that the surgeon can observe while operating.

Force plates are mechanical systems that measure the ground reaction forces created by someone standing or moving on them [31]. They can be used in surgical ergonomics research to quantify the weight distribution between the two legs while operating [22]. In neurosurgery, a possible application is the assessment of the effect of using the foot pedal of the craniotome or the bipolar cautery on posture. They can also be used not only to evaluate the posture of the primary surgeon but the assistant surgeon as well. In similar fashion, pressure sensors have been used to map and evaluate the pressure on the seat of the surgical chair, in a study comparing four different types of chairs [32].

2.3 Future Perspectives

Ergonomics research can help in the assessment and comparison between novel and existing tools, and between surgical approaches. It can also enable the establishment of guidelines and policies regarding the use of specific surgical tools, the neurosurgical microscope, and surgical chairs. Important projects specific to neurosurgery include, but are not limited, to: (1) the comparison of loupes, microscope and exoscope in various types of operations and different approaches, (2) the evaluation of the burden of assisting in cranial and spine surgery, (3) the comparison between performing specific tasks while standing versus while sitting and (4) the individualization of choosing a surgical chair/surgical shoes/surgical tools based on a surgeon's discrete body characteristics.

3 Conclusion

It is imperative that ergonomics research becomes an important part of the research output in all surgical specialties, including neurosurgery, as it can help in alleviating the burden of WMSDs. In doing that, surgeons can become more productive and healthier resulting in better outcomes and optimal patient care. As the current technology evolves into wireless designs, ergonomics research will become easier to perform in the sterile environment of the operating theatre.

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