International Journal of Industrial Ergonomics 64 (2018) 79–88

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: www.elsevier.com/locate/ergon

Contribution to the objective assessment of technical skills for surgery students: An accelerometer based approach

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ARTICLE INFO

Article history:
Received 20 June 2017
Received in revised form
4 October 2017
Accepted 5 December 2017

Keywords:
Objective assessment
Basic skills
Suturing
Dental pedagogic strategy
Accelerometers

ABSTRACT

Aim of study: Gestural skills assessment in odontology is a highly complex task. Although mandatory for certification, proficiency assessment is still required for parameters that are more objective. Our aim was to assess whether accelerometer sensors might contribute to distinguishing efficiency in therapeutic gesture from experts and novices in the realization of surgical sutures.
Material and method: 3 groups of participants: novices (n = 8), intermediaries (n = 14) and experts (n = 7) were enrolled in the study. They had to perform different types of odontological suture. We used 2 wireless wrist sensors to measure objectively the acceleration of both hands and to deduce the economy and the fluidity of the movement. A video recording was also used to complete the assessment.
Results: The time and motion criteria were documented to significantly correlate with the experience of the participant. The total time factor has a significant effect with the experience level (p = 0.006). The fluidity of the movement has also been shown to vary significantly between groups.
Conclusion: The use of accelerometers coupled with image analysis could make it possible to envisage in the long run an objective evaluation for this type of surgical gesture.

1. Introduction

The use of simulators and inanimate models for surgical training has slowly spread in training institutions around the world during the last ten years. Simulators allow trainers the freedom to assess and manage the complexity of the clinical scenario for students without risking patients' safety (Acton, 2015). The emergence of these technologies has not only revolutionized the training of surgical skills, but the assessment of surgeons in these techniques has become an important concern (Pellegrini, 2012). Moreover, being able to objectively assess surgeons' technical skills has become an important research topic and a principal concern for surgical training.

Most screen-based simulators allow direct assessment of gesture and enable immediate feedback. However, for other types of technologies such as inanimate models, an expert surgeon performs the assessment. Traditional skill assessment is subjective to the evaluator and can be influenced by several factors. To limit this problem, different strategies have been implemented, such as OSCE (objective structured clinical evaluation) (Scott et al., 2001), analysis, videos, and more recently haptic simulation (Joseph et al., 2014). This highlights the need for a more objective assessment (Shaharan, 2014). The aim of this paper is thus to propose a method for objective surgical skills assessment using motion sensors.

(Datta et al., 2001) proposed using motion-tracking analysis to objectively measure surgical skills. Their study suggested that hand motion analysis can be an effective objective measure of dexterity. However, their study focused only on quantity of hand movements and time to complete the task. (Sánchez et al., 2014) proposed a method of evaluating laparoscopic skills using accelerometers. However, their work only focused on economy of movement criteria. In order to assess the complexity of the surgical skills put into practice during a procedure, several criteria need to be assessed, some of which might not be covered by motion sensors. In

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https://doi.org/10.1016/j.ergon.2017.12.002
0169-8141/

Table 1
Movement analysis metrics used for surgical skills assessment.

Reference	Conceptual validation		
	Time	Economy of movement	Path Length
(Datta et al., 2001)	Yes	No	Yes
(Aggarwal et al., 2007)	Yes	Yes	Yes
(Datta et al., 2002)	Yes	Yes	Non-treated
(Brydges et al., 2006)	Yes	Yes	Non-treated
(Brydges et al., 2007)	Yes	Yes	Non-treated
(Smith et al., 2002)	Yes	Yes	Yes
(Moorthy et al., 2004)	Yes	Non-treated	Yes
(Bann et al., 2003)	Yes	Yes	Non-treated
(Brydges et al., 2006)	Yes	Yes	Non-treated

this paper, the complexity of surgical skills assessment is covered by completing the motion sensor data with criteria from an OSCE (Hanson et al., 2010; Niitsu et al., 2013). To validate the use of motion sensors (accelerometers) as a new objective evaluation strategy, we put in place a preliminary prospective study at the Nancy-Lorraine Surgery School. The study allowed us to check whether there is a relationship between the measurements made by motion sensors and a subjective evaluation when performing a basic surgical procedure in dentistry (sutures). A mixed method integrating objective and subjective criteria was then proposed and validated. The results obtained were then compared with the traditional OSCE based evaluation method.

The remainder of the paper is structured as follows: Section 2 presents an overview of research related to surgical skill assessment and particularly on the usage of accelerometers. Section 3 describes materials and methods used in the study. Sections 3.2 present the results, which are then discussed in Section 4. Section 5 presents the conclusions of the paper.

2. Related research

2.1. Surgical training and skills assessment

According to Fitts and Posner's theory of motor skill acquisition, it is divided into three stages (Fitts and Posner, 1967). The first stage is cognition; in this stage the learner is shown the basic elements of a surgical intervention, making a knot for example. The learner must understand the mechanics related to the skill, the way to move the hands, take the fill, etc. With practice, the learner goes through the integration stage; he becomes able to execute the task in a fluid manner with few interruptions. Then, in the automation stage, the activity is not only fluid but is carried out with almost no errors. When applied to surgical training, the first two steps of this model can be done without prior contact with patients through the acquisition of the basic skills of the surgical technique.

Despite technological advances, surgical education has remained almost unaltered for over a century. The “see one, do one, teach one” model, which until a few years ago was offering good results, is limited by the availability of expert surgical physicians, by the diversity of procedures, the amount of patients available and, more importantly, by the need to maintain patient safety (Morris, 2005). There are many surgical training devices that can be used in the learning process: inanimate models, virtual reality, synthetic and cadaveric animal models, as well as real patients for education of critical incidents (Acton, 2015; Reznick and MacRae, 2006). Some of these models are very expensive and some have limited availability. Using animals is difficult because of ethical concerns, high cost, and the need for special equipment. On the other hand, inanimate synthetic models are portable, reliable, and a little less expensive than earlier varieties.

Inanimate models are, however, at a disadvantage compared to virtual simulators because the latter allow us to directly assess the technical skill of the student without the intervention of an expert trainer. In order to objectively evaluate skills, performance verification lists or OSATS (Objective Structured Assessment of Technical Skills) are commonly used (Reznick et al., 1997). However, the use of OSATS requires the implication of an experienced practitioner as judge. Technological tools could be used to assess some skill parameters and can become complementary to the objectivity of the evaluator (Reznick and MacRae, 2006).

One of the challenges in skill assessment is to choose which parameters to measure (van Hove et al., 2010). Hand movement analysis allows measurement of motricity and dexterity (Mason et al., 2013). In surgical skill assessment, this analysis can easily be performed with a motor sensor or accelerometer (D'Angelo et al., 2015). Three parameters have mainly been used in studies concerning surgical skills: time, economy of movement, and path length. Table 1 summarizes the main studies concerning movement analysis in surgical skills assessment and the parameters that were used.

2.2. Assessment metrics

The metrics for assessing surgical skills performance can be divided into two categories: efficiency metrics and quality metrics (Fried and Feldman, 2008). Efficiency metrics are measurable physical parameters, requiring the use of motion devices to be acquired. They are objective, reproducible, and not prone to misinterpretation. An efficiency metric should not only provide information about the intervention, but also help to identify key success and failure factors, in addition to being able to distinguish an expert from a novice (Oropesa et al., 2011). Quality metrics concern the definition and execution of a task; they are parameters that cannot be quantified – for example, knowledge of the procedure, final outcome of the intervention, knowledge of instrument handling, etc. Table 2 and Table 3 summarize the most commonly used metrics to discern the surgeon's experience.

It appears that using a single type of metric to evaluate the surgeon's skills is not enough, but the assessment must be a combination of the two types (Fried and Feldman, 2008). Using only one

Table 2
Efficiency metrics for surgical skills assessment.

Efficiency metrics	Description	Units
Time	The time needed to complete an intervention. It's commonly related to surgical skills. The greater the experience in the intervention, the less time it takes to complete.	*min, sec*
Path Length	The cumulative distance based on tool movement during the intervention. It is also commonly related to the surgeon's precision.	*m, cm, mm*
Jerk	These are sudden movements resulting in changes in the acceleration.	$\frac{m}{sec^3}$
Speed	The speed of change of position of the instruments per second.	$\frac{m}{sec}$
Economy of movement (MOE)	Execution of the intervention with a limited number of movements. It is defined as the total number of hand movements per second (S. Bann et al., 2004).	$\frac{movements}{sec}$