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Computer-assisted assessment of one-handed knot tying skills performed within various contexts: a construct validity study

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Abstract

Background: The widespread use of computer-assisted assessment of technical proficiency in surgical residents shows the need for further investigations of the construct validity of these devices (eg, hand motion analysis) before implementation into competency testing.
Methods: Thirty general surgery residents performed 1-handed knot tying in 2 contexts: superficial and deep. The Imperial College Surgical Assessment Device (ICSAD) was used to evaluate performance. It was hypothesized that senior residents (postgraduate year [PGY] 4-5) would perform better then junior residents (PGY 1-3) and that the superficial version of the skill would be easier than the deep.
Results: Technical efficiency scores were better for seniors than for juniors ($P < .001$) and on the superficial versus the deep model ($P < .001$). Both groups were equally affected by the contextual changes to the skill, suggesting a consistent impact on the skill-specific movement patterns.
Conclusions: Additional evidence for the validity of ICSAD as a competency assessment tool has been shown. First, it distinguished senior and junior residents. Second, it discerned differences on the same skill performed in 2 different contexts.

Keywords: Surgical education; Accreditation; Technical skills; Motion analysis

Propelled by the Accreditation Council for Graduate Medical Education Outcome Project, recent efforts to describe comprehensively a set of skills needed by every physician have resulted in defining 6 core competencies that describe patient care, medical knowledge, practice-based learning and improvement, interpersonal and communication skills, professionalism, and systems-based practice. To assess whether individual physicians meet them, such competencies must be clearly defined and methods of quantification developed. For instance, the performance on technical skills reflects 1 component of surgical competency. Curricula that incorporate validated performance metrics, which assess quality and consistency of performance, should also require trainees to attain an objectively determined proficiency criterion [1] for advancement or competence. In defining the term "proficient," we use the approach proposed recently by Gallagher et al [1], who suggest that a proficient performer is one who, although not necessarily an expert as defined by Ericsson and Lehmann [2,3] in other psychomotor skills domains, has been able to acquire and consistently automate through deliberate practice the basic psychomotor skills required at their training level. This performer would have attained this goal and not simply fulfilled the required time commitment and case volumes.

Recently, the use of computer technology in technical assessment has received significant attention. Computer-assisted assessment of hand motions during performance of basic surgical skills has rapidly become an essential tool for evaluating the technical proficiency of junior residents [4]. Indeed, its most enthusiastic advocates maintain that it could become the sole evaluation method and possibly re-

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place the need for an expert evaluator. This computer-driven method allows for an objective assessment of technical skills, it permits data interpretation by a laboratory technician, and it has a low-operating cost, all of which promote it as a reliable, highly replicable, and inexpensive competency assessment method.

For any measurement method to be deemed applicable, 3 criteria must be met: it must be feasible to conduct, be reliable, and be valid [5]. Feasibility of a particular measurement determines that this method can be successfully accomplished in a required time frame or under specific budgetary and ethical constraints. Reliability is defined as the extent to which this measure or instrument yields the same results on repeated trials. Most important to the present study is the concept of validity, which refers to the degree to which a method accurately reflects or measures the specific construct that it is designed to assess. There are 5 dimensions in which the validity of a measurement method can be assessed: face, construct, content, concurrent, and predictive validities [5]. Although all 5 are important, construct, concurrent, and predictive validities are the 3 that have been most heavily focused on with respect to the Imperial College Surgical Assessment Device (ICSAD), one of the most-studied and widely used motion analysis systems [6–9]. To date, research with ICSAD shows good feasibility, reliability, and validity. For example, for both open and laparoscopic skills, a number of validation studies have shown that expert and novice surgeons can be differentiated using the ICSAD [10–14].

Still, the current trend toward using computer-assisted assessment of skills in the evaluation of junior residents' technical proficiency indicates that more extensive testing of the construct validity of such evaluation methods is required. One question that has not yet been well addressed in current literature is whether this measurement method can distinguish between performances on different versions of the same technical skill. Therefore, the purpose of the current study was to test a specific aspect of construct validity of ICSAD, namely, whether this measurement method is capable of discerning performances of the same basic technical skill of 1-handed knot tying when performed on a superficial surface and at depth.

In the realm of basic motor learning literature, skill difficulty can be described in 2 broad categories: nominal and functional difficulty. Nominal skill difficulty encompasses the requirements of a skill that remain constant, including both the perceptual and motor processes that must occur to ensure an appropriate outcome [15]. On the other hand, functional skill difficulty is associated with both the conditions under which the skill is being performed and the skill level of the performer [15]. Thus, by using the same standard skill of 1-handed knot tying, while manipulating the context under which the skill is performed, this study aimed to measure the change in performance that is seen when the functional difficulty of a basic knot tying skill is altered. Based on these concepts, it was hypothesized that knot tying on a superficial surface would show different movement patterns than the same skill performed at depth.

Methods

Participants

The participants in this study were surgical residents with the Center of Osteopathic Research and Education system in Ohio. (Participating member hospitals include Cleveland Clinic South Pointe Hospital, Cuyhahoga Falls General Hospital, Doctors Hospital of Stark County, Doctors Hospital Ohio Health and Grandview Medical Center; all academically sponsored by Ohio University College of Osteopathic Medicine.) Thirty residents of various surgical specialties ranging from postgraduate year (PGY) 1 to 5 were recruited and grouped according to level of experience, with PGY 1-3 ($n = 18$) classified as junior and PGY 4-5 ($n = 12$) classified as senior. None of the participants had any formal experience with bench model training. Participants signed an informed consent approved by the local ethics board committee.

Procedure and apparatus

Before the technical performance, all participants were asked to complete a written questionnaire designed to assess trainee knowledge. This 16-item multiple-choice questionnaire, developed by 4 surgeons, evaluated core concepts and similar surgical constructs as those required for the technical skill. All participants were then asked to perform 8 one-handed square knot ties in 2 distinct contexts while using their dominant hand. This skill was performed using 3-0 Sofsilk braided silk ties (TYCO Healthcare, Pointe-Claire, Canada). Participants were instructed to approximate 2 rubber tubes (set in a parallel orientation) on a bench model in order to minimize the distance between the simulated vessels while concentrating on proper technique rather than on time conservation. The model was placed either directly in front of each participant for performance on the superficial version of the skill (Fig. 1A) or inside an abdominal training model (TYCO Training Box) modified for the purpose of this study for performance of the skill at depth (Fig. 1B and C).

Assessment of technical performance

A computer-assisted method of evaluating technical surgical skills was used to assess the performance of the participants [14,16]. This method consists of quantifying hand motion characteristics by tracking the positions of magnetic markers placed on surgeons' hands using the ICSAD system. This setup consists of a commercially available motion tracking system (IsotrackII, Polhemus, VT). The positions of participants' hands, instrumented with small magnetic markers, were tracked in 3-dimensional space coordinates