



## Design and ergonomic assessment of an infusion set connector tool used in nursing work

Ehsan Garosi<sup>a</sup>, Adel Mazloumi<sup>a,b,\*</sup>, Reza Kalantari<sup>c</sup>, Zahra Vahedi<sup>a</sup>, Zahra Shirzhiyan<sup>d</sup>

<sup>a</sup> Department of Occupational Health Engineering, School of Public Health, Tehran University of Medical Sciences, Iran

<sup>b</sup> Sports Medicine Research Center, Neuroscience Institute, Tehran University of Medical Sciences, Tehran, Iran

<sup>c</sup> Department of Ergonomics, School of Health, Shiraz University of Medical Sciences, Iran

<sup>d</sup> Department of Biomedical Systems & Medical Physics, Tehran University of Medical Sciences, Iran

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### ABSTRACT

Nursing is a physically demanding job characterized by a high prevalence of fatigue and musculoskeletal disorders. One of the high-exertion and repetitive nursing tasks is the manual connection of an infusion set to a medical fluid bottle. Such physical work can be eased by the design of new hand tools. Correspondingly, this study designed and ergonomically assessed an infusion set connector tool (ISCT) and compared it with that of manual connection. First, a prototype of ISCT was designed to perform infusion set connecting task in the mechanical form. Subsequently, 12 nurses were asked to connect an infusion set to medical bottle in the form of manual and mechanical tasks and these tasks were evaluated using ergonomic indices including muscular activity level, force, posture, and subjective (Borg scale CR10) measures. Results showed that the activity levels (root mean square) of the extensor digitorum communis, flexor carpi radialis, biceps, triceps, and deltoid muscles remarkably decreased when the nurses used the ISCT. The postures of the wrist, arm, and shoulder regions were corrected from Rapid Upper Limb Assessment action level 3 to 2 when the designed tool was used. Additionally, the subjective perception of exertion was significantly lower with the use of the prototype.

### 1. Introduction

Nursing is a physically and psychologically demanding profession with a high prevalence of musculoskeletal disorders (MSDs) as indicated in several studies (Choobineh et al., 2010; Magnago et al., 2010; Menzel, 2007; Smith et al., 2003, 2006). Daraiseh et al., for example, reported that MSDs most frequently occur in the back, neck, and shoulders, followed by the upper back, hands/wrists, and knees/lower legs (Daraiseh et al., 2003). In Iran, the prevalence rates of low back, knee, shoulder, and neck pain were 73.2%, 68.7%, 48.6%, and 46.3%, respectively (Mehrdad et al., 2010). MSDs are also often cited as the reason for sickness-related absences and the high turnover of nurses (Blekesaune and Solem, 2005; Menzel, 2008).

Nurses' working conditions usually differ across countries, regions, and hospitals (Simon et al., 2008). These differences are attributed mainly to the provision of instruments and the quality of process management in hospitals. Nurses are involved primarily in the administration of medications in hospital wards and other relevant settings (Raju et al., 1989). As a subset of medication administration,

intravenous (IV) administration is routinely performed by nurses and widely used in hospitals for the transmission of fluids, including blood, drugs, and food in liquid form. The standard infusion equipment for IV administration consists of a bottle or bag containing a medical fluid for dispensation, a plastic administration set, and a suitable needle for insertion into a patient's vein (Flack and Whyte, 1974). Inserting a plastic administration set into a medical fluid container is part of the preparation and administration of IV medication. This task is performed in a manual way by nurses. In intensive care units in particular, the use of maintenance medical fluid is common over one work shift (Bihari et al., 2016), thereby increasing the frequency with which infusion sets are connected.

In manual infusion set connecting (ISC) task, nurses usually hold the bottle by one hand and push the infusion set with another hand to make a hole and insert it to the bottle in a specific position. Fig. 1 shows how the task is done by a nurse. In our experience, inserting the infusion set requires a significant gripping force and unnatural flexed and twisted postures of the hand. In the workstation with high height, the shoulder posture is considerable too. Awkward posture and excessive muscular

\* Corresponding author. School of Public Health and Institute of Public Health Research, Tehran University of Medical Sciences, P.O. BOX: 6446, Tehran 14155, I.R. Iran.

E-mail address: [amazlomi@tums.ac.ir](mailto:amazlomi@tums.ac.ir) (A. Mazloumi).

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Fig. 1. Manual infusion set connecting task.

force in manual tasks can be considered risk factors for the development of upper extremity disorders among nurses as they accomplish physical tasks (Li, 2002). Previous researches, including that conducted by (Mital and Kilbom, 1992; Punnett and Wegman, 2004), indicated that the use of arms and hands at an awkward posture and frequent motions of hands/wrists are associated with pain and discomfort. Other studies reported that flexion, extension, and radial and ulnar deviation in the wrist are related to carpal tunnel syndrome (CTS) in many professions (Armstrong and Chaffin, 1979; Tanaka et al., 1995). Moreover, in some studies, exposure to factors involving long duration, force, and awkward postures are known as the main physical risk factor for MSDs development (Gallagher and Heberger, 2013; Hoogendoorn et al., 1999).

Improving ergonomic factors, such as the design of tool and equipment, work environments, or both, and training workers in ergonomic principles are expected to reduce the risk of developing MSDs (Hoe et al., 2012) and ease physically demanding nursing tasks. The excellent ergonomic design of medical devices are necessary for guaranteeing safety for both patients and clinical care workers (Martin et al., 2008). Hand tool design/redesign plays an important role in easing the demands of manual work and controlling problems in duties that involve the use of hands and forearms and improves user job satisfaction (Kadefors et al., 1993a; Sperling et al., 1993). Medical tools and devices with ergonomic features also reduce muscle exertion because these instruments decrease the physical demands imposed when people carry out repetitive tasks (Gauthier and Lagacé, 2015; Kim, 2012).

Given the necessity of designing new tools for necessary work

improvements to physically demanding tasks in nursing, the aim of this study was to design a new tool and to compare its physical demand and risk to the manual method. It is hypothesized that by designing such ergonomic tool and using it in ISC task, required force and muscle activity will be decreased significantly. Meanwhile, the awkward hand-arm posture will be improved by using this tool. Indeed, the idea of applying a hand tool for ISC task originated from one of the researchers' experiences in nursing work. He is a practicing nurse in an Iranian hospital and a researcher focusing on ergonomics in healthcare.

## 2. Methods

An experimental study was carried out to evaluate manual and mechanical ISC tasks. In this mean, an infusion set connecting tool (ISCT) was designed and used to perform the mechanical ISC task.

### 2.1. Design of the ISCT

To achieve an ideal design which meets our goals, the idea of developing an ISCT was shared with an industrial design group. As mentioned earlier, among ergonomic risk factors, force is the main problem perceived by nurses during the manual ISC task. To solve this problem and to ensure the functional performance of the tool, the first-class lever model was used in the primary design. Another concern for manual ISC task was awkward posture in the hand and arm regions. In order to correct this problem, a handle (110 mm, length) in conjunction with a trigger (35°-angle to handle) was attached at the bottom of the main body of the ISCT. (Figs. 2 and 3).

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