International Journal of Industrial Ergonomics 56 (2016) 138–149

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

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

Preliminary study evaluating manual dexterity tests assessing gloves protecting against cuts and stabs by hand knives

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ARTICLE INFO

Article history:
Received 3 August 2015
Received in revised form
3 August 2016
Accepted 16 October 2016
Available online 24 October 2016

ABSTRACT

The paper presents preliminary results on the research methodology of evaluating the ergonomic properties of gloves protecting against cuts and stabs by hand knives. Four manual dexterity tests were selected for the study: TEST 1: evaluation of fine finger movements pursuant to PN-EN 420; TEST 2: cylinder grip and pull test according to PN-EN 1082 evaluating gross movements of the arms and hands; TEST 3: Purdue Pegboard Test evaluating fine finger movements; TEST 4: evaluation of gross movements of the arms and hands while performing simulated occupational tasks. The tested gloves differed in terms of construction and material (metal mesh or knitwear incorporating a metal yarn) and were selected depending on the scope of work activities performed during meat cutting and boning. The tests were conducted on a homogeneous group of subjects. During the performance of the four dexterity tests, we monitored the loading of four groups of muscles of the upper limb (adductor pollicis, extensor carpi radialis, flexor carpi ulnaris, and biceps brachii) using surface electromyography (EMG). Additionally, subjective sensations concerning the strain on the upper limb were evaluated using a questionnaire survey.

The objective of the study was to identify a group of tests that would be characterized by high sensitivity and ensure reliable assessment of gloves protecting against cuts and stabs by hand knives. The results showed that not all of the dexterity captured differences in the way the gloves affected dexterity. This was corroborated by electromyographic measurements, which revealed considerable differences in load of upper limb muscles when using various gloves and further supported by the subjective sensations of the participants, as reported in the questionnaire study. It was concluded that in order to reliably evaluate the ergonomic properties of gloves protecting against cuts and stabs by hand knives it is necessary to design new dexterity tests that would reflect actual workplace conditions, and could simulate occupational activities. Workplace observations helped to identify specific aspects of manual dexterity (fine, medium, gross), and types of hand movement associated with professional activities including different force configurations (finger flexion, wrist abduction, and pressing with the fingers and wrist). Based on those observations three new manual dexterity tests dedicated exclusively to evaluation of the ergonomic properties of gloves protecting against cuts and stabs by hand knives have been proposed.

1. Introduction

Occupational tasks involving hand knives pose a risk of hand injury due to cutting or stabbing. This concerns in particular workers in food processing plants (especially meat packers), as well as in the plastic, textile, and paper industries, and other types of activity where such tools are used (Hertz and Emmett, 1986).

Hand injury can be prevented, amongst others, by the use of appropriate protective gloves (Irzmańska, 2014). Such protective gloves can be classified into two groups: those designed for high risk tasks, in which workers use knives with sharp edges moving at a considerable force towards the other hand, and those designed for low risk tasks, in which workers use knives with edges that are not sharp or move away from the other hand. Gloves protecting the hands in high-risk situations are made of metal wire mesh. In a low risk setting, it is not necessary to use metal mesh, which has important ramifications for ergonomics.

Currently, the ergonomic properties of protective gloves are evaluated by means of two standard methods. The dexterity of fingers in protective gloves is assessed using a test in which subjects

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http://dx.doi.org/10.1016/j.ergon.2016.10.004
0169-8141/

pick up pins of varying diameters (specified in PN-EN 420:2003+A1:2012), while the degree of fit and anti-slip properties of gloves protecting against cuts and stabs by hand knives are evaluated by means of the cylinder grip and pull test (specified in PN-EN 1082-2:2002). It should be stressed that in the case of both standards, test results are based on subjective sensations linked to the fatigue of the upper limb, discomfort, and fitting problems (if present).

According to the literature data, recent years have seen intensive research efforts in the area of evaluating the ergonomic and manual dexterity properties of protective gloves. The factors affecting those properties include glove construction and materials. According to some authors, their optimization may lead to a reduction in the number of workplace accidents and upper limb injuries (Kovacs et al., 2002). At the same time, efforts are under way to develop new objective methods, not specified in international standards, which would also take into account biomechanical risk factors. There seem to be three main directions of research. The first one focuses on timed manual dexterity tests consisting of screwing or gripping small objects of different shapes with the hand or a tool (Sawyer and Bennett, 2006; Korniewicz et al., 2005; Bensel, 1993). The second direction concerns the function of the muscles of the upper limb (as measured by means of electromyography or dynamometry) during the performance of routine tasks at the workplace or during manual dexterity tests conducted in the laboratory (Yoo et al., 2011). Finally, the third direction involves studies of the mechanical and physical properties of glove materials in terms of thickness, bending rigidity, and friction (Harrabi et al., 2008). The usefulness of the various manual dexterity tests has been investigated only for gloves protecting against chemical, biological, and thermal factors (Gauvin et al., 2006). Twelve existing manual dexterity tests were evaluated in order to identify the most effective and sensitive ones. It was found that the Crawford Screws Test, the Grooved Pegboard Test, both Minnesota tests, the O'Connor Finger test, the test according to the standard ASTM F2010, and three Purdue tests are very sensitive (56%–67%), in contrast to the test specified in the standard PN-EN 420:2003+A1:2012 (3% sensitivity). According to the authors of this study, the best approach is to evaluate gloves pursuant to a combination method comprising several dexterity tests (both specified and not specified in the standards), e.g., a battery consisting of the Crawford Screws Test, the Pegboard Test, the Minnesota Test, and the Purdue Test (92% sensitivity).

Critical factors for workers exposed to the risk of cutting and stabbing by hand knives are a firm grip and sufficient tactile sensitivity of the hands (Zedalis and Kessler, 2007). Metal mesh gloves with a polyurethane tightener have been found to enhance manual sensitivity as the glove is prevented from slipping off the hand. It should be stressed that no known tests have been used to evaluate the ergonomic properties of gloves protecting against cuts and stabs by hand knives under conditions approximating real-life use conditions. And it should be borne in mind that ergonomically inappropriate gloves (excessively rigid mesh, thick anti-cut materials, materials without anti-slip properties, inadequate size) may adversely affect user comfort due to compromised precision, tactile sensitivity, grip force, and dexterity, and may lead to higher rates of accidents at work (Silverstein et al., 1986; Nordin et al., 1997; Putz-Anderson, 1990, Rempel et al., 1992; Drabek et al., 2010). The above aspects related to the selection of protective gloves should be evaluated using research methods that reflect actual conditions of use.

In this respect, an important gap concerning the selection of the methods of the protective glove evaluation for specific occupational tasks can be identified. There is only a very limited literature in this area, i.e. some recommendations on the selection of appropriate tests for specific tasks are provided for health professionals (Dianat et al., 2012). At the same time the assessment of gloves in terms of specificity of particular professional activities could give more reliable results.

Therefore, the main objective of the presented paper was to identify a group of tests that would ensure reliable assessment of gloves protecting against cuts and stabs by hand knives in terms of ergonomic properties by taking into account specific workplace conditions. In the first part of the study we analysed ergonomic properties of selected protective gloves typically worn by meat processing workers employing previously known manual dexterity tests (two tests specified in the relevant official standards and two tests described in the literature). It should be emphasized that the tests described in the article evaluate different aspects of hand performance rather than dexterity alone. According to the literature, manual dexterity can be divided into fine finger dexterity, or the ability to move the fingers fast and accurately while manipulating small objects, and hand dexterity, or the ability to make larger movements while manipulating the fingers. Therefore, in the present paper the term 'dexterity' will be used referring to both finger and hand dexterity. Tests results were verified by surface electromyography (EMG), which measured the loading of four groups of muscles of the upper limb as the subjects performed the tests. The goal was to identify tests with the highest degree of sensitivity that would make it possible to reliably evaluate protective gloves of this type in the future. Then workplace observations were carried out to identify specific aspects of manual dexterity, and types of hand movements associated with actual activities performed by meat processing workers. Based on those observations a set five of manual dexterity tests (cylinder grip and pull test according to PN-EN 1082, Purdue Pegboard Test and tree tests simulating workplace activities) dedicated exclusively to evaluation of the ergonomic properties of gloves protecting against cuts and stabs by hand knives have been proposed.

2. Study material and methodology

2.1. Characteristics of protective gloves

The most widespread types of gloves used for protection against cuts and stabs by hand knives were tested (Table 1).

2.2. Characteristics of the study group

The study group consisted of 10 randomly selected, professionally active, healthy males who used gloves protecting against cuts and stabs on a daily basis (at the time of the study workers of the meat processing plant). The study group was homogeneous in terms of age (20–30 years), height (165–175 cm) and weight (65–75 kg). The BMI ranged from 18.73 to 24.82. All the subjects were right-handed. Due to the fact that in practice the studied gloves are worn on the non-dominant hand (as it does not hold the knife and is at high risk of cutting or stabbing), all the tests were conducted for the left hand.

2.3. Experimental design

Ergonomic properties of selected protective gloves were evaluated based on:

- manual dexterity tests,
- measurements of loading of the upper limb using surface electromyography,
- questionary surveys regarding subjective assessment of ergonomic properties of protective gloves.