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Design options for improving protective gloves for industrial assembly work

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ABSTRACT

The study investigated the effects of wearing two new designs of cotton glove on several hand performance capabilities and compared them against the effects of barehanded, single-layered and double cotton glove conditions when working with hand tools (screwdriver and pliers). The new glove designs were based on the findings of subjective hand discomfort assessments for this type of work and aimed to match the glove thickness to the localised pressure and sensitivity in different areas of the hand as well as to provide adequate dexterity for fine manipulative tasks. The results showed that the first prototype glove and the barehanded condition were comparable and provided better dexterity and higher handgrip strength than double thickness gloves. The results support the hypothesis that selective thickness in different areas of the hand could be applied by glove manufacturers to improve the glove design, so that it can protect the hands from the environment and at the same time allow optimal hand performance capabilities.

1. Introduction

In many workplaces it is necessary to protect workers' hands by using gloves. The effects of gloves on different aspects of hand performance capability have been recognised and investigated in a large number of previous studies (Bradley, 1969; Swain et al., 1970; Riley et al., 1985; Bellingar and Slocum, 1993; Imrhan and Farahmand, 1999; Claudon, 2006; Chang and Shih, 2007; Dianat and Haslegrave, 2008). However, unlike studies of hand performance capabilities, very few studies have investigated glove design features. In one of the few attempts, Muralidhar et al. (1999) developed two prototype cotton gloves with the thickness varying between different areas of the hand, based on force distribution and sensitivity patterns on the palmar side of the hand (established from various studies), and compared the effects of wearing the prototype gloves with those of wearing a double glove. One of Muralidhar et al.'s prototype gloves had two and the other four layers of protection in selected hand areas. Although Muralidhar et al. found no significant difference in dexterity between the glove conditions (measured by time to complete a dexterity test), the two prototype gloves were shown to be better than the double glove in terms of handgrip strength.

The primary consideration in designing protective gloves is protection of the hand from injury or discomfort and it is believed that thicker gloves can provide better protection (Muralidhar et al., 1999). In other words, the primary concern when designing gloves has been hand protection rather than hand performance. This policy may be necessary for protection from hazards, but a uniform thickness of material can lead to gloves that are bulky and clumsy to use, perhaps creating other hazardous conditions such as inappropriate grasp on the tool, loss of grip strength or range of motion, or reduced sensory feedback and dexterity. The results of a study conducted by Akbar-Khanzadeh et al. (1995) at an automobile plant revealed that only 42% of workers reported comfort while using their protective gloves and also that, when such protective equipment was inappropriately designed, workers frequently opposed wearing it due to discomfort. As Feeney (1986) pointed out, the possibility of resistance to wearing protective equipment is one of the considerations that should be carefully examined during the design.

There are many design considerations, including material, condition of use, task requirements, comfort and environment, that together with glove manufacturing processes and cost make the

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issue of designing appropriate gloves a complex challenge (Dianat et al., 2012b). Fig. 1 shows a conceptual model of the relationship between design requirements, design considerations/constraints, worker and task. Worker characteristics and design requirements are the inputs to the model, while the design criteria that are generated through the model are the outputs. This model is to develop ergonomic design criteria for evaluation trials rather than a more general model of glove design, and therefore the non-ergonomic parts of design considerations/constraints (i.e. manufacturing process, cost) have been separated out. Glove thickness is obviously an important factor in glove design with its influence on dexterity and tactility, as well as on hand and finger (dis)comfort. Consequently, the material and thickness also have an influence on strength capability of handgrip, pinch grip and fore-arm torque. Some of the issues that need investigation, among others, are the extent to which gloves cause difficulty in flexing the finger joints and the patterns of discomfort in both barehanded and gloved conditions while working with hand tools. The present study was undertaken for this purpose. Two prototype pairs of gloves were designed and constructed, using the evidence that was currently available from published literature. Their effects on a number of hand performance capabilities were measured and the wearers' subjective assessments were collected. The results with the two prototype gloves were compared with those for bare hand, single-layered glove and double glove conditions. The present study differed from that of Muralidhar et al. (1999) in that the prototype gloves were constructed on the basis of different criteria and also that they were evaluated when performing a work task. The intention was to assist in introducing design alternatives for improving gloves for industrial assembly work. The results of two earlier studies (Dianat et al., 2010, 2012a) which had evaluated the effects of wearing gloves on several aspects of hand performance while working with hand tools (including screwdriver and pliers) showed that the effects of wearing gloves changed over a 2 h work period. So, to have a realistic evaluation of glove effects in a working context, glove evaluation studies need to consider actual working conditions in which gloves are being used by workers.

2. Methodology

There were two phases of work in this study. The first was to develop new designs of gloves and the second was to run an experiment to evaluate the designs.

2.1. Re-design of gloves

The prototype gloves were constructed by modifying a glove that is commercially available and widely used for industrial assembly work, the modification being to the thickness of material so that it could be suited to the hand/tool interaction in particular areas of the hand. The two prototype gloves constructed represented two different approaches. One was based on published evidence of the differences in the areas of discomfort between the bare hand and the gloved hand conditions, and the other was based on the need for finger and hand flexibility while working with tools such as screwdriver and pliers. In other words, the thickness of material was varied over the surface of the hand to reduce the discomfort of wearing gloves or to enhance performance capabilities.

2.1.1. Construction of the gloves

The gloves were made of cotton, the thickness of the basic material (of the commercially available glove) being 0.8 mm. The results of the two previous studies (Dianat et al., 2010, 2012a) had already shown that cotton gloves can be a better option for light assembly tasks than nylon or nitrile gloves (1 mm and 1.4 mm in thickness, respectively), which caused more adverse effects on some hand performance capabilities. Two comparison gloves were included in the evaluation trials: the commercial cotton glove and a double thickness (1.6 mm) cotton glove (one glove worn over another, the two being anchored by strategic stitching). The structures of the two prototype designs are shown in Table 1 and described below. Three sizes of each glove (small, medium and large pairs) were prepared for the evaluation trials.

To modify the cotton glove, the selected areas which would have just the thin layer of material were first mapped on to the glove.

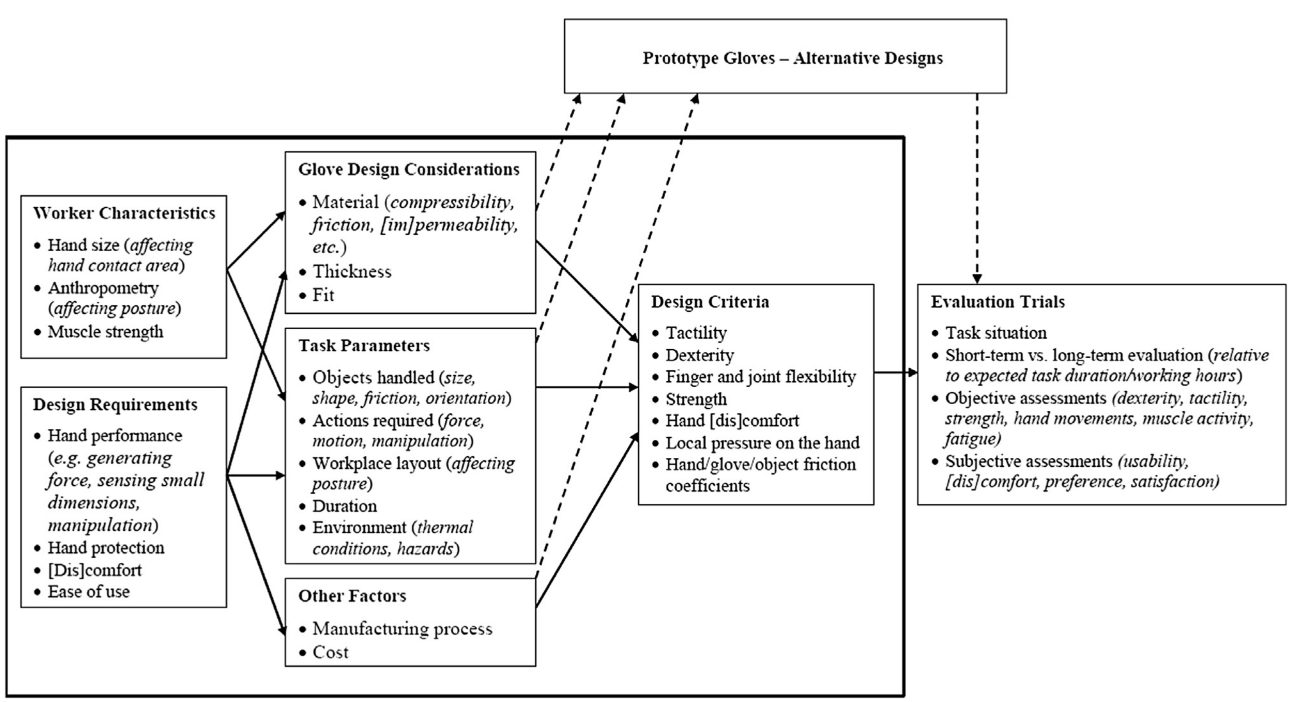

Fig. 1. Conceptual model of the relationship between design requirements, design considerations/constraints, worker and task.