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Case study on the effects of fit and material of sports gloves on hand performance

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ABSTRACT

Active and sports fashion in the high-end market focuses on fit, superior comfort and functional performance for various end-uses. However, the engineering design of sports gloves in relation to hand anthropometry measurements remains unclear. In this study, two types of ready-to-wear sport gloves, namely, war-gaming glove and hiking glove were purchased from the market. The glove dimensions, fabrication properties and the effect of glove fit on hand and finger dexterity were investigated. Thirty female individuals (20–29 years old) participated a series of hand performance tests and subjective perception rating assessments towards the gloves. Results indicated that the active range of motion of fingers, finger tactile sensitivity, gripping strength and ability to handle pegs and marbles decreased with the use of gloves compared with bare hands. The perceptions of comfort and ease of hand motions decreased with the increased of wear time. The glove fit in terms of finger length dimensions was significantly correlated with hand grip force. The glove fit in hand, wrist and finger circumference dimensions had significant impact on the ability to handle small objects. It is suggested that hand length, hand circumference, finger circumference and the ratio of finger length to palm length should be considered in the design and development of gloves to improve hand performance and comfort.

1. Introduction

Gloves are not only used to protect workers' hands in the industrial operation of tools and machines, but they are also worn in various sports activities to protect the hands. When performing sports exercises, such as hiking and cycling, a pair of gloves can help keep hands warm and protect them from potential injury and even the natural environment. For sports such as archery, fencing and war-gaming, which include the use of an apparatus, the use of good-fitting gloves allows good grip of the apparatuses, absorbs shock to protect hands from injury and reduces the chances of blisters and chafing (Mason et al., 2009; Purvis and Cable, 2000).

Nevertheless, gloves are one of the most difficult-to-engineer apparel products. They must have a complex construction to allow wearers to freely and comfortably move their hands to perform activities. Perfectly fitted gloves are difficult to find due to the limited sizes available on the market, and many fashion gloves on the market may only provide a single size to fit all customers. A good-fitting sports glove, however, not only protects the hand but also contributes to the wearer's hand performance. It is thought that ill-fitting gloves reduce the transmission of muscular forces to grip forces (Kovacs et al., 2002). Hsiao et al. (2015), and Yu et al. (2013), conducted studies on hand anthropometry to improve the glove fit and sizing system. However, the current glove-sizing system still can barely address the differences in hand and finger dimensional proportions amongst people of different sexes, races, ages and occupations (Gnaneswaran and Bishu, 2011; Hu et al., 2007; Mandahawi et al., 2008). For dress shirts, neck size, and sleeve length, as well as different fits, such as slim, athletic, regular and full, are available to accommodate the wide variations of body shapes and proportions. For gloves, however, manufacturers only allow customers to select the size either based on hand length (measured from the tip of digit 3 to the wrist crease) or hand circumference. In glove size development, hand dimensions, such as finger length, finger joint circumference, finger root circumference, palm length and wrist circumference, should also be taken into consideration.

Previous studies on hand function have indicated that the use of work gloves or protective gloves has a negative impact on hand performance in terms of strength and dexterity (Claudon, 2006; Irzmańska and Tokarski, 2017; Tian et al., 2016). The thickness and tenacity of gloves and the friction at the glove/hand interface were identified as the most important variables associated with glove design (Batra et al., 1994; Bishu et al., 1995; Buhman et al., 2000; Chang and Shih, 2007;

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Dianat et al., 2014; Wimer et al., 2010). Kovacs et al. (2002) and Wells et al. (2010) investigated the effects of glove size on hand effort and performance. Wear trials using appropriately fitted gloves, over-fitted gloves and/or under-fitted gloves were performed. The appropriately fitted gloves obtained the best grip force and comfort perception. However, inherent ambiguities exist in the dimension differences between the gloves and hands, the selection of glove materials and the perception of glove fitting and their corresponding effects on hand performance. An understanding on the effects of glove fit on various hand functions would provide important information for glove design. To suit the specific end-uses, gloves can be fabricated by using more than one type of material. The properties of the materials used not only affect the glove aesthetics, comfort and protective function but also influence the pattern design and contour of gloves and, thus, glove fit. Considering that sports apparels have become an important segment in the global apparel industry that caters to the next generation of consumers, this study aimed to evaluate the fit of two typical sports gloves with different dimensions and the effects of glove fit and material on hand strength, range of motion and finger dexterity compared with bare hands.

We hypothesize that (1) the fit, material and proportions of different dimensions of gloves are associated with hand performance and the (2) increase in space between the glove and hand at the finger area diminishes finger dexterity. The relationships between the glove fit and material with respect to different hand dimensions, hand performance and subjective perception of the gloves were evaluated.

2. Materials and methods

2.1. Subjects

Considering that genders, races, ages and occupations may lead to differences in hand sizes and dimensions, the participants involved in this study were limited to female university students in Hong Kong. Thirty participants were invited. Their ages were between 20 and 29 years (mean = 23.8, S.D. = 3.1), the average height was 160.5 cm (S.D. = 4.9) and the average weight was 51.1 kg (S.D. = 4.2). All of them were right-handed and healthy with no history of upper limb injury. Twenty-four key hand anthropometric measurements (11 length dimensions and 13 circumferential dimensions) for glove making, as shown in Table 1, were obtained by using a measuring tape and a digital calliper with an accuracy of 0.01 mm. Measurements were obtained following the ISO 7250–1:2008 standard. The hand measurements of all participants were obtained by the same operator. The experiment was approved by the Human Subjects Ethics Sub-Committee at Hong Kong Polytechnic University. A brief overview of the study was given to each participant and a written consent form was signed prior to the experiment.

2.2. Gloves

Two types of commercially available gloves used for hiking and war-gaming were studied (Fig. 1). They had similar designs with thinner fabric on the palm side, thicker fabric on the dorsum side, knitted elastic fabric on the finger web gusset and patches attached to the palm panel and fingertips. Decorative patches were located on the dorsum side of both gloves. There were three sizes of the hiking glove and four sizes of the war-gaming glove. Every size of the two types of gloves, total of seven pairs of gloves, were purchased for the experiment.

The 24 key dimensions of each glove were measured by using a measuring tape and a digital calliper. To evaluate the fit of the glove to the subjects' hands, the internal glove dimensions were measured when the glove was turned inside out. Each measurement of each glove was performed three times. The measurements were averaged (with standard deviation within 0.08 for the fingers lengths and circumferences measurements and within 0.17 cm for the other measurements) and presented in Table 2. The fit of the glove was quantified as the difference between the internal dimension and actual size of the hand. The larger the dimension difference between the glove and hand is, the poorer the glove fit will be. Glove dimensions should closely match the hand dimensions for optimal fit. Poor fit gloves hinder the hand motions, whereas good fit gloves allow the wearers to move their hands freely and comfortably.

Objective tests on the fabric were conducted because the physical and mechanical properties of glove materials also contribute to hand performance. Material thickness and density were recorded. Stress–strain behaviours were measured by using an Instron tensile tester, model 4411 (Massachusetts, USA). The stress of each fabric sample, which was extended up to 150% of its original length, was examined. The mean frictional coefficient (MIU) and surface roughness (SMD) were measured by the Kawabata Standard Evaluation System (KES) (Kato Tech Co., Ltd., Japan) with a KES-FB4 automatic surface tester. A higher MIU value indicated a lower tendency to slip, and a higher SMD indicated more surface unevenness.

2.3. Experimental procedures

All the sizes of the hiking glove and the war-gaming glove were given to the subjects for fitting. The subjects were asked to select the best-fitted gloves of each type for the experiment with the aid of a garment fit technician. Each subject was instructed to carry out a series of hand performance tests using the two gloves and barehanded (control experiment). All the tests in one subject were completed on the same day. Each set of tests on a glove took approximately 30 min, and a rest period of at least one hour between the test sets was implemented. The order in which gloves were worn was randomized for each subject to minimize a potential order effect. The subjects were provided with the details of the testing procedures and methods and had practice sessions to familiarize themselves with each test. A glove test consisted of the following steps:

1) The pair of gloves was worn, and the subject rested for 10 min.
2) The active ranges of motion (AROMs) of the proximal interphalangeal (PIP) joint of each finger and the interphalangeal (IP) joint of the thumb were measured by using a calibrated metal goniometer. The measurements were obtained on the dorsal aspects of each joint (Adams and Keyserling, 1993; Groth et al., 2001).
3) The grip strength of each hand was measured by using a JAMAR hand dynamometer (Härkönen et al., 1993; Mathiowetz, 2002; Mathiowetz et al., 1984; Shechtman et al., 2005). The dynamometer was set at the second handle position for all tests.
4) The finger tactile sensitivity was evaluated by using the Semmes–Weinstein monofilament test (SWMT) (Dianat et al., 2012; Essick et al., 2007; Jerosch-Herold, 2005; Lambert et al., 2009; Nurse and Nigg, 1999; Shih et al., 2001). A specific force was applied to the fingertips in the form of a monofilament vertically and slowly applied to the skin until it started to buckle. The participants were blindfolded and were instructed to respond when they felt the stimulus. The test began with the finest monofilament and continued with progressively thicker filaments until a positive response was achieved.
5) A pin insertion test, namely, the Purdue Pegboard (PP) test, was conducted to evaluate the finger dexterity in handling small objects (Bass and Stucki, 1951; Berger et al., 2009; Sawyer and Bennett, 2006; Tiffin and Asher, 1948). Two sub-tests were conducted in the left and right hands on the basis of the standardized procedure developed by Tiffin (1968). The tests consisted of using one hand to place as many pegs (cylindrical pins that were 3 cm long and 0.1 cm in diameter) as possible into a column of holes in 30 s.
6) A marble transport test was designed to evaluate the participant's ability in holding and handling a smooth, round object (Carpinella