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Study on Factors to Improve Comfort of Stab-resistant Vests Taking into Account Wearing Pressure and Movement Restriction

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Abstract

In this paper, we investigated factors affecting movement restriction while wearing stab-resistant vests with the aim of improving their comfort. We measured the contact area and pressure between the vest and a dummy, and performed sensory tests for movement restriction in the wearer's arms and upper body using four vests of different sizes, weight and types of stab-proof material. The pressure distribution of the vests on a dummy was measured and cross-sections of dummy-worn vests were obtained by 3D scan. For these measurements, we controlled the tightness value, the ratio between vest waist circumference and dummy. In order to check the influence of vests on the movement of the arm and upper body, subjects evaluated movement restriction and the feeling of pressure on the waist, chest, abdomen and back. We discovered that vests tend to hang on the neck point, shoulder, chest and back. The pressure on the chest increased with increasing tightness value, while the abdomen was under pressured to a forward bending position. Thus, shorter stab-resistant materials at the vest front have less movement restriction. In the arms, subjects reported less movement restriction when they felt that the shoulder area was softer. Therefore, we discovered that contact area and pressure should be considered in the design of stab-resistant vests to improve the comfort of the wearer.

Keywords: Stab-resistant Vest; Wearing Comfort; Restraint; Pressure

1 Introduction

Stab-resistant vests that cover the chest, abdomen and back (Fig. 1 (a) and (b)) are usually worn by police officers and security guards to protect their upper bodies against injury from knives and blades. In general the stab-resistant material, which is composed of a metal strip, is contained inside the vest as shown in Fig. 1 (c)-(e). Because of the presence of this stab-resistant material, the vest does not tend to fit comfortably on the human body, and thus restricts the wearer's movement, resulting in discomfort for the wearer [1]. There have been several studies on the

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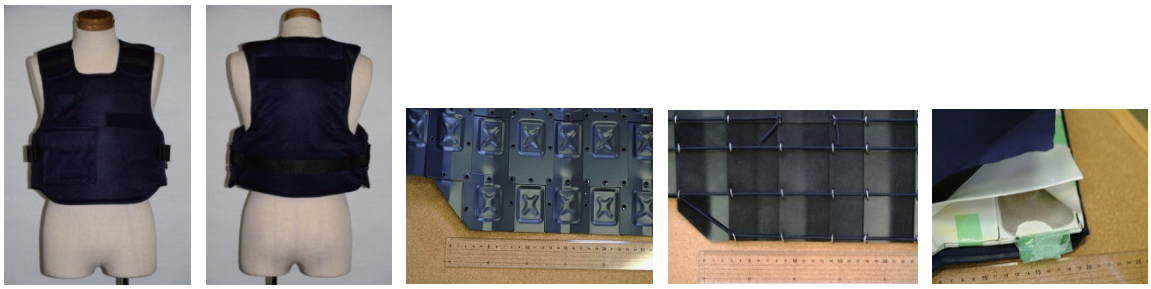
efficiency of stab-resistant materials. Ping Wang *et al.* [2] investigated the stab failure behaviors of coated and uncoated woven fabric using experimental and finite element analysis approaches. Alpyildiz *et al.* [3] constructed a new double-face knitted structure that shows better stab test results. Levinsky [4] investigated the mechanical properties and puncture resistance of two types of layered composite structures based on an aramid fabric covered with alumina micro particles and on polycarbonate. Jacobs *et al.* [5] proposed a simple model that can be used to calculate the performance of Dyneemaarmour against deformable bullets. Rochery *et al.* [6] developed and investigated a new double-face knitted structure for stab and cut resistance of knitted structures which is composed of tuck stitches and has the same back and front faces. Debra *et al.* [7] investigated the fragment protective performance of fabrics packs containing a para-aramid woven fabric using laboratory testing. Boussu [8] investigated the different types of the warp interlock to be defined according to their performance on delamination and impact resistances.



(a) (b) (c) (d) (e)

Fig. 1: Stab-resistant vest. (a) Front, (b) Back and (c-e) Stab-resistant materials; (c) Rivet type, (d) Ring type and (e) Pocket type

As described, most studies on stab-resistant vests are about stab-resistant tests measuring the mechanical properties of new stab-resistant materials so as to provide a better material for the vest. This approach is of course very important. However, the vest is a piece of clothing that is worn on a daily routine by wearers, so their comfort is also very important. In addition to the material properties of the stab-resistant vest, there are some requirements for making the vest both comfortable and safe. As a type of clothing, both the design of the vest and its flexibility has an effect on mobility and comfort. However, there have been insufficient studies on how comfortable it is to wear stab-resistant vests. How much a wearer's movement is constrained by wearing such a vest is also unclear. In terms of clothing comfort, the space between body and clothing is considered as an important effective factor especially in thermal protective clothing [9, 10]. Hadid *et al.* [11] evaluated whether physiological strain is alleviated by a new personal cooling system in a ballistic vest consisting of a layered vest and integrated blower that generate a flow of air. However, there are fewer studies about the space effect on the comfort of the stab vest. Huck *et al.* [12, 13] investigated garment ease in protective clothing for their effects on mobility and wearer acceptance. Wearing and moving comfort of a ballistic vest was investigated by Barker *et al.* [14] They compared comparative comfort performance of ballistic panel fabrications by sensory test. They mainly showed differences of comfort among vests from different panels which are inserted into the vest. Lee *et al.* [15] proposed ways to distribute the weight of a ballistic vest more uniformly using three-dimensional technology, especially taking into account the pressure distribution when jumping. However, they did not investigate the effect of material properties on movement restrictions and the pressure distribution on the entire upper body.

Therefore, we investigated the comfort of wearing stab-resistant vests while considering the