

DESIGN AND PERFORMANCE CHARACTERISTICS OF NEW FEMALE BULLETPROOF VESTS

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Abstract: *The new female bulletproof vest was designed with a superior female fit, this body armour providing a good balance between protection and comfort. One of the new issues in designing the female ballistic vest consists in taking into account the shape and bras size of Romanian female body, based on anthropometric survey using the 3D scanner technology. This bulletproof vest will provide comfort and mobility with the same or superior ballistic resistance properties versus standard body armour equipment. The ballistic performance parameters have been evaluated, in agreement with the international standards, in specialized laboratories of the Romanian MoD.*

Keywords: female bulletproof, vest, body armour

1. Introduction

When choosing a military body armour, it is important to consider where the armour will be worn. It is known that there are different levels of protection that can be offered by different body armours. However, protection issues do not mean everything when talking about individual ballistic protection equipment [1]. We are also taking into account the comfort provided by this kind of equipment. The body armour for military personnel should provide a balance of protection and comfort.

Until now, the Romania's female soldiers did not have any other choice than to wear men's bulletproof vest of smaller sizes. One does not have to be a great specialist in anatomy to know that men and women are not created equal in measurements and shapes. It is obvious that the woman's body shape is different than the man's one. That is why female soldiers need bulletproof vests made especially for their unique shapes. We cannot talk about the

design of a comfortable and ergonomic bulletproof equipment, providing the same or superior protection level, without performing in-depth anthropometric studies.

2. Anthropometric study

In order to build the database necessary for the design of ballistic protection equipment vest for Romania's female soldiers, an anthropometric survey using 3D human body scanning technology was carried out [2].

The survey was conducted on a total of 105 subjects using the VITUS Smart XXL scanner. It is designed to capture the surface of the human body in a couple of seconds and is based on the most accurate 3D laser triangulation optical system technology according with *EN ISO 20685: 2005 - 3D scanning methodologies for internationally compatible anthropometric databases*. The system provides protocols for extracting anthropometric data according with: *ISO 7520-1:2008 Basic*

human body measurement for technological design-Part 1: Body measurement definitions and landmarks and ISO 8559:1989 Garment construction and anthropometric surveys- Body dimensions [3].

For each of the 105 subjects a number of 150 parameters have been obtained using 3D scanning. Among them, 56 dimensional parameters were selected and processed by statistical methods, in order to design and produce an ergonomic bulletproof equipment for female staff. Some of the most important dimensions are the chest and under-chest circumferences. The dispersion diagram and the correlation between the two body sizes are presented in Figure 1.

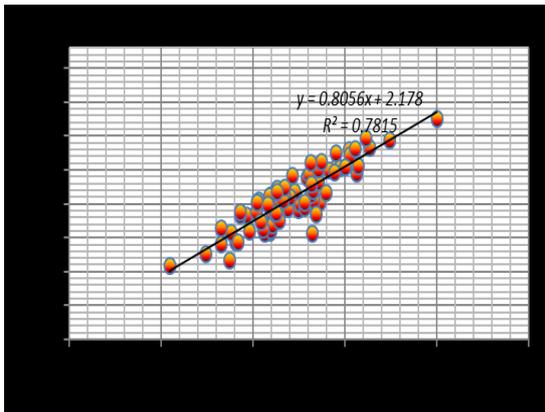


Figure 1. Dispersion diagram and regression line

By statistical analysis of these parameters the cup size distribution of the pilot sample was carried out. The highest percentage is for cup size C (32%), followed by size B (30%) and size A (25%).

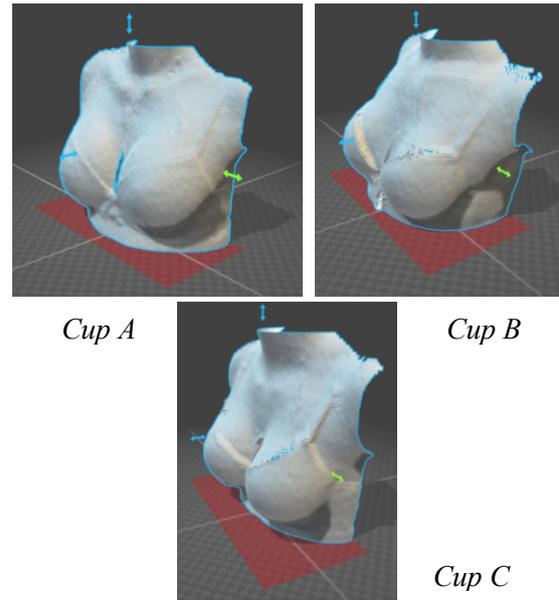


Figure 2. 3D shapes of avatar cups a) size S cup A, b) size S cup B, c) size M cup C

The size of female ballistic protection equipment was established and is given in Table 1.

Table 1. Size of female ballistic protection equipment

Body sizes		Size of bulletproof vest		
Chest circumference cm	Waist circumference cm	Size	Cup	
			Cup size	Note
87-89	68-72	S	A	For bra 75, cup A
89-91	68-72		B	For bra 75, cup B
91-93	73-78	M	C	For bra 75, cup C

Based on anthropometric measurements of this size S cup A and according with 3D shapes of the avatar cups (figure 2) the functional model of bulletproof vest was developed.

3. Evaluation of body-product dimensional correspondence

In order to evaluate the dimensional correspondence between the body and the physical model, the ballistic protection equipment was analysed using a manikin, adjustable to the dimensions of the body for which it was designed.

From the analysis of the body-product dimensional correspondence, it has been found that the front part inside the vest fits well with the size and the shape of the bust (figure 3).



*Figure 3. Ergonomic female's bulletproof vest
a. Front view, b. Rear view, c. Side view*

Assessment on the optimized functional model of ergonomic ballistic protection equipment for feminine personnel demonstrates its conformity with the design dimensions.

4. Testing of female bulletproof vest

Five female bulletproof vest were submitted to the test program in a specialized laboratory of Romanian MoD. The products have been tested for bullet resistance, in similar conditions with the equipment in endowment, according with the requirements of standard NIJ 0101.04 [4].



*Figure 4. Results of ballistic tests
a. Ergonomic female bulletproof vest (before tests), b. shooting views on ballistic package, c. bust impact (detail), d. back of ballistic package (detail).*

Ammunition of two calibers (9 mm FMJ bullets, with nominal masses of 8.0 g and 44 Magnum JHP bullets, with nominal masses of 15.6 g) were shot at a distance of 5 m. The depth left by bullets in the ballistic gelatin was measured, in order to assess the impact (the maxim depth accepted is 44 mm). It was of great interest to evaluate the impact in preformed cups, in order to check the behavior of selected materials for cups in terms of overall system performance.

The compliance with the bullet velocity requirements was determined using a HPI B462 ballistic chronograph (the minimum velocity accepted is 427 m/s).

There were no perforations of the tested products (figure 4), and the dimensions of depth in the ballistic gelatin did not exceed the standardized values.

The bullet resistance obtained was similar with the IIIA protection level, the highest protection level for flexible materials (without the addition of ceramic plates), as well as the unisex ballistic vests in the endowment.

5. Conclusions

The body armour for military personnel should provide a balance of protection and comfort. The novelty in the bulletproof

vest design consists in taking into account the size of Romanian female body and the technical solution for the preformed cups.

By statistical analysis of the parameters obtained through 3D technology, the necessary data have been used to make an ergonomic bulletproof vest, specially dedicated to female staff.

Preliminary assessment of the ergonomic ballistic protection equipment for feminine personnel, developed at functional model level, demonstrates its conformity with the design dimensions.

Performing ballistic tests in a specialized laboratory of the MoD confirmed the

protection level assured by the new ballistic protection equipment.

The new bulletproof vest is an ergonomic individual ballistic protection equipment, fitted to Romania's female soldiers, which assures the III A ballistic protection level.

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References

- [1] Niculescu C., Filipescu E., Avadanei M., 2010, *General aspects concerning the development of a female dimensional typology using 3D body scanning measurements*, Industria Textila nr. 6, vol.61, pages 271-275, Ed. CERTEX-Bucharest, ISSN 1222-5347
- [2] D. Yang, *Design, Performance and Fit of Fabrics for Female Body Armour*, A thesis submitted to the University of Manchester, 2011
- [3] N. James, *Body Armor for Law Enforcement Officers: In Brief*, Congressional Research Service, 2016
- [4] *** NIJ standard 0101.04, *Ballistic Resistance of Personal Body Armour*