2025-2 | 50th congress of the Société de Biomécanique
27-29 October 2025, Marseille, France

Multidisciplinary Biomechanics Journal

Influence of the female breast on a ballistic impact: effect of the size and location of the impact

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Received date: 04/04/2025
Accepted date: 27/06/2025
Publication date: 27/10/2025

Keywords: breast, BABT, impact, ballistic

1. Introduction

In law enforcement and the military, the number of women has increased significantly. Women now account for 17.3 % of the personnel in the French armed forces. This evolution raises the issue of adapting protective equipment to female anatomical characteristics, particularly regarding bulletproof vests (Pinkos et al., 2024). Studies indicate that bulletproof vests worn by women are generally not well suited to their anatomy (Coltman et al., 2021).

Moreover, the bulletproof vest does not guarantee absolute protection against injuries. Even without projectile penetration, ballistic impacts can cause severe Behind Armour Blunt Trauma (BABT) due to the impact energy and the dynamic deformation at the back of the bulletproof vest.

To assess the formation of the dynamic deformation cone of the backface, the gel block method is commonly used. The protocol developed by the Research and Expertise Centre for Logistics of the French Ministry of the Interior relies on SEBS gel blocks as substitutes for the thorax to assess the effectiveness of bulletproof vests (Bracq et al., 2021). In this context, this method was adapted by adding breast substitutes to simulate the interaction between projectiles and female morphology.

This study aims to analyse BABT cases affecting the female chest through an experimental approach. The objective is to provide quantitative data on ballistic impacts on the female breast, considering both the impact location and breast size.

2. Methods

2.1 Breast substitutes

Two breast sizes were studied, corresponding to a 90B and a 90D. These substitutes were made of a gel, composed of 10 % SEBS and 90 % mineral oil (Mauzac et al., 2010). Before carrying out tests, the substitutes were validated using biomechanical corridors (Wilhelm et al., 2003). Wilhelm defined these corridors based on gunshots to the breast of female post-mortem subjects with a cylindrical projectile of 140 g at 40 m/s. They represent the displacement of the projectile's rear during impact on subject.

2.2 Test protocol

The experimental setup used for ballistic tests is shown in figure 1.a. The shots were fired with a 9 mm Parabellum projectile at an initial velocity of 410 m/s on soft armour composed of 20 layers of a Dyneema SB117, a density of 216 g/m². Two impact configurations incorporating the substitutes were tested: between the breasts (Figure 1.b) and under the right breast (Figure 1.c). The surrogates were positioned on a gel block so that the point of impact was centred on the gel block. The distance between the nipples was 164 mm. To assess the influence of the breast, a reference configuration,

To cite this article: Elodie Dancerel-Bourlon, Rémi Delille, Olivier Mauzac, Nicolas Prat, Benjamin Bourel, Sébastien Roth, Franck Lauro, Influence of the female breast on a ballistic impact: effect of the size and location of the impact, *Multidisciplinary Biomechanics Journal*, 2025, vol. 2, p. 297–299, DOI: 10.46298/mbj.16227.

without substitutes, was set up (Figure 1.d). Four shots were performed per configuration and surrogate size.

2.3 Data analysis

Data analysis was performed using the MATLAB (MathWorks®) environment. A specific routine was developed to measure the maximum displacement of the backface deformation (BFD) in the cubic block corresponding to the reference. In parallel, the maximum value of the Energy Transfer Parameter (ETPmax) was determined for each experimental configuration. This measurement is expressed in m/s, is obtained from the maximum gel displacement as a function of time. The equation is ETP(t) = (1/300)*(x(t)*(dx(t)/dt)) where x(t) is the gel displacement in mm. The constant, 300, expressed in mm is used for normalisation, it corresponded to the thickness of the gel block. Statistical analysis was performed using the ANOVA test for both measurements studied.

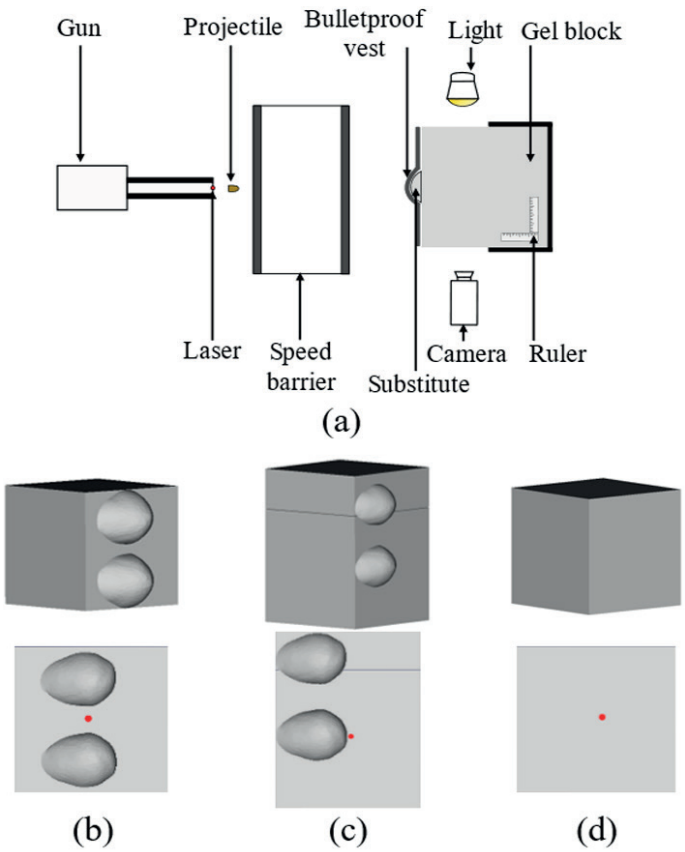

Figure 1. (a) Experimental setup **(b)** Case 1: Impact between the breasts, on the nipple line **(c)** Case 2: Impact 2 cm under the breast **(d)** Reference impact.

3. Results and discussion

3.1 Validation of breasts substitutes

Using the gel block and breast substitutes under shooting conditions identical to those in the Wilhelm study, the temporal displacement of the projectile's rear aligns with the corridors defined for post-mortem female subjects at the breast level.

3.2 BABT cases

The results show that the presence of breasts influences the ballistic response by reducing the BFD and the ETPmax value, with a more pronounced effect for larger breasts.

For ETPmax, all configurations with breasts showed significant differences compared to the reference, regardless of size. For BFD, no significant difference was observed with size 90B, except between the two impacts cases. However, for size 90D, all configurations differed significantly from the reference.

Table 1. Average maximum values obtained in the different shot setups.

	Size B		Size D	
	Disp.	**ETP**	**Disp.**	**ETP**
Case 1	38.11#	2.93*#	31.08*	2.13*#
Case 2	37.26#	1.00*#	27.87*	0.99*#
Reference	39.99	7.52	39.99	7.52

P<0.05 from reference (*) or other case (#).
With displacement in mm and ETP in m/s.

Despite the lower risk of internal injuries, the breasts remain vulnerable to major but non-lethal injuries.

4. Conclusion

The study highlighted the influence of the breasts on the BFD as well as on ETP value. The results show that the presence of breast substitutes reduces the values of BFD and ETPmax. These observations highlight the impact of thoracic morphology on the distribution of forces during a ballistic impact. These results open perspectives for the optimisation of personal protective equipment, by further integrating morphological differences between the sexes into their design. Additional studies, particularly on the interaction with different types of projectiles and protections, would allow these conclusions to be refined.

Acknowledgements

This study was conducted as part of a PhD thesis research project supported by the French "Direction Générale de l'Armement" (DGA) and the French "Agence de l'Innovation de Défense" (AID-DGA). The authors acknowledge the French Ministry of Interior for its financial and material support.

Contributor Roles

ED: Methodology, Investigation, Formal analysis, Writing original draft; RD: Conceptualization, Investigation; OM: Resources, Investigation, Writing-review & editing; NP: Project administration; BB: Software; SR: Supervision, Writing-review & editing; FL: Supervision, Writing-review & editing.

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