Summary Report of VIRTUS Pulse 2 Coverage Definitions and Assessments Methods.

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Requirement

VIRTUS Pulse 2 provides the opportunity to review the coverage requirements and performance of Combat Protective Equipment (CPE), including: performance of the hard plate, mass of the soft armour, coverage of the basic, soft and hard armour.

This document summarises the study "VIRTUS Pulse 2 Coverage Definitions and Assessment Methods" [1], which defines the coverage and sizing that new hard armour plates must meet. Full definitions, supporting evidence, limitation and data, are included in [1]. This activity was conducted in support of Soldier Training and Special Programmes (STSP) Defence Equipment and Support (DE&S) to support VIRTUS Pulse 2 System Requirements. This was split into three distinct parts, to inform:

1. **Number of plates:** Analyse and identify how 3, 4 and 5 plates can fit the UK military population.
2. **Plate dimensions:** Recommend Threshold and Objective lengths and widths that each plate should meet.
3. **Plate coverage scoring:** Suggest a scoring regime for the coverage of essential organs that will assist DE&S's assessment of bidder's submissions.

This deliverable is referred to as Tasks 3, 4, 5 and 6 of the IPP VIRTUS Pulse 2 and ISS Support.

Conclusions

This study reviews and recommends the optimum number of hard plate sizes (3, 4 or 5) which would be needed to cover the largest proportion of the UK (Army, male and female) population and recommends 5 plate sizes (Extra Small (XS) to Extra Large (XL)). The assessment is based on recommended essential medical coverage [2] for Threshold and Objective dimensions, with Figure 1 showing the key hard plate measurements and anatomical landmarks.

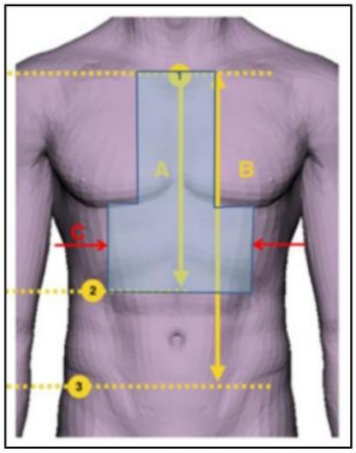

Figure 1: Suprasternal notch (1), lower border of ribcage (2) and iliac crest (3).
Threshold length is A (threshold dimensions in blue), objective length is B
C is recommended width for all plates. Geometric shape determines area coverage and fit.

Threshold dimensions are defined as the length (for vertical distance) and width (for horizontal distance) that a plate must meet to obtain acceptable medical coverage.

Objective dimensions are defined as lengths and widths that if exceeded by a plate coverage would not be improved.

The Threshold and Objective dimensions are based upon recommended essential medical coverage [2], which relate to external anthropometric landmarks, highlighted in Figure 1. These are the suprasternal notch to lower border of the ribcage (A) and the suprasternal notch to the iliac crest (B) for Threshold and Objective length respectively. The average widths of heart (95th percentile) and liver/spleen (50th percentile) for upper and lower Threshold widths respectively; and finally a fixed width of liver/spleen (50th percentile) for upper and lower Objective width.

Figure 2 graphically presents how 5 plates could fit the population, the line graphs represent the percentiles of male and female and the horizontal orange lines represent chosen threshold lengths (plate lengths). It is apparent males would utilise all 5 plate sizes, females would utilise 3 (XS, S & M). Figure 2 also provides indicative front and rear plate weights at realistic Areal Densities (AD) to defeat the VIRTUS Pulse 2 threats.

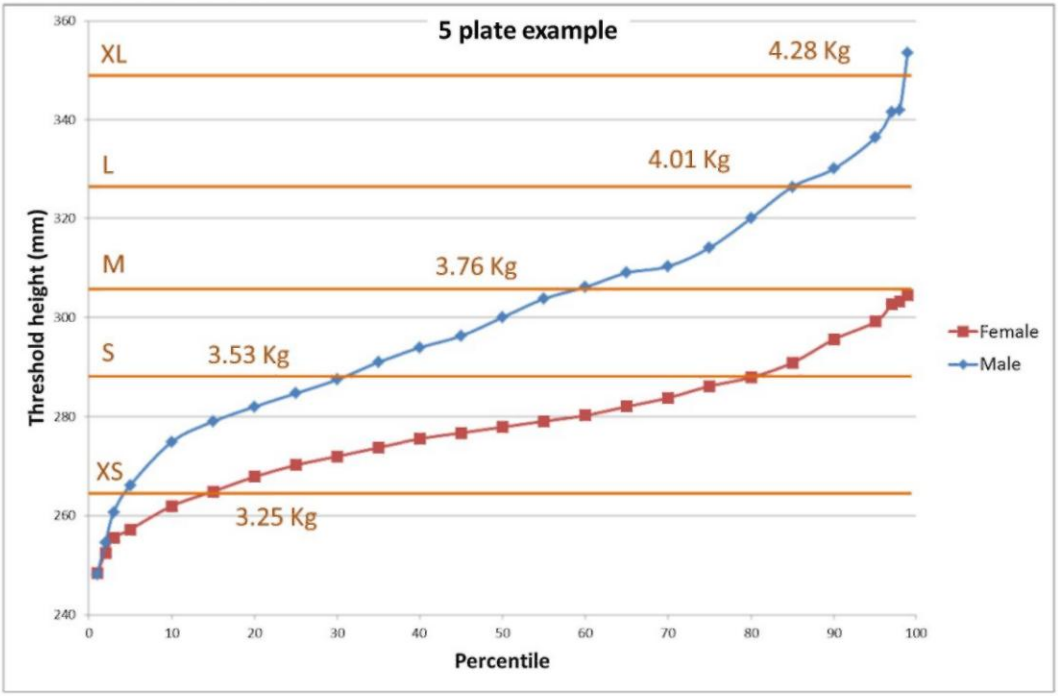

Figure 2: Example of how 5 plates could meet threshold lengths.

Table 1 summarises Figure 2, the threshold and objective lengths for the 5 plate sizes; along with the percentage range that each plate should fit, for the male and female population assessed. Before the final decision on actual plate dimensions is taken, the most up-to-date UK anthropomorphic data should be assessed.

		Plate Size				
		XS	**S**	**M**	**L**	**XL**
Male	**Maximum percentile**	5	30	60	85	99
	Minimum percentile	1	5	30	60	85
Female	**Maximum percentile**	15	80	99	N/A	N/A
	Minimum percentile	1	15	80	N/A	N/A
Threshold Length (mm)		265	287	306	326	348
Objective Length (mm)		282	310	349	375	399

Table 1: Possible threshold and objective lengths for 5 plates.

A scoring regime for hard plate coverage using the Weapon Target Interaction (WTI) tool [3] has been established that covers a range of attack angles (120° range of azimuth from front and rear and 40° range of elevation in 20° steps) and weightings in order to consider wider plate coverage.

The total number of impacts of Unsurvivable (U), Critical (C) and Severe (S) injuries that hard plates stop are calculated and output as a metric using WTI. These three types of injuries correspond to approximately 100%, 80% and 40% level of mortality and so the following weighted score is suggested:

$$\text{Weighted Coverage Score} = U + (0.8 \times C) + (0.4 \times S)$$

Recommendations

Number of plates

Dstl recommend 5 plate sizes (XS to XL) to ensure essential medical coverage and reduced burden is provided for the widest range of the population.

Threshold and Objective dimensions

Plate shape:

Figure 3 defines the Threshold dimensions. The ratio of top length to bottom length of all plates is recommended to be 0.42 to 0.58. All of these dimensions should be assessed to ensure they meet human factors requirements (not conducted in this task). This is especially important for the smallest individuals, as the suggested width may not be acceptable, and for seated individuals the Objective length may cause injury in some vehicle incidents.

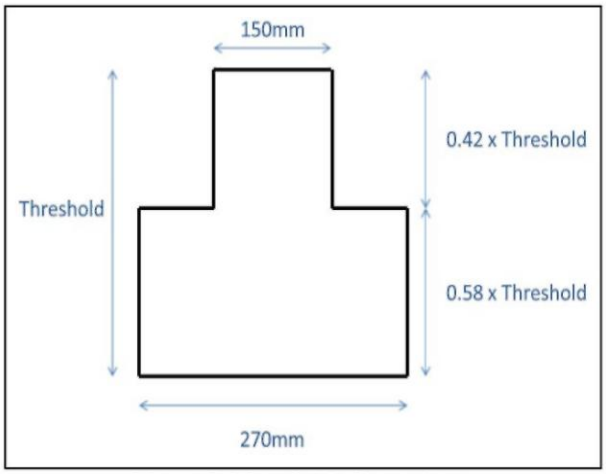

Figure 3: Threshold dimensions.

Threshold length:

The distance from the suprasternal notch to the lower border of the ribcage (10th rib) is recommended as the threshold length (A on Figure 1).

This length is defined for the largest percentile in the size range that the plates are intended to cover.

Objective length:

The distance from the suprasternal notch to the iliac crest is recommended as the objective length (B on Figure 1).

This length is defined for the smallest percentile in the size range that the plates are intended to cover.

Threshold widths:

Fixed widths are suggested for all lengths of plates;

270mm is the 50th percentile for lower dimensions and is suggested as the threshold bottom width;

150mm is the 95th percentile for upper dimensions and is suggested as the threshold top width.

Objective width:

A single width of 270mm is recommended for the Objective width – i.e. a rectangular plate.

Coverage Scoring

WTI assessments of plates should be used with the weighted metric of number of shot lines of unsurvivable, critical and severe injuries that are stopped. This score is given as:

$$\text{Weighted Coverage Score} = U + (0.8 \times C) + (0.4 \times S)$$

It is suggested that the lower score should be the Threshold dimension score and the upper score is the Objective dimensions score. The score out of 10 for a plate would then be given by where it sits linearly in-between the lower and upper scores.

Further weighting of these coverage scores in relation to other metrics such as weight, human factors and dynamic injury assessments needs to be considered to ensure that the most acceptable compromise of coverage and acceptability is achieved.

Method

The definition and derivation of Threshold and Objective dimensions was based on analysis of the available anthropometric [4] and Computed Tomography (CT) data [2], to assess and recommend the number of plate sizes required to provide essential medical coverage to the UK military population. Essential medical coverage is defined as coverage of the heart, aorta, liver and spleen [5].

The plate coverage scoring utilises the vulnerability model WTI, which uses shotline analysis of the human geometry (internal and external) to represent injuries from projectile penetrations and quantifies the coverage offered by different CPE/coverage options. Detailed documentation and the WTI Validation Logbook can be found within [3]. The output from these assessments will provide measures of performance for coverage, which will ultimately be used to assess candidate systems under the VIRTUS Pulse 2 competition. The probability of mortality related to the injury outputs from WTI are used to weight injury scores.

This study did not include human factors assessment, plate curvature or dynamic injury assessments for seated personnel so should not be used in isolation to determine the plate size or shape that is procured. It is recommended that separate human factors trials and assessments are conducted.

References

[1] Fryer R. "VIRTUS Pulse 2 Coverage Definitions and Assessment Methods" DSTL/TR097315. In preparation.

[2] Breeze J, Lewis EA, Fryer R. "Determining the dimensions of essential medical coverage required by military body armour plates utilising Computed Tomography". Injury 2016; 47: 1932-1938.

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[5] Breeze J, Fryer R, Lewis E, Hepper AE, Mahoney P, Clasper J. "Defining the essential anatomical coverage provided by military body armour against high energy projectiles". J R Army Med Corps 2016; 162: 284–290.

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