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TECHNICAL REPORT

Lightening Body Armor

Arroyo Support to the Army Response
to Section 125 of the National Defense
Authorization Act for Fiscal Year 2011

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Summary

The body armor that U.S. forces wear in Afghanistan is effective against ballistic threats: There have not been any known penetrations of the body armor or fatalities associated with the threat of projectiles that the currently issued body armor is designed to stop. The body armor is heavy, however, constituting approximately 30 percent of the total load that is carried into combat by a dismounted soldier or marine.

Congress has asked the question, How can body armor weight be reduced? Congress's perception is that Department of Defense (DoD) has been slow in developing and deploying lighter-weight body armor. In Section 125 of the National Defense Authorization Act for Fiscal Year 2011, Congress requested that a federally funded research and development center conduct a study of lightening body armor. The RAND Arroyo Center was selected to perform this study.

The study focus is on soldier protection from ballistic threats—both small arms fire and fragmenting munitions. The study concentrates on reducing the weight of the torso armor, since most of the body armor weight is in protecting the torso area of the body. Protection of the torso area is provided using soft body armor vests with ceramic plate inserts, and the ceramic plates are heavy. The weight range of a full-up torso body armor set is 27 to 38 pounds for small to extra-large sizes.

Body armor must be capable of meeting two requirements. First, the ceramic plates cannot be penetrated when struck by multiple ballistic rounds in a well-defined shot pattern. Second, the backface deformation (a surrogate measure of blunt force trauma) that occurs when the bullet impacts the ceramic plate must be no greater than 44 mm, as measured by indentation depth in the test material backing the plate. This depth is based on limited 1977 research using anesthetized animals. Additional mathematical modeling predicted that a backface deformation of 44 mm or less would result in a maximum 10 percent probability of lethality.

Comparison of Approaches

The four approaches to lighten body armor—refining requirements, using modular configurations, improving testing, and improving materials—are compared in Figure S.1. In some respects, refining requirements is the most difficult approach to implement: Changing the processes necessary to meet requirements is not very difficult, but the decision to change requirements in the first place is. A change from the currently accepted threat round that the body armor must be capable of stopping to a less capable round (in terms of muzzle velocity, bullet type, or caliber) would have serious consequences if the change were later shown to be unwarranted and additional lethal casualties result.

Figure S.1
Comparison of the Four Approaches to Reducing Body Armor Weight

Approach	Ease in Executing Change	Required Army Coordination	Estimated Weight Reduction	Comment
Refine requirements	Moderately difficult	DCS G-3, TRADOC	Small to moderate (~10–20%)	Consequence great if wrong
Use modular body armor configurations	Easy in principle	Field commanders, TRADOC	Moderate to large (~20–45%)	Questions remain about risks
Improve testing	Moderate	PEO Soldier, ATC	Small (~5–10%)	Requires coordination with other services, DLA, and SOCOM and DOT&E approval
Improve materials (R&D, procurement process)	Moderate (funding)	ASA(ALT), DCS G-8	Unknown at present	Long-term solution; appropriate procurement process depends on technological challenge

NOTES: TRADOC = U.S. Army Training and Doctrine Command; PEO = Program Executive Office; ATC = Aberdeen Test Center; DLA = Defense Logistics Agency; SOCOM = U.S. Special Operations Command; DOT&E = Office of the Director, Operational Test and Evaluation; R&D = research and development; ASA(ALT) = Assistant Secretary of the Army (Acquisition, Logistics and Technology); DCS = Army Deputy Chief of Staff.

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The least difficult approach is the use of modular body armor configurations, simply because the decision to use modular body armor has already been made. However, this approach carries the largest risk. If a commander decides to use a less effective body armor configuration (i.e., a lower level Body Army Protect Level [BAPL]) and his choice proves to be incorrect, avoidable casualties could result. The other two approaches we considered—improving testing and improving materials—involve some difficult choices but should not lead to catastrophic outcomes.

Each of the approaches requires Army and broader DoD coordination before it can be implemented. Both refining of requirements and using the modular body armor approach require high-level coordination because of the potential risk. Improving testing requires approval from the Office of the Director, Operational Test and Evaluation (DOT&E), and developing better materials requires funding and time.

With regard to estimated weight reductions, greater increases in reduction may be possible if some of the approaches are considered synergistically. For example, a larger weight loss should be achieved if the benefits derived from reduced requirements are combined with the benefits gained from improved testing coupled with modular configurations.

Conclusions

The conclusions of this study are as follows:

- Today, no “silver bullet” material solution exists that will greatly reduce body armor weight.
- Some means (mainly nonmaterial) are available that can reduce body armor weight.
- A combination of material and nonmaterial approaches to lighten body armor will result in greater weight reductions.
- Synergy of modular concepts may lead to greater weight reduction (e.g., integration of hard and soft body armor designs).
- Further reductions in weight will require a significant investment of money and time.

A 10 percent reduction in weight appears to be about the most that is realistic in the short term if overall protection is to remain constant. Even this small increment will be quite difficult to achieve, however. A longer-term solution to reducing body armor weight likely involves the development and integration of new materials. However, the technology is currently too immature to make reliable estimates about the weight and protective effectiveness of new materials.

There are some nonmaterial solutions available that can result in a greater than 20 percent weight reduction. For example, with modular body armor configurations, a 45 percent reduction results when BAPL 2 is selected instead of BAPL 5.¹ The problem is that the choice of the appropriate BAPL is a difficult decision. Also, a large inventory of body armor vests and plates must always be available to provide the various plates and vests in all sizes to forward to combat areas.

A combination of material and nonmaterial approaches should result in greater weight reduction. For example, if the plates are over-designed for the threat, then the requirements and testing procedures could be changed, resulting in thinner and lighter-weight plates.

A synergy of modular concepts may also lead to greater weight reduction. Soft and hard body armor should be developed and procured as one item. Today’s practice is to simply add hard plate inserts to a soft vest, but a systems approach would design a single body armor concept that optimized the characteristics of the two components.

Further reductions in weight will require a significant investment of money and time. Changes to the plate design could reduce the plate weight. For example, variable-thickness plates could be constructed that provide greater protection over the chest portion of the torso than over the abdomen portion. However, variable-thickness plates would involve changing the manufacturing process and the testing procedures.

Answers to the eight issues specifically raised by Section 125 are presented in the main body of the document.

Recommendations

As a result of our examination of the issues associated with reducing the weight of body armor, we propose four top-level recommendations:

¹ BAPL 5 includes an improved outer tactical vest with front, back, and side plates, while BAPL 2 uses a plate carrier without the side plates.

- First, development of significantly lighter, next-generation body armor using advanced technology materials will require more research, development, test, and evaluation (RDT&E) funding, though we have not attempted to quantify that requirement. The various RDT&E program elements also need to be better coordinated, and the various service efforts should be mutually supporting.
- Second, the threat level requirement should be consistent with the threat environment being encountered today and anticipated in the future.
- Third, the requirements-development process needs to be reviewed to ensure that coordination among the relevant stakeholder offices is continuous as requirements are developed. Making optimal trade-offs between protection, weight, ergonomic impact, and cost requires ongoing interaction among the user representative, the technical community, and the resource providers, from the start of requirements assessment to the publication of the requirements document.
- Fourth, performance—including weight—should be included as a contract award selection criterion when awarding production contracts for body armor. Currently, products that meet the threshold criteria are selected solely on a cost basis by the Defense Logistics Agency, so prospective producers have no incentive to improve body armor performance beyond the threshold.

We also propose five specific recommendations:

- Exceptions should be made to the Berry and Kissell Amendments, which limit the design and manufacturing of soft body armor intended for U.S. service members to American and Canadian producers. If offshore sources offer improved body armor solutions, they should not be denied to our service members.
- The 1977 Prather study that provided a preliminary correlation of mortality and backface deformation on soft body armor should be updated by conducting new research using today's body armor (soft and hard). New data will help improve requirements generation and make testing more realistic.
- Field commanders may be reluctant to utilize a BAPL lower than the maximum without some sort of decision aid tool to back up their assessment. The development of the Operational Requirements-based Casualty Assessment (ORCA)/Modular UNIX-based Vulnerability Estimation (MUVES) model should be continued and used to help develop a decision aid that field commanders can use to make BAPL decisions.
- A comprehensive trauma data collection and analysis process should be established to better inform researchers, developers and decisionmakers.
- Finally, research should be conducted to better understand how body armor weight degrades soldier combat performance. There is a trade between individual protection and individual—and unit—effectiveness. That trade space is not well understood today, so making assessments concerning developmental requirements and about BAPL during operations is currently difficult.