A Strategy for Enhancing Warfighter Survivability

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New American
Security

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ABOUT THIS REPORT

This report, the first in the *Super Soldiers* series, covers findings from the Center for a New American Security's study on dismounted soldier survivability. This study was conducted for the Army Research Laboratory to identify future concepts and technologies to improve soldier survivability and effectiveness over the next 20 to 30 years in order to identify high-payoff science and technology investment areas. While the primary audience for this report is the Army science and technology community, the report's findings and recommendations may be of interest to a broader group of stakeholders, including across the Army, the Joint Force, and the wider defense community.

Views expressed in this report are of the authors alone. CNAS does not take institutional positions.

Introduction

Survivability is an essential component of military effectiveness. Militaries have long invested in protection, such as helmets and armor, to improve the survivability of their troops on the battlefield. U.S. troops today have greater protection than their historical predecessors or other contemporary military forces around the globe. Nevertheless, this protection has limitations, and dismounted troops remain vulnerable to a range of threats.

The *Super Soldiers* series examines opportunities to improve dismounted soldier survivability in the near-, mid-, and far-term through changes to policies, improvements in equipment, and by harnessing emerging technologies. There is no magic solution for improving soldier survivability, but there are many opportunities that the Army can seize on that can yield significant improvements.

This first report in the *Super Soldiers* series presents an overview of the limitations of armor and a strategy for improving soldier survivability. Subsequent reports will include actionable recommendations for Army leaders to take today.

Armor's Limitations

Body armor saves lives. Modern ballistic body armor is truly a game-changing innovation that gives U.S. soldiers a significant battlefield advantage over adversaries. Over the past 15 years of war, body armor has proven its value in combat, stopping high-velocity rifle rounds and preventing potentially lethal injuries to the torso. However, current body armor systems suffer from three major shortcomings.

Current body armor does not adequately protect against blast-induced brain injury, a critical threat to soldiers. Traumatic brain injury, such as from improvised explosive devices (IEDs), is the "signature wound" of today's wars. Over 300,000 service members have suffered mild or moderate brain injury since 2000. Some of these injuries come from combat, including exposure to IEDs, but others likely come from occupational hazards such as falls, concussions, or repeat blasts from firing heavy weaponry.[1] Existing helmet and torso armor designs provide insufficient protection against this threat. While today's body armor, which consists of hard armor (ceramic plates) and flexible soft armor, protects against explosive fragments, it is not designed to protect soldiers from the pressure wave itself that comes from blast explosions. Even wearing a helmet, the head is largely exposed to harmful blast waves that can damage the brain. As a result, soldiers remain exposed to blast overpressure that can cause insidious and debilitating brain injury. Blast exposure can even come from firing heavy weapons, such as anti-tank recoilless rifles.

The weight of current armor negatively affects soldier performance. Body armor is heavy, bulky, and hot. The Army's current torso body armor system (Improved Outer Tactical Vest with ESAPI plates) weighs approximately 30–35 pounds, depending on size and specific configuration. This weight comes on top of an already physically overburdened soldier. A combat soldier's fighting load can exceed 60–80 pounds with body armor, weapon, ammunition, water, night vision goggles, radio, batteries, food, and other items. When carrying a rucksack with several days of supplies, a soldier's approach march load on patrol can reach 90–140 pounds.[2] These loads significantly exceed the recommended soldier maximum loads of 50 pounds fighting load and 70–75 pounds approach march load (total weight carried while moving to an objective). This weight has the immediate effect of reducing soldier mobility and performance. Additionally, over the course of a mission, the weight has a cumulative effect of increasing soldier fatigue, further reducing physical and cognitive performance. In hot climates, the increased thermal load that comes from body armor trapping heat on the torso can also severely negatively affect soldier performance and risk heat injury. In total, the benefits of body armor come at a heavy price in soldier performance. On today's modern battlefields, particularly against insurgents and guerrillas, U.S. soldiers often find their advantages in armor offset by a dramatic disadvantage against their enemies in tactical mobility on foot, an important component of overall soldier survivability.

Despite their weight, current systems still leave vulnerable areas exposed. Even with their weight, current body armor systems leave several vulnerable areas exposed to high-velocity ballistic (e.g., rifle) threats. Existing body armor provides effective ballistic protection to the torso but does not fully protect the head, face, neck, groin, upper side, or extremities. Soft armor protects soldiers from explosive fragments and pistol rounds, but not high-velocity rifle rounds. Soldiers have no protection from high-velocity ballistic injuries to the face. The reason for this lack of full-body protection is the daunting weight of armor. Hard ceramic armor, of the kind worn on soldiers' front, back, and sides, is effective in stopping rifle rounds but is extremely heavy. Covering additional areas on the body with hard armor is not feasible today without significantly lighter materials or augmenting soldier strength – for example, through the use of exoskeletons or human enhancement. In the medium-term, these technologies could provide modest gains, but in the long-term exoskeletons could significantly improve soldier survivability.

Opportunities to Enhance Soldier Survivability and Performance

There are a number of steps the Army can take to increase soldier survivability and performance over the next 20 to 30 years. Some of these efforts could yield modest improvements in the near-term (0–5 years) with existing technology. Over the long-term, more disruptive changes are possible by capitalizing on emerging technologies, such as exoskeletons and robotic teammates.

The Army should pursue a three-part strategy to increase dismounted soldier survivability and performance. This strategy would consist of three main lines of effort, intended to address the shortcomings of today's body armor systems.

1) Mitigate blast effects to the brain while improving understanding of blast injury mechanisms

The first line of effort would be to take immediate steps to mitigate blast effects on soldiers while increasing fundamental research into the mechanism of brain injury. The mechanism by which blast overpressure causes injury to the brain is poorly understood. While Department of Defense (DoD) research is under way in this area, more research is needed, including computational modeling of blast injury coupled with experimental data.

Even while this research continues, however, based on the current understanding of risks, the Army should take action now to reduce soldiers' brains' exposure to blast overpressure. Computational modeling of blast wave propagation through soldiers' skulls suggests that the current Army combat helmet is somewhat effective in reducing blast-induced pressure inside the brain, even though blast protection was not the helmet's intended purpose. Redesigned helmets, especially modular helmets with removable full-face shields, could be even more effective in protecting soldiers from harmful blasts, potentially reducing blast pressure in the brain by up to 80 percent compared to the current helmet.[3] The Army should also take immediate steps to better understand and limit soldiers' exposure to blast overpressure from heavy weapons, such as recoilless rifles.

Understanding the specific mechanism by which blast overpressure damages the brain is not necessary to take immediate steps today to reduce blast exposure. The Army should:

- Launch a longitudinal medical study, to include a blast surveillance program, to monitor, record, and maintain data on blast exposure in training and combat, in order to better understand the relationship between blast exposure and brain injury, including from repeated low-level exposures.
- Test existing helmets, including commercially available variants with modular mandible and face shields, to determine which configuration and materials best protect against primary blast wave injury, as a near-term mitigation against possible brain injury.
- Establish an interim requirement for helmet protection against blast overpressure.

- Increase research into the mechanism by which blast overpressure causes brain injury in order to further refine blast protection requirements over time.
- Increase research on the cumulative neurological effects on soldiers of repeated firing of heavy weapons such as recoilless rifles.
- Take prudent precautions when firing heavy weapons, such as the Carl Gustaf recoilless rifle, in training to improve soldier safety.

2) Optimize body armor design and use to improve overall soldier survivability

Two of the major limitations of body armor today – the lack of greater body area coverage and the weight burden of armor – stem directly from the weight of hard (ceramic) armor. Near-term prospects for significantly lighter materials are slim. Progress on better materials that could dramatically decrease weight while maintaining or increasing the level of protection has been incremental to date. Moreover, gains in weight reduction are often reinvested in a higher level of protection. Thus, even though armor materials have improved, the weight of armor has generally gone up with each successive generation. While modest improvements in material technology to improve weight are possible, dramatic material improvements are unlikely in the near-term.

However, there remain opportunities for increasing soldier survivability and performance by reducing weight in the near-term, even with existing technologies. Current body armor systems are likely overdesigned in several respects, resulting in opportunities to reduce weight without sacrificing protection against the most likely threats.[4] Because reduced weight would lighten the soldier's load and increase performance, soldier survivability as a whole could improve significantly. Situational awareness, mobility, marksmanship accuracy, and other aspects of mental and physical performance are all vital aspects of survivability. Body armor only provides a final layer of protection against ballistic injury. Until a bullet actually strikes a plate, the armor is essentially "parasitic weight," sapping performance without adding any immediate value.[5] While body armor provides a crucial advantage, finding the enemy and attacking first is the most ideal situation in combat.

This next line of effort would consist of both material and policy changes to optimize body armor design and use in order to reduce weight and improve overall soldier survivability. The Army should:

- Conduct additional research into the relationship between ballistic injury and material performance.
- Optimize body armor requirements to reduce weight.
- Conduct additional research into the relationship between soldier load and performance.
- Change policies: Establish a weight limit for individual soldier equipment; update and adhere to doctrine on soldier load; and delegate authority to battlefield commanders to tailor the level of protection based on the specific mission and threat.

Because these changes do not require fundamental advances in materials science, they could be implemented using existing technology in the near-term (0–5 years).

3) Capitalize on emerging technologies

In the mid- and long-term, a number of disruptive technologies have the potential to bend or break the "Iron Triangle" of protection, mobility, and lethality. Currently, the capabilities that a dismounted soldier brings to the battle are limited by the weight-carrying capacity of the soldier. New technology has enabled better situational awareness, connectivity, lethality, and protection, but it comes at a cost in weight. Any improvements in protection or lethality add weight, reducing mobility. Mobility can be increased by reducing weight – for example, by carrying less ammunition or armor – but this reduces protection or lethality. There is a tradeoff between protection, mobility, and lethality (the Iron Triangle) because a soldier's fundamental weight-carrying capacity remains limited by the human body.

A number of emerging technologies have the potential to radically change this paradigm, bending or breaking the Iron Triangle and improving overall survivability. This could be through significantly lighter materials to reduce weight, enhancing or augmenting human strength to carry more weight, off-loading weight from the soldier, or enhancing survivability without adding additional weight. Potentially promising technology areas include:

- Human performance enhancement to modestly increase soldiers' load-carrying capacity and/or increase situational awareness, decisionmaking, and lethality without adding additional weight.
- Novel materials to significantly reduce weight.
- Exoskeletons and exosuits to significantly increase soldiers' load-carrying capacity and/or reduce the metabolic cost of movement under load.
- Robotics to off-load soldier weight and increase soldier situational awareness, lethality, and protection without adding additional weight.
- Lightweight operational energy solutions to power exoskeletons, robotic teammates, and soldier equipment while reducing soldier load from batteries.

These technologies are in various states of maturity, and some of them face significant technology, policy, and cultural hurdles to implementation. While the prospects for disruptive change in the near-term (0–5 years) are low, modest improvements in soldier survivability and performance are possible in the mid-term (5–10 years). In the long-term (10+ years), there are promising opportunities for disruptive improvements in soldier survivability and performance with additional research and engineering into the most high-payoff areas.

Subsequent reports in this series will examine each of these elements of the strategy in detail, providing recommendations for technology investments and policy changes to improve dismounted warfighter survivability.

NOTES

[1] Defense and Veterans Brain Injury Center, "DoD Numbers for Traumatic Brain Injury, Worldwide – Totals," May 16, 2016, http://dvbic.dcoe.mil/files/tbi-numbers/DoD-TBI-Worldwide-Totals_2000-2016_Q1_May-16-2016_v1.0_2016-06-24.pdf.

[2] Kenneth Horn, Kimberlie Biever, Kenneth Burkman, Paul DeLuca, Lewis Jamison, Michael Kolb, and Aatif Sheikh, "Lightening Body Armor," RAND Corporation, 2012, 5–6.

[3] Michelle K. Nyein, Amanda Jason, Li Yu, Claudio Pita, John D. Joannopoulos, David F. Moore, and Raul Radovitzky, "In Silico Investigation of Intracranial Blast Mitigation with Relevance to Military Traumatic Brain Injury," *Proceedings of the National Academy of Sciences*, 107 no. 48 (November 2010), http://www.pnas.org/content/107/48/20703.

[4] A 2012 RAND report on lightening body armor reached a similar conclusion that current body armor is likely overdesigned. See Horn et al., "Lightening Body Armor," 10.

[5] J. Q. Zheng and S. M. Walsh, "Materials, Manufacturing, and Enablers for Future Soldier Protection," in *Lightweight Ballistic Composites*, 2nd ed. (Woodhead Publishing, 2016), 393–437.