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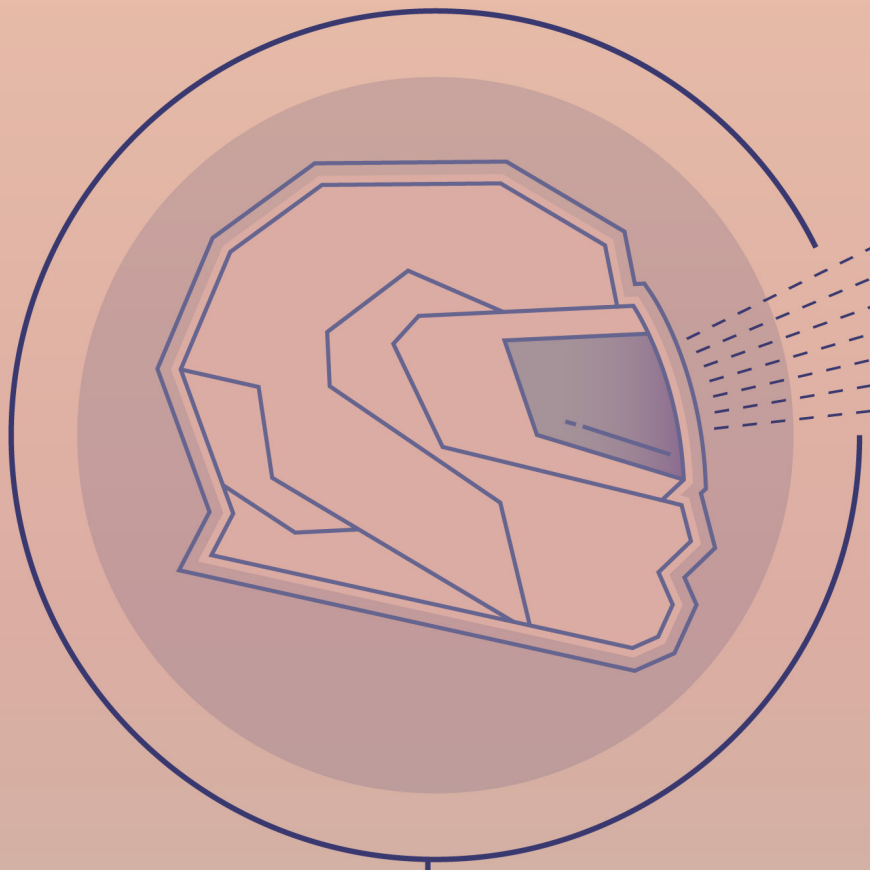

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Super Soldiers

Summary of Findings and Recommendations

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About This Report

This report, the seventh and last in the Super Soldier series, covers findings of the Center for a New American Security's study on dismounted soldier survivability. This report is in response to a study 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. The full series can be found at **cnas.org/super-soldiers**.

Views expressed in this report are of the authors alone. CNAS does not take institutional positions. Complete citations for this report's findings and recommendations can be found in previous reports.

Reports in the Super Soldiers series:

A Strategy for Enhancing Warfighter Survivability (April 2018)

Soldier Protection Today (April 2018)

Protecting Warfighters from Blast Injury (April 2018)

The Soldier's Heavy Load (September 2018)

Emerging Technologies (October 2018)

Human Performance Enhancement (October 2018)

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Key Findings

Soldier survivability is a function of protection and other relevant operational factors, such as situational awareness, mobility, and lethality. Throughout history, helmets and body armor have protected soldiers from injury but often at the cost of increased weight, reduced mobility, and reduced situational awareness. These tradeoffs remain relevant today.

Current body armor systems have proven their value in combat, but have three major shortcomings:

- Current helmet designs are not intended to protect the brain from blast injury, a significant gap in soldier protection. This protection gap stems in part from a lack of understanding of the primary mechanism of brain injury from blast waves.
- The weight of torso body armor diminishes soldier mobility and performance. Current torso armor systems are over-designed for the ballistic threats soldiers actually face in combat, adding unnecessary weight and hampering overall soldier survivability.
- Despite their weight, current body armor systems still leave vulnerable parts of the body, such as the face and head, exposed to ballistic threats. Adding more armor is not feasible, however, without significantly lighter armor or augmenting soldier strength to carry more weight.

In the near term, there are steps the Army can take to modestly improve soldier survivability by optimizing body armor and helmet design. This includes improving protection in key areas such as mitigating blast-induced brain injury, and reducing weight in other areas such as torso body armor, increasing mobility.

In the long term, emerging technologies such as robotics, exoskeletons/exosuits, and human enhancement have the potential to dramatically improve soldier survivability. In some cases, these technologies have the potential to fundamentally change a 3,000-year-old dilemma for foot soldiers in war: Their weapons and armor are limited by what they can carry into battle. The Army is already pursuing some of these technologies, but other areas lack investment and leadership.

Finally, while soldier survivability and protection are generally considered in the context of enemy threats, environmental hazards can pose threats to soldiers as well, sometimes even from friendly equipment. DoD studies have found that blast exposure from firing heavy weapons such as the Carl Gustaf recoilless rifle, even in training, is associated with short-term cognitive deficits.[1] Additionally, DoD studies have found higher rates of concussion and post-concussion associated symptoms among individuals with a history of prolonged exposure to low-level blasts from breaching and shoulder-fired weapons.[2] While further research is needed, there are concrete steps the Army can take today to improve soldier safety.

Recommendations

The Army should review its investment portfolio and re-balance resources as appropriate to ensure it is capitalizing on the most promising opportunities to improve soldier survivability. These include the following recommendations.

Improve Brain Protection from Blast Injury

The Army should increase its efforts to protect soldiers against blast-induced brain injury, with increased resources for testing, experimentation, and combat helmet development. Key actions include:

IMPROVE UNDERSTANDING OF BLAST-INDUCED BRAIN INJURY

- Expand on existing blast pressure monitoring in training and establish a longitudinal medical study on blast pressure exposure during combat and training in order to better understand the relationship between blast pressure exposure and brain injury.
- As part of this study, conduct a blast surveillance program to monitor, record, and maintain data on blast pressure exposure for any soldier who is likely to be in a position, in training or combat, where he or she may be exposed to blasts. Include brain imaging of soldiers who have been exposed to blasts as part of this study to better understand how blasts affect the brain.
- Accelerate computational modeling and experimental research, including with large animal models, into primary blast wave injury in order to better understand how blast overpressure damages the brain.

IMPROVE HELMET PROTECTION AGAINST BLAST PRESSURE

- 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.
- Conduct a tradespace study of various helmet designs in order to compare the amount of reduced blast pressure to any negative effects such as increased weight and torque on the neck, reductions in situational awareness, and other operational effectiveness metrics.
- Based on the results of the helmet tradespace study demonstrating the ability of certain designs to reduce overpressure exposure and the drawbacks of various designs, establish an interim requirement for protection against blast overpressure while continuing further research to refine the requirement over time.

IMPROVE SAFETY WHEN TRAINING ON HEAVY WEAPONS

- Take prudent precautions to improve soldier safety when training on heavy weapons, while conducting further research to better understand the cumulative effects on the brain of repeat heavy weapons firing.
- Expand ongoing studies of blast exposure in training to include all soldiers who are exposed to high overpressure weapons (e.g., Carl Gustaf, AT4, LAW, .50 caliber sniper rifles, explosives).
  - » Require all soldiers to wear blast gauges when training with high overpressure weapons.
  - » Blast gauge measurements should be recorded as part of a blast surveillance program and longitudinal medical study on blast pressure exposure and brain injury.
  - » Blast exposure history should be included as part of soldier service records (i.e., a "blast exposure record") in order to ensure that if medical issues arise later, soldiers receive care for any service-connected injuries.
- Review and update its firing limits for shoulder-fired heavy weapons, such as the AT4, LAW, and Carl Gustaf. Firing limits should: be revised downward to a level such that allowable exposures are not associated with cognitive deficits after firing; cover exposures across a longer time period, on the order of 72 to 96 hours; include a minimum safe distance for observers and instructors; account for the possibility of multiple types of heavy weapons being fired in a single day; and include cumulative annual and lifetime limits for blast exposure in training.
- Take prudent precautions to improve soldier safety when training on heavy weapons.
  - » Increase soldier and commander education about the importance of adhering to firing limits and wearing appropriate protective equipment, such as through a Safety of Use message.
  - » Hold commanders accountable, especially in special operations units, for enforcing limits on firing heavy weapons, such as the Carl Gustaf, in training and require that units record and report the number of shots fired by each soldier per day in training.

Soldiers from the Army's 75th Ranger Regiment fire a Carl Gustaf recoilless rifle during range training at Camp Roberts, California, in January 2014. Shoulder-fired anti-tank weapons have been associated with short-term cognitive deficits in servicemembers after firing, leading to the need for a blast exposure record for servicemembers. (U.S. Army)

  - » Review training guidance for shoulder-fired heavy weapons to maximize the use of sub-caliber training rounds whenever possible, especially by special operations forces.
  - » Investigate different methods for soldier familiarization and for establishing gunner and assistant gunner proficiency so that gunners, assistant gunners, and instructors are not unnecessarily exposed to blasts.
  - » Use blast gauges to explore modifying firing procedures, such as adjusting the position of assistant gunners, to reduce blast overpressure exposure.
  - » Explore the use of prepared firing positions in training with blast-absorbing materials to reduce ground reflection and/or shields to mitigate blast pressure waves.
- Investigate different helmet designs for duty positions that may be at greater risk for blast exposure, such as Carl Gustaf gunners and assistant gunners.

INVESTIGATE LONG-TERM OPTIONS FOR BLAST PROTECTION

- Investigate new helmet materials, shapes, and designs that might dramatically improve protection from primary blast injury.
- Explore opportunities for off-board protection from blast waves, such as from passive or active measures located on robotic teammates.
- Refine the blast pressure protection requirement over time as the understanding of TBI improves.

Lighten the Soldier's Load, Increasing Overall Soldier Survivability

OPTIMIZE SOLDIER LOAD AND PERFORMANCE

- Launch an authoritative study to better assess the relationship between load and combat effectiveness, building on existing literature.
- Undertake a thorough assessment of necessary supplies and the fidelity of timely resupply, and educate leaders on the importance of minimizing loads.

- Clearly delegate authority to company-level commanders to modify the level of protection as needed, based on the specific threat and mission.

OPTIMIZE BODY ARMOR DESIGN

- Optimize body armor requirements for the actual threat environment and not over-design body armor to protect against unrealistic combinations of threats, adding unnecessary weight.
- Conduct an assessment of the feasibility of tailored body armor and potential advantages in reduced weight, increased area coverage, and improved mobility. This assessment should include an evaluation of manufacturing methods to reduce the cost of adopting individually tailored solutions at scale.

Capitalize on Emerging Technologies to Dramatically Improve Soldier Survivability

NOVEL MATERIALS

- Pursue a hedging strategy in armor materials, investing in basic research in the most promising areas, such as synthetic diamond or two-dimensional polymers, while continuing to modestly improve current materials.

EXOSKELETONS AND EXOSUITS

- Establish an exosuit and exoskeleton development program consisting of prototyping, experimentation, concept development, and research tied to operational performance metrics. The goal of such a program should be to mature exosuit and exoskeleton technologies and concepts, with the aim of transitioning to a lower-body exoskeleton/exosuit acquisition program in five years and a full-body exoskeleton acquisition program in 10 years.

ROBOTICS

- Continue its investments in robotic teammates, such as the Squad Mission Equipment Transport program, and autonomous cargo resupply systems in order to reduce soldier load and improve mobility and effectiveness.
- Conduct research into new materials that could provide passive protection from ballistic and blast threats if used onboard air or ground robotic teammates.
- Continue to pursue robotic teammates to extend soldier lethality, situational awareness, and survivability.

A soldier demonstrates the Lockheed Martin ONYX lower body exoskeleton. Exoskeletons can assist warfighters in carrying heavy loads over uneven terrain with reduced energy expenditure, allowing greater mobility, reduced fatigue, and improved mission performance. (Lockheed Martin)

LIGHTWEIGHT OPERATIONAL ENERGY

- Capture the gains of commercially available energy solutions where possible, such as electric car batteries or structural carbon-fiber power sources.
- Invest in research that can be quickly integrated for military purposes, such as biobatteries, energy capture, and hybrid electric engines for robotic mules.
- Anticipate that energy will remain a limited resource that the Army has to manage, similar to ammunition or water, for the foreseeable future.

HUMAN PERFORMANCE ENHANCEMENT

- Study, evaluate, and approve human enhancement where appropriate, in accordance with ethical guidelines.

Physical fitness

- Investigate alternative physical fitness training methods to improve strength and operational performance on the battlefield.

- Leverage emerging technologies such as personal fitness trackers, consistent with DoD guidelines, to collect physical training data across the force and systematically evaluate the best methods for improving performance while avoiding injury.

Nutrition and dietary supplements

- Develop nutrition guides and provide the necessary supplements to develop muscle mass and improve performance as a part of nutrition planning, and limit unregulated supplement use.
- Where there is insufficient research with regard to a supplement's effectiveness, sponsor research to determine if the supplement has benefits to soldier performance.

Sleep

- Institute a comprehensive soldier sleep fitness program that implements the guidelines in A Leader's Guide to Soldier Health and Fitness (February 2016) and inculcates an attitude of "sleep as a weapon" in the force.
- Leverage personal fitness devices to track sleep patterns among soldiers and provide objective feedback on soldier sleep.

Pharmaceuticals and other enhancement techniques

- Institute a high-level policy review of potentially promising methods to enhance soldier physical and cognitive performance.
- Consider potential physical and cognitive enhancements on a case-by-case basis, evaluated based on the risks of the specific treatment and the relative operational advantages to soldier survivability.
- Investigate the efficacy, safety, and operational utility of physical and cognitive enhancement treatments, consistent with DoD medical guidelines.
- Participation in any research or operational use of enhancements should be voluntary, and the Army should institute procedures to ensure that soldiers are free from coercion, real or perceived, to take enhancements.

A soldier walks on a treadmill wearing an exosuit developed through the Warrior Web program while researchers at the U.S. Army Research Laboratory measure the soldier's energy expenditure. (Ron Carty/U.S. Army)

Conclusion

Soldier protection has evolved over millennia and will continue to evolve to meet threats found on the modern battlefield. The Army currently has hard armor solutions to defeat relevant ballistic threats, including those that are just emerging. The most significant gap in existing armor is a lack of adequate protection against brain injury from primary blast pressure waves. There are near-term options to mitigate this threat through improved helmet design, although more research on the specific mechanisms of brain injury is needed.

The weight of armor is a significant challenge to improving soldier survivability. Existing armor systems are heavy and add to an already overburdened soldier. In the near term, there are opportunities to modestly improve soldier mobility and survivability by lightening armor, improving doctrine and policies, enhancing soldier performance, fielding soft exosuits, and reducing the weight of other equipment such as batteries. In the mid-term, robotic teammates and rapid robotic resupply could off-load much, if not all, of the soldier's approach load. Robotic teammates also could significantly enhance soldier survivability by extending the eyes and ears of the squad, creating standoff from threats, and providing distributed protection and lethality. The fighting load, however, would remain a substantial burden. The only technology that can fundamentally alter the weight-mobility tradeoff of the infantry soldier is load-bearing powered exoskeletons.

In the long term, development of an operationally viable exoskeleton has the potential to radically transform infantry soldier survivability in unprecedented ways. Exoskeletons have significant hurdles to overcome, especially power, but these obstacles could be overcome with focused military investment. Many key technology areas for robotics and exoskeletons overlap, including control, sensing, actuation, and power, and an Army strategy that pursued these technologies in tandem would be well-poised to seize these opportunities.

The Army is pursuing some of these technology areas, such as robotic teammates and exoskeletons, but other areas such as human performance enhancement are lacking leadership and investment. The Army should review its investment portfolio and re-balance resources as appropriate to ensure it is capitalizing on the most promising opportunities to improve soldier survivability.

Even as the Army pursues these opportunities to enhance soldier survivability against existing threats, the Army must also stay alert to new threats to soldiers on the horizon. The rapid proliferation of low-cost commercially available drones represents a real three-dimensional threat to soldiers on the battlefield today.[3] Non-state actors such as the Islamic State and Yemeni Houthi rebels have already deployed small weaponized drones in combat.[4] Similarly, intelligent "smart rifles" and miniaturized precision-guided projectiles have the potential to dramatically increase the lethality available to ground troops – U.S. and adversaries alike.[5] Emerging technologies such as directed energy weapons (lasers or microwaves) may yield entirely new methods of injury, requiring new methods of protection.[6] The tools and methods of warfare are continually evolving, and soldier protection must evolve with them.

Endnotes

1. CDR Josh Duckworth, *Uniformed Services University of the Health Sciences*, U.S. Navy.

2. Walter Carr et al., "Relation of Repeated Low-Level Blast Exposure With Symptomology Similar to Concussion," *Journal of Head Trauma Rehabilitation*, 30 (1), 47–55.

3. For more on the threat from low-cost commercially available drones, see "Proliferated Drones," Center for a New American Security, drones.cnas.org.

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