

# ESSENTIAL APPROACHES TO THE FUTURE SOLDIER'S NECESSITY TO USE THE PASSIVE EXOSKELETON

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## ABSTRACT

*Ongoing technological advances have led to the facilitation of specific supply chain operations in general, and military supply chains in particular, in order to increase the effectiveness and efficiency of military and other operational logistics. In this regard, the robotic exoskeleton system plays a particularly important role, along with other technologies that facilitate the successful conduct of national and multinational military operations within the armies of the North Atlantic Alliance nations. In developing the content of this material, we have taken into account the requirements for the future soldier's behaviour and actions, which include extensive use of the passive exoskeleton to facilitate the transport of each soldier's payload of necessary supplies and weapons, as well as to increase individual mobility during offensive and/or defensive military actions. At the same time, we have highlighted the importance of qualified personnel's use of the exoskeleton system in the carrying out of operational logistic support activities for the fulfillment of missions assigned to the combat forces.*

**KEYWORDS:** future soldier, combat readiness, military actions, personal protective equipment, technological progress, exoskeleton, passive exoskeleton

## 1. Introduction

According to Alliance bodies, NATO's Very High Readiness Joint Task Force (VJTF) activated in 2023 a digital command and intelligence system based on the new battle management mechanism introduced in May 2020, with a clear impact on the characteristics of the future soldier's individual equipment. Within this framework, the advanced individual combat system was designed as a significant step

towards integrating key elements to be emphasised in the preparation and conduct of operations by the next generations of future soldiers, such as: protection, survivability, command and control, night vision mobility and lethality (Marrone & Muti, 2021).

The increase in the number of maneuvers and support operations specific to modern warfare that the soldiers of the next generation army will have to perform

implies an increase in their physical exertion. The new operational requirements call for appropriate solutions, the implementation of which must ensure an ergonomic and effective implementation of the relationship between the soldier and the combat equipment (vehicle and/or weapon system). This objective is based on the use of military exoskeletons, which embody the continuous technological advances associated with the complex efforts to accomplish combat missions by allied tactical combat structures within national and/or NATO force commands.

The exoskeleton is a wearable robotic device attached to the human body that works in complete synchrony with the limbs. This device enables the human-robot interaction by supporting the human user with the capability and reliability of a mechanical system, while the wearer controls it by using his or her intelligence and skills. Research into exoskeletons has lasted for half a century and shows the rapid development of new techniques and control algorithms embedded in these simple systems. Depending on the parameters of the applicable technologies and scenarios, individual exoskeletons have evolved in different configurations, being divided into two major categories: passive and active. If the user and exoskeleton are considered to function as a closed system and there is no consistent and constant way of transferring energy between them, the exoskeleton is passive (Zhou et al., 2020). This type of exoskeleton does not require the use of an external power source and therefore has the ability to operate for a long period of time.

Supported by biological mechanics, human movement and load mechanisms, the passive exoskeleton will allow the future soldier to facilitate lifting and carrying actions through mechanical levers. Soldiers will be able to carry more equipment without compromising their tactical movement. Some developed countries have come a long way recently in the development of passive exoskeletons by successfully testing and developing some of the technologies in the field (Zhou et al., 2020).

## **2. Importance and Benefits of the Future Soldier's Use of Passive Exoskeleton**

Modern soldiers will benefit from the features of passive combat exoskeletons, such as mobility, physical strength and protection. In particular, their importance is enhanced by the increased load-carrying capacity of soldiers from modern operational structures, who have to carry more equipment of greater weight, despite technological advances that make equipment lighter and more efficient (Martin, 2023). As a result, unpowered or passive exoskeletons can assist soldiers on the battlefield in performing repetitive tasks associated with rapid movements specific to tactical maneuvers or handling heavy loads during resupply operations. The technology is essentially a wearable mechanism that helps the warfighter or the operational logistics personnel perform difficult tasks by counteracting overstress on the lower back and legs (Keller, 2022). Figure no. 1 illustrates examples of how the passive exoskeleton can be used by the future soldier.



Figure no. 1: *Infantry soldiers from the U.S. Army equipped with exoskeletons*  
(Source: Keller, 2022)

In the past, fighters used to carry individual equipments of relatively light weight. For example, in the First World War, a soldier carried no more than 30 kg; in the Second World War, the load increased to 35-45 kg. In Afghanistan, British soldiers often carried as much as 50 kg, often to the detriment of operational performance. Historical data from the U.S. Army showed that in the two Gulf Wars (1991 and 2003), U.S. soldiers also carried loads of 59-68 kg. One study concluded that a soldier can optimally carry only one third of his body weight, which is a typical load of 20-25 kg,

about half of what modern soldiers (individually) have to carry during operations; other studies have demonstrated that soldiers can typically carry 20-30 kg of individual equipment in their daily training (Zhou et al, 2020).

Today's passive combat exoskeletons (weighing 1.5 kg and more, designed to provide individual assistance to each user) allow for agility of action depending on the challenges, requirements and peculiarities of weight, actuation technology and associated vulnerabilities. At the same time, these devices must be: resistant to combat

damage, whether it is shrapnel or bullets; robust enough to operate in a very hostile environment, exposed to fresh and salt water, mud, dust, sand, and subjected to harsh treatment, often in poor ground conditions, etc. (Kopp, 2011).

The following aspects of carrying heavy loads in operational environments for soldiers who don't use passive exoskeleton devices are associated with an increased risk of musculoskeletal injuries and reduced performance in combat and support operations. For example, in 2009-2010, the most common diagnosis among injured U.S. soldiers during combat operations was sprain, accounting for 33% of all injuries (Gruevski, 2022). Similarly, in the U.S. Army, approximately one-third of all musculoskeletal injuries sustained by soldiers were due to back strain caused by overuse from heavy lifting and other demanding tasks (U.S. Army Public Health Center, 2019). Sprains and back injuries accounted for 54% of all serious acute injuries among Canadian regular forces. Approximately 62% of injuries reported while carrying loads among Australian regular force soldiers were musculoskeletal. Based on the

individual survey responses, over 34% of Australian Defence Force soldiers reported being injured while carrying an average weight of 29.5 kg during logistic activities (Slaughter et al, 2023).

A research team at Vanderbilt University (Nashville, TN), in collaboration with specialists from the 101<sup>st</sup> Airborne Division (Ft. Campbell, KY) conducted the project "Evaluation of U.S. Army Soldiers wearing a back exosuit during a field training exercise", and demonstrated the need for the use of passive exoskeletons, following the identification of appropriate strength and endurance (physical stamina) limitations during specific field artillery missions, due to overuse and fatigue that negatively impact the health, performance and readiness of military personnel. The use of heavy equipment and ammunition has been observed to involve lifting, loading, unloading and handling of average weights of 15-60 kg or more (e.g.: emplacement / displacement or moving/lowering of a howitzer; transport and handling of projectiles required for resupply/reloading of heavy artillery pieces) (Slaughter et al., 2023), as shown in Figure no. 2.





Figure no. 2: *Images of U.S. Army soldiers demonstrating the use of exoskeletons for specific tasks in ammunition preparation, such as carrying, handling and loading howitzer rounds and charges*

(Source: Slaughter et al., 2023; DEVCOM Public Affairs Office, 2022)

On the basis of these findings, U.S. military researchers proceeded to demonstrate the usefulness of exoskeletons in assisting the future soldier in specific activities related to: reducing the risk of injury while performing tasks such as lifting, loading, unloading and carrying equipment and ammunition; faster movement on the battlefield; proper displacement during operations while carrying loads between 50-100 kg and over 100 kg; moving in a crouched position; climbing ladders and crawling in a confined space; moving and running on steep terrain; hand-to-hand combat; filling sandbags or loading / unloading construction materials; moving and / or loading combat casualties (injured, sick, etc.) into medical evacuation vehicles (ground or air); loading and unloading pallets; jumping from high places; landing after parachuting, etc. (Slaughter et al., 2023; DEVCOM Public Affairs Office, 2022).

Current studies on the development of passive exoskeletons are largely focused on enhancing the individual capabilities of military human logistic operators. The role

of these robotic devices is to enable military personnel performing operational logistics activities to handle significantly heavier loads, exceeding 25-35 kg/foot, in distribution activities required to perform resupply operations (Kinsey and Ti, 2023). Therefore, the use of the exoskeleton typically requires a redistribution of the vertical ground reaction force load from the shoulders to the feet of each military user in order to achieve the required force augmentation and protection (Periard-Fournier et al, 2020).

As a result, researchers at Vanderbilt University in the U.S. have designed the SABER prototype, as a wearable soft, lightweight passive exoskeleton that can be selectively engaged by soldiers to enhance tactical lifting capabilities. The design of this device is also suitable for supporting challenging operational logistics activities – such as ammunition resupply – as well as mitigating injury and fatigue, which are critical elements in sustaining combat and support structures over time (DEVCOM Public Affairs Office, 2022) (Figure no. 3).



Figure no. 3: *Use of the passive exoskeleton in specific military resupply activities*  
(Source: DEVCOM Public Affairs Office, 2022; Kopp, 2011)

For the military in NATO combat structures, exoskeleton systems are and will be important in operational scenarios, facilitating action and protection in complex environments characterised by continuous mobility, increased lethality and survival requirements. However, despite the fact that there are several potential working prototypes that can effectively reduce soldier fatigue and physical exertion, both in the United States and in other Alliance member states, there are no decisions for widespread use of exoskeletons due to low user adaptability and low ease of use (Mudie, 2022).

### 3. Conclusions

Looking ahead, the advanced individual combat system of the future will

be intelligently controlled and operated by the future soldier, based on modern actuation capabilities, including the lighter and more agile individual passive exoskeleton, which is and will be rapidly developed and coupled with frontier military technologies appropriate to the specific operations of evolving warfare.

Individual passive exoskeletons are lightweight, wearable, flexible and capable of supporting the upper body as well as the extremities (hands and feet). They are an effective solution for the future soldier during operations, providing a balance between weight and protection.

Technological advances appropriate to modern warfare will drive the technological evolution and performance growth of military passive exoskeletons, as

well as the development of the relevant market. The need to increase safety and efficiency in the conduct of future

operations will lead NATO member states to continue to invest in these devices, despite their high cost.

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