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# Advances in Technologies for the Soldiers of the Future

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**Abstract.** - Emerging technologies enhance soldiers' capabilities, improving safety, accuracy, and efficiency. Exoskeletons, AI, AR, biotechnology, nanotechnology, drones, smart materials, and communication technologies enable the optimization of strategies, decisions, resistance, and situational awareness, being key in modern armed forces. This review paper synthesizes the most relevant advances, their key technologies and the impacts they have on the efficiency of soldiers' strategies during their operations. A systematic PRISMA review was conducted across the SCOPUS, Web of Science, Taylor & Francis, PubMed, and ProQuest databases, identifying review articles on these advances, including practical cases of implementation in military forces in Latin America and Europe. The results show more recent advances such as drone swarms, biometrics for monitoring troops, and high-precision laser weapons. Despite challenges such as costs and technical training, these technologies transform defense, improving its effectiveness and security, driving greater capabilities, and providing competitive advantages in adverse events.

**Keywords:** emerging technologies, military innovation, technological innovation, security and defence.

# Avances en Tecnologías Para los Soldados del Futuro

**Resumen.** Las tecnologías emergentes y avances en robótica actualmente potencian las capacidades, seguridad, precisión y eficiencia de los soldados. Exoesqueletos, tecnologías de realidad extendida, biotecnología, nanotecnología, drones, materiales inteligentes y las tecnologías de comunicación permiten optimizar estrategias, decisiones, resistencia y conciencia situacional, siendo clave para las operaciones de defensa de las fuerzas armadas modernas. Este trabajo describe los avances tecnológicos más relevantes, sus impactos en para los soldados durante sus operaciones, sus desafios y limitaciones. Se realizó una revisión sistemática PRISMA® identificando artículos en bases como SCOPUS, Web of Science, Taylor& Francis, PubMed y ProQuest además de casos reales de uso de estas tecnologías en fuerzas militares de América de Norte y Europa. La incorporación de tecnologías que incluyen enjambres de drones, biometría para monitoreo de tropas y armas láser de alta precisión impulsan ventajas competitivas ante el enemigo a gran distancia, a pesar de esto, persisten desafíos como el costos y formación técnica de los soldados.

**Palabras clave:** tecnologías emergentes, innovación militar, innovación tecnológica, seguridad y defensa.

# I. INTRODUCTION

Currently, technology enhances aspects such as the effectiveness, security, and response capacity of soldiers, optimizing communication, surveillance, decision-making, and adaptability in combat, which is key to facing modern threats. The soldiers' use of technologies strengthens national defense, guarantees sovereignty, improves security, and positions countries in geopolitical competition. It also drives innovation, optimizes resources, and enables the efficient management of modern threats with reduced human risk. In this way, the impact of emerging technologies in the military field transcends the immediate operational benefits, contributing to the strengthening of institutional capacities and the promotion of global security. These innovations align with the Sustainable Development Goals (SDGs) [1], particularly SDG 16, which promotes the establishment of strong and resilient institutions, and SDG 17, as it requires partnerships to achieve its goals. Countries such as the United States, China, Russia, the United Kingdom, France, Israel, Germany, India, South Korea, and Japan are leading the way in integrating advanced technologies in military defense [2], while other nations are exploring their adoption to modernize their armed forces.

Technologies such as exoskeletons, artificial intelligence (AI), augmented reality (AR), brain-computer interfaces (BCIs), applied biotechnology, and 5G and 6G networks are shaping a paradigm shift in contemporary military strategies. These solutions strengthen situational awareness, optimize operational efficiency, and position technological innovation as a fundamental axis to ensure effectiveness in critical missions [3].

The modern soldier faces increasingly complex scenarios where the ability to adapt quickly and effectively utilize advanced technologies is essential for operational success. Solutions have been developed that improve mobility, physical endurance, and decision-making under dynamic conditions [4]. The adoption of technologies poses new ethical, technical, and strategic challenges that require clear regulatory frameworks and specialized training.

To understand the areas that have developed around the study of technologies for the soldiers of the future, Figure 1 has been made, which shows a bibliometric graph obtained from the analysis of 565 studies obtained in the SCOPUS database with the following text string: "*(future soldier OR soldier technology OR military technology OR combat systems) AND (wearable OR smart OR enhanced OR augmented) AND (communication OR networking OR connectivity OR data transfer) AND (sensors OR monitoring OR detection OR surveillance) AND (robotics OR autonomous OR drones OR unmanned) AND (training OR simulation OR education OR preparedness) AND (logistics OR support OR supply chain OR maintenance) AND (cybersecurity OR information security OR data protection OR threat assessment)*".

The bibliometric map in Figure 1 highlights that research on technologies applied to the soldiers of the future is addressed around two central axes: on the one hand, the development and application of advanced technologies such as artificial intelligence, robotics, sensors, nanotechnology, wearable devices, and communication systems; on the other, the analysis of the impact of these innovations on the physical, cognitive and decision-making capacities of military personnel. Concepts such as "*technology*", "*military operations*", "*military applications*" and "*soldier*" appear as predominant nodes, reflecting the importance of human-machine integration in the military field. The inter-

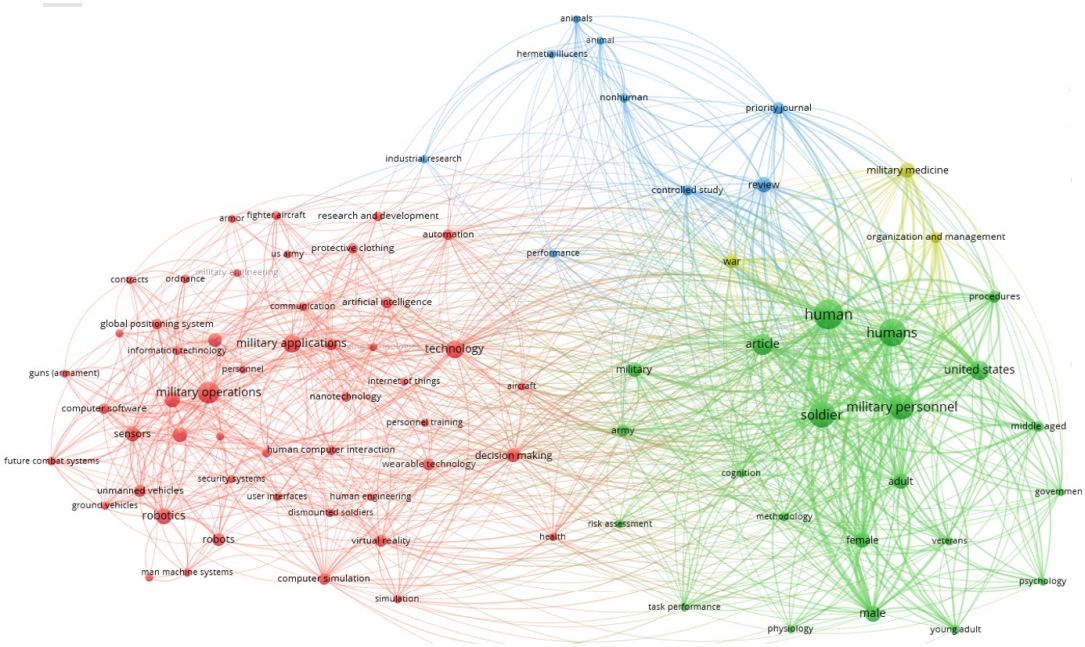


**Fig. 1.** Bibliometric graph highlighting studies related to technologies for soldiers of the future carried out with VOSViewer v.1.6.20.

connectedness between technological terms and human factors underscores the need to design solutions that not only enhance operational efficiency but also consider the health, performance, and safety of soldiers in complex environments. Additionally, the graph illustrates a growing interest in the scientific validation of these technologies through controlled studies, as well as in their institutional management and implementation, particularly in contexts such as military medicine and strategic defense organizations. All this points to a paradigm shift in the armed forces, where technological innovation and human adaptation are essential pillars to face the challenges of modern and future warfare.

The study of the advanced technologies addressed in Figure 1 and applied to the field of defence and security for soldiers may be of interest to researchers, academics, and professionals in the military, defence, and security fields, as well as developers of emerging technologies applied to tactical environments. The information provided may be relevant to defense policymakers, government institutions, companies in the military-technology sector, and international organizations seeking to optimize the readiness, security, and effectiveness of their armed forces through innovative solutions. Additionally, it can be useful for experts in ergonomics, occupational health, and the human factor who are interested in the impact of these solutions on the performance and well-being of soldiers.

This article aims to conduct a systematic review of the main technologies and development trends for soldiers of the future in the defense field, analyzing their operational impact, associated risks, and integration perspectives. The structure of the document addresses in Section 2 the methodology based on the guidelines of the PRISMA® methodology; Section 3 presents the results on (1) Technological developments for the soldiers of the future, (2) Impact of the use of technologies on the soldiers of the future, (3) Challenges in the use of technologies, and (4) Prospects in the use of technologies. Section 4 discusses technical, ethical, and strategic aspects related to the implementation and proper use of these technologies. Finally, the Conclusions are presented.

## II. METHODOLOGY

The systematic review of this article was conducted following a protocol based on the PRISMA methodology, with the aim of identifying and analyzing the most relevant advances in emerging technologies applied to various areas of defense and combat for military personnel. Systematic reviews published in the last ten years in scientific journals and specialized conferences were considered. The primary research question guiding this review was: What technologies are being developed to enhance the performance of future soldiers? The number of studies identified through various databases and repositories, as well as their corresponding text strings for the search, is presented in Table 1.

**Tabla 1.** Text strings used for scientific literature search.

| Database | Search string | Number of studies |
|---|---|---|
| Web of Science | `"future soldiers technologies" (Author Keywords) AND 2024 OR 2023 OR 2022 OR 2021 OR 2020 OR 2019 OR 2018 OR 2017 OR 2016 OR 2015 (Publication Years)` | 95 |
| Taylor & Francis | [Publication Title: ”future soldiers”] AND [Publication Title: ”technologies”] AND [Publication Date: (01/01/2019 TO 12/31/2024)] | 25 |
| Scopus | TITLE(”emerging” AND ”technologies”) AND PUBYEAR ¿ 2013 AND PUBYEAR ¡ 2025 | 110 |
| ScienceDirect | Title, abstract, keywords: ”emerging technologies” | 45 |
| IEEE Xplore | (”Document Title”: ”emerging”) AND (”Document Title”: ”technologies”) | 32 |
| **Total** | | **307** |

This literature review was developed in three stages: (1) formulation of research questions, (2) definition of study scope, and (3) design of a search strategy to identify and select relevant documents. Priority was given to the most significant articles, followed by rigorous data extraction and analysis. The review was guided by five research questions: (1) What technologies enhance soldiers' operational effectiveness? (2) What key advances support future soldier solutions? (3) What are the impacts of these technologies? (4) What ethical and social challenges arise? (5) What are the future defense prospects? To assess article quality, evaluation criteria were applied as detailed in Table 2.

Figure 2 illustrates the workflow used for selecting reference documents. The search included the keywords: `("future soldier" OR "soldier technology" OR "military technology") AND ("wearable" OR "smart" OR "extended reality")`. Papers that analyzed relevant developments in emerging technologies over the past decade were included, while those that focused exclusively on specific technical aspects, such as algorithms or simulations, were excluded.

**Tabla 2.** Quality Assessment Questions

| Quality Assessment Questions | Answer |
|---|---|
| Does the article describe technologies developed for use in military operations? | (+1) Sí / (+0) No |
| Does the paper address the impacts of these technologies on the effectiveness of defense operations? | (+1) Sí / (+0) No |
| Does the document include analyses of the ethical and social implications associated with emerging technologies? | (+1) Sí / (+0) No |
| Does the publication belong to a journal indexed in SJR? | (+1) Q1, (+0.75) Q2, (+0.5) Q3, (+0.25) Q4, (+0.0) Not classified |

### *A. Inclusion criteria*

Scientific articles, systematic reviews, technical reports, and case studies that addressed technologies applied to the optimization of soldiers' capabilities in military contexts, such as wearable devices, intelligent solutions, and extended reality technologies (AR, VR, and MR), were included for this study. The selected documents were published between 2015 and 2025, in English or Spanish, and were available in full text through recognized databases such as Scopus, Web of Science, Taylor & Francis, ScienceDirect, and IEEE Xplore, thus guaranteeing the quality and timeliness of the information analyzed.

### *B. Exclusion Criteria*

Those documents, which despite addressing emerging technologies such as wearables or extended reality, did not have a direct application in the military field or in the development of capabilities for future soldiers, were excluded. Likewise, publications of an informative nature, reports without peer review, press releases, blogs and non-academic books were discarded. Duplicate documents or preliminary versions, as well as studies published before 2015, were also eliminated, as they were considered obsolete for the purpose of this analysis.

## III. RESULTS

Technologies applied to the military field have multiple characteristics, impacts, and considerations in their use. In this section, the most representative advances, applications, and a description of their potential for defense activities are described.

### *A. Technological developments for the soldiers of the future*

This section describes the technological advances that are redefining the operational capabilities of modern soldiers, offering innovative solutions that strengthen their performance and adaptability in complex scenarios. Technologies such as exoskeletons, robotic suits, augmented reality (AR), advanced biotechnology, 5G networks, and autonomous drones have established themselves as key tools in improving safety, efficiency, and effec-

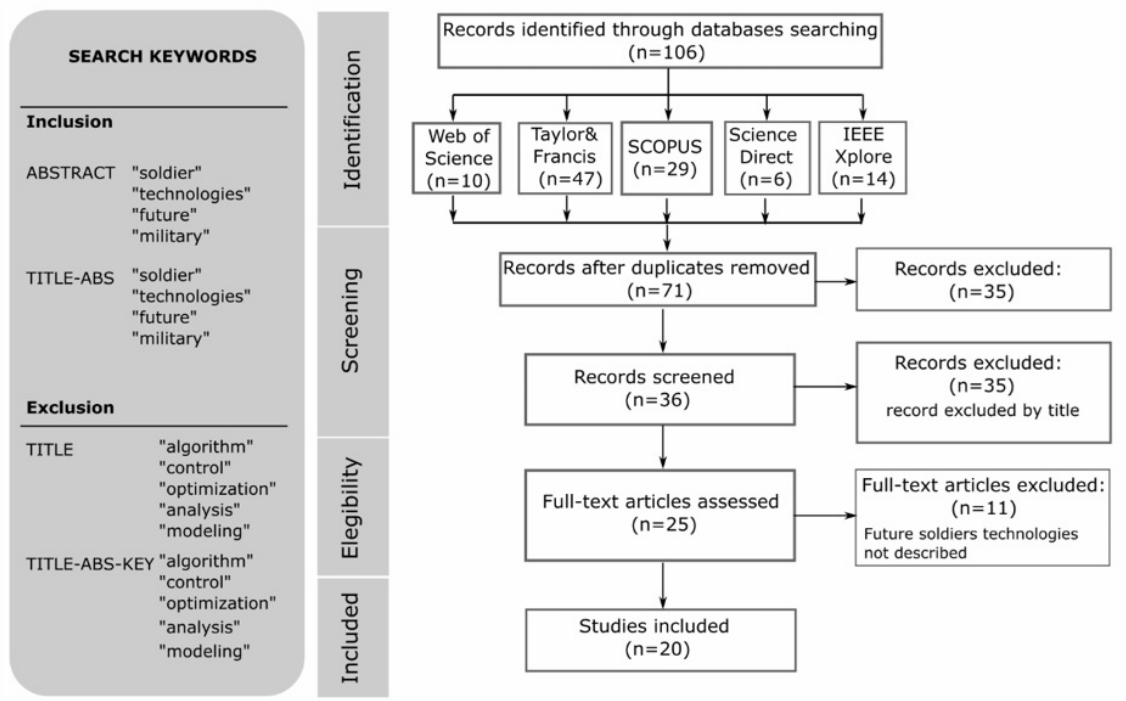


**Fig. 2.** Selection process of articles included in the study according to PRISMA® methodology.

tiveness on the battlefield [5][3][6]. Its applications, classifications and the ethical implications of its implementation are discussed below. Figure 3 summarizes and categorizes the technological advances addressed in this section.

### *Exoskeletons and robotic suits*

The development of exoskeletons represents one of the most relevant advances in the physical strengthening of the modern soldier. These devices are designed to enhance strength, endurance, and stability, thereby minimizing muscle fatigue during prolonged operations and optimizing the combatant's energy efficiency. A prominent example is Lockheed Martin's ONYX Exoskeleton, which provides active knee support, improving mobility in challenging terrain and reducing muscle fatigue under prolonged load conditions **??**. Recent studies have shown that the use of exoskeletons, such as the ONYX, not only increases load capacity and reduces wear but also significantly decreases metabolic demand during walking, thereby increasing operational efficiency [7].

The new generation of robotic suits incorporates advanced biometric sensors for real-time monitoring of vital signs, thereby enhancing both performance and risk prevention during missions [8] (Figure 4). Additionally, soft exosuits offer greater flexibility and comfort, enabling extended use in demanding environments and broadening their tactical applications [9].

### *Artificial intelligence*

Artificial intelligence (AI) is reshaping military operations by improving decision-making, real-time data analysis, and automating tactical tasks. It enables predictive threat analysis, multi-sensor detection, and action recommendations for units [10]. AI-powered drones and robots enhance reconnaissance and logistics with minimal human input,

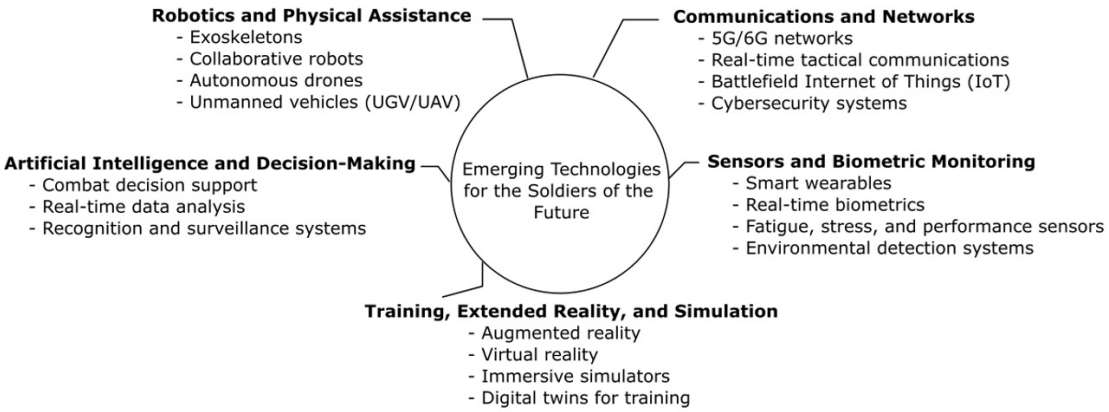


**Fig. 3.** Emerging technologies identified for use by soldiers in tactical and defense operations.

while sensor fusion creates real-time 3D battlefield views, improving awareness and reducing errors [11]. Ethical concerns include accountability and algorithmic bias. Figure 4 shows portable technologies such as physiological monitors, drones, communication power sources, and exoskeletons for mobility and protection.

### *Augmented and mixed realitye*

Augmented reality (AR) and mixed reality (MR) have established themselves as key technologies to optimize tactical perception and operational efficiency in military environments. Advanced devices, such as the Microsoft HoloLens 2, allow strategic maps, evacuation routes, intelligence data, and critical environmental elements to be overlaid directly into the soldier's field of vision, significantly improving real-time decision-making [12].

The integration of these technologies facilitates the projection of 3D images and identification systems of enemies and allies, reducing cognitive overload in high-pressure situations. Through intelligent Head-Up Displays (HUDs), soldiers receive immediate alerts, strategic updates, and mission orders, thereby increasing their situational awareness and ability to respond quickly and accurately.

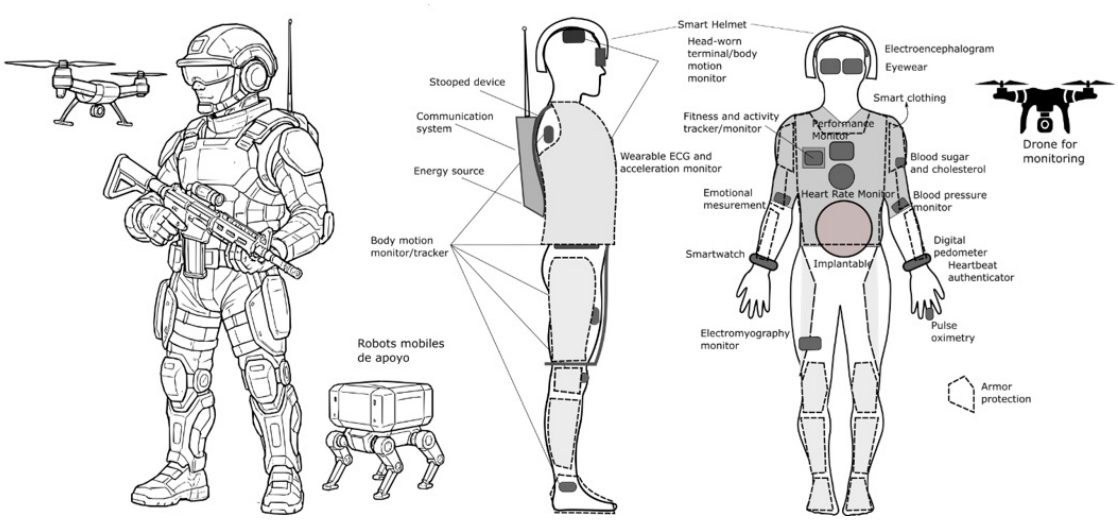


**Fig. 4.** Wearable devices for vital signs monitoring with the use of smart clothes, robots, and multiple sensors.

Virtual reality (VR) is widely used in military training, recreating realistic combat

scenarios where soldiers practice skills like threat detection, navigation, and rescue operations. Studies show that incorporating VR and augmented reality (AR) significantly enhances tactical skill retention, mental resilience, and adaptability [11]. These immersive simulations provide high-fidelity environments that improve training effectiveness.

### *Biotechnology applied to the military field*

Military biotechnology is reshaping how soldiers' health, performance, and recovery are managed in demanding scenarios. It includes advanced biometric sensors, gene therapies, and stress biomarkers to monitor and enhance physical and cognitive functions. Portable or implantable sensors track heart rate, oxygen saturation, hydration, and fatigue in real time, improving tactical and medical decisions [13][14]. Their use also accelerates recovery, reduces downtime, and increases troop availability in prolonged missions.

Gene therapy research explores ways to boost muscle endurance, speed up injury recovery, and improve cognitive adaptability in hostile settings. Tools like CRISPR are under evaluation to enhance physiological responses to extreme stress [15].

Early detection of stress biomarkers helps anticipate performance decline, aiding team management and mission planning. However, these advances raise ethical concerns around genetic modification, consent, and long-term effects. Thus, while biotechnology expands human potential, its application demands clear ethical frameworks and transparency.

### *Brain-Computer Interfaces (BCI)*

Brain-Computer Interfaces (BCIs) are among the most disruptive technologies in today's military, enabling control of devices via neural signals without physical movement. Their use demands strict safety protocols and ethical oversight to ensure responsible deployment.

In combat, BCIs improve reaction time, silent communication, and control of autonomous systems—critical for high-demand missions [16]. DARPA has shown their potential in managing drones, robots, and weapons with neural commands, reducing latency. BCIs also monitor soldiers' cognitive and emotional states in real time, enabling early responses to fatigue or stress, vital for sustained operations [17]. Strategically, BCIs could transform military capabilities and future warfare dynamics [18]. However, they raise ethical concerns around mental privacy, consent, and cybersecurity. Strong ethical frameworks are essential for their responsible integration [19].

### *Nanotechnology and smart materials*

Nanotechnology and smart materials are transforming soldiers' protection, mobility, and adaptability in demanding environments. Their integration raises concerns about sustainability, cost, and long-term toxicity, requiring strict regulation and safety protocols.

Key applications include smart fabrics in uniforms with self-healing, adaptive camouflage, and temperature regulation, enhancing survivability and comfort in extreme conditions [20]. Nanotech also enables ultra-light, high-resistance armor made from carbon

and graphene nanotubes, offering superior ballistic protection with less weight [11].

Nanosensors embedded in gear detect chemical, biological, and radiological threats in real time, improving tactical responses. Research is advancing implantable nanodevices for monitoring physiological data and delivering drugs in response to fatigue or injury. Together, these innovations are central to strengthening future soldiers' protection and operational resilience.

### *5G Networkss*

5G networks have enabled faster and more reliable connectivity on the battlefield, facilitating communication between units and the handling of advanced technological systems such as augmented reality devices and biometric sensors. This technology offers low latency and high data transmission capacity, improving coordination and real-time decision-making. In addition, 5G networks enable the efficient control of autonomous drone swarms and the integration of advanced artificial intelligence systems for tactical and strategic operations, increasing effectiveness in critical missions.

**Tabla 3.** Technologies, applications, benefits, and potential risks of using technologies for soldiers in the armed forces.

| **Technology** | **Applications** | **Benefits** | **Potential risks** |
|---|---|---|---|
| Exoskeletons | Physical assistance, load support | Increased strength, reduced fatigue | Mechanical failures, technological dependence |
| Augmented reality (AR) | Tactical visualization, immersive training | Better situational awareness, effective training | Cognitive overload, misinterpretation |
| Artificial intelligence (AI) | Image analysis, threat prediction | Quick decisions, early detection | Data biases, cyberattacks |
| Bioengineering | Muscle and cognitive optimization | Greater resistance, better recovery | Ethical dilemmas, unforeseen effects |
| Brain–computer interface (BCI) | Device control by thought | Speed of communication, tactical advantage | Risk of invasion of mental privacy |
| Nanotechnology and Smart materials | Ballistic protection, climate adaptability | Lighter armor, self-healing fabrics | High costs, vulnerability in extreme conditions |

### *Autonomous drones and smart swarms*

Autonomous drones are transforming military operations by enabling surveillance, reconnaissance, and logistical support missions with minimal human intervention. Equipped with artificial intelligence, these devices are not only capable of operating synchronously in swarms but also of adapting to changes in real-time, optimizing coverage in the field and significantly improving operational efficiency [21].

### *Precision Laser Weapons*

The development of laser weapons has expanded defensive and offensive capabilities by allowing the neutralization of threats with high accuracy and minimal collateral damage. These tools are crucial for countering airstrikes and safeguarding vital battlefield facilities [22].

## *A. Impact of the use of technologies on the soldiers of the future*

The use of these technologies has improved the efficiency, safety, and operational performance of soldiers. For example, drone swarms enable the execution of complex tactical missions more effectively [21], while biometric sensors monitor troops' health in real-time, preventing medical emergencies [12]. Additionally, AR and MR enhance training by simulating real-time combat environments.

5G networks and autonomous drones have optimized communication and reconnaissance in missions, reducing risks and maximizing the success of operations. These tools also increase the ability to respond to unforeseen threats, strengthening the adaptability of troops [8].

## *B. Challenges in the use of technologies*

The implementation of these technologies presents significant challenges. These include the high costs of development and implementation, as well as the need for specialized technical training for its effective use [5]. Ethical concerns also arise related to biometric data privacy and technological dependency, which could compromise autonomy in critical decisions.

The integration of AI into autonomous systems poses risks associated with potential errors in decision-making that occur without human intervention. This requires clear regulatory frameworks and strict oversight to ensure the safe and ethical use of these advanced tools.

## *C. Prospects of the technology use in soldiers of the future*

The future of military operations will be marked by the integration of even more advanced technologies. The use of artificial intelligence (AI) is expected to extend to predictive systems capable of anticipating threats and providing more accurate real-time analytics [16]. In addition, biometric sensors will evolve into predictive devices capable of analyzing complex physiological patterns and anticipating health issues before they manifest.

Another expected advance is the adoption of 6G networks, which will offer higher speed and lower latency, allowing instant and coordinated communication between soldiers and autonomous systems [11]. Likewise, the development of lighter and stronger materials for exoskeletons will further improve soldiers' mobility and endurance on the battlefield.

International collaboration will be essential to establish ethical and normative standards to guide the responsible development of these technologies. Clear regulations and

multilateral agreements will ensure their sustainable implementation, minimizing risks and maximizing benefits in the field.

### *D. Discussion*

Emerging technologies—exoskeletons, robotic suits, BCIs, AR, AI, 5G, and autonomous drones—are redefining modern soldiers by enhancing individual performance and collective efficiency for faster, more adaptable deployments. However, their use raises ethical and strategic concerns. Biometric data, autonomous systems, and sensitive information require regulations to protect privacy, ensure consent, and uphold human judgment. Technological dependence also increases vulnerability to cyberattacks and system errors.

These innovations impact not only defense but also civilian sectors like biotech and communications, while raising fears of warfare dehumanization and widening geopolitical gaps. Future advances—such as miniaturized exoskeletons, 6G, accessible BCIs, and predictive AI—offer tactical benefits but increase systemic risks and bioethical challenges.

The future soldier goes beyond technology integration, using smart sensors, visors, laptops, and GPS to enhance real-time decision-making. Yet, prolonged conflicts may degrade capabilities, demanding versatile soldiers skilled in combat, stabilization, negotiation, and reconstruction.

Ethical dilemmas emerge with enhancing drugs, neurotech, and genetic modifications, particularly around consent and long-term health risks [15]. In a volatile global landscape, developing cognitive skills, emotional resilience, and tactical adaptability is crucial. Programs like the Comprehensive Soldier Fitness Program highlight the role of psychological strength in high-stress missions. Thus, technological advancement must be balanced with strategies that ensure operational resilience, protect human capabilities, and promote ethical reflection on the limits of military innovation.

## CONCLUSIONS

The integration of emerging technologies—exoskeletons, AI, advanced communications, and extended reality—is redefining the modern soldier's capabilities. This synergy boosts tactical efficiency and real-time decision-making in complex, rapidly evolving scenarios. However, it also demands rethinking the human role in warfare, emphasizing physical, cognitive, and emotional resilience.

Military technological progress must be guided by ethical and strategic frameworks that protect human autonomy, particularly in areas like neurotechnology and genetic modification. Organizational resilience and long-term adaptability must be preserved to avoid overreliance on automation, ensuring readiness in low-tech or failure-prone environments. Innovation must align with principles of proportionality, transparency, and responsibility.

Future soldiers must be trained not only in advanced technologies but also in emotional resilience, technical expertise, and ethical reasoning. A holistic approach is essential to navigate highly automated and digitized combat settings, where human-machine collaboration will reshape the future of warfare and global security.

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