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THE EVOLUTION OF WARFARE – BIOTECHNOLOGICAL ADVANCEMENTS IN MILITARY OPERATIONS

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ABSTRACT

In the ever-evolving landscape of warfare, biotechnological advancements have emerged as a pivotal factor in shaping the modern battlefield. In today's volatile, uncertain, complex, ambiguous (VUCA) environment, military operations rely on emerging and disruptive technologies to gain an edge. This article delves into the multifaceted implications of integrating biotechnology into the nowadays warfare, exploring its impact on strategy, tactics and society. From enhanced human performance through genetic modifications to the development of novel bio-inspired materials, biotechnology has revolutionized the capabilities of armed forces worldwide. However, with these advancements come ethical, legal, and societal considerations that demand careful examination. This study aims to illuminate the transformative role of biotechnology in shaping the future of warfare and its broader implications for society.

KEYWORDS: biotechnology, disruptive technologies, societal considerations, tactics, VUCA

1. Introduction

With the dawn of the 21st century, the landscape of warfare has undergone a profound transformation, evolving from traditional to hybrid one, propelled by "*the revolutionary capabilities in the form of emerging and disruptive technologies (EDT)*" (Tudorache, 2023). At the forefront of this revolution stands biotechnology, a discipline that holds the promise of unprecedented innovation in military operations. As nations compete for strategic superiority in an increasingly complex geopolitical arena, integrating biotechnological capabilities into modern warfare has become imperative. However, the implications of this technological leap extend beyond the battlefield, permeating into society's fabric. Biotechnological innovations have revolutionized military capabilities globally, from enhancing soldier performance through gene editing to detecting chemical threats with precision using bio-sensors.

In response to geopolitical shifts and technological advancements, warfare is rapidly evolving. The integration of biotechnological innovations into military operations emerges as a pivotal driver of progress. Simultaneously, EDTs such as artificial intelligence (AI) and other

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disruptive developments are reshaping the modern warfare landscape. Biotechnology's significance transcends civilian sectors like medicine, engineering, and agriculture, but it plays a crucial role within military domains. Specifically, within military contexts, biotechnology serves as a cornerstone for enhancing sensor systems and implementing sophisticated counterespionage measures, thereby strengthening national security efforts. This underscores the need to employ biotechnology's capabilities to combat emerging security threats such as bioterrorism in today's complex global landscape (Billing & Fordy, 2021).

2. Literature Review

In general, studies related to the EDTs have emphasized their contribution to optimize modern military operations. For example, a study has outlined how rapid technological advancements may reshape warfare, potentially leading to a battlefield with reduced human presence. EDTs revolutionize battlefield roles, tasks, and decision-making and regarding the last of these, AI "*will increase commander's mental agility, on the one hand, and on the other hand, it will supplement the decisional expertise and the level of his emotional intelligence*" (Tudorache, 2021).

Another research, stressing particularly biotechnology, underscores the application of biotechnology in military domains, leveraging biological principles and technologies to tackle operational challenges, as shown in Figure no. 1. This may include the use of genetics to enhance soldier performance or the development of drugs or other substances to improve resilience, visual acuity and cognitive abilities. Despite past failures to mechanize human performance, biological enhancement poses health and ethical dilemmas as the future soldier is envisioned as optimized, sharp, agile, and resilient, rather than solely robust (Zanders, 2001).



Figure no. 1: *Biotechnology in the military operations*
(Source: Frew, 2019)

The topic was also debated by Muhammad Akram where he illustrated the idea that the significance of biotechnology extends to defence and security, evident in the development of biosensors, production of biological weapons, and utilization of DNA fingerprints in crime detection (Frew, 2019). Throughout history, biological

warfare has been a grim reality, dating back to ancient times when poisons, viruses, and plants were wielded as deadly tools in conflicts. Tactics such as water poisoning and the deliberate spread of disease-carrying pests were employed to devastating effect. However, with the advent of biotechnology, the landscape of warfare has evolved dramatically. Biotechnology, once heralded for its potential to improve lives, now poses a dual threat as a potential tool for biological warfare. The manipulation of microorganisms enables the creation of diseases that can disrupt ecosystems and contaminate crops, posing a grave risk to global security. Biological weapons, often consisting of disease-causing organisms or genetically modified variants, are deliberately crafted for use in biowarfare scenarios. Key examples include Bacillus anthracis, the causative agent of anthrax, and Yersinia pestis, responsible for both plague and haemorrhagic fever. These agents have the potential to cause widespread illness, disrupt troop movements, and undermine the effectiveness of military forces (Friedl, 2015).

Biotechnology presents a multitude of opportunities for enhancing military operations. By harnessing the principles and technologies of biology, the military can develop innovative solutions to address various challenges. This includes the use of genetic engineering to enhance soldier performance, and the creation of bio-sensors for detecting biological threats. Additionally, biotechnology enables advancements in areas such as medical interventions for wounded soldiers and the production of biological weapons for defensive or offensive purposes. Moreover, biotechnology can facilitate the production of more efficient and sustainable food and energy sources for military personnel, such as the Meals Ready-to-Eat (MREs) used by the American military. Biotechnology can be employed to enhance the nutritional content, flavour, shelf-life, and overall quality of these rations, ensuring that soldiers receive the necessary nutrients and energy to sustain them during demanding missions (Yahaya et al., 2021).

Another study that connects with the topic is discusses the ethical concerns related to biotechnology and its roles in gaining advantage in nowadays military operations. While it encompasses a wide range of applications, it is still relatively young and undefined. With its potential far exceeding current estimates, biotechnology involves manipulating living organisms to produce useful products. This includes advancements in personalized medicine, agricultural improvements, environmental remediation, and safer food production. Moreover, it extends into various commercial sectors, offering benefits for national security as well. The warfighter stands to benefit directly from biotechnology innovations, such as optimizing performance through balancing the human microbiome and improving environmental sensing. On the industrial front, biomaterials hold promise for developing advanced explosives, armour protection, and bio-based construction. However, the dual-use nature of biotechnology raises challenges, including the risk of misuse for offensive purposes or ecological harm. On the other hand, the author emphasizes that the pressing need for biotechnology in military contexts stems from various factors. Firstly, heightened competition from countries like China, which heavily invest in biotechnology, raises concerns regarding data security and potential weaponization. Secondly, the Department of Defense (DoD) must bolster biodefense capabilities to mitigate the risk of biological attacks, especially given uncertainties about the intentions of nations with active biotechnology programs. Thirdly, the COVID-19 pandemic has underscored the nation's lack of preparedness for biological incidents, prompting a reevaluation of readiness. Lastly, the widespread availability of biotechnology-related information and tools, such as DNA mapping presents both

challenges and opportunities for the warfighter, necessitating careful management of data security and accessibility (Aucouturier, 2020).

3. Research Methodology

This scientific paper delves into the pivotal role of biotechnology in shaping contemporary warfare. It meticulously examines the profound impact of biotechnological advancements on military strategies, tactics, and capabilities, shedding light on their intricate implications for both societal dynamics and international security paradigms. Through comprehensive analysis, the article endeavours to unravel the multifaceted ways in which biotechnology has reshaped the modern battlefield landscape, offering insights into its far-reaching consequences.

Therefore, the paper will strive to accomplish the subsequent research objectives:

– Investigating the impact of biotechnological progress in modelling contemporary military operations;

– Assessing the ethical dilemmas surrounding the use of biotechnology into modern warfare;

– Exploring the potential outcomes of further biotechnological innovations in military contexts and global security.

To achieve this, the study's hypothesis posits that advancements in biotechnological technology within military operations will result in more pronounced changes in military strategies, tactics, and capabilities, significantly influencing the conduct of conflicts. The author scrutinized the article's subject matter in conjunction with existing research in the field, establishing connections between the utilization of biotechnology in military operations across diverse scenarios. Various authoritative sources, such as military manuals and peer-reviewed articles, were consulted through empirical investigation to attain the intended outcome. The process of collecting and integrating data in the research is illustrated in Figure no. 2.

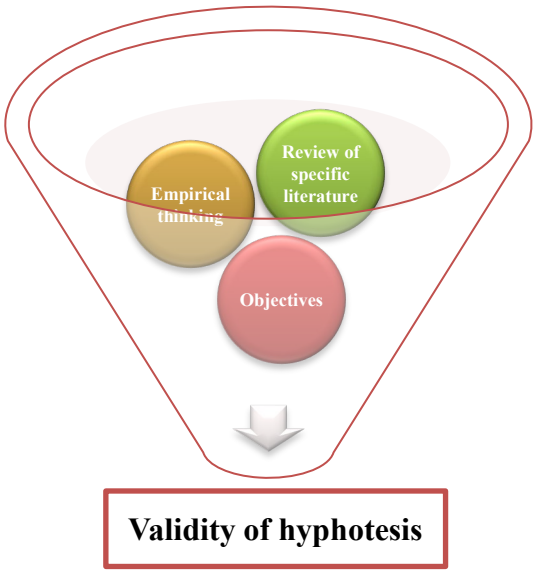


Figure no. 2: *The research methodology*
(Source: Authors' own research)

4. Recent Technological Advancements in Biotechnology in the Military Domain

Recent technological advancements in biotechnology have opened new horizons regarding their application in military operations.

Biotechnology plays a crucial role in safeguarding and enhancing the health of soldiers on the battlefield. Recent advancements in biotechnology have revolutionized medical care, offering innovative solutions for treating injuries and combating diseases in challenging field conditions. Recent research has led to the creation of treatments and technologies for wound care and disease management in challenging terrain conditions. For example, biotechnology has contributed to the development of advanced dressings that facilitate faster wound healing and reduce the risk of infections among military personnel (Williams & Armstrong, 2020).

Furthermore, the development of biotechnological materials that can be used in military equipment and in the construction of advanced protective structures represents another contribution of biotechnology. These

materials can have unique properties, such as high impact resistance or the ability to self-repair in case of damage, making them extremely valuable in challenging combat environments (Williams & Armstrong, 2020).

Additionally, biotechnology has brought significant improvements in the field of protection against biological weapons. Through advanced pathogen detection and identification technologies, the military can quickly identify and neutralize potential biological threats, thus protecting military personnel and civilian populations (Williams & Armstrong, 2020).

Biotechnology is also important in monitoring soldiers' health status in real-time, enabling timely interventions and medical support when needed. Through wearable biometric sensors and advanced diagnostic tools, military medical personnel can continuously monitor vital signs and detect potential health issues among soldiers, ensuring their well-being during military operations (National Research Council, 2001).

Moreover, biotechnology is also used in the development of innovative weapons and military equipment. For example, research on improving soldiers' cognitive and physical capabilities through genetic modifications or advanced medical treatments can contribute to increasing their efficiency and resilience during military missions.

One detailed example of biotechnology-derived equipment for military purposes is the development of bio-inspired materials, specifically lightweight yet strong materials modelled after spider silk. Spider silk is known for its remarkable strength and elasticity, making it an ideal candidate for applications requiring both durability and flexibility. Researchers have been studying the molecular structure of spider silk and using biotechnology techniques to replicate its properties in synthetic materials (National Research Council, 2001). These fibres are produced using genetically engineered microorganisms that mimic the spinning process of spiders, resulting in bio-inspired materials with exceptional strength-to-weight ratios, as seen in the Figure no. 3.

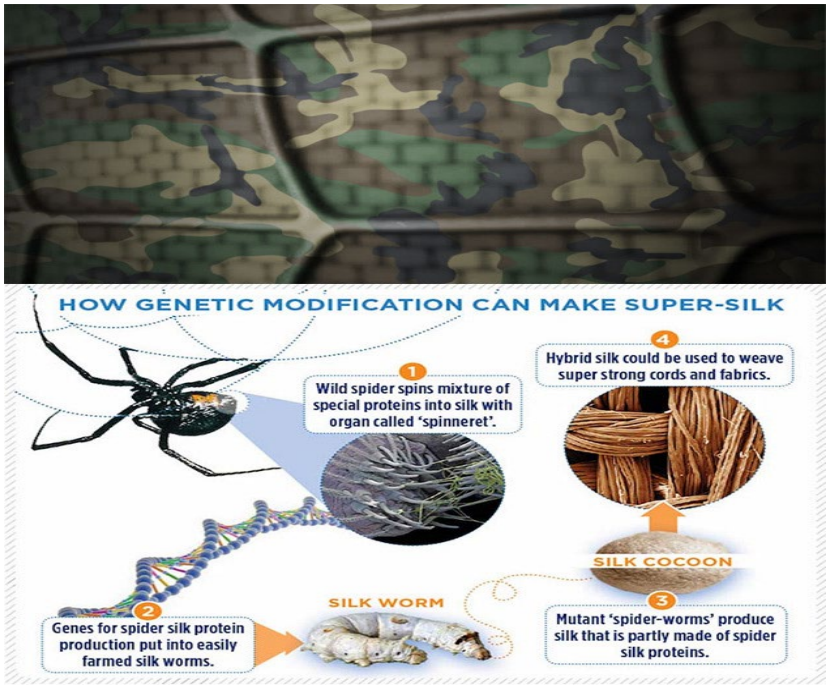


Figure no. 3: *Synthetic spider silk*
(Source: Chung, 2016)

Synthetic spider silk fibres have diverse military applications (National Research Council, 2001):

– Body armour – they enhance soldier protection against ballistic threats while maintaining mobility;

– Vehicle components – used in armour panels or reinforcements, they improve vehicle survivability without adding weight;

– Parachutes and ropes – offering durability and abrasion resistance, they benefit military parachutists and climbers;

– Personal protective equipment – integrated into helmets and gloves, they provide lightweight yet resilient gear for hazardous environments.

Thus, the impact of biotechnology on military capabilities is profound and diversified, with a wide range of applications in the development of innovative materials, advanced sensors, and bioengineering techniques, representing a vital component of modern military capabilities.

5. The Possible Threats and Risks Associated with Biotechnology

The utilization of biotechnology in the military domain brings about not only advancements but also potential threats and risks, including the looming spectre of bioterrorism and the proliferation of biological weapons, as shown in Figure no. 4. The dual-use nature of biotechnological research and development poses significant challenges, as technologies intended for beneficial purposes can be repurposed for malicious intent.

The COVID-19 pandemic has laid bare worldwide susceptibilities to biological hazards and redirected focus towards the potential for deliberate biological assaults. Recent strides in biotechnology offer significant potential in combating biological threats, whether they arise from intentional attacks or naturally emerging pandemics.

One of the foremost concerns is the deliberate misuse of biotechnological advancements to orchestrate bioterrorist attacks, posing grave threats to national security and public safety. Bioterrorism entails the deliberate release of harmful biological agents, such as pathogens or toxins, to cause widespread illness, panic, and disruption. The accessibility of biotechnological tools and knowledge increases the risk of malevolent actors, including terrorist organizations or rogue states, acquiring and weaponizing biological agents for nefarious purposes. Such attacks could target civilian populations, military personnel, or critical infrastructure, leading to catastrophic consequences and destabilizing societal impacts (Alleslev, 2021).

Moreover, the proliferation of biological weapons represents a significant challenge in the realm of biotechnology and military affairs. The convergence of biotechnology with other emerging and disruptive technologies enhances the feasibility and effectiveness of developing biological weapons with enhanced virulence, transmissibility, and stealth capabilities. Advances in genetic engineering and synthetic biology enable the creation of novel pathogens or the modification of existing ones to evade detection and countermeasures (Dieuliis, 2018).

Throughout history, biological weapons have played a role in warfare, dating back to ancient times. Various civilizations have employed biological weapons in warfare. In ancient times, tactics included contaminating arrows and water supplies with pathogens. Later, during conflicts like World War I and II, advances in microbiology facilitated the development and use of deadly bio-warfare agents like anthrax and plague-infected fleas. Even a minor biological weapon attack, regardless of casualties, can have serious repercussions. Technological progress has significantly enhanced the potential of biological weapons (Marler & Gerstein, 2022). The integration of biological data with AI and advanced genetic engineering enables the modification of pathogens, including the creation of new ones. Additionally, advancements in delivery

mechanisms, driven by increased computer power, allow for ultra-targeted biological warfare, potentially affecting specific ethnic groups or individuals.

Furthermore, the digitization and globalization of biotechnological research and development processes exacerbate the risk of unauthorized access, cyber threats, and illicit dissemination of sensitive information and biological materials. The interconnected nature of the global scientific community amplifies the potential for accidental or intentional leaks of dangerous pathogens or research findings, heightening the risk of misuse by malicious actors (US Army, 2021).

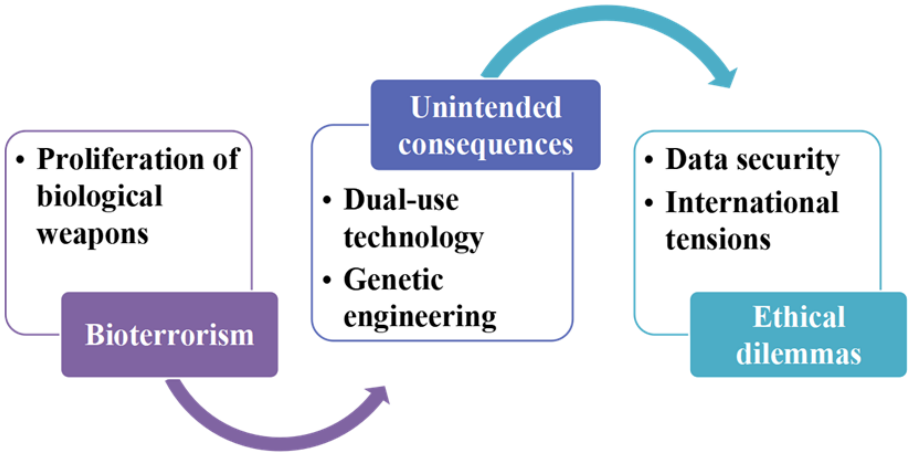


Figure no. 4: *Threats and Risks of Biotechnology*
(Source: Authors' own research)

In conclusion, while biotechnology offers immense potential for enhancing military capabilities and addressing security challenges, it also introduces new vulnerabilities and risks that must be carefully managed and mitigated.

6. Ethical Concerns regarding Biotechnology in the Military

The use of biotechnology in a military context raises numerous ethical and legal issues, especially regarding the protection of human rights and personal data. Such usage raises questions about upholding fundamental principles of human rights, such as the right to life, bodily integrity, and the right to privacy.

For example, genetic modifications made to soldiers to enhance their cognitive or physical capabilities raise serious concerns about informed consent and individual autonomy. Techniques like DNA sequencing facilitate the genetic engineering of viruses, increasing their virulence and transmissibility or even recreating extinct pathogens. Moreover, the collection and storage of biological or genetic data of military personnel to monitor their health status in real-time may infringe upon their rights to privacy and data protection (Hochachka, 1998).

Additionally, the use of biotechnology for military purposes raises questions regarding compliance with international laws and conventions on warfare and human rights. There must be assurances that the use of biotechnology in military operations adheres to international standards and norms, including prohibitions on the use of biological weapons and inhumane methods of warfare. Biotechnological research enables the manipulation of pathogens to enhance their effectiveness as targeted weapons. The decreasing costs of synthesizing biological agents heighten the risk of unknown agents being weaponized.

These advancements, often digitized or stored in the cloud, also raise concerns about vulnerability to cyberattacks and theft (Pohanka, 2019).

Furthermore, there are concerns about the potential misuse of biotechnology for unethical or illegal purposes, such as bioterrorism and the proliferation of biological weapons. Measures must be taken to prevent the use of biotechnology in such activities and to protect the security and well-being of citizens (US Army, 2021).

Despite the global efforts to curb the proliferation of biological weapons through treaties like the Biological Weapons Convention (BWC), concerns persist regarding compliance and enforcement. The BWC, an international treaty aimed at prohibiting the development, production, and stockpiling of biological and toxin weapons, has faced challenges related to compliance (Stanciu & Gimiga, 2023). There have been allegations and suspicions of countries conducting research into biological weapons in violation of the treaty, although proving such violations definitively can be challenging.

The implementation of biotechnology in the military domain requires a balanced and responsible approach that takes into account the ethical and legal implications, as well as the protection of human rights and personal data. It is essential to have adequate regulatory and oversight mechanisms to ensure that the use of biotechnology for military purposes complies with ethical and legal standards.

7. Conclusions

Consequently, recent technological advancements in biotechnology have significantly transformed the way military forces conduct their operations. These advancements have brought substantial benefits, such as improving operational capabilities and protecting soldiers in challenging battlefield environments.

However, along with these benefits come risks and threats, such as bioterrorism and the proliferation of biological weapons.

Concerns about data security and the ethical aspects of genetic manipulation of soldiers underscore the need for a careful and ethical approach to the application of biotechnology in the military domain. The development and implementation of appropriate policies and regulations are vital to ensure responsible and ethical use of biotechnology while safeguarding the security and integrity of military forces and civilian populations.

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