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MAGNUZ–MUFLON: A Multimodal Bioelectronic Medicine Platform for the Rehabilitation of Chronic Pain and Post-Traumatic Stress Disorder: Current Status and Future Perspectives

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ABSTRACT

Background: Chronic pain and post-traumatic stress disorder (PTSD) are closely interconnected pathological conditions characterized by central sensitization, autonomic dysregulation, neuroinflammation, and reduced quality of life. Contemporary rehabilitation increasingly relies on multimodal approaches capable of simultaneously targeting nociceptive, psycho-emotional, and neuroimmune mechanisms [1-8].

Objective: To summarize the biophysical rationale, clinical experience, and future development prospects of the MAGNUZ–MUFLON multimodal platform for the rehabilitation of patients with chronic pain and PTSD [9-15].

Main Text: The MAGNUZ–MUFLON platform integrates bioresonance stimulation, pulsed electromagnetic fields, low-intensity pulsed ultrasound, electrotherapy, wearable physiological monitoring, and telerehabilitation components within a unified bioelectronic framework. Preliminary investigations reported pain reduction ranging from 32% to 55%, improvement in functional mobility by 18–22%, enhancement of sleep quality by 4.8 points, approximately 33% reduction in PTSD-related symptoms, decrease in C-reactive protein levels from 14.6 to 4.9 mg/L, and reduction of rehabilitation duration from 18.4 to 9.3 days [9,10,14].

Conclusions: Current evidence suggests that multimodal bioelectronic rehabilitation represents a promising direction in personalized rehabilitation medicine. However, the available data are predominantly derived from pilot investigations and require confirmation through multicenter randomized controlled studies [9-15].

Keywords: Chronic Pain; PTSD; Bioelectronic Medicine; Multimodal Rehabilitation; Neuromodulation; Bioresonance Therapy; Telerehabilitation

Abbreviations: IASP: International Association for the Study of Pain; PEMF: Pulsed Electromagnetic Field Therapy; TENS: Transcutaneous Electrical Stimulation; EMS: Electrical Muscle Stimulation; LIPUS: Low-Intensity Pulsed Ultrasound

Introduction

According to the current definition of the International Association for the Study of Pain (IASP), chronic pain is recognized as a distinct pathological condition that extends beyond a simple consequence of tissue injury. Its pathophysiology involves central sensitization, autonomic nervous system dysfunction, neuroinflammatory processes, and altered neurotransmitter regulation [1,7]. Patients simultaneously affected by chronic pain and PTSD represent a particularly challenging clinical population. Contemporary research indicates a bidirectional relationship between pain and trauma-related disorders: persistent nociceptive activity may exacerbate psycho-emotional disturbances, whereas chronic stress responses may contribute to the maintenance of pain sensitization and disability [4]. Several classical concepts have influenced the emergence of modern bioelectronic medicine. These include Blackman's studies describing frequency-dependent biological responses to electromagnetic fields [5], Liboff's ion-cyclotron resonance model [6], and the landmark paper by Famm et al., A Jump-Start for Electroceuticals, which established a conceptual framework for therapeutic neuromodulation technologies [2]. Against this scientific background, a series of investigations conducted at the National Technical University "Kharkiv

Polytechnic Institute" focused on the development of the MAGNUZ–MUFLON platform for multimodal rehabilitation of chronic pain and post-traumatic disorders [9-15].

Evolution of the Magnuz–Muflon Concept

The first practical stage in the development of the platform involved the creation of the multiphysical rehabilitation device MUFLON X for patients with post-traumatic syndromes [9].

Subsequent research led to the development of the expanded MAGNUZ–MUFLON architecture, integrating:

- Bioresonance Stimulation;
- Pulsed Electromagnetic Field Therapy (PEMF);
- Transcutaneous Electrical Stimulation (TENS);
- Electrical Muscle Stimulation (EMS);
- Low-Intensity Pulsed Ultrasound (LIPUS);
- Digital physiological monitoring;
- Telerehabilitation Components [10,14].

A further stage of development introduced a multi-atlas approach for localization of therapeutic intervention zones and algorithm-based treatment personalization [12,15].

Biophysical Foundations of Multimodal Neuromodulation

A distinctive feature of the MAGNUZ–MUFLON platform is the use of two carrier channels operating within different physical domains. According to the proposed concept, the combination of dual carriers with multicomponent low-frequency modulation may simultaneously influence nociceptive processing, autonomic regulation, microtrophic tissue responses, and psycho-emotional status [10-13]. An additional line of investigation has focused on the possible role of tissue zeta potential, electrokinetic interactions, and electroosmotic modulation of the fascial matrix as mechanisms potentially contributing to enhanced biological responsiveness [11,13] (Table 1).

Table 1: Conceptual Architecture of the MAGNUZ–MUFLON Platform.

Component	Proposed Function
Electromagnetic carrier (450–520 kHz)	Bioelectrical modulation
Ultrasonic carrier (300–3000 kHz)	Mechanical tissue stimulation
Low-frequency modulation chords (0.1–1000 Hz)	Multilevel physiological regulation
PEMF protocols	Anti-inflammatory and regenerative support
TENS/EMS modules	Neuromuscular modulation
Digital monitoring	Physiological feedback
Multi-atlas system	Personalized treatment planning

Table 2: Summary of Clinical Outcomes Reported for MUFLON X and MAGNUZ–MUFLON.

Outcome Parameter	Reported Change
Pain intensity (VAS)	↓ 32–55%
PTSD-related symptoms (CAPS 5)	↓ ≈33%
Sleep quality	+4.8 points
Anxiety level	−5.2 points
Functional mobility	↑ 18–22%
C-reactive protein (CRP)	14.6 → 4.9 mg/L
Immunoglobulin G (IgG)	10.2 → 12.8 g/L
Rehabilitation duration	18.4 → 9.3 days
Treatment adherence	>85%
Adverse events	<5%

Clinical Experience

Available clinical investigations remain predominantly pilot in nature; nevertheless, they have consistently demonstrated positive trends in patients with chronic pain and post-traumatic disorders [9,10,14]. The reported findings suggest a potential synergistic contribution of multimodal neuromodulation to rehabilitation outcomes and support further clinical investigation of the proposed approach [9,10,14] (Table 2).

Challenges and Future Perspectives

Despite encouraging preliminary observations, most studies have involved relatively small patient cohorts and have not yet been validated in multicenter settings [9,10].

Several important scientific questions require further investigation:

- Mechanisms of multilevel electromagnetic modulation;
- The role of electrokinetic processes within biological tissues;
- Electroosmotic Interactions within the fascial matrix;
- Automated approaches to treatment personalization [11-15].

Future development may include integration of artificial intelligence, closed-loop feedback systems, and adaptive real-time control of therapeutic protocols, thereby moving toward personalized bioelectronic rehabilitation technologies [14,15].

Conclusion

The MAGNUZ–MUFLON platform represents a promising interdisciplinary development at the intersection of rehabilitation medicine, physiotherapy, bioelectronic medicine, and digital health technologies. Research conducted at NTU "KhPI" demonstrates the progressive evolution from the MUFLON X bioresonance system to-

ward a comprehensive multimodal rehabilitation platform for patients with chronic pain and PTSD [9-15]. Although current evidence remains preliminary, the reported clinical observations support continued investigation of the technology. Future multicenter randomized controlled studies will be required to establish efficacy, define optimal treatment protocols, and clarify the underlying biophysical mechanisms.

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