Digital and information technologies in the engineering education and sports rehabilitation for the reintegration of war veterans

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ABSTRACT

The article focuses on the reintegration of war veterans from military service to civilian life, which includes the restoration of their physical and mental health, social adaptation, return to family life, job search, and integration into society, development of engineering sciences for the formation of assistive technology devices for improving of the life quality. In order to promote the reintegration of war veterans, a program of physical and sports rehabilitation has been developed. The program of physical and sports rehabilitation of war veterans is considered as a complex of specially designed physical exercises, educational and training classes using therapeutic and sports techniques aimed at restoring the physical and mental health of war veterans after suffering injuries, physical and psycho-emotional stress associated with the war and, as a result, overcoming post-traumatic stress disorders.

Keywords: war veteran reintegration; physical education and sports rehabilitation; rehabilitation program; health restoration; digital technologies, ICT

1. INTRODUCTION

Transitioning from military service to civilian life presents significant challenges for war veterans, including physical injuries, psychological trauma, and the need for social reintegration. Effective rehabilitation must therefore address not only physical recovery, but also cognitive, emotional, and psychosocial well-being. In this context, physical education and sports rehabilitation emerge as essential components of a comprehensive reintegration strategy[1]. The especial role is attracted to the development of engineering sciences for the formation of assistive technology devices for improving of the life quality.

Recent advances in digital and information technologies have created new opportunities for personalised and efficient rehabilitation. Digital technologies – such as wearable sensors, augmented reality, and artificial intelligence – enable adaptive exercise protocols, remote supervision, real-time feedback, and data-driven progress monitoring[2-4]. Simultaneously, information technologies provide the necessary infrastructure for secure data collection, transmission, storage, and analytics, ensuring system scalability, user accessibility, and clinical decision support[5-8]. These innovations are particularly important for veterans with limited mobility or those living in remote areas, as they help remove barriers to consistent and high-quality rehabilitation.

The aim of the article is to present and experimentally validate a technology-enhanced rehabilitation and reintegration program for war veterans, integrating digital and information technologies to support physical recovery, psycho-emotional stabilisation, and successful return to civilian life.

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2. METHODOLOGICAL MODEL

The methodology of the rehabilitation and reintegration program comprises four sequential phases, each targeting key aspects of recovery and support for war veterans[9]. The development of assistive technology devices for improving of the life quality is one of the key tasks of the modern challengers.

Phase I – Baseline Assessment. Participants undergo standardised functional tests, such as the 6-Minute Walk Test and the Timed Up and Go test, to evaluate physical endurance and mobility[10].

Wearable inertial measurement units (IMUs) are used to assess balance, gait, and muscle activity, generating objective data for personalised planning. Comparable fractal and statistical modelling approaches have also been implemented in optical-coherence diagnostics of birefringent biological tissues and in methods for restoring the spatial phase distribution of complex optical fields within singular optics frameworks[11-12].

Phase II – Personalised Program Generation. An AI-based expert system processes assessment data to generate customised training protocols, dynamically adjusting intensity, duration, and complexity in real time based on individual progress[13].

Phase III – Interactive Training Modules. A cross-platform application delivers augmented reality (AR)–guided exercises with live posture correction and motivational prompts, synchronised with sensor feedback to ensure precision and engagement[14].

Phase IV – Cognitive and Psycho-Emotional Support. The final phase incorporates tele-counselling, mindfulness modules, and virtual peer-support groups to promote mental well-being and social reintegration.

3. ARCHITECTURE OF THE REHABILITATION PLATFORM

The program is implemented through a multi-tier platform architecture comprising hardware and software components designed for scalability, security, and real-time responsiveness[15]. Key subsystems include:

– Platform Architecture: A microservices-based framework using Node.js and Docker containers for modular deployment; load balancing via NGINX ensures high availability and horizontal scalability.

– Sensor Layer: Wearable IMUs strategically placed on the ankle, knee, and pelvis capture tri-axial accelerations (±16 g) and angular velocities (±2000°/s) at 50 Hz, transmitting data via Bluetooth Low Energy with encryption. The implementation of sensor feedback mechanisms is partly inspired by optical manipulation techniques used in structured light diagnostics[16].

– Real-Time Data Processing Engine: Utilizes a pipeline of signal conditioning (4th-order Butterworth filters), quaternion-to-Euler transformations, and gait event detection algorithms executing within 10 ms per data frame using C++ and Python modules.

– User Interface and AR Feedback: A React Native client displays customizable exercise dashboards, live kinematic plots, and AR overlays (ARKit/ARCore) to correct posture. Haptic vibration and audio cues reinforce proper movement execution.

– Cloud Infrastructure and Analytics: AWS-based backend with ECS-hosted microservices, S3 for encrypted session storage (AES-256), Lambda functions for feature extraction, and Amazon Redshift for data warehousing. LightGBM models update exercise difficulty rules, and Clinician Alerts via SNS notify medical staff of deviations. Coherence-based methods and correlation optics offer promising directions for enhancing precision in medical diagnostics and may complement future AI-based modules[17].

The system's effectiveness in improving physical endurance and mobility is evidenced by measurable gains in the 6-Minute Walk Test and Timed Up and Go, as illustrated in Figs. 1 and 2.

4. EXPERIMENTAL VERIFICATION

A randomized controlled pilot study was conducted with 40 war veterans (mean age 35 ± 7 years) allocated equally to intervention and control groups over a 12-week period.

Primary outcomes:

– 6-Minute Walk Test (6MWT) to assess endurance.

– Timed Up and Go (TUG) to evaluate functional mobility.

– PTSD Checklist (PCL-5) for psycho-emotional assessment.

Secondary outcomes included the System Usability Scale (SUS) for user experience and session adherence rates monitored via logs.

Results: The intervention group improved 6MWT distance by 32 ± 5 m compared to 18 ± 6 m in controls ($p < 0.01$). TUG times decreased by 2.1 ± 0.4 s vs. 1.3 ± 0.5 s ($p < 0.05$). PCL-5 scores declined by 12 ± 3 points vs. 7 ± 4 points ($p < 0.01$). SUS scores averaged 85/100, and adherence rates exceeded 90%.

The positive impact on psycho-emotional well-being is further illustrated by PCL-5 score dynamics shown in Fig. 3.

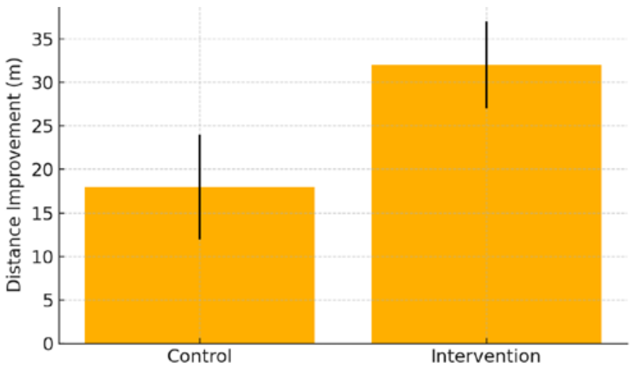

Fig. 1. Comparison of 6MWT improvement for control and intervention groups

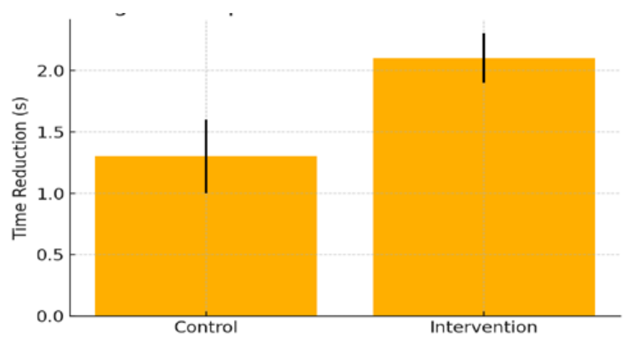

Fig. 2. Comparison of TUG time reduction for control and intervention groups

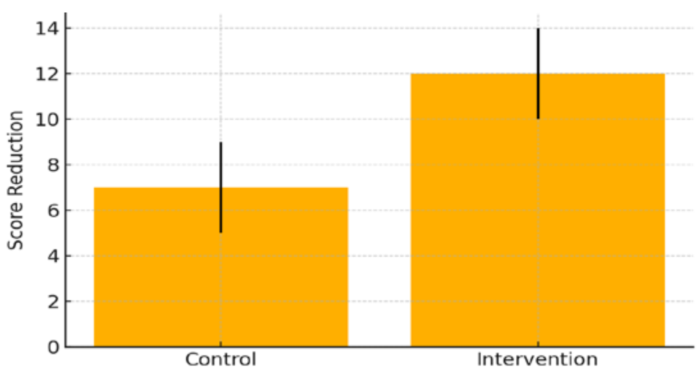

Fig. 3. Comparison of PCL-5 score reduction for control and intervention groups

5. CONCLUSION

The presented technology-enhanced rehabilitation and reintegration program demonstrated a statistically significant improvement in physical performance, psycho-emotional state, and user engagement among war veterans. The integration of wearable sensors, real-time data analytics, and augmented reality within a scalable digital infrastructure enabled personalised and adaptive rehabilitation strategies tailored to individual needs. The conditions for improving the live excisting of victims of military operations are analysed.

The use of information technologies – such as secure cloud-based storage, machine learning-driven decision support, and telecommunication modules – ensured continuity, accessibility, and medical oversight throughout the intervention. High adherence rates and favourable usability scores confirm the feasibility and acceptability of the proposed approach in remote or resource-limited settings.

The results of the experimental validation indicate that such a multimodal, data-driven system can effectively support both physical recovery and psycho-social reintegration of war veterans.

The integration of advanced diagnostics based on the analysis of optical singularities may further expand the capabilities of wearable rehabilitation systems[18]. Future research will focus on longitudinal monitoring, the integration of smart textiles and advanced biosensors, and the development of predictive analytics modules to further optimise rehabilitation outcomes and personalise care trajectories.

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