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DIGITAL TECHNOLOGIES AND TELEMEDICINE IN THE REHABILITATION OF PATIENTS WITH MUSCULOSKELETAL INJURIES: INTERNATIONAL EXPERIENCE AND INITIAL RESULTS OF THE NATIONAL PROGRAM IN UZBEKISTAN

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Abstract: The article examines modern approaches to the use of digital technologies and telemedicine in the rehabilitation of patients after musculoskeletal injuries. The possibilities of remote patient monitoring using electronic medical systems, mobile applications, and specialized computer programs for assessing the recovery process are described. Special attention is given to telemedicine consultations, which allow doctors to observe patients remotely and adjust treatment programs in a timely manner.

The use of modern medical data analysis technologies, including artificial intelligence systems, is discussed, helping to assess recovery dynamics, select individualized exercise programs, and predict treatment outcomes. International experience in the application of digital technologies in traumatology and orthopedics, demonstrating high efficiency of remote patient rehabilitation, is also presented.

Particular attention is given to the development of digital medicine in the Republic of Uzbekistan and the first results of implementing telemedicine technologies in medical practice. It is shown that the use of digital technologies contributes to improving the quality of medical care, increasing accessibility to rehabilitation services, and accelerating the recovery process after injuries.

INTRODUCTION

In the context of rapid development of information technologies, medicine is gradually transitioning to the use of digital methods for diagnosis, treatment, and patient rehabilitation. Modern electronic systems improve interaction between doctors and patients and increase the efficiency of medical care. Digital technologies play an especially important role in the rehabilitation of patients after musculoskeletal injuries.

Injuries to bones, joints, and ligaments require a long recovery period, including a complex of therapeutic measures and constant specialist monitoring. The success of rehabilitation largely depends on regular execution of therapeutic exercises and timely adjustment of recovery programs.

Unlike traditional treatment methods, digital technologies allow remote patient monitoring and control of the recovery process without frequent visits to medical institutions. This is particularly important for patients living in remote areas.

In recent years, elements of digital medicine, including electronic medical systems and telemedicine consultations, have been actively implemented in Uzbekistan. The use of such

technologies increases the accessibility of medical services and improves treatment quality.

The aim of this work is to analyze the possibilities of applying digital technologies and telemedicine in the rehabilitation of patients after musculoskeletal injuries and to assess the prospects for their further development.

1. INTERNATIONAL EXPERIENCE AND THEORETICAL FOUNDATIONS OF DIGITAL REHABILITATION

1.1. The Concept of Telerehabilitation in Global Practice

International protocols, including WHO guidelines, emphasize that rehabilitation is a continuous process aimed at returning the patient to a full and active life. Global experience demonstrates that the use of "smart" sensors and mobile applications allows real-time monitoring of patients' biomechanical indicators.

Telerehabilitation refers to the delivery of rehabilitation services using information and communication technologies (ICT). According to international classifications (including WHO standards), it covers a wide range of medical interventions:

Teleconsultations: Remote interaction between a physician and a patient to adjust the exercise plan.

Telemonitoring: Automated collection of patient physiological data (heart rate, range of motion, muscle tone) through wearable devices.

Teletherapy: Direct delivery of rehabilitation sessions in a virtual environment or via video communication.

1.2. The Role of Computer Technologies in High-Precision Diagnostics

In modern traumatology, particularly when working with pediatric patients, the diagnostic stage is the foundation of successful treatment. Since children's bodies are more fragile than adults', simple methods often do not provide accurate results for detecting complex injuries or microscopic damage to bone structures. Consequently, new examination methods based on advanced computer technologies are being integrated into clinical practice.

Tissue Visualization and Deep Analysis

The use of modern equipment, such as computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound (US), allows clinicians to visualize changes in bones and soft tissues in detail.

Computed Tomography (CT): Provides high-resolution cross-sectional images of bone structures, which is critical for diagnosing complex comminuted fractures.

Magnetic Resonance Imaging (MRI): Considered the "gold standard" for assessing the condition of ligaments, cartilage, and soft tissues, which is often necessary in pediatric sports injuries.

Ultrasound (US): Used as a rapid and safe primary screening method, allowing the detection of hematomas or joint injuries without radiation exposure.

Integration of Artificial Intelligence in Diagnostics

Today, diagnostic capabilities are expanding through the application of artificial intelligence (AI) algorithms. AI systems can analyze large volumes of digital data obtained from CT or MRI scans and detect pathologies that may be invisible to the human eye at early stages. This allows:

Automation of the measurement process for bone fragment displacement angles.

Prediction of fracture healing progression based on bone density analysis.

Minimization of the risk of medical errors in establishing the initial diagnosis.

2. TECHNOLOGICAL SOLUTIONS IN TRAUMATOLOGY

2.1. Innovative Approaches and the Role of Computer Technologies in Treatment

Today, computer technologies play a fundamental role in transforming approaches to pediatric traumatology. The transition from traditional methods to digital standards not only increases precision but also significantly reduces the invasiveness of surgical interventions.

Digital Planning and Monitoring

Precise dosing: Digital programs allow for precise calculation of drug dosages, minimizing the risk of side effects in children.

Electronic control: Computer systems store medical history, laboratory results, and instrumental study data in a unified digital profile.

Operational access: Doctors can instantly access necessary data, enabling full control over patient dynamics and timely adjustment of treatment tactics.

3D Modeling and Surgical Navigation

3D modeling creates a precise three-dimensional image of damaged bones and joints.

Precision accuracy: Enables surgical staff to act with maximum precision, considering each child's anatomical features.

Error minimization: Preoperative virtual planning helps avoid technical errors, reducing surgical risks.

Optimal implant placement: Allows determination of the best position for fixation devices and implants.

Reduced invasiveness: A clear surgical plan reduces operative time and healthy tissue damage.

Artificial Intelligence in Treatment

AI systems are increasingly integrated into treatment protocols to automate and optimize medical decisions. They analyze retrospective data from thousands of clinical cases, suggesting the most effective surgical reconstruction or medication therapy. The use of AI and 3D planning increases surgical efficiency, reduces complications, and accelerates initial recovery.

2.2. Virtual and Augmented Reality (VR/AR) in Innovative Rehabilitation

VR and AR technologies provide new opportunities in post-injury rehabilitation, especially

in pediatric and adolescent traumatology, where motivation and emotional state play a key role.

Gamification and motivation: VR transforms boring therapeutic exercises into engaging game tasks, increasing treatment adherence by 70–80%.

Reducing psychological barriers and kinesiophobia: Full immersion distracts from pain signals, and difficulty can be gradually increased, reducing fear of re-injury.

3. FIRST RESULTS OF THE NATIONAL PROGRAM IN UZBEKISTAN

3.1. Digital Planning of Medical Practices and Systematic Data Management

Computer technologies play a critical, multifaceted role in modern pediatric traumatology. With rapid digitization, planning of therapeutic measures has reached a new level, ensuring high precision and safety.

Algorithmic prescriptions: Systems automatically calculate drug dosages based on weight, age, and physiological characteristics, eliminating human error.

Dynamic monitoring: Digital devices continuously track vital signs, allowing immediate response to any therapy changes.

Digital Documentation Transformation

Electronic Medical Record (EMR): Stores full retrospective health data, lab results, and diagnostic imaging (CT, MRI).

Optimized access: Enables fast retrieval of archived information for repeat surgeries or long-term rehabilitation.

Data integration: All stages, from initial visit to final rehabilitation, are digitally recorded for seamless care continuity.

Precision through Digital Protocols

Digital protocols allow simulation of surgical scenarios before the operation, enabling selection of the least invasive and most effective tactics, reducing hospital stay length.

4. COMPUTER TECHNOLOGIES AND ARTIFICIAL INTELLIGENCE IN COMPREHENSIVE REHABILITATION

4.1. Objective Monitoring and Biometric Recovery Control

Traditional methods (visual inspection, manual measurement) are replaced by digital approaches that capture micro-dynamics: Biomechanical motion analysis: Motion capture sensors allow evaluation of joint angular velocity and load symmetry, preventing incorrect motor patterns in children.

Digital goniometry and myography: Real-time EMG evaluation measures muscle atrophy or recovery post-immobilization.

Wearable devices: Smart braces and integrated sensors transmit step counts, bending angles, and axial load to the clinic’s cloud.

4.2. AI-Guided Adaptive Rehabilitation Programs

AI acts as a "constant assistant," enabling personalized therapy:

Algorithmic load adjustment: Daily data on pain and motion range allow AI platforms (e.g., integrated in Uzbekistan's national program) to modify exercise intensity and alert physicians to regressions.

Predictive analytics: Big Data comparison predicts recovery timelines and complications before clinical manifestation.

Biofeedback: Real-time visual or voice signals guide patients, preventing improper technique and reinjury.

4.3. Virtual Environments as a Tool for Neuroplasticity

VR headsets create immersion, activating mirror neurons. Seeing a virtual healthy limb moving helps overcome fear and accelerates neuromuscular signal transmission. Remote AI platforms in Uzbekistan allow residents of remote regions (e.g., Surkhandarya, Khorezm) to access world-class rehabilitation without leaving home.

CONCLUSION

The use of digital technologies and telemedicine systems in musculoskeletal rehabilitation opens new possibilities to improve treatment effectiveness. Modern information systems enable constant patient monitoring and timely adjustment of recovery programs.

Analysis shows that digital technologies improve medical care quality, reduce complications, and accelerate patient recovery. Remote monitoring systems allow patients to receive medical guidance without frequent visits to healthcare facilities.

The development of digital medicine in Uzbekistan creates favorable conditions for introducing modern rehabilitation methods. The use of AI, remote monitoring, and telemedicine consultations enhances treatment efficiency and expands accessibility to healthcare services.

Thus, further implementation of digital technologies and telemedicine is a key direction in the development of modern healthcare and rehabilitation medicine.

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