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Advances in Multidisciplinary Research: Technology, Economy, Management and Health

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Smart Orthopaedic Rehabilitation Using AI and Wearable Sensors: Integrating Physiotherapy, IoT, and Intelligent Movement Analysis

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Abstract

Orthopaedic rehabilitation is a cornerstone of recovery after joint arthroplasty, ligament reconstruction, fracture fixation and the conservative management of degenerative musculoskeletal disease. Its effectiveness, however, depends on factors that conventional service models struggle to control: the dose, quality and consistency of exercise performed outside the clinic, the accuracy with which clinicians can quantify movement, and the timeliness with which programmes are adapted to patient progress. This chapter examines how the convergence of wearable inertial sensing, Internet of Things (IoT) architectures, and artificial intelligence (AI) is reshaping orthopaedic physiotherapy into a continuous, data-informed and increasingly personalised service.

The chapter develops an integrated conceptual framework that links the biopsychosocial and ICF-based view of function with motor learning theory, behaviour-change science, and technology adoption models. It then critically reviews evidence from the past decade on telerehabilitation, sensor-based biofeedback, remote patient monitoring and machine-learning-based outcome prediction. Thematic sections analyse the sensing layer (inertial measurement

units, surface electromyography, marker less vision), IoT system architecture, algorithmic approaches to activity recognition, exercise-quality assessment, kinetic estimation and risk stratification, and condition-specific applications in knee osteoarthritis, arthroplasty, anterior cruciate ligament injury and shoulder rehabilitation.

The argument advanced is threefold. First, the strongest current evidence supports digital and sensor-enabled rehabilitation as a non-inferior, scalable alternative or adjunct to conventional care for selected populations, but evidence for superiority, long-term outcomes and cost-effectiveness remains limited. Second, the clinical value of these systems lies less in sensing or classification accuracy per se than in closing the loop between measurement, feedback, clinical decision-making and behaviour change. Third, translation is constrained by validity gaps in free-living conditions, algorithmic bias, limited explainability, data governance, and organisational factors. The chapter concludes with practical and policy recommendations and a research agenda emphasising pragmatic trials, standardised validation, explainable and federated learning, and equity-sensitive design.

Keywords: orthopaedic rehabilitation; wearable sensors; inertial measurement units; Internet of Things; machine learning; telerehabilitation; biofeedback; movement analysis; digital health

1. Introduction

1.1 Background

Musculoskeletal conditions are among the largest contributors to disability worldwide. Hip and knee osteoarthritis alone account for a substantial and growing share of years lived with disability, a trend driven by population ageing and rising body mass index.[1] Musculoskeletal disorders more broadly threaten healthy ageing by limiting mobility, independence and participation.[2] Surgical