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GUEST EDITORIAL

Unlocking Movement: How Wearables Transform Biomechanical Assessment and Rehabilitation

Tahir Masood

Associate Professor in Department of Physical Therapy and Health Rehabilitation, College of Applied Medical Sciences, Jouf University, Saudi Arabia/ Member International Advisory Board, JRCRS

Address of Correspondence:
Tahir Masood
Email ID: tmasood@ju.edu.sa

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Globally, approximately 1.7 billion individuals live with musculoskeletal conditions, which are the primary driver of disability. This includes low back pain, the single most disabling condition in 160 countries. The impact on individuals is profound, limiting their mobility and dexterity, potentially forcing early retirement, and diminishing their well-being and social participation[1]. The development of wearable technologies, like those monitoring physical activity or individual body segment motion, has been driven by the incorporation of sensing, processing, storage, and communication features. Wearable technology can be defined as "*Sensors and/or software applications (apps) on smartphones and tablets that can collect health-related data remotely, i.e., outside of the healthcare provider's office. The data can be collected passively or may require a user's input.*"[2]

The utilization of wearable technology is expanding across multiple disciplines, such as in the evaluation of athletic performance. While the use of inertial measurement units (IMUs) is dominant, studies also utilize accelerometers and flex sensors to reduce costs and improve accessibility. Applications span injury prevention, performance assessment, and potential coaching improvements through long-term monitoring of biomechanical risk factors. Wearable devices offer the advantage of in-field monitoring, providing more realistic data compared to laboratory settings. Although IMUs exhibit some measurement errors, their reliability in capturing joint kinematics makes them popular. Real-time feedback, demonstrated to improve technique in some sports, is a promising feature, but widespread adoption is hindered by the need for robust wireless data transfer and user-friendly data interpretation. Smartphone applications are emerging as a solution for data display. Despite variations in reporting detail, the research confirms the potential of wearable sensors to provide valuable biomechanical data for various sports applications[3]. Similarly, according to a recent systematic review on the use of such technology in running biomechanics, wearables offer a promising way to measure running biomechanics in real-world settings. While current studies often use single IMUs on young recreational runners on treadmills, future work is needed to optimize sensor placement, types, and outcome measures for broader application[4].

The significant potential of wearable IMUs to revolutionize gait analysis, moving beyond lab-based systems, by evaluating the accuracy of IMUs against gold-standard optical motion capture (OMC) systems has been reported. The most common IMU configuration involves lower-body placement, particularly on the lower back, feet, and shanks. Single sensors on the lower back effectively measure spatiotemporal parameters like cadence, while multi-sensor setups improve accuracy for a wider range of gait metrics. Kinematic parameters show consistently strong agreement with OMC data, regardless of sensor placement or configuration. While IMUs demonstrated high agreement with OMC systems, validation limitations remain, hindering their widespread clinical adoption, necessitating future improvements in sensor positioning, signal processing, and validation protocols[5].

Additionally, research into the application of wearable technology is widespread in the context of assessment and rehabilitation of physical disorders. For example, wearable sensors are increasingly used in studies related to upper extremity musculoskeletal conditions, demonstrating significant potential for advancing healthcare technologies in assessment and treatment. They enable clinical evaluations, home-based monitoring, and the recording of daily activity, as well as the assessment of physical risk factors in environments like workplaces. However, there is a need for more rigorous research designs to produce stronger evidence. Are some studies integrate IMUs with surface electromyography to capture both motion and muscle activity. Currently, the primary role of wearables is focused on assessment rather than treatment, as evidenced by the higher number of assessment-oriented studies[6].

Conclusion

Wearables have increasingly been used for biomechanical assessment and rehabilitation playing an important role in advancing personalized medicine in physical therapy. There is significant potential for AI and machine learning to analyze large datasets and provide predictive insights as well as endless possibilities of integration of wearables and motion capture with other emerging technologies, such as virtual reality and augmented reality. However, the potential cost barriers and the need for wider accessibility associated with such technology should be acknowledged. Similarly, the importance of proper training and expertise in interpreting the data generated by these technologies as well as ethical considerations related to data collection and storage cannot be overestimated. There is a need for seamless integration of these technologies into existing clinical workflows. It is worth reminding that technology enhances, but does not replace, the patient-therapist relationship.

Physical therapists should embrace these technologies and contribute to their ongoing development and implementation since they are unlocking movement and transforming the field of physical therapy.

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