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# Effectiveness of Wearable Technologies in Sports Therapy: Surface EMG and Accelerometers

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**Abstract:**

High-intensity, high-frequency exercise loads render muscle, ligament, and joint injuries among the most common ailments in training and competition. Affected athletes often experience persistent muscle weakness, compensatory movement patterns, and recurrent injuries. In recent years, the application of wearable devices in sports rehabilitation has mitigated these negative effects. Common types include surface electromyography (sEMG) and accelerometers. Compared to traditional exercise therapy, wearable technology integrates quantitative data, providing a more reliable understanding of the athlete's injury and helping physicians develop more effective rehabilitation plans. However, when analyzing the effectiveness of these two wearable technologies, accelerometers and surface electromyography, several potential factors and limitations still need to be considered, such as the high cost, which may limit their widespread adoption and effectiveness in the field of sports therapy. Based on existing clinical and sports science research, this paper evaluates the effectiveness of sEMG and accelerometers in sports therapy, focusing on their benefits in movement quality assessment, training load management, and individualized rehabilitation plan development. It also briefly explores the potential of combining wearable data with artificial intelligence modeling for injury risk assessment and rehabilitation decision support.

**Keywords:** Wearable technology; surface electromyography (sEMG); accelerometers; sports rehabilitation.

## 1. Introduction

In recent years, rapid advancements in technology have promoted a better and more convenient life for people. Prior to the advent of wearable technology in sports therapy, therapists primarily relied on visual observation, which often lacked the objective, quantifiable data crucial for optimizing an athlete's

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recovery process. Nevertheless, the integration of wearable technologies has revolutionized sports therapy. These devices now play a critical role in gathering accurate data that specify biomechanical, physiological, and performance-related data of athletes. Through the use of sensors, wearable technologies allow for the continuous monitoring of functional movements, workload intensity, and biometric markers, which are essential for maximizing performance while minimizing the risk of injury. These technologies provide real-time feedback on an athlete's condition, enabling immediate adjustments to training regimens based on accurate, data-driven insights. This capacity to monitor and analyze an athlete's workload and physiological responses ensures that therapy and training plans can be tailored more precisely, fostering both recovery and performance enhancement [1].

Accordingly, the advancements in wearable technology brought the sports therapy field to multiple types of wearable devices, which are associated with different purposes that serve different monitoring of injuries. The integration of surface electromyography (sEMG) and accelerometers allows for more accurate interpretation by therapists. Traditionally, therapists relied on qualitative assessments, which were often influenced by personal biases and subjective evaluations. In contrast, the use of wearable technology provides therapists with quantitative data that supports diagnosis and interpretation, ultimately improving the accuracy of evaluations. These quantitative metrics include vital signs such as heart rate and oxygen saturation, as well as physical performance indicators like acceleration, speed, muscle strength, balance, stride, and gait patterns [2].

Surface-EMG includes electrode bars, amplifiers, physical 3D enclosures, and a recording device. First, the 3D enclosures are placed on the patient's specific muscle part. Then, the electrodes detect minute electrical potentials generated by muscle fibers during contractions. These signals are then further transmitted to the amplifier and recording device for further analysis of the patient's muscle fiber recruitment on a specific muscle part. Surface-EMG technology measures action potentials generated when muscle fibers contract. This technology also provides the basic information of muscle activation patterns, intensity, timing, and fatigue levels on the superficial level as the deeper levels of muscles generate less muscle activation, providing temporal and quantitative insights into the patient's muscle activity. Of course, there are also potential limitations of using the wearable technology Surface-EMG; examples include crosstalk between muscles, limited monitoring scope, and muscle substitutions. These factors may affect the accuracy and comprehensiveness of the data collected during rehabilitation [3].

In addition to sEMG, accelerometers are another wearable technology widely used in sports therapy to measure the activity levels, external load, and movement patterns of a patient. In particular, this wearable technology measures and stores the change of velocity when the body is performing in physical activities. Unlike the sEMG tracking muscle recruitment of the patient, the accelerometers mainly monitor the biomechanics such as joint movement and range of motion, serving as a significant tracking system in rehabilitation. For instance, if there were any changes in the patients' movement feedback, accelerometers can provide rapid quantitative measurements that therapists can quickly alter the rehabilitation plan. Nevertheless, there might also be underlying limitations to the wearable technology accelerometers, one outstanding example is placement consistency. Data might be inconsistent when the patient chooses to change the placement of accelerometers, which may lead to misinterpretation of the collected data [4]. This review aims to critically evaluate the effectiveness of Surface-EMG and accelerometers in sports therapy, focusing on their practical applications and identifying the limitations in rehabilitation.

## 2. Evolution of Wearable Technology in Sports Therapy

When reviewing the history of wearable technologies in the field of sports therapy, the first superb milestone is in the mid-20th century. During this arc, the focus of wearable devices was on simple sensors and pedometers, examples of which were Hewlett Packard's algebraic calculators watch released in 1977, which was used to monitor recovery time. Another important early device was the Portable Stereo Sony Walkman, introduced in 1979, which was used as a GPS tracker for patients. As the 20th century progressed, a significant shift occurred, particularly from basic pedometers to the early forms of accelerometers. a great example of this shift was the introduction of the mBracelet in 1998. The mBracelet, worn on the wrist, was designed to monitor activity tracking and heart rate monitoring, which is closely correlated with some functions of a current accelerometer. This transition marked a leap forward in the ability to monitor not just movement but also physiological parameters, providing more detailed insights into an individual's health and recovery. The 21st century saw the integration of multiple sensors into a single, compact device. A notable example was the launch of the Apple watch in 2014 [5]. This smart device can monitor a patient's condition constantly in the day in different methods with quantitative data, significantly reducing the inconvenience of multiple devices. To summarize, the quick advancements in technology through the 20th century to the 21st century led to tremendous enhancements in rehabilitation programs.

## 3. Surface Electromyography in Sports Therapy

Surface Electromyography is a wearable device is a wearable device designed to measure the electrical activities in the skeletal muscles of the human body. By capturing this electrical activity, sEMG provides clinicians with detailed insights into a patient's muscle recruitment, activation patterns, and fatigue levels. The device consists of several essential components: electrode bars, amplifier, 3D enclosures, and a recording system. The electrode bars, which are placed on the skin above specific muscle groups, detect the electrical signals produced during muscle contractions. These signals are then transmitted to the amplifier and the recording system to collect data for the therapists. A study demonstrated that the ones or participants that received feedback from sEMG had better outcomes in their training process than the ones who did not receive feedback from sEMG, highlighting the strength of the technologies support towards improving on motor unit recruitments for an athlete or patient [6].

## 4. Accelerometers in Sports Therapy

Accelerometers are wearable devices that track an athlete's movement during physical activities, providing real-time data on changes in velocity and body movements. This data is crucial for therapists to monitor training intensity and assess movement efficiency, allowing for the development of precise rehabilitation strategies. In rehabilitation settings, accelerometers help identify movement abnormalities, such as gait issues or improper posture, which can impact the recovery process. By analyzing these movement variables, therapists can make informed adjustments to training loads and activities, optimizing recovery while minimizing the risk of further injury. Overall, accelerometers play a key role in sports therapy by offering objective, data-driven insights that support individualized rehabilitation plans, ultimately leading to more effective and targeted recovery strategies [4].

## 5. Applications of Wearable Technologies in Sports Therapy and Rehabilitation

The practical and clinical applications of wearable technologies have shown a significant upward trend in recent years. This indicates an increasing incorporation of these devices in clinical practices, providing valuable empirical evidence and real-time feedback for rehabilitation. This integration fosters a multidisciplinary approach, with sports therapists, coaches, and sports scientists working together as wearable technology continues to enhance training processes and technological developments [7, 8].

A key demonstration of the effectiveness of wearable technologies, such as electromyography and accelerometers, is their real-world application in sports therapy. Initially, surface electromyographs have been utilized to monitor identify erroneous movement patterns in different focused muscle groups. In a study examining sEMG feedback based on muscle fatigue, the findings demonstrate how Surface EMG features are correlated with fatigue levels and dynamic tasks. By linking specific EMG metrics to performance decrements, the research provides strong evidence that sEMG can serve as an effective marker for neuromuscular fatigue. As fatigue levels will be an intermediate factor that influences injury, sEMG can be used as a marker to point out adjusting plans during rehabilitation procedures. In the case of the real world, this can be a highlighter to change training loads or recovery protocols to prevent injuries that occur due to muscle fatigue [9].

Surface electromyographs and accelerometers provide valuable insights into a patient's condition and recovery progress, widely used in rehabilitation to support therapists and clinicians. A prominent application of sEMG is in monitoring the reconstruction of the anterior cruciate ligament (ACL). In a study examining how EMG signals aid in determining which muscles to train and in applying an exercise model for rehabilitation, the researchers tested muscle activation in the quadriceps using Surface EMG at different stages of ACL injury recovery to guide further training tasks. Similar studies have also highlighted the role of biofeedback from electromyographs in ACL injury reconstruction, emphasizing that both therapists and patients can objectively observe the presence of AMI through the biofeedback device. This allows therapists to provide clearer instructions and progressively more challenging goals, demonstrating the importance of surface electromyographs in restoring quadriceps function and improving knee stability during the ACL rehabilitation process [10].

Additionally, accelerometers are increasingly used in ACL recovery protocols to quantify activity intensity, movement patterns, and step counts in individuals undergoing ACL reconstruction. One study demonstrates how accelerometers and other wearable devices track quadriceps movement patterns to monitor recovery progress. Furthermore, the integration of EMG biometric feedback with accelerometer data enhances the rehabilitation pro-

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cess, providing valuable insights into muscle activities and movement patterns. This highlights the importance of empirical and quantitative data collected by wearable technologies, reinforcing their effectiveness in real-world applications for injury monitoring and rehabilitation [11].

## 6. Challenges and Limitations

Limitations and challenges are still an issue in both wearable technologies, which further impedes the expanding use of this wearable technology. A major limitation of sEMG is its susceptibility to 'crosstalk,' where electrodes pick up electrical signals not only from the target muscle but also from adjacent muscles, compromising signal accuracy. Another challenge is the tendency of experts and researchers to either overestimate or underestimate the feedback provided by sEMG. Some professionals, due to the ease of collecting data, may overestimate its capabilities, while others may fail to fully appreciate its utility, leading to misinterpretation or neglect of the technology's potential in clinical settings. Moreover, the occasional unreliable biofeedback provided by the sEMG is only one piece of the limitations for the wearable device. The fragile electrode adhesion to the patient's skin can also be a potential limitation for long term recording for quantitative data. Especially in dynamic sport activities that involve high intensity, it is extremely difficult to maintain for the sEMG's electrode bars to adhere on the skin, leading to potential user frustration, ultimately resulting in insufficient amount of data collected by the technology.

Accelerometers, while valuable in tracking movement dynamics, also have their own set of limitations. Unlike sEMG, accelerometers do not provide direct insights into muscle activity or strength. As a result, they require integration with other technologies to create a more comprehensive understanding of muscle function. In addition, wearing accelerometers for a long period of time can cause further skin irritation. This is due to the prolonged skin contact with the wearable technology, with underlying reasons including moisture from sweat and friction, which can cause irritation, redness, or dermatitis. These reasons are all correlated to the main issue of discomfort during long term equipment use of the wearable device accelerometers [12].

There are not only challenges that the device has itself has limited its effectiveness in the sports therapy field, but there are also external challenges. High prices for wearable devices have been one of the main barriers to impeding the widespread use of wearable technologies in rehabilitation practices. Another external factor that impedes the widespread use of sEMG is the technical and administrative barriers. Research on sEMG has largely been confined to smaller studies conducted by engineers and life scientists in specialized research centers, with limited involvement from clinical practitioners. As a result, the lack of infrastructure and expertise within health institutions poses a barrier to the broader implementation of these technologies in clinical practice [13].

## 7. Conclusion

Wearable technologies such as sEMG and accelerometers have demonstrated significant potential in sports therapy, offering valuable insights into muscle activity, movement dynamics, and rehabilitation progress. Both devices have shown promise in improving clinical decision-making, enhancing rehabilitation strategies, and fostering a multidisciplinary approach in sports therapy. However, despite their effectiveness, there are inherent limitations and challenges associated with these technologies. The precision of sEMG can be compromised by signal interference from adjacent muscle groups and issues with electrode adhesion during high-intensity activities. Similarly, while accelerometers provide useful data on movement dynamics, they do not directly measure muscle activity or strength and may cause skin irritation with prolonged use. In the future, the integration of artificial intelligence (AI) could significantly enhance injury prediction by leveraging data from wearable technology algorithms. This integration could be transformative, enabling real-time monitoring and feedback, which are crucial for rehabilitation programs as they provide therapists with timely, actionable insights. Ultimately, AI reinforces the effectiveness of monitoring rehabilitation associated with the quantitative data provided by the wearable technology, fostering an ensured condition for patients, underscoring the significance to integrate AI in the future into therapy processes that include the use of wearable technologies.

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