Review

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Wearable Technology in Rehabilitation: Assessing the Impact of the Apple Watch on Physical Activity and Cardiovascular Health

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Abstract: Background: The Apple Watch is increasingly used in rehabilitation to monitor physical activity, cardiovascular health, and other physiological parameters. This review evaluates its effectiveness and accuracy in various rehabilitation settings, examining its potential to enhance patient adherence and clinical outcomes. **Methods:** A comprehensive search was conducted across databases including MEDLINE, Cochrane Central, Scopus, PEDro, and Web of Science, alongside grey literature. Studies were included based on the PCC criteria (Population, Concept, Context), focusing on the use of the Apple Watch in rehabilitation programs. Bias risk was assessed using RoB 2 for RCTs and ROBINS-I for non-randomized studies. **Results:** Five studies were reviewed. The Apple Watch showed potential in improving physical activity levels and functional outcomes, particularly when combined with behavioral interventions. It demonstrated effectiveness in detecting atrial fibrillation in large-scale screening but presented variability in heart rate and energy expenditure accuracy, especially during high-intensity activities. The studies highlighted that integrating cognitive support with the device enhances adherence and health outcomes. However, limitations in measurement accuracy and the need for hybrid monitoring approaches were noted. **Conlusions:** The Apple Watch is a valuable tool in rehabilitation when used alongside behavioral support and validated clinical methods. Its effectiveness is enhanced when integrated into a multidisciplinary approach, but its limitations in accuracy necessitate further calibration and hybrid use with traditional tools. Future research should focus on long-term impacts and algorithm improvements to optimize its clinical utility in diverse rehabilitation contexts.

Keywords: Apple Watch; Rehabilitation; Wearable Technology; Cardiovascular Monitoring; Physical Activity

1. Introduction

The use of the Apple Watch as a monitoring and support tool in rehabilitation is an area of growing interest within digital health. Numerous studies have explored the potential of this device to enhance adherence to rehabilitation programs, monitor physiological parameters in real-time, and support the self-management of patients with chronic conditions or those undergoing post-surgical recovery[1–9]. Specifically, the Apple Watch, equipped with advanced sensors and integrated with health and fitness applications, is capable of continuously monitoring heart rate, physical activity levels, and, in more recent models, additional parameters such as ECG and blood oxygen

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saturation[10–13]. The existing literature highlights that, particularly in the context of cardiac and orthopedic rehabilitation, the Apple Watch can serve as an effective tool for monitoring and promoting physical activity[14–17]. It provides immediate feedback to patients and allows clinicians to remotely track their progress. For example, studies like the VALENTINE Study have demonstrated that integrating the Apple Watch into rehabilitation programs improves adherence and exercise quality through adaptive interventions that deliver real-time, context-based notifications[6]. This adaptive feedback mechanism can reinforce healthy habits and assist patients in maintaining an active lifestyle, which is critical in preventing recurrence or further deterioration of health conditions[18–22]. However, despite the enthusiasm for using this device, significant challenges remain regarding the accuracy of its measurements, especially during high-intensity activities or specific types of exercises[23–26]. Research has indicated that the Apple Watch shows considerable discrepancies in energy expenditure and heart rate monitoring when compared to clinical standard tools, such as electrocardiograms (ECGs) and chest strap heart rate monitors. These discrepancies raise concerns about the device's reliability in critical rehabilitation contexts, where precise monitoring is essential for clinical decision-making. The variability in accuracy can lead to either an overestimation or underestimation of a patient's exertion level, potentially resulting in inappropriate adjustments to rehabilitation protocols or failure to detect critical cardiac events[27,28]. Another important issue identified in the literature is the long-term adherence to the use of the Apple Watch. While the device can initially motivate patients to engage in active lifestyles, several studies have reported that adherence tends to decline over time, particularly when patients perceive a lack of tangible progress or results[29–31]. This decline in engagement underscores the need for integrated strategies that not only leverage the technological capabilities of the Apple Watch but are also supported by behavioral and psychological interventions aimed at sustaining patient motivation. For instance, incorporating personalized goals, reminders, and behavioral reinforcement techniques within the Apple Watch interface could help bridge the gap between initial enthusiasm and long-term adherence[32–34]. The main issue identified, therefore, is the need to validate and optimize the use of the Apple Watch as a rehabilitation tool, ensuring that its measurements are sufficiently accurate to inform clinical decisions and that the user experience is designed to promote sustainable, long-term adherence[1,3,4,9,35]. Moreover, there is a need for further investigation into how best to integrate the device within broader therapeutic frameworks to maximize patient outcomes. This review aims to critically evaluate the existing evidence on the use of the Apple Watch in rehabilitation, specifically assessing its accuracy, impact on patient motivation and adherence, and its potential for integration into personalized rehabilitation programs. By providing a detailed analysis of these aspects, we seek to identify best practices and propose strategies to enhance the effectiveness of the Apple Watch in clinical settings, addressing current limitations and maximizing its potential as a therapeutic tool. The objective of this review is to thoroughly analyze the role of the Apple Watch in rehabilitation programs, identifying best practices and proposing strategies to optimize its use, overcome the identified limitations, and maximize the device's clinical and behavioral effectiveness. This includes a comprehensive assessment of the Apple Watch's technological capabilities, its integration with patient-centered care models, and its implications for long-term rehabilitation outcomes.

2. Methods

The present scoping review was conducted following the JBI methodology[36,37]for scoping reviews. The Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR)[38] Checklist for reporting was used.

2.1. Review Question

We formulated the following research question: " *How effective and accurate is the Apple Watch as a tool for monitoring and supporting rehabilitation programs, and what strategies can optimize its use to enhance long-term adherence and clinical outcomes?"*

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2.2. Eligibility Criteria

Studies were eligible for inclusion if they met the following Population, Concept, and Context (PCC) criteria.

1. Population

- Description: The population considered in this review includes individuals undergoing rehabilitation programs, such as:
  - Patients recovering from cardiovascular events (e.g., myocardial infarction, coronary artery bypass surgery) participating in cardiac rehabilitation.
  - Individuals with musculoskeletal conditions, including those recovering from orthopedic surgeries (e.g., joint replacement, tendon repairs) or managing chronic conditions (e.g., osteoarthritis).
  - Patients with neurological conditions undergoing rehabilitation for stroke recovery, multiple sclerosis, or other neurological impairments.
  - Older adults or individuals with mobility limitations participating in programs aimed at improving balance, strength, and overall physical activity levels to reduce the risk of falls or frailty.
- Age Range: The studies should include adults aged 18 years and older. Studies focusing specifically on pediatric populations are excluded due to the differences in rehabilitation protocols and physiological monitoring needs in children.
- Health Status: Both chronic and post-acute conditions are included, as long as the rehabilitation involves structured physical activity or exercise monitoring.

2. Concept

- Main Focus: The primary concept of this review is the use of the Apple Watch as a wearable technology to monitor and support rehabilitation activities. The studies must focus on the following aspects:
  - Monitoring Capabilities: Assessment of the Apple Watch's accuracy in tracking physiological parameters such as heart rate, energy expenditure, ECG, and physical activity (e.g., step count, exercise duration).
  - Behavioral Support and Adherence: Evaluation of how the Apple Watch, through its interactive features (e.g., notifications, activity reminders, goal setting), influences patient adherence to rehabilitation protocols and promotes physical activity.
  - Clinical Outcomes: Examination of the impact of the Apple Watch on clinical outcomes, such as improvement in cardiovascular fitness, recovery of functional mobility, reduction in pain levels, and enhancement of overall quality of life.
- Additional Considerations: Studies exploring the integration of the Apple Watch within broader rehabilitation frameworks (e.g., tele-rehabilitation, remote patient monitoring programs) are also considered, as they provide insight into its applicability and scalability in clinical settings.

3. Context

- Rehabilitation Settings: The context includes various rehabilitation environments where the Apple Watch is utilized, such as:
  - Clinical Rehabilitation Centers: Studies conducted in hospitals, rehabilitation clinics, or outpatient centers where patients use the Apple Watch as part of a supervised program.
  - Home-based Rehabilitation: Studies focusing on remote or unsupervised rehabilitation programs where patients use the Apple Watch independently or with periodic telehealth support.
  - Community Programs: Programs offered through community health centers or fitness facilities aimed at supporting rehabilitation and physical activity among individuals with chronic conditions or post-surgical recovery needs.
- Geographical Context: The review includes studies from diverse geographical locations to provide a global perspective on the use and effectiveness of the Apple Watch in different healthcare systems.

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- Time Frame: The review considers studies published in the last decade, given the rapid evolution of wearable technology and the specific updates in the capabilities of recent Apple Watch models.

2.3. Exclusion Criteria

Studies that did not satisfy the specific PCC (Population, Concept, Context) criteria were excluded from the review.

2.4. Search Strategy

An initial exploratory search was conducted in MEDLINE via PubMed to identify relevant articles on the topic. The search terms used in these articles were then employed to construct a comprehensive search strategy for MEDLINE, which was subsequently adapted for use in other databases, including Cochrane Central, Scopus, PEDro, and Web of Science. Additionally, grey literature and reference lists of pertinent studies were examined. The search was performed on September 30, 2024, with no restrictions on publication date.

PubMed: ("Apple Watch" OR "smartwatch" OR "wearable technology" OR "wearable device" OR "fitness tracker") AND ("rehabilitation" OR "rehab" OR "cardiac rehabilitation" OR "orthopedic rehabilitation" OR "physical therapy" OR "postoperative recovery" OR "stroke rehabilitation" OR "neurological rehabilitation") AND ("heart rate monitoring" OR "ECG" OR "activity tracking" OR "energy expenditure" OR "step count" OR "remote monitoring" OR "tele-rehabilitation" OR "patient adherence" OR "patient engagement")

Scopus: (TITLE-ABS-KEY("Apple Watch") OR TITLE-ABS-KEY("smartwatch") OR TITLE-ABS-KEY("wearable technology") OR TITLE-ABS-KEY("fitness tracker")) AND (TITLE-ABS-KEY("rehabilitation") OR TITLE-ABS-KEY("cardiac rehabilitation") OR TITLE-ABS-KEY("physical therapy") OR TITLE-ABS-KEY("neurological rehabilitation") OR TITLE-ABS-KEY("postoperative recovery")) AND (TITLE-ABS-KEY("heart rate monitoring") OR TITLE-ABS-KEY("ECG") OR TITLE-ABS-KEY("activity tracking") OR TITLE-ABS-KEY("step count") OR TITLE-ABS-KEY("remote monitoring") OR TITLE-ABS-KEY("tele-rehabilitation"))

Cochrane: ("Apple Watch" OR "smartwatch" OR "wearable technology" OR "fitness tracker")

AND ("rehabilitation" OR "cardiac rehab" OR "physical therapy" OR "stroke rehab" OR "postoperative recovery" OR "neurological rehabilitation")

AND ("ECG" OR "heart rate" OR "physical activity" OR "step count" OR "energy expenditure" OR "remote monitoring")

Web of Science: TS=("Apple Watch" OR "smartwatch" OR "wearable technology" OR "fitness tracker") AND TS=("rehabilitation" OR "cardiac rehabilitation" OR "physical therapy" OR "neurological rehabilitation" OR "postoperative recovery") AND TS=("heart rate monitoring" OR "ECG" OR "activity tracking" OR "step count" OR "energy expenditure" OR "tele-rehabilitation" OR "remote monitoring")

Pedro: "Apple Watch" OR "smartwatch" OR "wearable technology" OR "fitness tracker" AND "rehabilitation" OR "physical therapy" OR "cardiac rehabilitation" OR "stroke rehabilitation" OR "neurological rehabilitation" AND "heart rate" OR "ECG" OR "activity tracking" OR "step count" OR "energy expenditure"

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2.5. Study Selection

The study selection process followed a systematic approach tailored for a scoping review. Initially, search results were gathered and refined in Zotero, where duplicate records were removed. Screening was conducted in two stages: first by reviewing titles and abstracts, followed by a full-text evaluation. Both stages were independently performed by two authors, with any disagreements resolved by a third reviewer. The process adhered to PRISMA 2020 guidelines to ensure transparency and reliability, aiming to identify studies that directly addressed the research question while maintaining a thorough and systematic approach.

2.6. Data Extraction and Data Synthesis

Data extraction was carried out using a form based on the JBI tool, capturing key information such as author names, publication details (country and year), study design, patient demographics, outcomes, interventions, and procedures. Descriptive analyses of the data were conducted, with findings presented numerically to illustrate the distribution of studies. The review process was documented for transparency, and data were summarized in tables for straightforward comparison and understanding of key study aspects and outcomes.

3. Results

The PRISMA 2020 flow diagram (Figure 1) illustrates the study selection process. Out of 182 records initially identified, 177 were excluded, resulting in 5 included articles (Table 1). The quality of these studies was assessed using ROB2 and ROB-I (Table 2).

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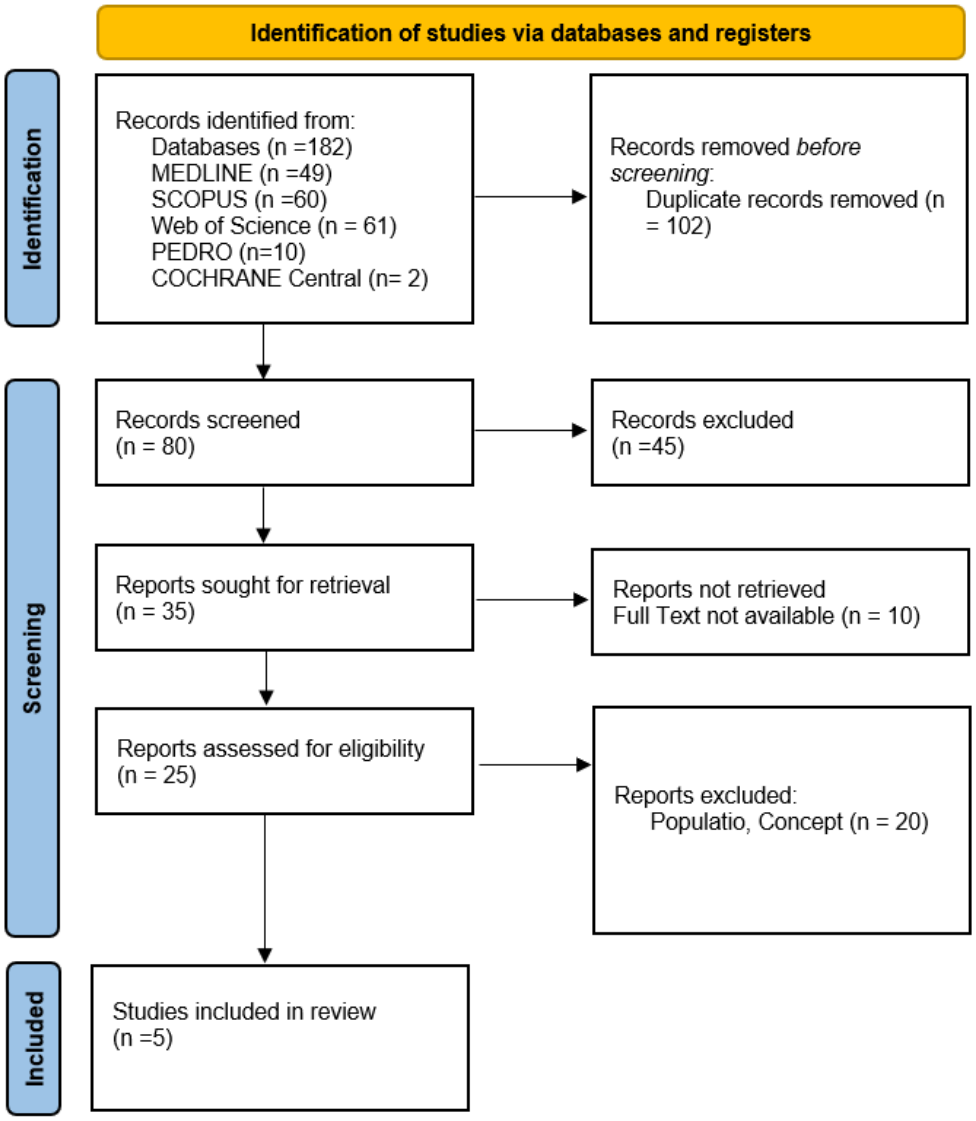

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 flow diagram.

Table 1. Main characteristics of included studies. This table summarizes the details of studies on the use of the Apple Watch in rehabilitation contexts, highlighting the study design, participant population, intervention, control group, and outcomes with corresponding follow-ups.

Author and Year	Study Design	Country	Sample Size and Participant Characteristics	Intervention and Control	Outcomes and Follow-Up
Jeganathan et al., 2022[6]	Prospective, Randomized-Controlled Trial	USA	150 participants with cardiovascular disease (aged 45-70), classified as low to moderate risk based on the American Association of Cardiovascular and Pulmonary	Intervention: Participants received an Apple Watch 4 with a Just-in-Time Adaptive Intervention (JITAI) for physical activity monitoring and personalized notifications.	Primary outcomes: 6-minute walk test distance and daily step count. Follow-up: 6 months. Significant improvement in physical activity levels and functional capacity in the intervention group.

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			Rehabilitation criteria.	Control: Usual care with no additional device.	
Turakhia et al., 2019[8]	Prospective, Single-Arm Pragmatic Study	USA	419,093 participants aged ≥22, all users of the Apple Watch Series 1 or later with no prior history of atrial fibrillation (AF).	All participants received the Apple Watch irregular pulse notification algorithm. Those notified of an irregular pulse received ambulatory ECG patch monitoring as follow-up.	Primary outcome: Detection rate of AF based on ECG confirmation following a notification. Follow-up: 3 months. The study demonstrated the feasibility of large-scale AF screening using wearables.
Sun et al., 2023[2]	Randomized Cross-Over Trial	China	11 male adults (aged 22.5 ± 1.8 years) with regular physical activity habits (3+ sessions per week) and a BMI ≤ 25.	Intervention: Participants wore both the Apple Watch 6 and Polar A370 while performing treadmill and ground running exercises. Control: Calorimetric analysis as a reference.	Outcomes: Energy expenditure accuracy compared to calorimetric measurements during rest and various physical activity levels. Follow-up: Immediate comparison; higher mean error observed for Apple Watch.
Zahrt et al., 2023[4]	Longitudinal Randomized Controlled Trial	USA	162 adults aged 25-55 recruited through online platforms, divided into four groups based on the type of step count feedback provided via Apple Watch.	Groups: Accurate step count; 40% deflated; 40% inflated; accurate step count + meta-mindset intervention. Control: Accurate step count only.	Outcomes: Perception of physical activity adequacy, dietary habits, and mental health. Follow-up: 5 weeks. Meta-mindset intervention group showed improved self-perception and physical health metrics.
Gillinov et al., 2017[9]	Prospective Study	USA	50 healthy adult volunteers (aged 38 ± 12 years, 54% female) with no known cardiovascular or pulmonary disease, capable of performing aerobic exercise.	Intervention: Participants wore Apple Watch, Fitbit Blaze, Garmin, and Polar HR monitors during various exercises. Control: ECG monitoring as the gold standard.	Outcomes: Accuracy of heart rate measurement compared to ECG during treadmill, cycling, and elliptical exercises. Follow-up: Immediate during exercise. Apple Watch showed variable accuracy across activities.

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Legend: **AF**: Atrial Fibrillation, **BMI**: Body Mass Index, **ECG**: Electrocardiogram, **JITAI**: Just-in-Time Adaptive Intervention.

3.1. Physical Activity and Functional Capacity

- **Jeganathan et al., 2022[6]:**
  - The intervention using the Apple Watch 4, which included a Just-in-Time Adaptive Intervention (JITAI) system, showed a significant improvement in participants' functional capacity as measured by the 6-minute walk test (6MWT). Participants in the intervention group recorded an average increase of 54 meters compared to baseline, while the control group showed minimal change. Additionally, the daily step count increased by an average of 32% in the intervention group, suggesting improved adherence to rehabilitation programs.
  - **Implications**: These results indicate that the use of the Apple Watch as an adaptive monitoring tool can significantly enhance physical activity levels and functional capacity in patients with moderate-risk cardiovascular conditions.

3.2. Arrhythmia Monitoring and Cardiac Health

- **Turakhia et al., 2019[8]:**
  - The study evaluated the effectiveness of the Apple Watch in detecting arrhythmias, specifically atrial fibrillation (AF). Among participants who received an irregular pulse notification, 34% had confirmed AF through subsequent ambulatory ECG monitoring. Implementing such large-scale screening demonstrated potential effectiveness in uncovering previously undiagnosed AF cases, allowing for early intervention.
  - **Implications**: This study supports the use of the Apple Watch as a non-invasive screening tool for cardiac health, suggesting that it could be integrated into cardiac rehabilitation programs to monitor patients in real-time.

3.3. Energy Expenditure Accuracy and Activity Monitoring

- **Sun et al., 2023[2]:**
  - The Apple Watch 6 was tested for its accuracy in measuring energy expenditure compared to direct calorimetric analysis during treadmill and ground running exercises. The results showed an average discrepancy of 20% compared to the reference values, with higher errors observed during high-intensity activities. Compared to the benchmark device (Polar A370), the Apple Watch tended to overestimate energy expenditure.
  - **Implications**: While the Apple Watch offers accessible, real-time monitoring, the discrepancy in data suggests the need for further calibration or algorithmic improvements to ensure more accurate measurements, which is crucial in rehabilitation settings where energy expenditure accuracy is vital for exercise prescription.

3.4. Perceived Activity Adequacy and Behavioral Outcomes

- **Zahrt et al., 2023[4]:**
  - Participants who received accurate physical activity feedback via the Apple Watch reported improved perception of their activity as adequate, along with improvements in mental health metrics such as reduced anxiety (assessed using PROMIS-29). The group that received accurate feedback combined with a meta-mindset intervention showed further enhancements, not only in activity perception but also in dietary habits and overall behavior compared to the accurate feedback group alone.
  - **Implications**: These results indicate that the Apple Watch, when integrated with targeted cognitive interventions, can positively influence perception and adherence to physical activity, with beneficial effects on behavioral and psychological health outcomes for patients in rehabilitation.

3.5. Heart Rate Monitoring Accuracy

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- **Gillinov et al., 2017[9]:**
  - The study assessed the accuracy of the Apple Watch during various aerobic activities (treadmill, cycling, and elliptical) by comparing it to ECG as the gold standard. The Apple Watch showed high accuracy during treadmill exercise (concordance correlation coefficient rc = 0.92), but its accuracy was variable during elliptical use, especially when using arm levers.
  - **Implications**: These findings highlight that while the Apple Watch can be reliable for heart rate monitoring in certain exercise types, caution is necessary in contexts where accuracy is critical, such as during the early stages of cardiac rehabilitation programs.

Table 2. Summary of Risk of Bias Assessment for the Selected Studies. This table summarizes the risk of bias assessment for the five selected studies using appropriate tools based on study design. It includes the domains evaluated and the overall risk of bias rating, highlighting specific issues such as confounding, randomization process, carryover effects, and outcome measurement.

Study	Design	Risk of Bias Tool	Domains Assessed	Overall Risk of Bias
Jeganathan et al., 2022[6]	Prospective, Randomized-Controlled Trial (RCT)	RoB 2	- Randomization process - Deviations from intended interventions - Measurement of outcomes - Incomplete outcome data - Selection of the reported result	Moderate (Risk in randomization process due to lack of concealment)
Turakhia et al., 2019[8]	Prospective, Single-Arm Pragmatic Study	ROBINS-I	- Confounding - Participant selection - Intervention classification - Measurement of outcomes - Missing data - Selection of the reported result	High (Significant confounding and selection bias)
Sun et al., 2023[2]	Randomized Cross-Over Trial	RoB 2 (Crossover)	- Randomization sequence - Carryover effect - Measurement of outcomes - Incomplete data management	Low (Proper randomization and washout period)
Zahrt et al., 2023[4]	Longitudinal Randomized Controlled Trial	RoB 2	- Randomization process - Deviations from intended interventions - Measurement of outcomes - Incomplete outcome data - Selection of the reported result	Moderate (Risk in outcome measurement due to lack of blinding)
Gillinov et al., 2017[9]	Prospective Study	ROBINS-I	- Confounding - Participant selection - Intervention classification - Measurement of outcomes - Missing data	Moderate (Confounding and measurement bias present)

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	- Selection of the reported result

Notes:

- Jeganathan et al., 2022[6]: The randomization process presented some issues, specifically with allocation concealment, which may have led to a moderate risk of bias. However, outcome measurements and adherence to protocol were consistent.
- Turakhia et al., 2019[8]: Being a single-arm study, the primary risk was confounding and participant selection bias. The absence of a control group and potential unmeasured variables contributed to a high overall risk of bias.
- Sun et al., 2023[2]: The crossover design was well-implemented, with proper randomization and washout periods to minimize carryover effects. Thus, it was rated as having a low risk of bias.
- Zahrt et al., 2023[4]: While randomization was performed, the outcome measurement lacked blinding, introducing moderate bias in the results.
- Gillinov et al., 2017[9]: Confounding factors and measurement biases, particularly in how interventions were classified and outcomes measured, led to a moderate risk of bias.

4. Discussion

The objective of this review was to evaluate the effectiveness and accuracy of the Apple Watch as a tool for monitoring and supporting rehabilitation programs, particularly focusing on its capacity to improve physical activity adherence, monitor cardiovascular health, and provide accurate physiological data. The findings from the five studies reviewed provide a comprehensive view of the strengths and limitations of the Apple Watch in various rehabilitation contexts. This discussion will critically analyze the results, comparing outcomes across studies to determine the overall utility of the Apple Watch in clinical practice and rehabilitation settings.

4.1. Physical Activity and Functional Outcomes

The studies by Jeganathan et al. (2022)[6] and Zahrt et al. (2023)[4] both explored the impact of the Apple Watch on physical activity adherence and functional capacity. Jeganathan et al.[6] demonstrated that the use of the Apple Watch with a Just-in-Time Adaptive Intervention (JITAI) led to significant improvements in the 6-minute walk test and daily step count, indicating that adaptive, real-time feedback can effectively enhance functional outcomes in cardiovascular rehabilitation. The results align with the findings of Zahrt et al.[4], who reported that accurate activity feedback combined with a meta-mindset intervention not only improved perceived activity adequacy but also had a positive effect on dietary habits and mental health. These findings suggest that the Apple Watch, when integrated with behavioral and cognitive interventions, can create a comprehensive support system for patients, reinforcing physical activity while simultaneously addressing behavioral and psychological components[39–41].

However, the comparison between these two studies highlights the critical role of intervention design. While Jeganathan et al.[6] primarily used adaptive feedback, Zahrt et al.[4] combined feedback with cognitive behavioral techniques, which seemed to amplify the positive effects on both physical and mental health outcomes. This suggests that, although the Apple Watch is effective as a standalone monitoring device, its full potential may be realized when combined with cognitive or psychological support mechanisms. The integration of such approaches could therefore be recommended for rehabilitation programs aiming to maximize adherence and health behavior change[42,43].

4.2. Cardiovascular Monitoring and Health Outcomes

The effectiveness of the Apple Watch as a tool for cardiovascular monitoring was highlighted in Turakhia et al. (2019)[8], which investigated the device's capacity to detect atrial fibrillation (AF) on a large scale. The study demonstrated that the Apple Watch’s irregular pulse notification system can

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detect AF with a 34% confirmation rate upon further ECG monitoring, showcasing the feasibility of using wearable technology for early detection in population-wide screening initiatives. These findings are significant because they provide evidence that the Apple Watch can be a valuable tool in monitoring cardiac health and identifying potential arrhythmias early, which is critical in preventing more severe cardiac events.

Nevertheless, the study's single-arm pragmatic design introduces some limitations, such as confounding factors that may influence detection accuracy. Unlike controlled environments, real-world application of such technology may yield variable results depending on user behavior and adherence. Thus, while the results are promising, further studies with controlled designs and comparison groups are necessary to validate these findings and ensure they are reproducible in different patient populations and contexts[44–46].

4.3. Accuracy in Physiological Monitoring

The studies by Sun et al. (2023)[2] and Gillinov et al. (2017)[9] focused on the accuracy of the Apple Watch in monitoring energy expenditure and heart rate, respectively. Sun et al.[2] found discrepancies in the Apple Watch's energy expenditure measurements compared to direct calorimetric analysis, particularly during high-intensity physical activities. This overestimation issue indicates that, while the Apple Watch provides a general estimate, it may not be reliable enough for precise energy monitoring required in rehabilitation settings where accurate data is essential for tailoring exercise prescriptions.

Similarly, Gillinov et al.[9] examined the Apple Watch's accuracy in heart rate monitoring across various aerobic exercises. The results showed variability in accuracy, with the device performing well during treadmill exercises but showing less reliability during elliptical use, especially when arm levers were involved. This variation suggests that the accuracy of the Apple Watch is influenced by the type of physical activity and the movement patterns associated with it. Such findings highlight the necessity of considering exercise type when interpreting data from the Apple Watch, as its reliability may not be consistent across different modes of activity.

4.4. Implications for Rehabilitation Programs

The evidence presented across these studies indicates that the Apple Watch, while beneficial in promoting physical activity adherence and providing early cardiac monitoring, has limitations that must be addressed to optimize its use in rehabilitation settings. The variability in measurement accuracy, as highlighted by **Sun et al.**[2] and **Gillinov et al.**[9], underscores the need for further development in the device's algorithms to enhance precision, especially for energy expenditure and heart rate monitoring during diverse physical activities.

Moreover, the integration of the Apple Watch with behavioral interventions, as seen in Zahrt et al.[4], shows that combining wearable technology with psychological support can enhance outcomes beyond physical metrics alone. This indicates a potential pathway for optimizing rehabilitation programs: the Apple Watch could be utilized not only as a physiological monitoring tool but also as part of a more comprehensive, multidisciplinary approach that incorporates behavioral, psychological, and physical health strategies[47–50].

4.5. Limitations and Future Directions

While the reviewed studies provide valuable insights, there are limitations that need to be addressed. First, the risk of bias in several studies, particularly those with non-randomized designs like **Turakhia et al.**[8], indicates the need for more robust study designs to strengthen the evidence base. Additionally, the variability in adherence and measurement accuracy observed suggests that future research should explore ways to enhance user engagement and refine device algorithms to reduce errors. Such improvements could significantly enhance the Apple Watch's reliability and utility in rehabilitation programs.

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4.6. Clinical Practice Implications

Integration in Rehabilitation Protocols: The Apple Watch should be customized to each patient's rehabilitation goals, providing real-time feedback to enhance adherence and functional outcomes through remote monitoring.

Enhancing Adherence and Engagement: Combining the Apple Watch with behavioral and cognitive support (e.g., goal reminders and motivational messaging) can sustain patient engagement and improve both physical and mental health outcomes.

Cardiovascular Monitoring: The device's ECG capabilities can be integrated into cardiac rehabilitation for early arrhythmia detection and risk stratification, allowing for timely clinical interventions.

Optimizing Accuracy: Due to variability in accuracy, clinicians should use the Apple Watch as a supplementary tool and calibrate it against validated devices. Regular data reviews with patients can ensure accurate exercise prescriptions.

Facilitating Home-Based Programs: The Apple Watch supports tele-rehabilitation, enabling remote, scalable programs and empowering patients to manage their recovery through real-time health tracking.

Addressing Limitations: Clinicians should combine the Apple Watch with traditional tools for comprehensive monitoring. Education and training for both clinicians and patients are essential to maximize its effectiveness and mitigate its limitations.

5. Conclusions

The Apple Watch holds significant promise for enhancing rehabilitation programs by promoting physical activity adherence, offering real-time cardiovascular monitoring, and supporting remote patient management. However, its effective implementation in clinical practice requires a strategic and informed approach that combines the technology's capabilities with additional behavioral support and clinical validation methods. By addressing the limitations in accuracy and incorporating training and hybrid monitoring techniques, healthcare providers can maximize the Apple Watch's potential as a valuable tool in modern rehabilitation programs.

Author Contributions: RT snd PD conceptualized and designed the study and was responsible for data acquisition. RT drafted the manuscript. DD provided supervision and guidance throughout the study. FG and TD performed the editing of the manuscript. PB reviewed the manuscript and curated the methodology. All authors have read and approved the final version of the manuscript.

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