Review article

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Progress in the management of type 2 diabetes mellitus: a narrative review of telerehabilitation and wearable devices

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Type 2 diabetes mellitus (T2DM) management demands innovative strategies that address its complex nature. Telerehabilitation and conventional rehabilitation, which utilize wearable devices, represent promising avenues in this regard. This narrative review synthesizes the current literature to comprehensively compare these modalities in terms of accessibility, monitoring mechanisms, patient adherence, cost-effectiveness, and social support. Telerehabilitation offers unparalleled convenience, real-time monitoring, and personalized feedback through wearables, thereby fostering greater patient engagement and adherence compared to conventional rehabilitation. However, conventional rehabilitation provides face-to-face interactions, immediate feedback, and a more personalized touch, albeit with logistical challenges and higher costs. This review emphasizes the significance of patient preferences, technological access, and healthcare infrastructure in selecting the appropriate approach. It also calls for further research into long-term outcomes, cost-effectiveness, and the optimal integration of wearable technology in diabetes management programs. Ultimately, both telerehabilitation and conventional rehabilitation demonstrate considerable potential in empowering individuals with T2DM, underlining the imperative for tailored and patient-centric interventions in diabetes care. The review also stresses the significance of integrating patient preferences and their level of comfort with technology when deciding on treatment approaches. It also takes into account the diverse socioeconomic contexts and healthcare infrastructures globally, which can affect the viability and efficacy of both telerehabilitation and conventional rehabilitation. Moreover, the integration of wearable technology in diabetes management programs holds promise for enhancing self-management capabilities and promoting healthier lifestyles. However, it is essential to tackle prospective discrepancies in access to these technologies and ensure fair distribution. Looking forward, ongoing research efforts should focus on justifying long-term outcomes, optimizing cost-effectiveness, and refining implementation strategies to maximize the benefits of both modalities.

Keywords: Tele rehabilitation, Wearable devices, Exercise, diabetes Mellitus, Therapeutic exercise, Physical fitness

Highlights

- Telerehabilitation and wearable-based rehabilitation strategies are increasingly recognized for their positive impact on managing type 2 diabetes mellitus. These approaches enable individuals to engage in guided physical activity and self-care routines from the comfort of their homes, making diabetes management more accessible and sustainable. Telerehabilitation involves remote supervision through video calls, mobile apps, or online

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platforms, allowing healthcare providers to deliver tailored exercise regimens and lifestyle guidance.

Introduction

Type 2 diabetes mellitus (T2DM) is a global health concern with a steadily increasing prevalence that poses significant challenges to healthcare systems worldwide. The multifaceted nature of T2DM necessitates comprehensive management strategies that encompass lifestyle modifications, pharmacotherapy, and ongoing monitoring of key health indicators [1]. In recent years, the convergence of healthcare and technology has sparked innovation in diabetes management, particularly through the utilization of wearable devices in rehabilitation programs.

The use of wearable technology in both telerehabilitation and traditional rehabilitation has shown promise in improving the management of T2DM [2]. During telerehabilitation, which uses digital and telecommunication platforms to deliver rehabilitation interventions remotely, patients can participate in the recommended activities from the comfort of their homes [3]. Wearable technology is used in conjunction with this strategy to monitor physiological data in real-time and give patients and healthcare professionals insightful feedback. Conventional therapy, in contrast, usually entails in-person sessions held in medical facilities or specialist rehabilitation centers [4]. Wearable technology is, nevertheless, being added to these sessions more frequently in order to support data gathering, monitoring, and customized feedback.

This narrative review seeks to provide a comprehensive examination of the comparative effectiveness of telerehabilitation and conventional rehabilitation with wearable devices in T2DM management. By synthesizing the existing literature and empirical evidence, we aim to elucidate the strengths and limitations of each approach across various dimensions, including accessibility, monitoring mechanisms, patient adherence, cost-effectiveness, and social support [5]. Through this exploration, we offer insights that can inform decision-making processes for healthcare providers, policymakers, and individuals living with T2DM.

Moreover, this review adds to the larger conversation about how technology-driven solutions might be integrated into the treatment of chronic illnesses [6]. We intend to encourage more research and innovation in this field by showcasing the potential of wearable technology and telerehabilitation in T2DM care. Our ultimate objective is to further our knowledge of the best approaches to managing T2DM and to enhance the lives of those who are impacted by this common and difficult illness [7].

It is impossible to overestimate the significance of exercise and physical activity (PA) in the management of T2DM. Exercise is essential for preventing and managing T2DM and its associated problems, in addition to dietary and pharmaceutical therapies [8]. According to current guidelines, people with T2DM should perform weight training 3 times a week in addition to 150 minutes or more of moderate-intensity aerobic exercise each week [9]. There is evidence that going above these recommendations has a significant positive impact on blood sugar regulation and the prevention of cardiovascular illnesses [10].

In addition, the detailed characteristics of T2DM pose extra challenges to consistent exercise compliance. Many people with T2DM face obstacles like erratic energy levels, neuropathy, muscular weakness, and joint discomfort, which can make PA difficult and uncomfortable [11]. Those with T2DM also frequently worry about hypoglycemia during or after exercise, which further discourages regular PA [12].

Exercise adherence is significantly hampered in T2DM patients by social and environmental factors as well. PA can be hindered by limited access to safe and appropriate exercise facilities, including parks or gyms, especially for individuals who live in low income or metropolitan regions [13].

Furthermore, a lack of social support—from friends, family, or medical professionals—can lower accountability and motivation for sticking to exercise plans.

In addition, people with T2DM faced previously unheard-of difficulties in adhering to their exercise regimens at the start of the coronavirus disease 2019 pandemic [14]. Movement restriction, the closing of athletics facilities, and worries about viral spread interfered with PA routines, making sedentary behavior worse and jeopardizing metabolic health [4].

In order to effectively address these complex obstacles to exercise adherence in people with T2DM, extensive and customized strategies are needed. A few possible strategies to address these obstacles include personalized exercise recommendations, instructions on controlling blood sugar levels while exercising, the availability of accessible and inclusive exercise options, and the use of technology-based interventions like online fitness programs or telehealth consultations [15].

Additionally, fostering supportive social networks and addressing systemic inequalities in access to resources and opportunities for PA are crucial steps in promoting long-term adherence to exercise among individuals with T2DM [16].

In addition, an individual's age, financial situation, educational background, and real-world obstacles like employment obligations and long commutes to rehab facilities might make it more difficult for them to participate in inpatient and outpatient rehabilitation programs [10]. People from poorer socioeconomic backgrounds, for instance, might find it difficult to afford exercise equipment or fitness center memberships [17]. Elderly people might also have physical restrictions or a fear of getting hurt. Furthermore, people with hectic work schedules might find it difficult to find time to exercise [11].

Furthermore, mental health conditions including anxiety and depression can pose serious obstacles to exercise engagement for people with type 2 diabetes [18]. The psychological strain of dealing with a chronic illness such as diabetes, in addition to daily stressors, can discourage people from exercising [19]. Furthermore, people with comorbidities related to diabetes may be discouraged from beginning or continuing an exercise regimen due to misconceptions or worries regarding the possible hazards associated with exercise [20].

Exercise is viewed by many as requiring significant time and organizational and personal commitment. As a result, many T2DM patients are unable to benefit from organized

rehabilitation programs, which feeds the vicious cycle of poor illness management and increased risk of complications [21].

Given these challenges, there is an urgent need for tailored interventions and innovative approaches to promote exercise adherence among individuals with T2DM. Strategies aimed at addressing barriers to participation, such as offering flexible scheduling options, utilizing telehealth platforms for remote supervision and support, and providing culturally sensitive and personalized exercise plans, show promise in enhancing engagement and outcomes in T2DM management [22]. Furthermore, community-based projects, peer support groups, and educational initiatives can be extremely helpful in fostering an atmosphere that encourages frequent engagement in PA [23]. Healthcare professionals can empower people with T2DM to take control of their health and reduce the risks associated with this chronic condition by addressing the numerous barriers to exercise adherence [24].

A flow chart in Fig. 1 summarizes the difference between telerehabilitation and conventional rehabilitation.

Use of wearable devices among adults with T2DM

According to surveys conducted in the last 5 years, the use of wearable devices is increasing globally. One survey conducted in 2019 (Fig. 2) described 1,149 self-reported cases of diabetes mellitus among whom 51.2% of the patients were female, 59.3% were Caucasian, and 51.6% had a college degree. One quarter (25%) of wearable device users shared information with their healthcare practitioners. Similarly, a 2020 survey conducted by the American Diabetes Association found that approximately 30% of adults with T2DM use some form of wearable technology. In 2022, around 25% of respondents said they used wearable technology, while approximately 40% reported using health apps and wearable devices in 2023 [25] (Fig. 2). Database of 2024 need to be updated.

Methodology

An electronic databases search, including PubMed, MEDLINE, and Google Scholar, was conducted to identify relevant studies published between 2010 and March 2024 for this narrative review. The primary question used to evaluate this study was, "Which mode of rehabilitation (telerehabilitation or conventional) is effective for T2DM patients?"

1. Inclusion and exclusion criteria

Studies were included if they examined the use of telerehabilitation or conventional rehabilitation with wearable devices in T2DM management and provided relevant outcome measures. Studies were excluded if they were not available in English or lacked sufficient detail regarding the intervention and outcomes.

2. Keywords

MeSH keywords were used (Table 1).

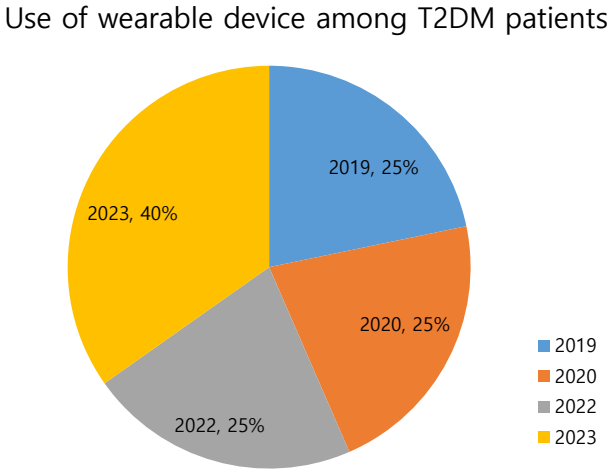

Fig. 2. Use of wearable devices among type 2 diabetes mellitus (T2DM) patients from 2019–2023.

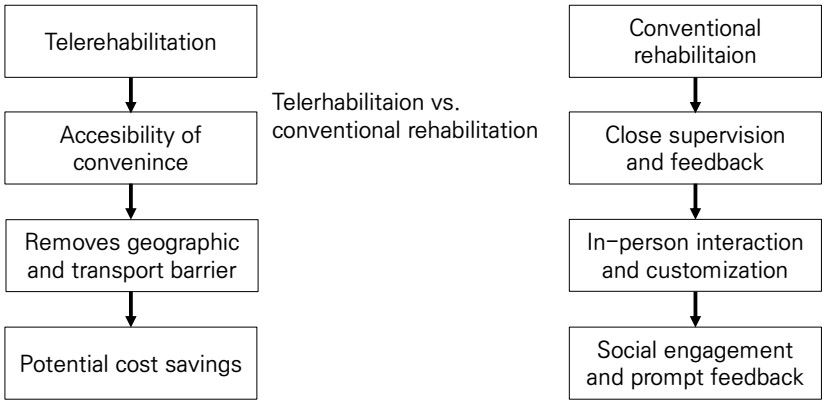

Fig. 1. Telerehabilitation vs. conventional rehabilitation.

Table 1. MeSH keywords

	Keywords
PubMed	("Telerehabilitation" [MESH]) AND "Diabetes Mellitus" [MESH] "Telerehabilitation" [MESH] AND "Diabetes Mellitus" [MESH] "Blood Glucose" [MESH] "Telerehabilitation" [MESH]) AND "Wearable Devices" [MESH] AND "Telerehabilitation" [MESH]) AND "Conventional Rehabilitation" [MESH] AND "Wearable Devices [MESH] AND" Type 2 Diabetes" [MESH] AND "Wearable Devices [MESH] AND "Conventional Rehabilitation " [MESH] "Wearable Devices [MESH] AND "Exercise" [MESH])
MEDLINE	(MH "Telerehabilitation") AND (MH "Diabetes Mellitus") (MH "Diabetes Mellitus, Type 2") AND (MH "Wearable Devices) AND (MH "Conventional Rehabilitation") AND (MH "Blood Glucose") AND (MH "Exercise")

MeSH, medical subject heading.

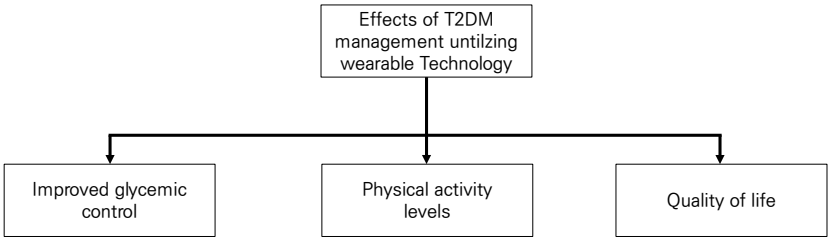

Fig. 3. Primary outcome used for the management of type 2 diabetes mellitus (T2DM) with wearable devices.

Results

Both telerehabilitation and conventional rehabilitation approaches augmented with wearable devices hold promise in the effective management of T2DM. While comparative studies provide insights into their relative efficacy, addressing challenges and considerations is critical for optimizing their implementation and maximizing benefits for individuals with T2DM.

1. Telerehabilitation vs. conventional rehabilitation

A study has evaluated the effectiveness of telerehabilitation in T2DM management. They found that telerehabilitation interventions, utilizing wearable devices for remote monitoring and exercise prescriptions, resulted in significant improvements in glycemic control, PA levels, and quality of life among individuals with T2DM [13].

In a study participants with T2DM were provided with a telerehabilitation program comprised of home-based exercise sessions that were monitored by wearable devices. The study reported a significant reduction in glycosylated hemoglobin (HbA1c) levels and improvements in cardiovascular fitness compared to those of the control group receiving standard care [25].

A study investigated the effectiveness of a conventional rehabilitation program augmented with wearable devices in T2DM management. Participants attended supervised exercise sessions at a rehabilitation center while wearing activity trackers and heart rate monitors. The results showed improvements in physical function, glucose control, and self-management behaviors [26].

Similarly, the impact of a structured exercise program combined with wearable technology in individuals with T2DM. Participants attended regular exercise sessions led by physiotherapists while wearing activity trackers and receiving real-time feedback on their performance. The study demonstrated significant improvements in glycemic control, insulin sensitivity, and cardiovascular fitness [21,25].

An observational study by the effectiveness of telerehabilitation versus conventional rehabilitation with wearable devices in T2DM management. The results indicated comparable improvements in glycemic control and physical function between the 2 modalities, with telerehabilitation showing advantages in terms of accessibility and convenience [21].

A comprehensive review provided an overview of telemedicine interventions, including telerehabilitation, in diabetes care. The authors discussed various modalities of telemedicine, including remote monitoring, virtual consultations, and mobile health applications, and their impact on glycemic control, patient satisfaction, and healthcare utilization. While the review covered a broad spectrum of telemedicine applications, it includes insights into the effectiveness of telerehabilitation with wearable devices in T2DM management [27].

A study concluded that the role of wearable technology in diabetes management, including its application in rehabilitation programs. The review summarized studies investigating the role of wearable devices, such as continuous glucose monitors, activity trackers, and smart insulin pumps, in improving glycemic control, PA levels, and adherence to treatment regimens among individuals with diabetes. The authors highlighted the potential of wearable technology to enhance rehabilitation outcomes and support self-management in diabetes care [26].

It has been explored implementation science perspectives on telerehabilitation in diabetes care. The authors discussed factors influencing the adoption, implementation, and sustainability of telerehabilitation interventions in real-world settings, including organizational readiness, stakeholder engagement, and policy considerations [28]. While the review focused on

telerehabilitation broadly, it offered insights into the challenges and opportunities of integrating wearable devices into rehabilitation programs for diabetes management [28].

Despite the promising results of telerehabilitation and conventional rehabilitation with wearable devices in T2DM management, several challenges exist. These include technological barriers, patient adherence, reimbursement issues, and the need for healthcare provider training and support [29].

Additionally, the integration of wearable technology into rehabilitation programs requires careful consideration of privacy, data security, and regulatory compliance to ensure patient safety and confidentiality.

The primary outcome used to evaluate the management of T2DM with wearable devices is mentioned in Fig. 3.

Discussion

Wearable technology-based telerehabilitation and traditional rehabilitation have demonstrated the potential to enhance multiple facets of T2DM care. The benefit of telerehabilitation is accessibility; it allows people to take part in therapy sessions from a distance, removing obstacles like geographic location and transportation problems. Additionally, wearable technology allows for real-time monitoring of important health indicators, which makes tailored interventions and feedback possible. Research has indicated enhancements in glycemic control, PA levels, and overall quality of life for participants in telerehabilitation initiatives.

Wearable technology integration is advantageous for conventional rehabilitation as well, despite its more conventional approach. Face-to-face meetings have the advantage of close supervision, prompt feedback, and customized solutions according to each client's needs. Wearable technology improves progress tracking and monitoring, thereby enabling medical professionals to modify rehabilitation schedules as necessary. Conventional rehabilitation provides a more individualized and involved experience for participants, even though it might not be as convenient as is remote access [23].

The distant accessibility of telerehabilitation fosters inclusion by giving people in underserved or rural areas access to specialized diabetes management programs that might not be offered locally. Many patients find it more realistic to participate because of the flexibility of scheduling remote sessions, which also lessens the strain of travel and accommodates busy lifestyles [23].

Additionally, the continuous monitoring facilitated by wearable devices enables early detection of fluctuations in health parameters, prompting timely interventions and preventing potential complications. This proactive approach contributes to better long-term outcomes and empowers individuals to take an active role in managing their condition. Conventional rehabilitation, complemented by wearable technology, offers a hands-on approach that fosters a strong patient-provider relationship. In-person interaction allows for nuanced assessment of progress and challenges, facilitating tailored interventions that address individual needs effectively. Furthermore, the social support and camaraderie fostered in group rehabilitation settings can enhance motivation and adherence to treatment plans [17,29].

The comparison between telerehabilitation and conventional rehabilitation with wearable devices in T2DM management highlights several important considerations for optimizing patient care and improving outcomes in this chronic condition.

Accessibility and convenience

The benefit of telerehabilitation is that it allows people to receive rehabilitation treatments from a distance, circumventing obstacles like time, location, and transportation issues. Wearable technology offers convenience and flexibility by enabling people with T2DM to participate in rehabilitation activities from the comfort of their own homes. Conversely, some patients may find it logistically difficult to travel to medical facilities or specialist clinics for conventional rehabilitation. Nonetheless, it is crucial to guarantee fair access to telerehabilitation services, especially for people with low income or computer literacy [30].

Monitoring mechanisms and personalization

Wearable technology is used in both traditional rehabilitation and telerehabilitation to track important health metrics and provide tailored feedback. With the use of wearable technology, blood glucose levels, PA levels, and other pertinent data may be tracked in real-time, which helps with personalized treatment programs and exercise recommendations. Additionally, wearable technology facilitates data collection and remote supervision, which enables medical professionals to track patients' progress and modify interventions accordingly. To optimize its usefulness and efficacy, wearable technology integration into traditional rehabilitation may necessitate more training for medical personnel [31].

Patient adherence and engagement

Involving people with T2DM in rehabilitation programs is essential to attaining favorable health results. Wearable technology is used in telerehabilitation to provide interactive features, educational materials, and motivational assistance to encourage patients to stick with their treatment plans. Patients are empowered to actively participate in their health management through the use of remote monitoring and feedback systems, which also promote self-management practices. In contrast, traditional rehabilitation allows for face-to-face monitoring, social engagement, and prompt feedback from medical professionals, which promotes motivation and a sense of responsibility. Customized to each patient's preferences and needs, strategies to improve patient adherence may include goal-setting, incentive programs, and peer support networks [31,32].

Cost-effectiveness and sustainability

The comparative analysis of wearable device-assisted tradi-

tional rehabilitation and telerehabilitation based on wearable technology costs depends on a number of aspects, such as long-term sustainability, reimbursement policies, and infrastructure requirements. Because telerehabilitation cuts down on travel costs, hospital overhead, and healthcare professional time, it may result in potential cost savings. Furthermore, telerehabilitation platforms' scalability enables a wider audience to receive services, especially in isolated or underprivileged areas. However, healthcare companies may face financial difficulties due to the initial cost of investing in IT infrastructure and continuing maintenance expenses. Conventional rehabilitation, in contrast, can offer prospects for higher income through direct service delivery but might also come with a larger upfront investment in facility equipment and staff training [33].

Social support and community engagement

For people with T2DM, telerehabilitation and traditional rehabilitation are equally important in building social support systems and community involvement. Platforms for telerehabilitation can host online peer support groups, educational workshops, and virtual group sessions, bringing people together via similar experiences and fostering a sense of community. Wearable technology facilitates social engagement by allowing users to communicate with peers and healthcare providers about their progress, accomplishments, and challenges. In a similar vein, traditional rehabilitation programs include chances for in-person communication, group activities, and community-based projects, which cultivates a sense of community and support among participants. There are various do and don'ts of both telerehabilitation and conventional rehabilitation, which are demonstrated in Fig. 4 [17,33].

Outcome variables

We evaluated the role of technology, and specifically mobile phones, on diabetes management, focusing on HbA1c as the main outcome measure. The study found a similar effect on glycemic control which reported decreases in HbA1c by 2% and 1.1%, respectively, in the technology groups, with no significant difference between intervention and control groups. It emphasizes the importance of performance-based assessments over self-report assessments for accurate outcomes. The study used both HbA1c and the 6-minute walk test as outcome measures and adopted a conservative minimal important change criterion of ≥0.5% for HbA1c, as designated by diabetes care physicians for achieving successful glycemic control [25]. Another study also found that quality of life of diabetic patients improved as did general fitness and wellbeing [31].

Clinical relevance

The comparison of wearable technology-assisted traditional rehabilitation versus telerehabilitation in the management of T2DM highlights the subtleties and complexity of contemporary healthcare delivery.

Several important judgments about the viability, efficacy, and ramifications of each technique can be made by analyzing the literature and empirical data.

There are 2 different but complimentary approaches to controlling T2DM: telerehabilitation and traditional rehabilitation using wearable technology. Utilizing wearable technology and communications technologies, telerehabilitation offers remote access to rehabilitation services while fostering accessibility, flexibility, and convenience. In contrast, wearable technology is used in traditional rehabilitation programs to improve intervention customization, monitoring, and feedback

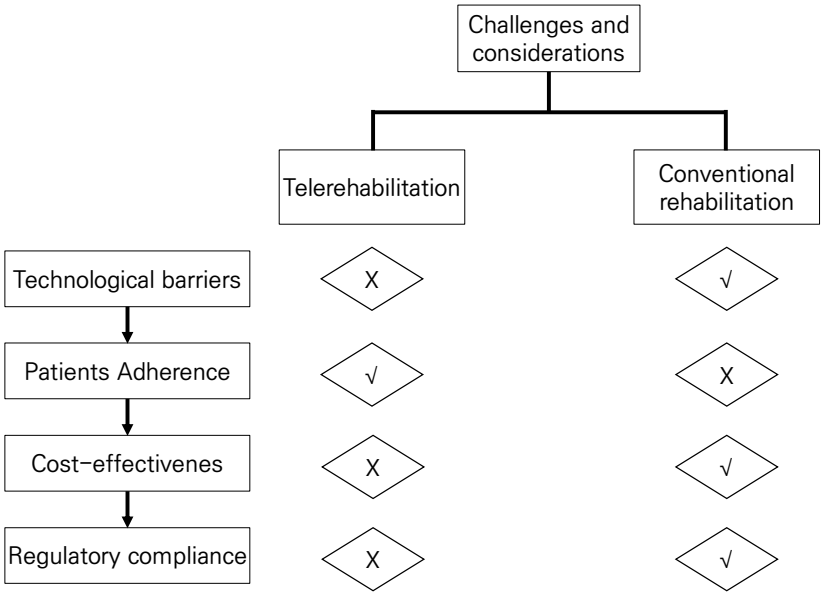

Fig. 4. Do and don'ts of both telerehabilitation and conventional rehabilitation.

in traditional healthcare settings.

Main findings

First, in order to address each patient's unique requirements, preferences, and adherence challenges, both modalities place a high priority on individualized and patient-centered therapy.

Second, wearable technology is used by telerehabilitation systems to provide interactive features, educational materials, and remote support mechanisms, enabling people to actively participate in their health management.

Third, traditional rehabilitation programs encourage accountability and incentives among participants by providing social engagement, peer support, and prompt feedback.

Limitations and future implications

There are few randomized controlled trials and other types of research that previously addressed our question. Studies focusing on T2DM and wearable devices were also limited.

Utilizing wearable technology to improve monitoring, engagement, and results, the integration of wearable devices into rehabilitation programs signifies a paradigm shift in the management of T2DM. Wearable technology allows for data-driven decision-making, remote monitoring, and real-time tracking of health metrics. This allows for more individualized interventions and treatment modifications. Additionally, wearable technology empowers patients, encourages self-management practices, and gives them a sense of control over their health results.

Both traditional rehabilitation using wearable technology and telerehabilitation have advantages, but there are drawbacks as well. These include patient adherence, reimbursement rules, technology obstacles, and infrastructure issues in the healthcare system. A holistic strategy that includes stakeholder involvement, workforce training, and technology infrastructure investment is needed to address these issues. Furthermore, to maximize the potential of interventions, eliminate access inequities, and optimize their effectiveness, continued research and innovation are necessary.

Conclusion

In conclusion, telerehabilitation and conventional rehabilitation with wearable devices represent promising strategies in T2DM management, each offering unique strengths and opportunities for improving patient outcomes. By integrating technology-driven solutions with traditional rehabilitation approaches, healthcare providers can optimize care delivery, enhance patient engagement, and ultimately, improve the quality of life for individuals living with T2DM. Continued collaboration, innovation, and investment in digital health solutions are essential to address the evolving needs of patients and advance the field of T2DM management in the modern era.

Notes

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