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MINI-REVIEW

Prescription digital therapeutics in obesity management: Present and future

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Abstract

Prescription digital therapeutics (PDTs) are emerging as innovative solutions in the management of obesity, complementing traditional methods such as lifestyle interventions, pharmacotherapy, and surgery. This mini-review explores the current landscape and future potential of PDTs in obesity management. We begin by defining PDTs and examining key players and products in the market. These products exemplify the integration of artificial intelligence -driven personalized coaching and real-time data tracking to enhance user engagement and treatment efficacy. Clinical evidence supporting the effectiveness of PDTs in promoting weight loss and improving metabolic health is discussed, with an emphasis on the comparative studies with traditional interventions. The review also addresses challenges such as regulatory hurdles, user adherence, data privacy, and accessibility issues. Looking forward, advancements in technology, personalized medicine, and better integration with healthcare systems are poised to further enhance the impact of PDTs. This article underscores the potential of PDTs to revolutionize obesity management and calls for continued innovation and research in this field.

Keywords: Obesity; Digital therapeutics; Software; Prescription

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1. Introduction

Obesity is a persistent disease that is becoming more common and is now regarded as a worldwide epidemic, raising global public health concerns over the past five decades, owing to its adverse impacts on quality of life, the risk for other diseases, and healthcare expenses.[1] Epidemiological research has shown a connection between a high body mass index (BMI) and a wide array of chronic illnesses, including non-alcoholic fatty liver, cardiovascular disease, diabetes mellitus, various cancers, musculoskeletal disorders, chronic kidney disease, and mental health issues. These conditions negatively impact individuals' quality of life and drive up healthcare costs. The World Health Organization defines obesity as a state of excessive or abnormal fat accumulation that poses additional health risks. Overweight is defined as a BMI above 25 kg/m² and obesity as a BMI over 30 kg/m². The obesity epidemic that has spread across many regions in recent decades is largely attributed to a sedentary lifestyle and reduced overall physical activity, combined with the consumption of unhealthy diets, such as those high in sugar and refined carbohydrates. This is compounded by a variety of genetic, endocrine, metabolic, and environmental factors, which are now recognized as the primary common causes of this global health issue.[2]

Lifestyle intervention represents the cornerstone of treatment for obesity. It is a multicomponent strategy that encompasses lifestyle or behavioral training, dietary change, and an increase in physical activity. Apart from lifestyle intervention, a few drugs have been approved for the management of obesity, complementing lifestyle modifications. These drugs such as orlistat, naltrexone/bupropion, liraglutide, lorcaserin, and phentermine/topiramate work to strengthen the patient's urge to modify their eating behaviors and produce an energy deficit. However, these drugs pose the additional risk of side effects of which the patient should be aware. Apart from this, nowadays, patients have surgical options, such as gastric banding, sleeve gastrectomy, and Roux-en-Y gastric bypass. Since lifestyle intervention is the central pillar for managing obesity, digital therapeutics (DTx) with their key focus on improving the lifestyle of patients are gaining momentum.[3]

DTx refer to the application of high-quality software programs to prevent, manage, or treat a medical disorder or disease.[4] Recently, DTx has surfaced as a novel strategy for managing chronic diseases that are amenable to behavioral modifications. In response to the COVID-19 public health emergency, the U.S. Food and Drug Administration (FDA) has relaxed rules to expand access to digital health devices that can be used for remote monitoring and management of diseases.[5] Table 1 presents various definitions of DTx. At present, DTx products are mainly applied to conditions that are modifiable through behavior change, such as obesity and type 2 diabetes mellitus. For instance, Welldoc Communications offers diabetes management software for mobile phones that connects to web-based data analytics, creating an interactive platform for real-time information and analysis between patients and healthcare providers.[6] Other companies in the digital healthcare space for diabetes and weight management include Noom, Livongo, Omada, Voluntis, and Lark.

This mini-review examines evidence-based therapeutic interventions powered by high-quality software programs, excluding interventions that rely solely on short message services, telephone calls, or online web-based servers. The objective of this mini-review is to evaluate the current state and the future potential of prescription DTx (PDTs) in obesity management.

2. Current landscape of PDTs in obesity management

2.1. Definition and scope

2.1.1. PDTs

PDTs include a class of evidence-based, software-driven interventions designed to treat, manage, or prevent medical conditions. Unlike general wellness applications, PDTs require a prescription from a healthcare provider, underscoring the need for their clinical validation and regulatory oversight. These therapeutic applications deliver therapeutic interventions directly to patients using smartphones, tablets, and other digital devices, integrating seamlessly into daily life and offering continuous, personalized care.[11] The workflow of PDT solutions is depicted in Figure 1.

2.2.2. Regulatory aspects and approval processes

The regulatory landscape for PDTs is rigorous, ensuring that these digital interventions meet high standards of safety and efficacy. In the United States, the FDA plays a pivotal role in the approval process of PDTs. The FDA's Digital Health Software Precertification (Pre-Cert) Program is designed to streamline the evaluation of software-based medical devices, fostering innovation while maintaining rigorous standards. This program assesses software developers based on five excellence principles: product quality, patient safety, clinical responsibility, cybersecurity responsibility, and proactive culture.[12]

To gain FDA approval, PDTs undergo a comprehensive evaluation that includes clinical trials to demonstrate their safety and effectiveness. This process is similar to that for traditional pharmaceuticals and medical devices. PDT

Table 1. Definitions of digital therapeutics based on institutions[7]

Institute	Definition of digital therapeutics
European data protection supervisor	DTx are evidence-based therapeutic interventions driven by software to prevent, manage, or treat a medical disorder or disease. In other words, DTx are patient-facing software applications that help patients treat, prevent, or manage a disease and that have a proven clinical benefit.[8]
Ministry of food and drug safety, South Korea	DTx are software, which can be used as a medical device to provide evidence-based therapeutic intervention to patients for prevention, control, or treatment of medical disabilities and/or diseases. DTx are applied to patients who require therapeutic intervention.[9]
Digital therapeutics alliance	DTx deliver medical interventions directly to patients using evidence-based, clinically evaluated software to treat, manage, and prevent a broad spectrum of diseases and disorders.[10]

Abbreviation: DTx: Digital therapeutics.

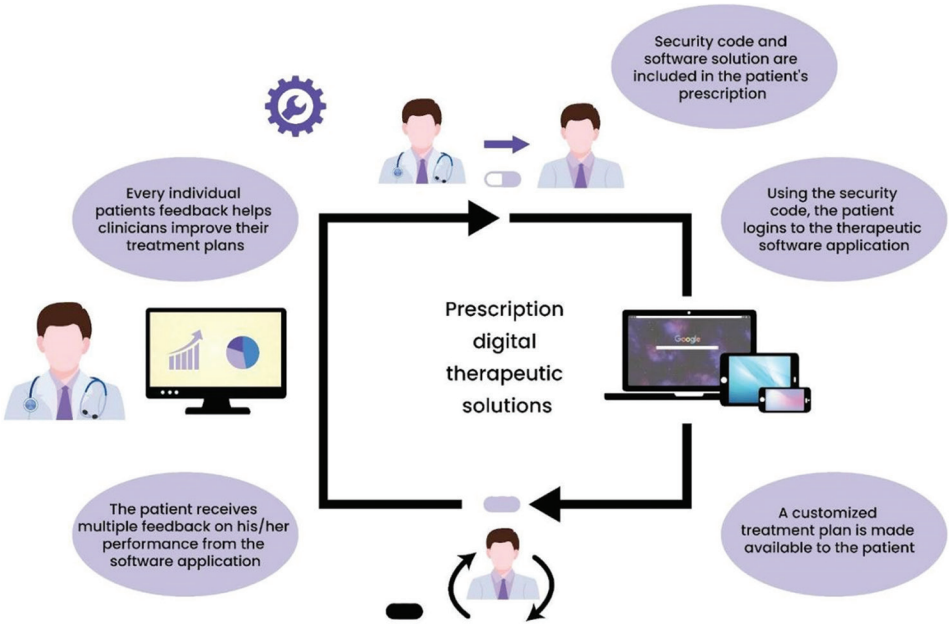


Figure 1. The workflow of prescription digital therapeutic solutions. Image is created by author.

developers must provide robust evidence from randomized controlled trials (RCTs) or other well-designed studies showing that the DTx achieve the intended health outcomes. In addition, the software must adhere to strict data privacy and security standards, ensuring the protection of patient information in compliance with regulations like the Health Insurance Portability and Accountability Act (HIPAA).[13]

Beyond the FDA, other regulatory bodies worldwide, such as the European Medicines Agency and various national health authorities, have established guidelines and frameworks for the approval and oversight of PDTs. These regulations ensure that PDTs can be safely and effectively integrated into healthcare systems globally, providing patients with reliable and clinically validated DTx options.[14]

In summary, PDTs represent a transformative approach in managing obesity, blending advanced technology with clinical rigor. The stringent regulatory pathways they navigate underscore their potential as powerful tools in modern healthcare, offering personalized and effective interventions to combat obesity and improve overall health outcomes. Figure 2 illustrates the uses of DTx.

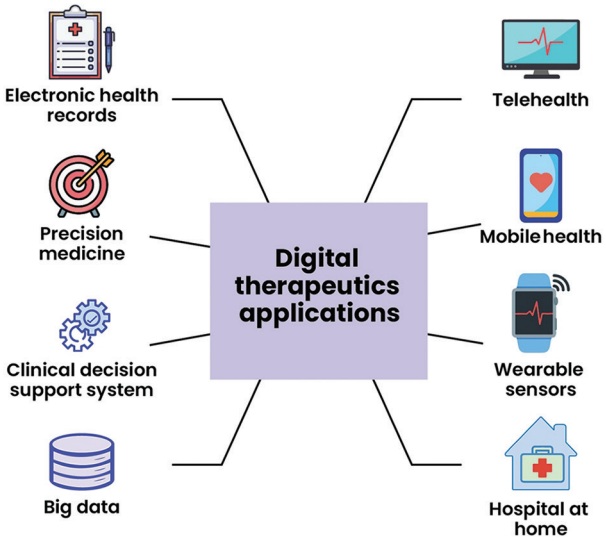


Figure 2. Uses of digital therapeutics. Image created by author.

3. DTx for obesity: An integrated and multidisciplinary approach

Diseases like obesity and eating behavioral disorders are complex in nature and require a mix of lifestyle changes and medical treatment for effective management.[15]

Addressing both physical and mental health is crucial for lifestyle modifications. High motivation is essential for adherence to these changes. Patients can develop stimulus control by managing eating-related cues, using cognitive techniques to address maladaptive thinking, and enhancing coping skills for emotional regulation and stress management.[3] These psychological mechanisms, vital for mental health, are closely linked to physical health and influence clinical outcomes. Consequently, mental health should be a key component of DTx for

obesity and eating-related problems. However, previous self-management DTx studies have often overlooked mental health, focusing instead on behaviors such as glucose and weight monitoring, medication adherence, food logging, and physical activity.[16,17] Most mobile health interventions have only shown improvements in physical health outcomes, such as hemoglobin A1c levels or body weight, but have not effectively addressed mental health issues.[18-20] Factors like motivation, depression, anxiety, and self-esteem are predictors of successful weight control. Therefore, developing practical DTx for obesity and eating behavior problems requires a multidisciplinary approach that includes psychological components.[21]

3.1. Key players and products

Omada Health is a prominent provider of DTx focused on obesity management and chronic disease prevention. The Omada Health program is built on a comprehensive, behavior change-oriented platform that integrates human coaching, peer support, digital tools, and data-driven insights. Key features include personalized health coaching, an interactive mobile app, and digital tracking tools for monitoring weight, diet, and physical activity. The user interface is designed to be intuitive and engaging, offering goal-setting capabilities, educational content, and progress tracking. The platform uses cognitive-behavioral techniques to help users develop lasting healthy habits. Participants receive wireless scales and activity trackers, which integrate their health data into the app for real-time feedback and personalized recommendations. Omada's evidence-based approach has proven effective in clinical trials, showing significant weight loss and improved health outcomes for participants.[22]

Noom is a well-known PDT that uses a psychology-based method to promote sustainable weight loss and manage obesity. At the heart of Noom's program is its mobile application, which offers various features to assist users on their weight loss journey. Notable features of Noom include customized meal plans, calorie tracking, and an extensive food database to aid users in making informed dietary decisions. The app incorporates cognitive-behavioral therapy techniques to address the psychological aspects of eating, fostering healthier habits and behaviors. In addition, Noom provides virtual coaching from trained professionals who offer guidance, motivation, and accountability. The user interface is designed to be intuitive and engaging, with daily lessons, quizzes, and progress tracking tools to keep users actively engaged in their health goals. By combining behavioral science, personalized coaching, and technology, Noom strives to offer a comprehensive and user-friendly solution for effective obesity management.[23]

WellDoc is a pioneering digital health company that offers BlueStar®, a comprehensive DTx platform initially developed for diabetes management and now expanded to address obesity and other chronic conditions. BlueStar® provides personalized, real-time guidance to users via a mobile app that integrates with various health data sources, including wearable devices, glucose monitors, and fitness trackers. The platform uses artificial intelligence (AI) to deliver customized coaching and educational content based on individual user data, assisting users in managing their diet, physical activity, medication adherence, and overall health behavior. The app features an intuitive and user-friendly interface with dashboards displaying health metrics, progress tracking, and actionable insights. Clinicians can access patient data through a dedicated portal, enabling better-informed treatment decisions and more personalized care. BlueStar® has been validated in multiple clinical studies demonstrating its effectiveness in improving health outcomes and is approved by regulatory bodies like the FDA, ensuring its credibility and reliability as a PDT.[24,25]

3.2. Mechanisms of action

PDTs leverage several mechanisms to effectively manage obesity. Central to their approach are behavioral interventions rooted in cognitive-behavioral therapy principles, which help users modify unhealthy eating patterns and adopt healthier behaviors. Gamification techniques further enhance user engagement and adherence by making the process more interactive and motivating. In addition, PDTs utilize data tracking and personalization through wearables and mobile apps, which monitor physical activity, dietary intake, and other health metrics, providing users with real-time feedback and personalized insights. Advanced technologies such as AI and machine learning play a critical role in this personalization, analyzing user data to create tailored treatment plans that adapt to individual needs and progress. Together, these mechanisms create a comprehensive and dynamic approach to obesity management, fostering sustained behavior change and improved health outcomes. The differences between conventional pharmacotherapy and DTx are shown in Table 2.

3.3. Clinical evidence and effectiveness

3.3.1. Issues of DTx in obesity treatment

Based on the current status of the field, there as six major constructive issues currently facing the application of DTx in the management of obesity and eating-related problems (Figure 3).

3.3.1.1. Comprehensiveness of an individual's multifactorial health condition

As noted previously, obesity and eating behavior issues are complex and multifaceted in nature.[3] To thoroughly understand and monitor the progress of weight control

Table 2. Differences between conventional pharmacotherapy and digital therapeutics[7]

Category	Pharmaceutical	Digital therapeutics
Development cost	Very high cost (about $1.8B)	Comparatively low cost
Development period	Approximately more than 10 years	Approximately<10 years
Manufacturing	Continuous production required through manufacturing facilities	No additional manufacturing is required after initial development
Phases of clinical trials	Human pharmacology study (Phase 1) Exploratory study (Phase 2) Confirmatory study (Phase 3)	Exploratory study (Pilot, optional) Confirmatory study (Pivotal)
Regulation	Pharmaceutical law applicable	Medical device law applicable
Medication monitoring	Manual monitoring done	Real-time automatic monitoring done
Medication adherence	50%	80%
Prerequisites	Not required	Digital device, appropriate level of cognitive ability needed
Prescription	Mandatory (ETC only)	Mandatory (PDTs only)
Data security	Not applicable	Need cyber security and data protection solutions

Abbreviations: ETC: Essential-therapeutic-category; PDT: Prescription digital therapeutic.

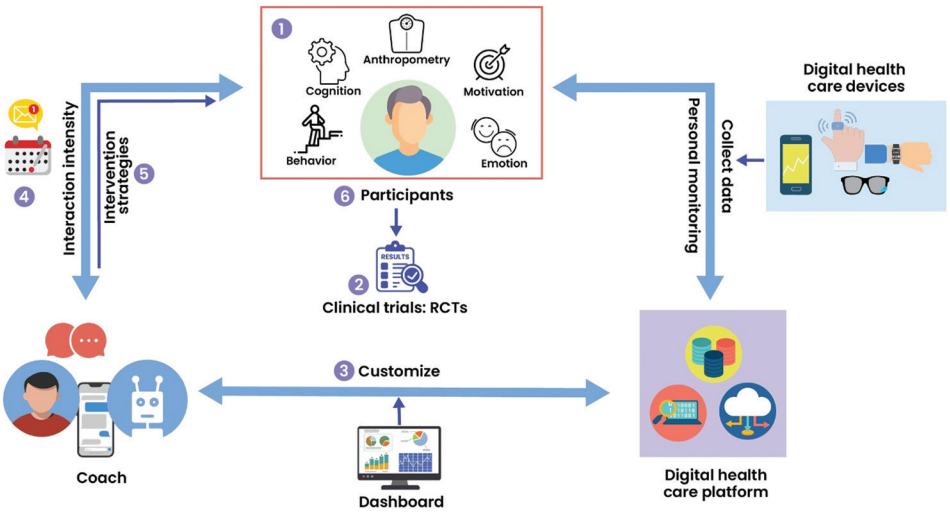


Figure 3. The workflow of digital therapeutics used in obesity management. Image created by author.
Abbreviation: RCTs: Randomized controlled trials.

and eating patterns, it is recommended to address multiple domains including behavioral, cognitive, emotional, motivational, and anthropometric aspects.[21] Since behavior styles and engagement with DTx are greatly influenced by cognitive structuring and emotional regulation, an integrated clinical approach that incorporates all these elements is essential for effectively addressing obesity-related challenges.

3.3.1.2. Efficacy of DTx in RCTs

The goal of RCTs is to evaluate the effectiveness of new treatments while reducing potential biases, such as the placebo effect. During the RCTs, both the efficacy and safety of treatments are established, which are critical factors for FDA approval. While many studies have investigated digital interventions for weight loss, not all have been structured as RCTs.[26] To conclusively demonstrate the effectiveness of new DTx, RCTs are essential. One of the most critical and challenging aspects of designing RCTs for DTx is creating an appropriate control group. Digital interventions encompass a wide range of features, such as self-monitoring, cognitive-behavioral therapy, user interface/user experience, and human coaching. This diversity makes it difficult to determine which specific features are effective and which should be compared in the trials.[27] Selecting the primary active ingredient of DTx and creating a specific active sham control group (an identical DTx platform without the primary active ingredient) presents

significant challenges. Achieving a fully blinded condition, akin to placebo-controlled trials for medications, is also difficult. Consequently, new RCT frameworks tailored to DTx have been developed. These include the multiphase optimization strategy, sequential multiple assignment randomized trials, micro-randomized trials, clustered RCTs, unequal allocation RCTs, and control optimization trials. Each of these designs addresses different research questions, aiming to provide gold-standard evidence in clinical medicine. In addition, due to the digital nature of these technologies, RCTs for DTx can employ fully digital, innovative designs, incorporating digital enrollment, digital intervention, and digital outcome phenotyping, potentially eliminating the need for on-site visits. Table 3 presents a summary of multiple clinical trials.

3.3.1.3. Individual feedback tailoring in DTx

Personalized PDTs have the capability to provide customized feedback using individualized data across various domains, as previously discussed. It has been demonstrated that this personalized approach is essential because it significantly impacts engagement with digital interventions and the potential for sustained lifestyle modifications over time.[21] However, the majority of interventions delivered through mobile applications employ standardized behavioral approaches (such as reminders for monitoring and appointments, and general health education), utilize content that is uniformly generated, or incorporate algorithms that are minimally customized and focus narrowly on domains like diet, physical activity, and body weight.[32,33] These approaches have demonstrated constraints in engaging participants in the intervention and sustaining treatment effectiveness. Therefore, utilizing tailored feedback and adaptive interventions based on baseline and/or real-time multifaceted assessments (including behavior, emotions, cognition, and motivation) can enhance both engagement and the overall efficacy of DTx. Moreover, incorporating additional factors such as genetic predispositions, social and economic circumstances, and coexisting health conditions could further optimize the development of personalized DTx solutions.

3.3.1.4. Temporal strategies for intervention frequency

The engagement rate in DTx is significantly influenced by temporal methods for intervention frequency. In general, an intervention can be applied at three different time points: daily, weekly, and monthly. Prior research using weekly or monthly interventions revealed high rates of attrition.[35] Given that DTx engagement rates impact clinical outcomes, it is imperative to take into account the level of contact between physicians and users. Higher involvement may be stimulated by daily interventions that are more intensive. However, users and coaches may find a too frequent intervention taxing or tiresome. By using cutting-edge digital technologies like AI and machine learning to replace tedious tasks with automated services, this can be lessened.[36]

3.3.1.5. Psychological theory for intervention strategies based on empirical evidence

While digital health technologies have advanced significantly, it is essential to evaluate the integration of evidence-based behavior change strategies and clinical protocols within these modalities. Evidence-based interventions refer to strategies supported by empirical evidence demonstrating their effectiveness and accountability. Key psychological interventions, such as cognitive-behavioral therapy, dialectical behavioral therapy, acceptance and commitment therapy, and mindfulness-based cognitive therapy, are well-established in clinical practice. Cognitive-behavioral therapy, particularly, is widely utilized across various mental health conditions, prompting researchers to explore its expansion through digital platforms. Incorporating these scientifically

Table 3. Summary of clinical trials and studies evaluating the effectiveness of prescription digital therapeutics in obesity management[28]

Study	Population	Intervention	Delivery digital device
Spring *et al.*[29]	Adults with obesity	Technology-supported	Smartphone, web portal
Nezami *et al.*[30]	Mothers with overweight and obesity, children aged 3 – 5 years	Smart group (mobile application-supported)	Smartphone
Spring *et al.*[31]	Adults aged 18 – 65 years	Temporally simultaneous intervention	Smartphone
Kim *et al.*[32]	Old adults with diabetes (mean age 60)	Mobile-based glucose diary	Smartphone
Fitzsimmons-Craft *et al.*[33]	Women with eating disorders	CBT-guided self-help	Smartphone
Lowe *et al.*[34]	Female and male adults with a BMI in the range of 27 – 43	Time-restricted eating	Smartphone, wearable devices
Kim *et al.*[21]	Overweight and obese women adults	Human-based digital CBT	Smartphone, web portal

Abbreviations: CBT: Cognitive-behavioral therapy; BMI: Body mass index.

validated intervention strategies into DTx is crucial for enhancing their efficacy.

In a study by Strombotne *et al.*,[37] 2 years of virtual coaching and ketogenic diet led to a significant reduction in BMI and monthly usage of diabetes medication in diabetic patients. In addition, involving healthcare professionals, including doctors, nurses, psychologists, and trainers, in the development of DTx can ensure the reliability and effectiveness of these interventions.

3.3.1.6. Target populations

Most DTx focusing on lifestyle modifications or eating-related issues have primarily concentrated on adults. Despite the correlation between childhood/adolescent obesity and adult metabolic diseases, there is a notable scarcity of studies examining DTx interventions in youths. For effective treatment of children and young adults, involving their caregivers or guardians in the intervention process is deemed more effective in achieving positive clinical outcomes. Similarly, involving families in interventions aimed at older adults, who often contend with existing metabolic or psychiatric conditions, is recommended to enhance the success of DTx approaches. In addition, clinicians are advised to tailor strategies according to specific target symptoms such as major depressive disorder, eating disorders, diabetes, or hypertension.

4. Challenges and limitations

4.1. Challenges

4.1.1. Regulatory and approval challenges

The regulatory landscape for PDTs in obesity management presents significant hurdles, varying widely across different regions. Obtaining approval involves navigating complex processes that differ in requirements and timelines between jurisdictions. Harmonizing these regulations globally is crucial for ensuring timely access to innovative therapies and fostering broader adoption in healthcare systems.

4.1.2. User engagement and adherence

Effective engagement and sustained adherence pose substantial challenges for PDTs in obesity management. Issues such as user motivation, interface design, and personalized feedback mechanisms influence long-term participation. Strategies incorporating behavioral science principles, real-time feedback, and gamification are being explored to enhance user engagement and promote adherence to PDTs.

4.1.3. Data privacy and security

Concerns regarding the privacy and security of patient data loom large in the adoption of PDTs. Compliance with stringent regulations like General Data Protection Regulation and HIPAA is essential to safeguarding sensitive health information. Robust encryption protocols, anonymization techniques, and transparent data handling practices are critical for maintaining patient trust and regulatory compliance.

4.1.4. Accessibility and equity

The accessibility of PDTs remains constrained by factors including cost barriers and varying levels of digital literacy among diverse populations. Addressing these disparities requires proactive efforts to reduce costs, improve user education, and ensure equitable access to DTx solutions. Collaboration between stakeholders in healthcare, technology, and policy sectors is essential for advancing accessibility and fostering inclusive healthcare delivery through PDTs.

4.2. Limitations with DTx use in hospital settings

Despite extensive efforts to develop various types of DTx, their integration into clinical settings remains incomplete due to several limitations. Presently, two significant concerns hindering the scalability and effectiveness of DTx are low user engagement and insufficient efficacy.[35] Next, akin to traditional pharmaceuticals, DTx must undergo RCTs as part of the approval process to confirm their safety and efficacy before they reach the market.[5] However, DTx software can be updated and adjusted in response to FDA guidance at any time, unlike traditional pharmaceuticals. Cybersecurity and data rights present additional challenges that hinder widespread adoption of DTx. One potential solution involves forming partnerships between industries and academic institutions; for instance, companies developing successful DTx collaborate with academic groups to ensure scientific rigor, in scenarios similar to how traditional pharmaceuticals are developed.

5. Future directions

The future of PDTs in obesity and diabetes management is poised for significant advancements, driven by emerging technologies and personalized medicine. Innovations in technologies such as AI, augmented reality (AR), and virtual reality (VR) are set to transform PDTs, offering more immersive and engaging interventions. AI can enhance the personalization of treatment plans by analyzing vast amounts of user data, while AR and VR can create interactive experiences that make lifestyle changes more engaging. Wearable technology is also advancing rapidly, providing continuous, real-time health data that can be seamlessly integrated with PDTs to offer more precise and timely interventions.

Personalized medicine is another promising avenue, with genetic insights allowing for highly individualized treatment strategies. The use of big data and advanced analytics will enable PDTs to deliver more tailored interventions, considering each individual's unique behavioral, emotional, and physiological profile. Big data is helpful for training of health models, which can be further leveraged to bring DTx solutions for chronic diseases into real life.[38]

Integrating PDTs into standard healthcare practices will be crucial for their widespread adoption. This will require strong collaboration between tech companies and healthcare providers to ensure that PDTs are effectively integrated into patient care plans. In addition, the future regulatory landscape will need to evolve, with advocacy for standardized regulations across regions to ensure the safety, efficacy, and accessibility of PDTs.

Overall, the future of PDTs in obesity management holds great promise, with technological innovations and personalized approaches driving more effective and engaging solutions. This progress will ultimately empower the affected individuals to take a more proactive attitude in managing obesity and improve the overall health outcomes.

6. Conclusion

PDTs have revolutionized the approach to obesity management by integrating advanced digital technologies with behavioral medicine. These innovative solutions, like WellDoc's BlueStar®, provide personalized health guidance and real-time support, significantly enhancing patient engagement and adherence. Clinical studies have validated the effectiveness of PDTs, underscoring their potential in improving health outcomes for individuals with obesity.

Despite their promise, PDTs face challenges such as regulatory hurdles, user engagement issues, data privacy concerns, and accessibility barriers. Addressing these challenges through improved regulatory frameworks, user interface enhancements, robust data security measures, and efforts to bridge the digital divide is essential for realizing the full potential of these digital interventions.

In future, the continued advancement of technology, including AI, wearable devices, and personalized medicine, will further drive the impact of PDTs in obesity management. Integrating these tools within healthcare systems and establishing standardized regulatory policies will be crucial for scaling their benefits. As PDTs evolve, they offer the promise of more effective obesity management and empower individuals to take proactive control of their health, adapting to the ever-evolving digital healthcare.

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Conflict of interest

The authors declare that they have no competing interests.

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Writing–review & editing: All authors

Ethics approval and consent to participate

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Consent for publication

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Availability of data

Not applicable.

References

1. Bray GA, Frühbeck G, Ryan DH, Wilding JPH. Management of obesity. *Lancet*. 2016;387(10031):1947-1956.

   doi: 10.1016/S0140-6736(16)00271-3

2. Boutari C, Mantzoros CS. A 2022 update on the epidemiology of obesity and a call to action: As its twin COVID-19 pandemic appears to be receding, the obesity and dysmetabolism pandemic continues to rage on. *Metabolism*. 2022;133:155217.

   doi: 10.1016/j.metabol.2022.155217

3. Wadden TA, Tronieri JS, Butryn ML. Lifestyle modification approaches for the treatment of obesity in adults. *Am Psychol*. 2020;75(2):235-251.

   doi: 10.1037/amp0000517

4. *Digital Therapeutics Alliance. A New Category of Medicine*. Arlington: Digital Therapeutics Alliance; 2020. Available from: https://dtxalliance.org [Last accessed on 2021 Feb 23].

5. Patel NA, Butte AJ. Characteristics and challenges of the clinical pipeline of digital therapeutics. *NPJ Digit Med*. 2020;3:159.

   doi: 10.1038/s41746-020-00370-8

6. Quinn CC, Shardell MD, Terrin ML, Barr EA, Ballew SH, Gruber-Baldini AL. Cluster-randomized trial of a mobile phone personalized behavioral intervention for blood

glucose control. *Diabetes Care*. 2011;34:1934-1942.

doi: 10.2337/dc11-0366

7. Wang C, Lee C, Shin H. Digital therapeutics from bench to bedside. *NPJ Digit Med*. 2023;6(1):38.

doi: 10.1038/s41746-023-00777-z

8. *European Data Protection Supervisor. Digital Therapeutics (DTx)*; 2022. Available from: https://edps.europa.eu/press-publications/publications/techsonar/digital-therapeuticsdtx_en [Last accessed on 2024 Jun 02].

9. *Ministry of Food and Drug Safety (Korea). Guideline on Review and Approval of Digital Therapeutics (For Industry)*; 2020. Available from: https://www.mfds.go.kr/eng/brd/m_40/view.do?seq=72624&srchfr=&srchto=&srchword=&srchtp=&itm_seq_1=0&itm_seq_2=0&multi_itm_seq=0&company_cd=&company_nm=&page=1 [Last accessed on 2024 Jun 02].

10. *Digital Therapeutics Alliance. Digital Therapeutics Definition and Core Principles*; 2019. Available from: https://dtxalliance.org [Last accessed on 2024 Jun 02].

11. Dang A, Arora D, Rane P. Role of digital therapeutics and the changing future of healthcare. *J Family Med Prim Care*. 2020;9(5):2207-2213.

doi: 10.4103/jfmpc.jfmpc_105_20

12. Lottes AE, Cavanaugh KJ, Chan YY, *et al*. Navigating the regulatory pathway for medical devices-a conversation with the FDA, clinicians, researchers, and industry experts. *J Cardiovasc Transl Res*. 2022;15(5):927-943.

doi: 10.1007/s12265-022-10232-1

13. Kepplinger EE. FDA's expedited approval mechanisms for new drug products. *Biotechnol Law Rep.* 2015;34(1):15-37.

doi: 10.1089/blr.2015.9999

14. Burns L, Le Roux N, Kalesnik-Orszulak R, *et al*. Real-world evidence for regulatory decision-making: Updated guidance from around the world. *Front Med* (*Lausanne*). 2023;10:1236462.

doi: 10.3389/fmed.2023.1236462

15. Castelnuovo G, Pietrabissa G, Manzoni GM, *et al*. Cognitive behavioral therapy to aid weight loss in obese patients: Current perspectives. *Psychol Res Behav Manag*. 2017;10:165-73.

doi: 10.2147/PRBM.S113278

16. Garabedian LF, Ross-Degnan D, Wharam JF. Mobile phone and smartphone technologies for diabetes care and selfmanagement. *Curr Diab Rep.* 2015;15:109.

doi: 10.1007/s11892-015-0680-8

17. Holtz B, Lauckner C. Diabetes management via mobile phones: A systematic review. *Telemed J E Health*. 2012;18:175-184.

doi: 10.1089/tmj.2008.0099

18. Ku EJ, Park JI, Jeon HJ, Oh T, Choi HJ. Clinical efficacy and plausibility of a smartphone-based integrated online real-time diabetes care system via glucose and diet data management: A pilot study. *Intern Med J*. 2020;50:1524-1532.

doi: 10.1111/imj.14738

19. Guo H, Zhang Y, Li P, Zhou P, Chen LM, Li SY. Evaluating the effects of mobile health intervention on weight management, glycemic control and pregnancy outcomes in patients with gestational diabetes mellitus. *J Endocrinol Invest*. 2019;42:709-714.

doi: 10.1007/s40618-018-0975-0

20. Kirwan M, Vandelanotte C, Fenning A, Duncan MJ. Diabetes self-management smartphone application for adults with type 1 diabetes: Randomized controlled trial. *J Med Internet Res*. 2013;15:e235.

doi: 10.2196/jmir.2588

21. Kim M, Kim Y, Go Y, *et al*. Multidimensional cognitive behavioral therapy for obesity applied by psychologists using a digital platform: Open-label randomized controlled trial. *JMIR Mhealth Uhealth*. 2020;8:e14817.

doi: 10.2196/14817

22. Sepah SC, Jiang L, Ellis RJ, McDermott K, Peters AL. Engagement and outcomes in a digital diabetes prevention program: 3-year update. *BMJ Open Diabetes Res Care*. 2017;5(1):e000422.

doi: 10.1136/bmjdrc-2017-000422

23. May CN, Cox-Martin M, Ho AS, *et al*. Weight loss maintenance after a digital commercial behavior change program (Noom Weight): Observational cross-sectional survey study. *Obes Sci Pract*. 2023;9(5):443-451.

doi: 10.1002/osp4.666

24. Quinn CC, Clough SS, Minor JM, Lender D, Okafor MC, Gruber-Baldini A. WellDoc mobile diabetes management randomized controlled trial: Change in clinical and behavioral outcomes and patient and physician satisfaction. *Diabetes Technol Ther*. 2008;10(3):160-168.

doi: 10.1089/dia.2008.0283

25. Kumbara AB, Iyer AK, Green CR, *et al*. Impact of a combined continuous glucose monitoring-digital health solution on glucose metrics and self-management behavior for adults with type 2 diabetes: Real-world, observational study. *JMIR Diabetes*. 2023;8:e47638.

doi: 10.2196/47638

26. Levine BJ, Close KL, Gabbay RA. Reviewing U.S. Connected diabetes care: The newest member of the team. *Diabetes Technol Ther*. 2020;22:1-9.

27. Arigo D, Jake-Schoffman DE, Wolin K, Beckjord E, Hekler EB, Pagoto SL. The history and future of digital

health in the field of behavioral medicine. *J Behav Med*. 2019;42:67-83.

doi: 10.1007/s10865-018-9966-z

28. Kim M, Choi HJ. Digital therapeutics for obesity and eating-related problems. *Endocrinol Metab* (*Seoul*). 2021;36(2):220-228.

doi: 10.3803/EnM.2021.107

29. Spring B, Pellegrini CA, Pfammatter A, *et al*. Effects of an abbreviated obesity intervention supported by mobile technology: The ENGAGED randomized clinical trial. *Obesity* (*Silver Spring*). 2017;25:1191-1198.

doi: 10.1002/oby.21842

30. Nezami BT, Ward DS, Lytle LA, Ennett ST, Tate DF. A mHealth randomized controlled trial to reduce sugar-sweetened beverage intake in preschool-aged children. *Pediatr Obes*. 2018;13:668-676.

doi: 10.1111/ijpo.12258

31. Spring B, Pellegrini C, McFadden HG, *et al*. Multicomponent mHealth intervention for large, sustained change in multiple diet and activity risk behaviors: The Make Better Choices 2 randomized controlled trial. *J Med Internet Res*. 2018;20:e10528.

doi: 10.2196/10528

32. Kim EK, Kwak SH, Jung HS, *et al*. The effect of a smartphone-based, patient-centered diabetes care system in patients with type 2 diabetes: A randomized, controlled trial for 24 weeks. *Diabetes Care*. 2019;42:3-9.

doi: 10.2337/dc17-2197

33. Fitzsimmons-Craft EE, Taylor CB, Graham AK, *et al*. Effectiveness of a digital cognitive behavior therapy-guided self-help intervention for eating disorders in college women: A cluster randomized clinical trial. *JAMA Netw Open*. 2020;3:e2015633.

doi: 10.1001/jamanetworkopen.2020.15633

34. Lowe DA, Wu N, Rohdin-Bibby L, *et al*. Effects of time-restricted eating on weight loss and other metabolic parameters in women and men with overweight and obesity: The TREAT randomized clinical trial. *JAMA Intern Med*. 2020;180:1491-1499.

doi: 10.1001/jamainternmed.2020.4153

35. Torous J, Michalak EE, O'Brien HL. Digital health and engagement-looking behind the measures and methods. *JAMA Netw Open*. 2020;3:e2010918.

doi: 10.1001/jamanetworkopen.2020.10918

36. Kavakiotis I, Tsave O, Salifoglou A, Maglaveras N, Vlahavas I, Chouvarda I. Machine learning and data mining methods in diabetes research. *Comput Struct Biotechnol J*. 2017;15:104-116.

doi: 10.1016/j.csbj.2016.12.005

37. Strombotne KL, Lum J, Pizer SD, Figueroa S, Frakt AB, Conlin PR. Clinical effectiveness and cost-impact after 2 years of a ketogenic diet and virtual coaching intervention for patients with diabetes. *Diabetes Obes Metab*. 2024;26:1016-1022.

doi: 10.1111/dom.15401

38. Kim HC, Lee H, Lee HH, *et al*. Korea Hypertension Fact Sheet 2023: Analysis of nationwide population-based data with a particular focus on hypertension in special populations. *Clin Hypertens*. 2024;30:7.

doi: 10.1186/s40885-024-00262-z