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GAMIFIED MOBILE HEALTH INTERVENTIONS FOR SELF-MANAGEMENT IN ADOLESCENTS AND YOUNG ADULTS WITH TYPE 1 DIABETES MELLITUS: A NARRATIVE REVIEW

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ABSTRACT

This narrative review synthesizes current evidence on how gamified mobile health (mHealth) platforms influence health, behavioral, and psychosocial outcomes in adolescents and young adults (AYA) with Type 1 Diabetes Mellitus (T1DM). A literature search identified a critical empirical gap: no primary gamification trials specifically targeting or reporting disaggregated outcomes for emerging adults (ages 18–25) were identified in the reviewed literature base. Consequently, this review evaluates evidence from randomized controlled trials, observational studies, scoping reviews, and umbrella reviews across younger cohorts to analyze why child-centric gamification models fail to meet the transitional needs of adolescents and young adults (AYA). The analysis focuses on digital elements, theoretical grounding, and longitudinal retention. Results indicate that gamified interventions enhance initial user engagement and short-term behavioral modifications, notably increasing self-monitored blood glucose frequency. While interventions yield positive psychosocial responses, changes in glycated hemoglobin (HbA1c) rarely achieve clinically durable normalization. Longitudinal evaluations consistently demonstrate a novelty effect, wherein engagement declines as manual data-entry burdens outweigh extrinsic rewards, driving high attrition. Although gamified mHealth applications provide psychosocial support and facilitate disease management, current evidence does not support their use as standalone tools for glycemic normalization. Sustained clinical efficacy requires shifting focus from extrinsic rewards toward comprehensive behavioral frameworks. Theoretical alignment with models such as Self-Determination Theory is insufficient unless paired with strong usability, age-appropriate design, seamless hardware integration, and structured clinical care.

KEYWORDS

Type 1 Diabetes, Gamification, Mobile Health (mHealth), Self-Management, Adolescents, Young Adults

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1. Introduction

Type 1 Diabetes Mellitus (T1DM) is a chronic autoimmune condition characterized by pancreatic beta-cell destruction, leading to absolute insulin deficiency and lifelong exogenous insulin dependency (American Diabetes Association Professional Practice Committee, 2025; Cloarec et al., 2025). Across pediatric, adolescent, and young adult populations, T1DM imposes significant clinical, cognitive, and psychosocial demands, requiring continuous and rigorous self-care behaviors (Beh et al., 2026; Monaghan et al., 2015). Core self-care tasks include frequent blood glucose monitoring, accurate carbohydrate counting, timely insulin administration, and structured physical activity (Beh et al., 2026; Cloarec et al., 2025). Clinical guidelines emphasize individualized glycemic targets and sustained engagement, with continuous glucose monitoring (CGM) increasingly serving to optimize therapy and mitigate acute and chronic complications (American Diabetes Association Professional Practice Committee, 2025; Danne et al., 2017).

Managing T1DM is particularly challenging during adolescence and young adulthood, a developmental phase marked by profound physiological, psychological, and social shifts, as well as a growing drive for autonomy (Aljohani et al., 2024). During this period, emerging adults transition from family-centered pediatric care to adult health services, requiring increased self-advocacy (Aljohani et al., 2024; Iyengar et al., 2019). Suboptimally coordinated transitions frequently lead to disengagement from routine care, compromised continuity of follow-up, and disrupted self-management behaviors (Aljohani et al., 2024; Garvey et al., 2022; Iyengar et al., 2019). Glycemic control frequently worsens during this period due to care fragmentation and competing life priorities, including education, employment, shifting interpersonal relationships, and identity formation (Iyengar et al., 2019; Monaghan et al., 2015). Systematic evidence confirms that this transition increases the risk of worsening glycemic control and clinic disengagement. Evaluating structured transition

programs presents distinct challenges due to methodological heterogeneity and a scarcity of theory-driven models (Aljohani et al., 2024). Adherence correlates directly with glycemic control in youth (Hood et al., 2009). As young individuals assume responsibility for their care, adherence and clinic attendance often decline; mobile health (mHealth) applications target these barriers by providing interactive education and facilitating clinician communication (Trnka et al., 2024).

Beyond biomedical challenges, T1DM imposes a substantial psychosocial burden. Many adolescents and young adults experience diabetes distress—the emotional strain driven by the daily demands of self-management and the ongoing struggle to maintain target glycemic levels (de Wit et al., 2022; Kiriella et al., 2021; Monaghan et al., 2015). Diabetes burnout—characterized by mental, emotional, and physical exhaustion—is closely associated with elevated diabetes distress and depressive symptoms, manifesting as a profound detachment from self-management responsibilities and healthcare disengagement (de Wit et al., 2022; Kiriella et al., 2021). Psychosocial distress is clinically significant as it impairs treatment adherence, self-management, and quality of life (de Wit et al., 2022; Kiriella et al., 2021; Monaghan et al., 2015). International guidelines strongly advocate integrating psychosocial support into routine diabetes care (de Wit et al., 2022). However, a substantial gap persists between these recommendations and standard clinical practice (Hilliard et al., 2016).

Mobile health (mHealth) interventions—including smartphone applications, digital diaries, remote feedback, and automated reminders—can support self-management in this population by reducing disease burden and enhancing patient-provider communication (Beh et al., 2026; Trnka et al., 2024). Due to high technology adoption rates, these digital tools are particularly suited for children and adolescents (Trnka et al., 2024), offering high scalability, low delivery costs, and widespread accessibility (Deniz-Garcia et al., 2023). Additionally, many leverage Social Cognitive Theory constructs to promote self-management and patient empowerment (Beh et al., 2026).

Nevertheless, the availability of mHealth applications does not automatically translate into sustained use. Evidence from the broader mHealth literature indicates that patient engagement frequently declines following initial adoption, with substantial attrition driven by fading novelty effects, the burden of repetitive manual data entry, and challenges in sustaining long-term motivation (Amagai et al., 2022; Baumel et al., 2019; Beh et al., 2026; Deniz-Garcia et al., 2023). The trial history of the adolescent diabetes application *bant* illustrates this problem. Although an initial pilot evaluation of *bant* showed a 50% increase in daily blood glucose monitoring frequency (Cafazzo et al., 2012), a subsequent 12-month randomized controlled trial found no statistically significant improvements in HbA1c or secondary clinical outcomes, largely owing to declining user engagement (Goyal et al., 2017). This discrepancy between short-term adoption and long-term clinical benefits exposes a major limitation of current mHealth designs.

To address declining engagement, many digital health interventions incorporate gamification—defined as the use of game design elements in non-game contexts (Deterding et al., 2011). Clinical gamification uses game mechanics—such as points, badges, levels, and avatars—to foster intrinsic motivation and improve adherence to self-management regimens (Cugelman, 2013; Deterding et al., 2011; Johnson et al., 2016). Gamification strategies align closely with established self-regulatory behavior change techniques; specifically, a systematic review of health apps demonstrated a high prevalence of features designed to facilitate self-monitoring, goal setting, and performance feedback (Edwards et al., 2016). An evaluation of eight free, commercially available gamified mobile applications for pediatric T1DM self-management identified character-care, quiz, and narrative-driven themes as the predominant design paradigms, relying mostly on basic reward systems like points and levels rather than social features (Alsalman et al., 2020). A systematic review of gamified eHealth interventions for pediatric and youth chronic care identified rewards, scoring, creative control, and social interaction as the most prevalent mechanics; fewer than half justified their choice of mechanics, and few explicitly grounded their designs in behavioral change theories (Stutvoet et al., 2024). Despite the popularity of these techniques, systematic syntheses of their clinical and behavioral efficacy in adolescent and young adult cohorts remain limited.

Gamification research frequently operationalizes Self-Determination Theory (SDT), which posits that volitional behavior and sustained motivation are contingent upon the satisfaction of three fundamental psychological needs: autonomy, competence, and relatedness (Johnson et al., 2016; Ryan & Deci, 2000). Addressing these needs is vital in pediatric T1DM care, where glycemic control depends on consistent, long-term daily self-management (Beh et al., 2026; Klaassen et al., 2018). In line with this model, qualitative and design research for pediatric T1DM applications identifies character-care mechanics, peer challenges, routine reminders, and point-based reward systems as key features supporting motivation in nutrition, physical activity,

and glucose monitoring (Alsalman et al., 2021). Translating motivational theory into clinically effective digital interventions remains challenging.

Empirical evidence regarding these interventions yields divergent outcomes. Systematic reviews and scoping analyses of digital health interventions for pediatric and youth diabetes care demonstrate heterogeneous methodologies, inconsistent theoretical foundations, and highly variable clinical outcomes (Beh et al., 2026; Sapkota et al., 2026); a broader review of pediatric chronic disease platforms confirmed a lack of standardized evaluation frameworks (Stutvoet et al., 2024). Although some digital platforms increase user engagement, data-logging frequency, and psychosocial well-being, others show no statistically significant long-term reductions in glycated hemoglobin (HbA1c) (Beh et al., 2026; Sapkota et al., 2026). A key limitation of these interventions is their reliance on extrinsic incentives, such as points and badges, without grounding in behavioral change theory. This design choice often produces short-lived interest rather than sustained habits (Nasri et al., 2025); systematically reviewed apps frequently feature reward mechanisms lacking any explicit theoretical rationale (Stutvoet et al., 2024). In adolescents and young adults, sustained clinical efficacy depends on whether the intervention can support routine, long-term treatment adherence, rather than on its initial visual appeal (Beh et al., 2026; Nasri et al., 2025).

Given the heterogeneity in intervention design, methodology, and reported outcomes, a narrative synthesis accommodates the diverse evidence on gamified mHealth for this population. This paper maps clinical, behavioral, and digital health findings to evaluate effective gamification elements, identify current design gaps, and inform theory-driven, developmentally appropriate interventions for adolescents and young adults with T1DM. This review focuses on the transition to adult care, examining why gamified systems built for younger patients fail to meet the clinical, logistical, and psychosocial needs of emerging adults (ages 18–25).

2. Methodology

2.1. Research Design

This narrative review integrates and critically evaluates research on gamified mobile health (mHealth) interventions for adolescents and young adults with Type 1 Diabetes Mellitus (T1DM). Given the methodological, clinical, and technological diversity of digital health interventions—ranging from randomized controlled trials (Castensøe-Seidenfaden et al., 2018) to hardware-integrated platforms (Klingensmith et al., 2013)—a narrative review approach was selected to integrate these varied study designs, behavioral mechanisms, and clinical outcomes (Beh et al., 2026). This review evaluates structural features, behavioral mechanisms, and clinical limitations across representative interventions according to predefined thematic eligibility criteria.

This approach also accounts for clinical heterogeneity, as glycemic outcomes and self-management practices fluctuate across the pediatric-to-adult spectrum (Clements et al., 2016; Foster et al., 2019). Transition literature emphasizes the risk of self-management decline during transfer to adult care (Aljohani et al., 2024; Garvey et al., 2017). Registry data indicate that glycemic control typically deteriorates through mid-adolescence before improving in young adulthood (Clements et al., 2016). Clinical guidelines and international consensus statements provide the benchmark targets, such as continuous glucose monitoring metrics, used to evaluate the efficacy of these digital tools (Danne et al., 2017).

Rather than comprehensively mapping every available platform, this review focuses on recurring design patterns and gamification mechanics (Nasri et al., 2025), evaluating their alignment with basic psychological needs and prevalent clinical challenges, such as diabetes distress and burnout (Kiriella et al., 2021). To contextualize these findings, the review establishes a two-tier literature framework. While the primary thematic synthesis is restricted to peer-reviewed, disease-specific interventions, the narrative concurrently integrates broader, non-diabetes behavioral health and digital engagement frameworks to evaluate the long-term self-management potential of gamified mHealth architectures (Cugelman, 2013; Fleming et al., 2016).

2.2. Search Strategy and Literature Selection

Literature was identified using PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar to capture biomedical, behavioral, and digital health evidence (Beh et al., 2026; Cloarec et al., 2025; Trnka et al., 2024). Google Scholar, snowballing, and manual reference searching were used as supplementary sources to identify theoretical frameworks, clinical guidelines, and potentially relevant studies not captured by primary search strings. Search queries combined terms across four domains: clinical condition, intervention modality, engagement mechanics, and target population. To ensure methodological transparency without converting the narrative framework into an exhaustive systematic protocol, a representative search syntax (as executed in PubMed/MEDLINE) was structured as follows: ("Type 1 Diabetes" OR "T1DM" OR "diabetes mellitus, type 1"[MeSH Terms]) AND ("mHealth" OR "mobile health" OR "digital health" OR "mobile applications"[MeSH Terms]) AND ("gamification" OR "gamificat*" OR "game mechanics" OR "serious games") AND ("adolescents" OR "young adults" OR "emerging adults"). This string was adapted for Scopus, Web of Science, and Google Scholar. Database searches were restricted to peer-reviewed, English-language articles. Database searches ran from inception through June 2026, with an update in July 2026 to incorporate the most recent peer-reviewed evidence. Although no chronological restrictions were applied to the search queries, the publication dates of the synthesized primary empirical and comparative studies spanned from 2012 to 2026 (Cafazzo et al., 2012; Modi et al., 2026). This 14-year horizon contextualizes the technological evolution from early standalone smartphone applications to contemporary, sensor-integrated digital platforms.

The primary author screened retrieved records against predefined thematic criteria, and any discrepancies were resolved through consensus with co-authors. Included studies evaluated gamified mobile health tools, web-based platforms, or device-integrated systems supporting T1DM self-management in adolescents and young adults (ages 12–25). Given that no primary gamified randomized controlled trials restricted exclusively to emerging adults (ages 18–25) were identified in the literature, studies with overlapping youth cohorts were included to analyze existing digital intervention designs. Specifically, adolescent and pediatric evaluations—including the bant RCT (ages 11–16; Goyal et al., 2017) and the Didget® system trial (ages 5–24; Klingensmith et al., 2013)—as well as broader real-world assessments of platforms such as mySugr (Dehong et al., 2019), were analyzed rather than excluded outright. These pediatric cohorts provide the closest available empirical baseline. Synthesizing their gamification elements, behavior change techniques, and engagement patterns established a baseline to evaluate these mechanics against the unique needs of transitioning young adults. Evaluating pediatric and adolescent interventions within a transition framework helps explain why child-centric game mechanics fail during the transfer to adult care, addressing a key gap in emerging adult mHealth research. Non-gamified digital health trials and transition studies were included selectively to establish comparative benchmarks and clinical context (Aljohani et al., 2024; Modi et al., 2026). Studies were excluded if they focused exclusively on Type 2 or gestational diabetes, lacked T1DM-specific self-management features, evaluated non-gamified tools (except where selectively retained as comparative clinical benchmarks or care transition frameworks), or consisted of non-peer-reviewed grey literature (Beh et al., 2026). Non-T1DM digital health literature was selectively included (Tier 2) to contextualize gamification mechanics and theoretical frameworks when T1DM-specific evidence was lacking. The initial literature search across electronic databases retrieved 482 records. Following a preliminary review of titles and abstracts against the review's thematic scope, 78 articles were selected for detailed full-text evaluation. The structured literature search identified 31 peer-reviewed, T1DM-specific publications for formal thematic extraction and categorization within the primary synthesis pool (Tier 1), as detailed in Table 1. To maintain methodological homogeneity, this primary pool was strictly limited to peer-reviewed literature evaluating diabetes-specific digital interventions. Concurrently, 9 publications were purposively retained outside the systematic synthesis pool to serve as supplementary theoretical and contextual benchmarks (Tier 2) (Amagai et al., 2022; Baumel et al., 2019; Cugelman, 2013; Deniz-Garcia et al., 2023; Edwards et al., 2016; Fleming et al., 2016; Johnson et al., 2016; Lister et al., 2014; Nasri et al., 2025). These Tier 2 sources provide critical comparative evidence regarding real-world digital attrition, behavior change techniques, and agile co-design frameworks, which are essential for interpreting the clinical and developmental challenges of emerging adults during transition. Together with 2 foundational methodological and conceptual references (Deterding et al., 2011; Hong et al., 2018), the comprehensive bibliography comprises 42 sources.

Table 1. Taxonomy and Thematic Breakdown of the Included Literature Base for Formal Synthesis (N=31)

Category	Purpose in the Narrative Synthesis	<i>n</i>	Key References
Primary Studies and Application Analyses	Evaluations of gamified T1DM platforms, mobile tools, or design prototypes	8	Alsalman et al. (2020, 2021); Cafazzo et al. (2012); Castensøe-Seidenfaden et al. (2018); Debong et al. (2019); Goyal et al. (2017); Klaassen et al. (2018); Klingensmith et al. (2013)
Comparative Clinical Benchmark	Non-gamified digital health trial retained as a clinical control baseline	1	Modi et al. (2026)
Systematic, Scoping & Umbrella Reviews	Syntheses of mHealth adoption, digital health dynamics, and gamification mechanics	6	Beh et al. (2026); Cloarec et al. (2025); Priesterroth et al. (2019); Sapkota et al. (2026); Stutvoet et al. (2024); Trnka et al. (2024)
Clinical Guidelines & Theoretical Frameworks	Care standards, pediatric-to-adult transition models, and behavioral psychology frameworks	16	Aljohani et al. (2024); American Diabetes Association Professional Practice Committee (2025); Clements et al. (2016); Danne et al. (2017); de Wit et al. (2022); Foster et al. (2019); Garvey et al. (2017, 2022); Hilliard et al. (2016); Hood et al. (2009); Iyengar et al. (2019); Kiriella et al. (2021); Michie et al. (2013); Monaghan et al. (2015); Ryan & Deci (2000); Sawicki et al. (2011)

Note. N = total number of synthesized publications; n = number of publications assigned to each thematic category.

2.3. Analytical Framework

To evaluate behavioral and motivational mechanisms, this narrative review integrates the Behavior Change Technique Taxonomy v1 (BCTTv1; Michie et al., 2013) and Self-Determination Theory (SDT; Ryan & Deci, 2000). The BCTTv1 helps identify active intervention components, distinguishing basic self-monitoring from advanced self-regulatory strategies such as goal setting, action planning, and feedback (Edwards et al., 2016; Michie et al., 2013; Priesterroth et al., 2019). This distinction draws directly on cybernetic self-regulation models and behavioral coaching research (Cugelman, 2013). In parallel, SDT is used to evaluate how specific game mechanics influence the satisfaction of three basic psychological needs: autonomy, competence, and relatedness. Meeting these needs is essential for supporting intrinsic motivation and sustaining long-term digital engagement in pediatric and adolescent diabetes care (Klaassen et al., 2018; Nasri et al., 2025; Ryan & Deci, 2000). Rather than serving as quantitative coding matrices, these complementary frameworks provide a qualitative structure to examine how specific gamification designs facilitate or impede long-term adherence. We synthesized these perspectives into a conceptual model that maps

the progression from gamification mechanics and behavior change techniques to psychological need satisfaction and clinical outcomes.

Figure 1 conceptualizes the pathway linking gamification mechanics to behavior change, psychological need satisfaction, and clinical outcomes. This model represents a synthesis-derived conceptual framework rather than an empirically validated structural model.

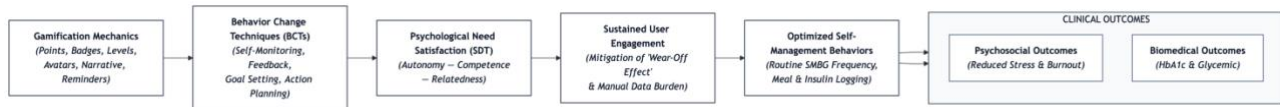


Fig. 1. Conceptual Framework of the Gamification-to-Clinical Outcome Cascade

Note. The diagram illustrates the sequential operational pathway of gamified mobile health (mHealth) interventions in Type 1 Diabetes Mellitus (T1DM) self-management, from initial digital engagement elements to final clinical metrics. BCTs = Behavior Change Techniques; SDT = Self-Determination Theory; SMBG = Self-Monitoring of Blood Glucose.

2.4. Data Synthesis and Critical Interpretation

The literature was synthesized around key thematic domains: structural application characteristics, gamification mechanics, glycemic trajectories during care transition, user retention, and psychosocial well-being. In evaluating clinical efficacy, primary randomized controlled trials (Castensøe-Seidenfaden et al., 2018; Goyal et al., 2017) and systematic reviews (e.g., Beh et al., 2026; Sapkota et al., 2026) were accorded primary interpretive weight, whereas pilot, feasibility, and usability studies served to identify user experience patterns, system utility, and implementation barriers (Klaassen et al., 2018). Finally, owing to its narrative review framework and the substantial heterogeneity of the synthesized evidence, this review did not involve formal protocol registration, dual independent screening, or quantitative meta-analysis, opting for qualitative synthesis rather than statistical pooling.

The synthesis prioritized the evaluation of sustained engagement. In mHealth interventions, user retention typically declines after initial adoption, limiting the effectiveness of chronic disease management tools (Amagai et al., 2022; Baumel et al., 2019; Nasri et al., 2025). Studies tracking engagement at multiple time points were analyzed to characterize long-term usage patterns (Castensøe-Seidenfaden et al., 2018; Goyal et al., 2017). Similarly, long-term trials were prioritized to evaluate whether psychosocial benefits, such as reduced diabetes distress, persisted beyond the active intervention period (Modi et al., 2026).

The synthesis also accounted for study limitations, such as small sample sizes, brief follow-up durations, pilot designs, and limited external validity. Furthermore, the review evaluated intervention replicability and whether gamification mechanics were grounded in behavioral theory rather than added as superficial incentives. Finally, attrition rates and missing data handling strategies, such as 'missing at random' assumptions, were critically appraised across primary evaluations (e.g., Modi et al., 2026) to properly contextualize preliminary efficacy claims.

This methodology provided a structured, transparent narrative synthesis of a highly heterogeneous evidence base. Targeted searches, clear eligibility criteria, standardized extraction, and explicit theoretical frameworks provided a structured evaluation of gamified mHealth interventions for adolescents and emerging adults with T1DM. For each study, information regarding population characteristics, intervention design, gamification mechanics, behavioral techniques, study design, outcomes, and key methodological limitations was extracted. Rather than exhaustively cataloging every platform, the synthesis focuses on representative interventions that illustrate recurring design patterns, theoretical models, and implementation barriers.

2.5. Critical Appraisal of Included Studies

Instead of employing formal quality scoring, this review applied a qualitative appraisal based on core principles from the Mixed Methods Appraisal Tool (the 2018 version of the MMAT; Hong et al., 2018). MMAT domains served as a qualitative framework to evaluate methodological constraints, such as design appropriateness (randomized trials vs. feasibility pilots), attrition rates, and outcome reporting completeness. Identified methodological limitations determined study weighting: small or short-term studies (e.g., Klaassen et al., 2018) were classified as exploratory feasibility data, whereas longitudinal comparative trials (e.g., Castensøe-Seidenfaden et al., 2018; Goyal et al., 2017) provided the main basis for evaluating clinical and behavioral efficacy. Pilot, feasibility, and prototype evaluations were classified as exploratory evidence due to small sample sizes, design-level constraints, or short follow-up durations. This category included clinical pilots with small cohorts (Cafazzo et al., 2012, N=20; Klaassen et al., 2018, combined N=21), descriptive or caregiver-informed app-design analyses (Alsalman et al., 2020, 2021), and a larger pilot RCT retained as a non-gamified behavioral benchmark (Modi et al., 2026, N=162). Conversely, large-scale 12-month randomized controlled trials evaluating longitudinal clinical efficacy—specifically Goyal et al. (2017) and Castensøe-Seidenfaden et al. (2018)—were accorded primary interpretive weight when evaluating durable biomedical and behavioral outcomes.

3. Results

Results are organized into four domains: structural characteristics and theoretical grounding, gamification mechanics, glycemic trajectories and biomedical outcomes, and user engagement and psychosocial well-being. The synthesis focuses on representative platforms—*bant*, Didget®, PERGAMON/TIKI TAKO, Young with Diabetes, and Saudi caregiver prototypes—contextualized by broader systematic review data.

3.1. Structural Characteristics and Theoretical Underpinnings of Included Interventions

Gamified mHealth interventions for adolescents and young adults with T1DM share a common functional core. Most platforms support core self-management tasks, such as blood glucose logging, insulin tracking, carbohydrate counting, and digital diary functions (Priesterroth et al., 2019; Trnka et al., 2024). Platforms differ primarily in how they integrate explicit behavioral support, motivational design, and theoretical grounding (Priesterroth et al., 2019), as seen in systems like *bant* and PERGAMON (Cafazzo et al., 2012; Klaassen et al., 2018).

Evaluations of PERGAMON/TIKI TAKO revealed gaps between theoretical design goals and actual user engagement. Although the system mapped constructs from Self-Determination Theory and Persuasive System Design onto its gamification layers, implementation challenges showed that theoretical grounding did not overcome user-interface friction or age-related usability barriers (Klaassen et al., 2018). High technical complexity and cognitive burden contributed to low System Usability Scale scores and substantial participant attrition (Klaassen et al., 2018). Among the primary studies evaluated, explicit theoretical documentation was rare; while platforms frequently incorporated feedback and goal tracking, few cited an underlying psychological theory or taxonomy during intervention design.

Applying the Behavior Change Technique Taxonomy v1 (BCTTv1; Michie et al., 2013), Priesterroth et al. (2019) demonstrated that self-monitoring and feedback predominate across diabetes applications, whereas action planning, social support, and reward-based incentives appear far less frequently. Explicit theoretical frameworks are rarely operationalized across the reviewed interventions. For instance, key platforms demonstrating theoretical integration, such as PERGAMON, were evaluated only in small-scale pilot designs (pre-pilot n = 7, pilot n = 14; combined n = 21) characterized by low baseline expectations and high recruitment attrition. Small sample sizes and exploratory designs in these feasibility trials limit the generalizability of their findings to broader clinical populations.

3.2. Taxonomy and Distribution of Gamification Mechanics

Gamification in diabetes applications is often limited to a narrow set of mechanics rather than integrated game architectures. Commercial app-store analyses indicate that feedback mechanisms constitute the most prevalent gamification technique, whereas narrative context and avatar implementation remain exceptionally rare (Priesterroth et al., 2019), though character-care mechanics appear in specialized pediatric applications (Alsalman et al., 2020). In a review of free T1DM applications, Alsalman et al. (2020) evaluated eight gamified tools organized around character care, quizzes, and storytelling themes, noting that although apps frequently used points and levels, social networking features were not identified among the evaluated applications.

Advanced mechanics are primarily concentrated in research prototypes rather than commercial platforms. The *PERGAMON* platform, for example, utilized a multi-tiered point system (Experience, Knowledge, Evolution) tied to an adventure narrative and seven educational mini-games covering carbohydrate counting and insulin administration (Klaassen et al., 2018). In pilot testing, participants rated the overall *PERGAMON* platform 6.83/10 during the pre-pilot phase—with the standalone TikiTako adventure game receiving a lower score of 5.67/10—which converged to 6.07/10 during the main pilot phase as users characterized the graphics and narrative as 'childish' (Klaassen et al., 2018).

Other interventions linked rewards directly to glucose testing and task completion, promoting short-term participation and regular logging. In the *bant* pilot, for example, 161 rewards were distributed across participants, averaging eight rewards per user (Cafazzo et al., 2012). Caregiver-informed design research in Saudi Arabia reinforced these principles: caregivers favored character care, peer challenge mechanics, point and level systems, and automated reminders for insulin dosing and blood glucose testing (Alsalman et al., 2021).

Unlike academic prototypes, commercial platforms such as *mySugr* use a "diabetes monster" avatar companion to encourage self-monitoring (Edwards et al., 2016), combining it with point-based challenges and automated data synchronization (Dehong et al., 2019). Observational evaluations of *mySugr* demonstrate high initial acceptability and frequent logging; however, longitudinal data indicate that commercial platforms face attrition dynamics and modest glycemic impacts similar to academic tools when lacking clinical oversight (Dehong et al., 2019). Observational and pilot evaluations show that platforms with automated data transfer improve short-term logging adherence. Without structured clinical support, these tools fail to deliver statistically significant improvements in glycemic control (Cafazzo et al., 2012; Dehong et al., 2019), with feasibility pilots of research prototypes omitting metabolic endpoints altogether in favor of usability and psychological distress metrics (Klaassen et al., 2018).

Few evaluated interventions incorporated social or competitive features, such as leaderboards or peer communication tools (e.g., Castensøe-Seidenfaden et al., 2018; Klaassen et al., 2018). Gamification in T1DM applications is implemented selectively, with elaborate mechanics confined primarily to research prototypes such as the *PERGAMON* platform (Klaassen et al., 2018). However, the evidence supporting these mechanics carries a high risk of confounding bias. Systematic reviews of health gamification show that over half of empirical studies fail to compare gamified interventions against non-gamified controls (Johnson et al., 2016). Primary evaluations of both commercial applications like *mySugr* and descriptive app-store syntheses often lack active control groups or rely on retrospective observational designs, limiting causal interpretation of specific game mechanics regarding behavioral or glycemic outcomes.

Table 2 summarizes the structural characteristics, gamification mechanics, and reported outcomes of the individually named interventions identified in the primary literature. Interventions with broader eligibility ranges—such as the *Didget*® trial (N=147, ages 5–24; Klingensmith et al., 2013)—were included as overlapping youth cohorts because the sample was predominantly pediatric and lacked disaggregated data for emerging adults aged 18–25. Aggregated reviews (e.g., Beh et al., 2026; Sapkota et al., 2026) are synthesized in the main text rather than tabulated, as they do not evaluate single platforms.

Table 2. Summary of Named Gamified Interventions and Reported Outcomes

Intervention / Platform	Source	Population & Design	Gamification Elements	Reported Outcomes
bant (pilot)	Cafazzo et al. (2012)	Adolescents with T1D; pilot study, n = 20	Point-based incentive/reward system; wireless BG transfer; out-of-range trend alerts; coaching	A total of 161 rewards were distributed (averaging 8 per participant). Daily self-monitoring of blood glucose (SMBG) frequency significantly increased by 50%, rising from a baseline of 2.4 to 3.6 measurements per day (P = .006, n = 12). No significant changes in HbA1c were observed.
bant (RCT)	Goyal et al. (2017)	Adolescents 11–16 y; 12-month RCT, n = 92 (46 intervention, 46 usual care)	Same reward-based incentive system as pilot	No significant change in primary/secondary clinical outcomes (linear mixed models); variable engagement reported, with only a defined subset of users regularly accessing the platform.
Didget®	Klingensmith et al. (2013)	Children, adolescents, young adults with T1D (n=147, ages 5–24; formal eligibility range, predominantly pediatric sample with no disaggregated 18–25 subgroup analysis)	Blood glucose meter combined with a handheld gaming system; unlockable game content tied to monitoring behavior	Meter results correlated significantly with reference (YSI) and HCP measurements; overall satisfaction rated good to excellent by subjects, caregivers, and HCPs
PERGAMON / TIKI TAKO	Klaassen et al. (2018)	Adolescents 12–18 y with T1D (≥6 months' diagnosis); pre-pilot n = 7 (2 weeks) + pilot n = 14 (6–8 weeks); Netherlands	Serious game (main narrative + 7 mini-games), 3-tier point system (Experience/Knowledge/Evolution), rule-based Virtual Coach, sensor network (glucometer, pedometer, insulin pen)	Below-average usability (SUS: pre-pilot M = 44.58, pilot M = 50.18); platform rated 6.83/10 (pre-pilot) and 6.07/10 (pilot) overall; substantial recruitment attrition (16 of 30 eligible participants withdrew, mainly due to time constraints); only 4 participants felt the platform supported their diabetes management.
Commercial gamified apps (n = 8 identified)	Alsaman et al. (2020)	Free apps on Google Play / App Store	Character care, quizzes, storytelling themes; no social networking feature identified	Not a clinical evaluation; descriptive review of app features only
Caregiver-informed screen design (prototype, 13 screens)	Alsaman et al. (2021)	Caregivers of children with T1D, Saudi Arabia	Character care, "challenging friend," points/levels/leaderboard, reminders/notifications	Caregiver acceptability/preference data; no clinical outcome reported

Intervention / Platform	Source	Population & Design	Gamification Elements	Reported Outcomes
mySugr	Debong et al. (2019)	Real-world T1D users; observational evaluation (n=198)	Character-care avatar ("diabetes monster"), point challenges, automated BG sync, trend analysis	High initial engagement and user satisfaction; increased SMBG frequency; modest, non-significant trends in long-term HbA1c normalization without clinical coaching.
Young with Diabetes	Castensøe-Seidenfaden et al. (2018)	Adolescents and young adults with T1D (N=151, ages 12–22); 12-month RCT	Peer-to-peer social networking, peer support features, interactive problem-solving tools, supportive feedback	Paradoxical statistically significant increase in HbA1c in the intervention group compared to standard care (adjusted mean difference +4.1 mmol/mol, P=.04); positive user perception of peer and psychosocial support, but no glycemic benefit.

3.3. Clinical Context: Glycemic Trajectories, Transition Vulnerabilities, and Biomedical Efficacy

Glycemic control typically deteriorates during adolescence before gradually improving in early adulthood (Clements et al., 2016; Foster et al., 2019), a trajectory further complicated by care fragmentation during the transition to adult care (Aljohani et al., 2024; Garvey et al., 2017; Iyengar et al., 2019; Monaghan et al., 2015). Within this context, gamified mHealth interventions tend to demonstrate greater impacts on behavioral and psychosocial metrics than on objective glycemic endpoints.

Several detailed evaluations omitted HbA1c as a primary endpoint, prioritizing usability and psychosocial measures. For instance, the *PERGAMON* pilot focused on usability via the System Usability Scale and emotional distress via the Problem Areas in Diabetes questionnaire (PAID), framing the work as a feasibility trial (Klaassen et al., 2018).

Gamified tools often improve self-monitoring, app engagement, and treatment participation, yet their effects on HbA1c remain inconsistent. In a scoping review, Beh et al. (2026) noted that among the nine included studies reporting glycemic outcomes, four demonstrated statistically significant improvements in HbA1c, while the remaining five reported stability or no change. Gamification was identified in five studies, including *bant*, which awarded experience points for blood glucose logging (Beh et al., 2026). Similarly, an umbrella review by Sapkota et al. (2026) observed directional HbA1c reductions across all included reviews, though statistically significant improvements were rarely confirmed.

Individual trials reported similar mixed findings. Evaluations of the Young with Diabetes app (Castensøe-Seidenfaden et al., 2018) and the *bant* platform (Goyal et al., 2017) demonstrated divergent glycemic trajectories: the 12-month trial of *bant* yielded no significant differences in HbA1c between intervention and control groups, whereas the Young with Diabetes trial resulted in a statistically significant increase in HbA1c in the app cohort compared to standard care (adjusted mean difference: 4.1 mmol/mol, P = .04).

This disconnect between behavioral logging and objective glycemic control is further mirrored in research prototypes such as *PERGAMON*, where short-term exposure failed to translate into active therapeutic support for the majority of participants, even though psychosocial metrics like diabetes distress remained stable (Klaassen et al., 2018). Broader evaluations and randomized trials indicate improvements in psychosocial functioning and behavioral logging without parallel improvements in glycemic markers (Beh et al., 2026; Modi et al., 2026). Across primary evaluations, metrics of behavioral engagement did not correspond directly to long-term glycosylated hemoglobin trajectories.

User engagement consistently declines over time, with usage dropping sharply after initial adoption. In chronic disease management, clinical value depends on sustained daily use rather than initial downloads. Evaluating long-term usage is hindered by substantial user attrition. Dropout rates reach 40% in randomized controlled trials and 49% in observational studies, compromising statistical power and sample representativeness (Amagai et al., 2022; Deniz-Garcia et al., 2023). Additionally, primary trials frequently

recruited from tertiary care settings, combining structured clinical oversight with financial incentives. This pattern was observed in the 12-month *bant* randomized trial, where mobile analytics categorized participants into high, moderate, low, and very low engagement tiers (Goyal et al., 2017).

The PERGAMON pilot studies reported heterogeneous platform usage patterns. In the pre-pilot group, usage ranged from complete non-use to 40 hours over two weeks ($M \approx 10$ hours), whereas 57% of pilot group participants used the platform weekly, totaling between 10 minutes and 18 hours over 6–8 weeks (Klaassen et al., 2018). Qualitative feedback attributed this drop to design mismatches: participants rated the game as highly difficult (8.4–8.5 out of 10) while describing its storyline and graphics as 'childish,' creating an age-inappropriate barrier to retention (Klaassen et al., 2018).

Automated data synchronization, hardware integration, and real-time clinician feedback aim to reduce the burden of manual logging. However, empirical trials show that automated telemetry alone cannot guarantee long-term user retention, as several platforms suffer rapid drop-offs in engagement despite automation (Cafazzo et al., 2012; Castensøe-Seidenfaden et al., 2018; Klaassen et al., 2018). In the PERGAMON trial, data transmission failures between glucometers and the app—alongside unrealistic assumptions regarding continuous wearable use—directly compromised system usability (Klaassen et al., 2018). By contrast, the Didget® hardware-integrated system received positive feedback from users and clinicians for ease of use, monitoring adherence, and habit formation (Klingensmith et al., 2013).

4. Discussion

4.1. Interpretation of Gamification Mechanics and Behavioral Alignment

This synthesis shows a fundamental divergence in gamified mobile health (mHealth) platforms for Type 1 Diabetes Mellitus (T1DM) self-management among adolescents and young adults. Automated data transmission facilitates initial app adoption by reducing manual logging burden, as shown in the *bant* pilot (Cafazzo et al., 2012) and the Didget® gaming meter trial (Klingensmith et al., 2013). However, these automated systems rely heavily on extrinsic reinforcement, making them vulnerable to declining engagement. Even simplified data entry fails to sustain long-term adherence once the novelty of reward mechanics fades (Goyal et al., 2017).

The commercially available diabetes applications evaluated in this review predominantly relied on a narrow selection of Behavior Change Techniques (BCTs), focusing primarily on self-monitoring and feedback (Priesterroth et al., 2019). Complex mechanisms, including action planning, incentive structures, and narrative progression, remain underutilized (Edwards et al., 2016; Priesterroth et al., 2019). The failure of the PERGAMON platform, despite its sophisticated motivational architecture, illustrates that theoretical alignment alone cannot overcome technical and cognitive friction. Synchronization failures and complex interfaces increase daily management burden, undermining users' sense of competence and accelerating app abandonment (Klaassen et al., 2018; Ryan & Deci, 2000). This design focus appears to leave evaluated applications centered primarily on passive data logging rather than supporting deeper self-regulatory processes (Priesterroth et al., 2019).

More broadly, formal behavioral theories are rarely integrated into application development. While features often reflect implicit feedback loops, explicit theoretical frameworks are rare. When behavioral theories are explicitly reported within the pediatric T1DM mHealth literature, Social Cognitive Theory (SCT) constructs—particularly self-efficacy and behavioral capability—predominate (Beh et al., 2026), whereas Self-Determination Theory (SDT) remains largely confined to conceptual frameworks and isolated research prototypes (Klaassen et al., 2018; Nasri et al., 2025). Collectively, these findings suggest that reliance on extrinsic reward systems alone is unlikely to sustain long-term engagement. This pattern is exemplified by the 12-month *bant* randomized controlled trial, where user engagement declined rapidly as the cumulative burden of manual glucose and meal logging outweighed the perceived value of digital incentives (Goyal et al., 2017); a rapid decline in user engagement documented across the health gamification literature (Lister et al., 2014; Nasri et al., 2025). Addressing this attrition may require moving from extrinsic reinforcement toward theory-driven frameworks like SDT that foster intrinsic motivation (Nasri et al., 2025; Ryan & Deci, 2000). Interventions based on SDT aim to support autonomy through flexible goal setting, competence via progress

tracking, and relatedness through communication channels. Nevertheless, trials like PERGAMON demonstrate that technical barriers and age-inappropriate designs often prevent these theoretical models from promoting sustained adherence (Klaassen et al., 2018).

Long-term clinical efficacy requires theoretically grounded interventions, high usability, and practical integration into daily routines (Beh et al., 2026; Castensøe-Seidenfaden et al., 2018; Sapkota et al., 2026; Trnka et al., 2024).

4.2. The Dichotomy Between Behavioral Adherence and Biomedical Efficacy

Empirical evidence demonstrates a persistent discrepancy between behavioral adherence (e.g., logging frequency) and physiological endpoints, specifically glycated hemoglobin (HbA1c). In an umbrella review, Sapkota et al. (2026) identified consistent directional reductions in HbA1c across all included reviews, though statistically significant improvements were rarely confirmed. This uniform directional trend may partially reflect publication bias and small-study effects, as feasibility studies with neutral or null biomedical outcomes are often underrepresented, potentially overestimating intervention efficacy (Sapkota et al., 2026). In adequately powered, long-term randomized controlled trials, this biomedical benefit is substantially less consistent, with no significant between-group HbA1c differences observed at 12 months (Castensøe-Seidenfaden et al., 2018; Goyal et al., 2017). Consequently, biomedical efficacy remains inconsistent across primary trials despite initial gains in behavioral engagement. Digital platforms can effectively alleviate diabetes-specific distress and burnout. However, they do not directly alter the physiological and metabolic variables that dictate glycemic control. Improving biomarker outcomes may require integrating passive data logging with clinically guided therapeutic decision-making. Standalone gamification mechanics cannot manage complex clinical tasks, such as precise insulin titration or carbohydrate-ratio adjustments (Castensøe-Seidenfaden et al., 2018; Goyal et al., 2017; Modi et al., 2026). Instead, game elements serve primarily to encourage engagement within routine clinical care. Their main value lies in reinforcing daily self-monitoring, providing clinicians with the accurate real-world data needed for timely treatment adjustments (Beh et al., 2026; Goyal et al., 2017; Sapkota et al., 2026).

4.3. Psychosocial Well-Being and the Healthcare Transition Gap

Within the scope of the synthesized literature, no primary empirical gamification trials were identified as being designed specifically for emerging adults (ages 18–25). This primary focus on pediatric populations leaves a distinct gap in the literature; while clinical transition frameworks emphasize autonomous self-advocacy (Garvey et al., 2017; Sawicki et al., 2011), existing gamified platforms often remain structurally configured for parental oversight and child-centric reward loops (Alsalman et al., 2020; Stutvoet et al., 2024). For emerging adults navigating educational, professional, and personal independence (Monaghan et al., 2015), basic mechanics like avatars and badges often feel childish and age-inappropriate (Klaassen et al., 2018). This design misalignment promotes disengagement precisely when the risks of clinic attrition and glycemic deterioration peak (Aljohani et al., 2024; Iyengar et al., 2019). This decline in engagement represents a major clinical concern, as care fragmentation during the transfer to adult services is strongly associated with deteriorating glycemic control and clinic attrition (Aljohani et al., 2024; Garvey et al., 2017; Iyengar et al., 2019). Reduced care continuity combined with increasing self-management responsibility elevates the risk of acute complications, including severe hypoglycemia and diabetic ketoacidosis (Aljohani et al., 2024; Garvey et al., 2022).

The value of gamified interventions depends less on isolated game mechanics and more on sustaining motivation and alleviating emotional burden. As the PERGAMON trial illustrates, theoretically grounded systems fail to engage users if usability and age-appropriate design are neglected (Klaassen et al., 2018). Although glycemic reductions remain inconsistent, non-gamified digital health studies offer useful comparison points. For example, a pilot randomized controlled trial by Modi et al. (2026) showed that a digital intervention significantly reduced diabetes distress and adherence barriers at long-term follow-up.

Systematic evidence points to structural design principles for psychosocial well-being: platforms prioritizing supportive feedback and clinician communication (Castensøe-Seidenfaden et al., 2018; Cloarec et al., 2025) yield more consistent psychological benefits than competitive mechanics. Although extrinsic elements like leaderboards can initially motivate users, public rankings risk inducing social anxiety, reputation maintenance concerns, and unsustainable engagement spikes (Nasri et al., 2025). Fostering competence and relatedness through peer support and collaboration provides a more durable psychological complement to clinical care during transition, even without clear glycemic benefits (Castensøe-Seidenfaden et al., 2018; Nasri et al., 2025).

4.4 Methodological Limitations of the Review

This narrative synthesis has several methodological limitations. First, a meta-analysis could not be conducted, and pooled effect sizes for secondary outcomes—such as HbA1c changes or standardized mean differences in diabetes distress—were not calculated. Quantitative synthesis was impossible due to substantial heterogeneity in participant age, intervention duration (2 weeks to 12 months), and gamification features (ranging from point systems to serious games).

Second, the methodological quality of the included primary studies presents significant interpretive challenges. Many of the evaluated primary systems were pilot or feasibility trials characterized by constrained sample sizes and brief follow-up periods, often suffering from high attrition rates (e.g., Klaassen et al., 2018); this rapid decline in user engagement is a well-documented limitation across the broader digital health literature (Amagai et al., 2022; Baumel et al., 2019). Furthermore, selection bias limits the primary evidence. Included trials frequently recruited highly motivated cohorts from tertiary clinics with structured oversight (Castensøe-Seidenfaden et al., 2018; Goyal et al., 2017). These controlled settings—sometimes involving gamified incentives (Goyal et al., 2017)—do not reflect typical, unsupervised real-world application use. Additionally, even the largest, 12-month randomized controlled trials—including evaluations of the Young with Diabetes app (N = 151) and the bant platform (n = 92)—face inherent methodological constraints, particularly the impossibility of blinding participants and clinicians to digital behavioral interventions.

Third, there is a substantial risk of publication bias and selective reporting; smaller feasibility trials with neutral or null biomedical results remain systematically underrepresented, potentially overestimating the perceived efficacy of digital interventions across existing syntheses (Sapkota et al., 2026). Finally, this review did not employ a formal framework to grade the certainty of the evidence, such as the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) approach. These findings represent a qualitative synthesis of preliminary trends rather than a basis for clinical guidelines.

4.5. Implications for Future Intervention Design

Translating mHealth engagement into clinical benefits requires moving from standalone applications toward tools integrated into routine medical care. Systems should prioritize seamless, automated data transfer by directly integrating with continuous glucose monitoring (CGM) and automated insulin delivery systems, thereby mitigating manual logging burdens. Future interventions for emerging adults should replace child-centric reward mechanics with designs grounded in Self-Determination Theory to foster intrinsic motivation, peer collaboration, and age-appropriate psychosocial support.

5. Conclusions

Current evidence suggests that gamified mHealth applications can increase blood glucose monitoring frequency and support psychosocial well-being in specific clinical contexts. A discrepancy persists between initial behavioral engagement and durable biomedical efficacy, as long-term randomized controlled trials inconsistently report statistically significant improvements in glycated hemoglobin (HbA1c). Reliance on basic reward mechanics, such as points and badges, leaves platforms vulnerable to declining engagement as the novelty fades and manual logging burdens persist. Theory-driven platforms also fail to achieve long-term adoption if usability, technical reliability, and age-appropriate design are neglected.

Directions for Future Research

1. **Interoperability with Automated Technologies:** Future interventions should mitigate manual logging burdens through direct integration with continuous glucose monitoring (CGM) systems and automated insulin delivery devices. Rather than assuming device integration is simple, future designs must prioritize technical reliability and automated data transfer under real-world conditions.

2. **Developmentally Tailored AYA Co-Design:** Researchers should move beyond child-centric models and involve emerging adults (ages 18–25) directly in app design to address the practical and psychosocial challenges of healthcare transition. Given that caregiver-informed design work has focused almost exclusively on younger children (Alsalman et al., 2021), analogous co-design studies conducted directly with emerging adults represent a critical empirical gap.

3. **Longitudinal Trials and Methodological Rigor:** Future studies should incorporate prospective trial registration, adequate sample power, and transparent reporting of predefined biomedical outcomes to mitigate publication bias and strengthen the quality of future evidence syntheses. This approach is critical because existing umbrella reviews show consistent trend-level HbA1c reductions that rarely achieve statistical significance (Sapkota et al., 2026)—a pattern likely amplified by the underreporting of null secondary outcomes in small feasibility trials.

Current evidence indicates that gamification is best viewed as a supportive adherence tool rather than an independent therapeutic strategy. The clinical value of mHealth interventions in Type 1 Diabetes will depend on their integration with behavioral theory, automated devices, and routine care, rather than on standalone game mechanics.

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