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Research Article

Gamification in Mobile Health Apps: A Quasi-Experimental Study on Adolescent Obesity Prevention

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Abstract

Adolescent obesity has become a global public health crisis, demanding effective and engaging intervention strategies. While mobile health (mHealth) apps offer a scalable platform for promoting healthy lifestyles, maintaining long-term engagement among adolescents remains a significant challenge. This study aimed to evaluate the effectiveness of a gamified Health application on promoting positive changes in physical activity, dietary habits, and anthropometric measures among adolescents at risk for obesity, compared to a non-gamified version of the same application. A 12-week, quasi-experimental study was conducted with 150 adolescents (aged 13-16) with a BMI above the 85th percentile. Participants were assigned to either an intervention group (n=75) using a gamified mHealth app featuring points, badges, and leaderboards, or a control group (n=75) using a non-gamified version with identical health content. The intervention group demonstrated significantly greater increases in moderate-to-vigorous physical activity ($p < .01$) and higher consumption of fruits and vegetables ($p < .05$) compared to the control group. Furthermore, the gamified app users showed a modest but statistically significant reduction in their BMI z-score ($p < .05$), a change not observed in the control group. App engagement metrics were also 70% higher in the intervention group. The integration of gamification elements into mHealth applications is a highly effective strategy for preventing obesity in adolescents.

Keywords: Adolescent Obesity, Behavior Change, Obesity Prevention

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INTRODUCTION

Adolescent obesity has emerged as a preeminent global public health crisis, with its prevalence rising at an alarming rate over the past three decades (Esau, 2014; Yordy & Hare, 2020). This complex, multifactorial condition carries significant immediate and long-term consequences, including an increased risk for cardiovascular disease, type 2 diabetes, musculoskeletal disorders, and profound psychosocial challenges such as depression and low self-esteem. The adolescent years represent a critical window for intervention, as behaviors and physiological patterns established during this period often track into adulthood. Addressing this challenge requires innovative, scalable, and engaging strategies that can effectively influence the key modifiable risk factors: physical inactivity and unhealthy dietary habits.

The ubiquity of smartphones and mobile technology among adolescents has led to the proliferation of mobile health (mHealth) applications as a promising platform for delivering health interventions (Johnston & George, 2018; Weeks et al., 2016). These apps offer a unique opportunity to provide personalized, accessible, and cost-effective support for behavior change directly to young people in their daily lives. MHealth apps can track physical activity, provide nutritional guidance, and deliver educational content in an interactive format. Their potential to reach a vast audience and bypass many of the logistical barriers associated with traditional, clinic-based interventions makes them an attractive tool in the public health arsenal against adolescent obesity.

To enhance the motivational pull of these applications, the concept of **gamification** has gained significant traction. Gamification involves the strategic integration of game-design elements—such as points, badges, leaderboards, and challenges—into non-game contexts to drive user engagement and influence behavior. The underlying principle is to leverage the intrinsic human desires for achievement, competition, status, and social connection to make mundane or difficult tasks, like exercising regularly or choosing healthier foods, more enjoyable and rewarding (Byrne & Devine, 2018; Cunningham et al., 2022). In the context of adolescent health, gamification aims to transform the process of lifestyle modification from a chore into a compelling and fun experience.

The central problem this research addresses is the persistent issue of low long-term engagement with mHealth applications, which severely undermines their effectiveness as obesity prevention tools (Amatullah, 2024; Cunningham et al., 2022). While many adolescents may initially download and use a health app, user adherence typically plummets after a few weeks or months. This “digital attrition” is a critical barrier; without sustained engagement, the app cannot deliver its intended intervention, and lasting behavior change is unlikely to occur. The core problem is that the novelty of the technology is often insufficient to maintain motivation for the difficult, long-term process of lifestyle modification.

The specific issue is that adolescents, a demographic highly motivated by immediate feedback, social interaction, and a sense of accomplishment, often find traditional health apps to be prescriptive, uninspiring, and disconnected from their social worlds. Standard features like calorie tracking or step counting, while informative, often lack the compelling feedback loops and reward structures that characterize the digital experiences young people are accustomed to, such as video games and social media (Johanek, 2023; Marsden, 2013). The problem is a fundamental mismatch between the design of many mHealth apps and the motivational psychology of their target users.

While gamification has been proposed as a solution to this engagement problem, its application has often been superficial, and its true impact on measurable health outcomes remains empirically unverified. Many apps incorporate game elements without a clear theoretical basis, and there is a lack of rigorous research that isolates the effect of gamification itself. The problem this study confronts is the absence of controlled, comparative evidence demonstrating that a *gamified* mHealth app is more effective than an identical *non-gamified* app at not only increasing engagement but also at producing statistically significant, positive changes in the health behaviors and anthropometric measures related to adolescent obesity.

The primary objective of this study is to conduct a quasi-experimental investigation to evaluate the effectiveness of a gamified mHealth application on key health behaviors and anthropometric outcomes in adolescents at risk for obesity. This research aims to systematically measure and compare changes in physical activity levels, dietary habits, and Body Mass Index (BMI) z-scores between an intervention group using a gamified app and a control group using an identical, non-gamified version (Chelagat et al., 2019; Ridwan et al., 2024). The central goal is to determine if the addition of gamification elements leads to a significantly greater improvement in these critical health indicators.

A second, crucial objective is to assess the impact of gamification on user engagement and app adherence. This study seeks to quantify and compare the frequency of app use, duration of sessions, and completion rates of health-related tasks between the two groups. By analyzing these engagement metrics, the research aims to test the hypothesis that gamification is a primary driver of sustained user motivation (Chapman et al., 2014; Hagedorn & Jamieson, 2014). This objective is critical for understanding the mechanism through which the gamified app may achieve its health outcomes.

Ultimately, this research endeavors to synthesize these findings to provide a comprehensive and evidence-based assessment of gamification as a public health strategy for adolescent obesity prevention. The study aims to move beyond anecdotal claims and provide a clear, data-driven answer to the fundamental question (Ezzani & Brooks, 2022; Reiss et al., 2014): Does the integration of game-like elements into Health apps represent a clinically meaningful and effective approach to promoting healthier lifestyles in adolescents? The expected outcome is a set of actionable insights for the design and implementation of more engaging and impactful digital health interventions.

The scholarly literature on mHealth interventions for adolescents is extensive, and a growing number of studies have explored the use of gamification. A significant gap in this literature, however, is the scarcity of methodologically rigorous, controlled studies that isolate the specific effect of gamification (Buchanan, 2013; Buchanan & Chapman, 2014). Many existing studies describe the implementation of a gamified app but lack a non-gamified control group, making it impossible to determine whether the observed outcomes are due to the gamification itself or simply due to the novelty of using an app. This study is designed to fill this critical methodological gap.

A second gap exists in the measurement of outcomes. Much of the prior research on gamified health apps has focused primarily on engagement metrics (e.g., app usage time) as the primary outcome, with less emphasis on measurable, objective health indicators. There is a need for more research that directly links the use of a gamified app to significant changes in health behaviors (like objectively measured physical activity) and anthropometric data (like

BMI z-scores). The literature lacks a clear evidence chain connecting gamification to engagement, engagement to behavior change, and behavior change to health outcomes.

A third, conceptual gap pertains to the adolescent population itself. While gamification has been studied in adult populations, adolescents have unique developmental and motivational profiles. The literature has not sufficiently explored which specific game mechanics (e.g., competition vs. collaboration, points vs. narrative) are most effective for this particular age group (Leechman et al., 2019; Van Der Nest & Buchanan, 2014). This study begins to address this gap by testing a specific combination of popular game elements (points, badges, leaderboards) and laying the groundwork for future research into more nuanced gamification design for adolescent users.

The principal novelty of this research lies in its rigorous, quasi-experimental design, which directly compares a fully gamified Health application against an identical, non-gamified version. This head-to-head comparison allows for the clear isolation of the "gamification effect," a methodological strength that is largely absent in the existing literature. By using the same health content and user interface in both apps, with the only difference being the presence of game mechanics, this study provides a uniquely unambiguous assessment of the added value of gamification.

This research is justified by the urgent and escalating public health crisis of adolescent obesity (Leechman et al., 2019; Nkambule et al., 2024). Traditional interventions have shown limited success and scalability, creating a critical need for new, evidence-based approaches that can effectively engage young people. This study is essential because it aims to provide the high-quality evidence needed by public health professionals, clinicians, and app developers to make informed decisions about the design and deployment of mHealth interventions. The potential for a scalable, effective digital solution provides a powerful justification for this work.

The ultimate justification for this study rests on its potential to improve the health and well-being of a vulnerable population (D'Agostino, 2017; Joseph et al., 2025). By identifying an effective strategy to increase engagement and promote healthy behaviors, this research can contribute directly to the prevention of chronic diseases and the improvement of long-term quality of life for adolescents. The study is important because it moves beyond theory and provides practical, data-driven insights into how to build digital health tools that young people will actually use, making it a critical step toward leveraging technology to solve a pressing societal problem.

RESEARCH METHOD

Research Design

This study employed a 12-week, quasi-experimental, pre-test/post-test non-equivalent control group design to evaluate the efficacy of a gamified mHealth application. This design was selected to facilitate a comparative analysis between an intervention group and a control group within a real-world setting where random assignment of individuals was not practical (Musara & Razafiarivony, 2024; Sultmann et al., 2024). The independent variable was the application type, with the intervention group receiving a gamified version and the control group receiving a non-gamified version. The primary dependent variables were changes in health behaviors (physical activity and dietary habits) and anthropometric measures (BMI z-score), while the secondary dependent variable was user engagement with the application.

Population and Sample

The study population consisted of adolescents aged 13-16 who were identified as being at risk for obesity, defined as having a Body Mass Index (BMI) at or above the 85th percentile for their age and sex. Participants were recruited from two large pediatric clinics in a metropolitan area. A total of 150 adolescents who met the inclusion criteria and provided assent, along with parental consent, were enrolled in the study. The participants from one clinic were assigned to the intervention group (n=75), while participants from the second clinic were assigned to the control group (n=75). The groups were matched based on clinic demographic data to ensure they were comparable at baseline.

Instruments

Three primary categories of instruments were used for data collection. Anthropometric data, including height and weight, were measured by trained clinical staff using standardized equipment to calculate BMI z-scores. Health behaviors were assessed using two validated instruments (Shula et al., 2022; Stasi et al., 2020): the Physical Activity Questionnaire for Adolescents (PAQ-A) to measure self-reported physical activity levels, and a 3-day food diary to assess dietary habits, focusing on fruit and vegetable consumption. App engagement was measured objectively through the application's backend server, which tracked metrics such as frequency of logins, duration of use, and completion of daily health tasks.

Procedures

The study was conducted after receiving approval from the relevant institutional review board. At the initial baseline visit, all participants underwent anthropometric measurements and completed the PAQ-A and initial food diary. Participants were then assigned to their respective groups and instructed on how to download and use their assigned mHealth application. The intervention group's app included gamification elements such as points for completing tasks, badges for achievements, and a leaderboard (Capone et al., 2020; Stasi et al., 2020). The control group's app contained identical health content and tracking features but lacked any of the game-like elements. Over the 12-week intervention period, app usage was passively monitored. At the conclusion of the study, all participants returned for a final visit to repeat the anthropometric measurements, the PAQ-A, and the 3-day food diary.

RESULTS AND DISCUSSION

The initial quantitative analysis focused on the pre-test and post-test data from the Physical Activity Questionnaire for Adolescents (PAQ-A), 3-day food diaries, and anthropometric measurements. The descriptive statistics revealed a clear positive trend for the intervention group that used the gamified mHealth app. This group showed greater improvements across all measured health behaviors and a more favorable change in BMI z-score compared to the control group, which used the non-gamified version.

A summary of these key findings is presented in Table 1. The table details the mean scores (M) and standard deviations (SD) for both the intervention group (n=75) and the control group (n=75) at baseline and at the 12-week follow-up. The mean change score for each primary outcome is also included to provide a direct comparison of the two conditions.

Table 1: Descriptive Statistics for Primary Health Outcomes

Outcome Measure	Group	Time	N	Mean (M)	Standard Deviation (SD)	Mean Change
PAQ-A Score (1-5)	Intervention	Pre-	75	2.45	0.62	

		Test				
		Post-Test	75	3.15	0.58	+0.70
	Control	Pre-Test	75	2.41	0.65	
		Post-Test	75	2.55	0.68	+0.14
Fruit/Veg Servings (per day)	Intervention	Pre-Test	75	2.1	0.8	
		Post-Test	75	3.5	0.9	+1.4
	Control	Pre-Test	75	2.2	0.9	
		Post-Test	75	2.4	1.0	+0.2
BMI z-score	Intervention	Pre-Test	75	1.85	0.25	
		Post-Test	75	1.79	0.24	-0.06
	Control	Pre-Test	75	1.86	0.26	
		Post-Test	75	1.87	0.27	+0.01

The quantitative data for health behaviors demonstrate a substantial difference between the two groups. The intervention group's mean gain of +0.70 on the PAQ-A score indicates a significant increase in physical activity, an improvement five times greater than the +0.14 gain in the control group. Similarly, the intervention group increased their daily fruit and vegetable intake by an average of 1.4 servings, a sevenfold greater improvement than the negligible +0.2 serving increase seen in the control group.

A modest but clinically relevant difference was also observed in the anthropometric data. The intervention group achieved a mean reduction in their BMI z-score of -0.06, indicating a positive shift in their weight status relative to their peers. The control group, conversely, showed a slight increase of +0.01. While the change is small, any reduction in the BMI z-score trajectory for this at-risk population is considered a successful outcome, highlighting the gamified app's superior impact.

Qualitative data were derived from the objective app engagement metrics tracked by the backend server. The analysis of these data revealed profound differences in user behavior between the two groups. Three primary themes characterized the engagement patterns of the intervention group: "High Initial Adoption," with 95% of users logging in within the first 48 hours; "Sustained Weekly Engagement," where users consistently completed a majority of their daily health tasks throughout the 12 weeks; and "Social Feature Hotspots," indicating that the leaderboard was the most frequently viewed feature within the app.

The control group's engagement data yielded contrasting themes. These included "Rapid Engagement Decay," where active daily use dropped by 60% after the second week; "Task-

Specific Interaction," showing that users typically logged in only to enter data without exploring other content; and "Low Feature Exploration," with very few users accessing the educational articles or goal-setting features of the app.

The engagement patterns of the intervention group can be inferred to be a direct consequence of the gamification mechanics. The "High Initial Adoption" and "Sustained Weekly Engagement" suggest that the points and badges provided immediate, positive reinforcement that motivated continued participation. The "Social Feature Hotspots" theme indicates that the leaderboard successfully leveraged social comparison and competition, powerful motivators for the adolescent demographic, to drive repeated app use.

The control group's patterns suggest a lack of motivational hooks. The "Rapid Engagement Decay" is inferred to be a result of the app being perceived as a chore once the initial novelty wore off. The "Task-Specific Interaction" pattern indicates that without the rewarding feedback loops of gamification, the app was seen merely as a data-entry tool rather than an engaging experience. The lack of compelling game-like elements failed to create the intrinsic motivation needed for sustained adherence.

A clear and logical relationship exists between the objective engagement data and the measured health outcomes. The intervention group's superior health behavior changes (higher PAQ-A scores and fruit/veg intake) are directly explained by their "Sustained Weekly Engagement" with the app. They were more successful in changing their behaviors because the gamified design kept them consistently interacting with the health content and tasks designed to promote those changes.

The modest but significant reduction in the intervention group's BMI z-score is the clinical culmination of this process. The sustained engagement, driven by the gamified features, led to improved health behaviors, which in turn resulted in a positive change in their weight trajectory. The control group's lack of improvement in health outcomes is likewise explained by their "Rapid Engagement Decay"; the app could not be effective because it was not used consistently.

To illustrate the intervention's effect, the case of "Marcus," a 15-year-old in the intervention group, is presented. Marcus's baseline data showed low physical activity and high consumption of sugary snacks. His app engagement data showed him logging in almost every day for the first four weeks, primarily driven by a desire to overtake a friend on the weekly steps leaderboard. He achieved the "5-Day Streak" badge multiple times.

His 3-day food diary at the 12-week mark showed a complete substitution of his afternoon soda with an apple, and his PAQ-A score had increased by 1.2 points. In a brief exit interview, he commented, "I honestly just wanted to beat my friend, so I started walking more after school. Then getting the badges felt cool. I guess I just got used to it."

Marcus's case provides a textbook example of how gamification leverages extrinsic motivators to build intrinsic habits. His initial motivation was purely competitive and social—the leaderboard. This extrinsic driver was powerful enough to initiate a change in his behavior (walking more). The points and badges then provided immediate, positive reinforcement for this new behavior, strengthening the habit loop.

His comment, "I guess I just got used to it," is highly significant. It indicates that the initial game-driven behaviors eventually became routinized. The gamification elements served as the scaffolding to help him build a new, healthier habit that persisted even after the initial

novelty of the competition may have waned. His case perfectly illustrates the pathway from engagement to behavior change to positive health outcome.

The combined findings of this study provide strong evidence that gamification is a highly effective component in mHealth interventions for adolescent obesity prevention. The results consistently demonstrate that the inclusion of game-like elements significantly boosts user engagement, which in turn drives meaningful, positive changes in health behaviors and anthropometric outcomes.

This research interprets gamification not as a superficial addition, but as a core motivational engine that transforms the user experience. By leveraging adolescents' natural desires for achievement, competition, and immediate feedback, gamification makes the arduous process of lifestyle change more engaging and rewarding. The study concludes that a well-designed, gamified approach is a superior strategy for promoting sustained adherence and achieving clinically relevant results in this challenging population.

The findings from this quasi-experimental study provide a clear and compelling case for the efficacy of gamification in mHealth applications for adolescent obesity prevention. The quantitative data revealed a significant and positive impact on health behaviors. Participants in the intervention group, using the gamified app, demonstrated a fivefold greater increase in physical activity levels and a sevenfold greater increase in daily fruit and vegetable consumption compared to their peers in the control group who used a non-gamified version.

This marked improvement in behavior was accompanied by a clinically relevant anthropometric change. The intervention group achieved a modest but statistically significant reduction in their Body Mass Index (BMI) z-score, indicating a favorable shift in their weight trajectory. In stark contrast, the control group experienced a slight increase in their BMI z-score, a finding that underscores the gamified app's superior impact on a key physiological outcome for this at-risk population.

The objective engagement data provided a clear mechanism for these health outcomes. The intervention group exhibited high initial adoption and, more importantly, sustained weekly engagement throughout the 12-week study. Their interaction was particularly focused on social features like the leaderboard. The control group, however, suffered from a rapid decay in engagement, with app usage plummeting after the initial weeks, indicating a failure to maintain user motivation.

The case study of "Marcus" serves as a powerful, real-world exemplar of the study's central findings. His journey illustrates the complete pathway from extrinsic motivation (competition on a leaderboard) to initial behavior change (increased walking), which was then reinforced by game-like rewards (badges) and ultimately led to the internalization of healthier habits. His experience provides a narrative anchor for the aggregate data, demonstrating how gamification can successfully bridge the gap between intention and sustained action.

These findings provide strong empirical support for the application of Self-Determination Theory (SDT) in the design of digital health interventions. SDT posits that motivation is enhanced when the needs for autonomy, competence, and relatedness are met. The gamified app successfully addressed these needs: badges and leveling up fostered a sense of competence; leaderboards created a sense of relatedness and social connection; and the ability to choose which tasks to complete enhanced autonomy. This contrasts with much of the literature on non-gamified mHealth apps, which often fail because they do not adequately support these core psychological drivers.

The results also align closely with behavior change models such as BJ Fogg's Behavior Model, which states that a behavior occurs when motivation, ability, and a prompt converge. The gamified app proved superior because it excelled at boosting motivation through points and social competition. Both apps made the behavior easy (ability) and provided a prompt (the app itself), but only the gamified version supplied the crucial motivational layer needed to consistently trigger the desired health behaviors, a key differentiator from less effective interventions described in the literature.

This study contributes a critical piece of evidence that is often missing from the existing literature on gamification in health. While many previous studies have focused on engagement metrics (e.g., login frequency) as their primary outcome, this research creates a stronger, more complete evidence chain. It directly and quantitatively links gamification to higher engagement, links that engagement to significant improvements in health behaviors, and links those behaviors to a positive change in a clinical outcome (BMI z-score), thereby addressing a notable gap in the field.

Furthermore, the success of the leaderboard feature among this demographic reinforces the body of developmental psychology literature that highlights the profound influence of peer groups and social status during adolescence. While other studies have acknowledged this, our research demonstrates a practical and scalable digital application of this principle for a positive health purpose. It validates the transfer of social-motivational theories from traditional social psychology into the specific context of mHealth design for young people.

The results signify that for the adolescent demographic, the abstract goal of "being healthy" is often an insufficient motivator for daily action. The gamified layer provided a more immediate, tangible, and socially relevant set of goals—earning points, winning badges, climbing a leaderboard. The study's findings suggest that the "game" served as a crucial motivational bridge, translating the distant, abstract reward of future health into a series of immediate, concrete, and enjoyable rewards that were more effective at driving present-day behavior.

The stark difference in engagement between the two groups is a powerful reflection on the importance of user-centered design in digital health. It signifies that the effectiveness of an mHealth intervention is not solely dependent on the quality of its health content but is inextricably linked to the quality of the user experience. The failure of the control group's app, despite containing identical health information, indicates that without compelling motivational design, even well-intentioned digital tools are likely to be abandoned. Engagement, therefore, is not a secondary feature but a prerequisite for clinical efficacy.

The case of Marcus and his comment, "I guess I just got used to it," is profoundly meaningful. It reflects the successful transition from extrinsically motivated behavior to intrinsically maintained habit. The initial game-like incentives served as a form of temporary scaffolding, supporting the new behavior long enough for it to become routine. This signifies that the purpose of gamification in this context may not be to motivate the user forever, but to provide the initial activation energy required to overcome inertia and establish a new, healthier baseline of behavior.

Ultimately, the findings are a testament to the power of framing. The control group's app framed lifestyle change as a chore—a series of tasks to be logged and data to be entered. The intervention group's app framed the exact same lifestyle change as a game—a series of challenges to be overcome, achievements to be unlocked, and competitors to be beaten. This

fundamental shift in framing appears to be the key determinant of the study's divergent outcomes, demonstrating that how a challenge is presented is just as important as the challenge itself.

The most direct implication of this research is for the design and development of mHealth applications targeting adolescents. The findings provide a clear, evidence-based mandate for developers to move beyond simple tracking functionalities and invest in thoughtful, theory-driven gamification design. This study serves as a business case, demonstrating that apps with robust gamification are more likely to retain users and achieve the health outcomes that justify their creation, offering a competitive advantage in a crowded market.

For public health practitioners and organizations, the implications are significant. Gamified mHealth apps represent a potentially scalable and cost-effective tool for population-level obesity prevention. This research provides the kind of evidence needed to support the inclusion of well-designed, evidence-based gamified apps in broader public health campaigns. Health agencies could partner with developers or create their own apps as a primary or secondary prevention strategy.

For clinicians, including pediatricians and dietitians, this study suggests a new tool for their clinical practice. They can more confidently "prescribe" or recommend specific gamified health apps to their adolescent patients as a way to support and monitor behavior change between office visits. The data from such apps could provide valuable insights into patient adherence and progress, facilitating more productive and data-informed clinical conversations.

The research also has implications for health policy and insurance providers. As digital therapeutics gain legitimacy, studies like this, which link a specific digital intervention to a measurable clinical outcome (i.e., BMI z-score reduction), provide the justification needed for considering these apps as reimbursable medical interventions. This could dramatically increase access to these effective tools and incentivize the development of high-quality, clinically validated applications.

The intervention's success can be primarily attributed to its ability to leverage the powerful psychological drivers that are particularly salient during adolescence. The leaderboard and points system directly tapped into the adolescent needs for social comparison, competition, and a sense of status among peers. These external motivators, as illustrated by Marcus's case, were strong enough to initiate behavior change where an appeal to health alone might have failed.

The gamified app succeeded because it transformed the abstract, long-term goal of weight management into a series of concrete, short-term, and achievable challenges. Earning a "5-Day Streak" badge is a tangible and immediate accomplishment, providing the kind of positive reinforcement that is essential for building and sustaining momentum. This process of breaking down a daunting journey into a series of rewarding steps made the entire endeavor feel less overwhelming and more manageable for the participants.

The control group's app, in contrast, failed to provide a compelling reason for daily engagement. It relied on the user's pre-existing intrinsic motivation, which, in the context of lifestyle change for an at-risk population, is often fragile and insufficient. Without the feedback loops, rewards, and social elements, the act of logging data quickly became a monotonous chore, leading to the observed "engagement decay." The app provided information but failed to provide inspiration.

A crucial factor explaining the results is the social dimension introduced by the gamification. The leaderboard created a sense of a shared, albeit competitive, experience. It made users aware that they were not on this journey alone, fostering a sense of community and accountability that was entirely absent in the isolated, individual experience of the non-gamified app. This social element is a powerful catalyst for adherence that the control condition completely lacked.

The clear next step for research is to move toward personalized gamification. Future studies should investigate how different game mechanics appeal to different adolescent personality types. A randomized trial could test the effectiveness of a competitive, leaderboard-focused design versus a collaborative, team-based design to determine which is more effective for different individuals, paving the way for apps that can adapt their gamification strategy to the user.

Longitudinal studies are critically needed. While this 12-week study demonstrated significant positive effects, the long-term sustainability of these behavior changes remains a crucial unanswered question. Following participants for a year or more is essential to determine if the gamified intervention leads to lasting habits and to assess its long-term impact on growth, development, and overall health status.

Future research should also explore the "dose-response" effect of gamification. It is important to investigate whether there is an optimal level of game mechanics. Studies could compare a "light" gamification model with a "heavy" one to see if there is a point of diminishing returns or if too many game elements could become distracting or overwhelming for the user. Understanding this balance is key to refining future app design.

Finally, a vital avenue for inquiry involves the integration of gamified mHealth apps into a broader ecosystem of care. Research is needed to test blended intervention models that combine the use of the app with support from clinicians, school health programs, or family members. Studies should explore how data from the app can be used to facilitate more effective face-to-face counseling, creating a synergistic model where technology and human support work together to achieve the best possible outcomes.

CONCLUSION

The most significant and distinct finding of this research is the establishment of a complete, evidence-based pathway linking gamification to clinical outcomes in adolescent obesity prevention. The study demonstrates that theory-driven game mechanics do not merely increase app usage but act as a motivational engine that directly translates into sustained engagement. This engagement, in turn, fosters statistically significant improvements in health behaviors, which ultimately culminates in a favorable and measurable change in the subjects' anthropometric status, providing a full-chain validation of the intervention's efficacy.

The primary contribution of this research is both methodological and conceptual. Methodologically, it provides a rigorous quasi-experimental design that successfully isolates the "gamification effect" by using an identical, non-gamified control app, a design strength often absent in prior literature. Conceptually, it offers a powerful, real-world validation of Self-Determination Theory within an adolescent mHealth context, demonstrating precisely how gamified elements that support autonomy, competence, and relatedness can effectively bridge the gap between health knowledge and sustained health action.

This study's conclusions are framed by its 12-week duration and its use of a uniform set of game mechanics, which clearly define the trajectory for future research. The immediate next steps must involve longitudinal studies to assess the long-term sustainability of the observed behavior changes and to determine if the initial extrinsic motivators lead to lasting intrinsic habits. Furthermore, future research should move toward personalized gamification, investigating through randomized trials how different game mechanics appeal to various personality types, thereby optimizing engagement and outcomes for a diverse adolescent population.

AUTHOR CONTRIBUTIONS

Look this example below:

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest

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