MIERNICZEK, Mateusz, MIERNICZEK, Maria, MIERNICZEK, Aleksandra, KACZMARSKA, Kinga, ROSOŁOWSKA, Kinga and DUDEK, Jarosław. Digital Health Interventions for School-Aged Children: Effectiveness, Implementation, and Impact on 24-Hour Movement and Psychosocial Well-Being. Journal of Education, Health and Sport. 2025;81:66752. eISSN 2391-8306.
https://doi.org/10.12775/JEHS.2025.81.66752
https://apcz.umk.pl/JEHS/article/view/66752

The journal has had 40 points in Minister of Science and Higher Education of Poland parametric evaluation. Annex to the announcement of the Minister of Education and Science of 05.01.2024 No. 32318. Has a Journal's Unique Identifier: 201159. Scientific disciplines assigned: Physical culture sciences (Field of medical and health sciences); Health Sciences (Field of medical and health sciences).
Punkty Ministerialne 40 punktów. Załącznik do komunikatu Ministra Nauki i Szkolnictwa Wyższego z dnia 05.01.2024 Lp. 32318. Posiada Unikatowy Identyfikator Czasopisma: 201159. Przypisane dyscypliny naukowe: Nauki o kulturze fizycznej (Dziedzina nauk medycznych i nauk o zdrowiu); Nauki o zdrowiu (Dziedzina nauk medycznych i nauk o zdrowiu).
The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 19.11.2025. Revised: 26.11.2025. Accepted: 26.11.2025. Published: 27.11.2025.

Digital Health Interventions for School-Aged Children: Effectiveness, Implementation, and Impact on 24-Hour Movement and Psychosocial Well-Being

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Abstract

Introduction: Insufficient physical activity and prolonged sedentary behavior among school-aged children pose significant public health challenges. Historically, digital screens were viewed as drivers of this "sedentary pandemic," but post-2020 trends have repurposed digital tools, mobile apps, wearables, and exergames, as vectors for health promotion. This review synthesizes evidence on the effectiveness and theoretical mechanisms of these interventions, analyzing their impact on the 24-hour movement paradigm.

Material and Methods: A narrative review was conducted focusing on studies published between 2013 and 2025. Relevant literature was identified through PubMed, Web of Science, and Scopus. Interventions were categorized by technology type, setting (school vs. home), and outcomes, including physical activity (PA), sedentary time, sleep, and psychosocial well-being.

Results: Findings reveal a dichotomy between improved physical fitness and habitual behavior change. While apps improve metrics like agility, their impact on daily habitual activity is inconsistent. However, digital tools significantly reduced sedentary time (Mean Difference -33.12 min/day) and extended sleep (+17 min/night). Structural school-based programs, such as the "Super Quinas" project, outperformed standalone home interventions, achieving significant gains in MVPA (+18 min/day). Effectiveness relied on Behavior Change Techniques, though the "novelty effect" often limited engagement to 4–8 weeks.

Conclusions: Digital health interventions offer promising opportunities to enhance pediatric well-being, particularly when embedded in "phygital" educational settings. Future research must address the "digital divide" and focus on strategies to sustain intrinsic motivation beyond the initial novelty phase.

Keywords: Digital health; Physical activity; School-aged children; Wearable devices; Exergames; Gamification; 24-hour movement behaviors

1. Introduction

Physical inactivity and prolonged sedentary behavior among school-aged children are recognized as major public health challenges worldwide, contributing significantly to the rising prevalence of obesity, cardiometabolic risks, musculoskeletal disorders, and reduced psychosocial well-being. Schools and families have traditionally been viewed as critical environments for promoting healthy behaviors; however, conventional interventions often struggle to engage students effectively or sustain participation over time. Against this backdrop, the intersection of digital technology and pediatric public health has evolved into one of the most dynamic frontiers in modern medicine.

For decades, the public health narrative has largely framed digital screens as the antagonist - a primary driver of the sedentary pandemic and a disruptor of sleep hygiene. However, the post-2020 landscape, accelerated by the necessities of the COVID-19 pandemic, has witnessed a significant paradigm shift. Digital health technologies, including mobile applications (mHealth), wearable activity trackers, immersive exergames, and online educational platforms, are now being repurposed as innovative vectors for health promotion. These tools offer unique opportunities for self-monitoring, real-time feedback, gamification, and peer interaction, potentially addressing the scalability crisis of traditional public health programs by meeting digital natives in their preferred environment.

The theoretical promise of these interventions lies in their ability to operationalize psychological frameworks, such as Self-Determination Theory, through features like goal setting, rewards, and social connectivity. By transforming physical activity from a chore into a gamified experience, digital tools aim to bridge the gap between intent and behavior. Moreover, recent approaches have moved beyond analyzing physical activity in isolation, adopting the

24-Hour Movement Behavior paradigm that integrates physical activity, sedentary time, and sleep quality as interconnected determinants of health.

Despite this promise, the transition from theoretical potential to clinical efficacy is complex. Evidence regarding the effectiveness, acceptability, and long-term impact of digital health interventions remains heterogeneous. While recent systematic reviews report small-to-large beneficial effects on physical fitness parameters and sedentary time reduction, findings regarding habitual, moderate-to-vigorous physical activity (MVPA) are often inconclusive or modest. Furthermore, the digital divide poses a critical ethical challenge; the Inverse Care Law suggests that interventions may be least effective for vulnerable populations who lack the necessary access to devices or digital literacy, potentially exacerbating health inequities.

This narrative review aims to synthesize current evidence on digital health interventions for school-aged children, focusing on studies published between 2013 and 2025. It moves beyond aggregate outcomes to explore the underlying intervention mechanisms, analyzing their impact not only on physical activity but also on the broader 24-hour movement paradigm and psychosocial well-being. Additionally, this review examines implementation factors, barriers, and facilitators that influence effectiveness in both school and home environments, providing a roadmap for future phygital (physical + digital) health strategies.

2. Methods

This narrative review examined digital health interventions aimed at promoting physical activity, reducing sedentary behavior, and supporting well-being in school-aged children (6-18 years). A literature search was conducted in PubMed, Web of Science, and Scopus for studies published between 2013 and 2025. The search strategy focused on identifying relevant literature using the following specific keywords: Digital health, Physical activity, School-aged children, Wearable devices, Exergames, Gamification, and 24-hour movement behaviors.

Included studies comprised randomized controlled trials, quasi-experimental designs, longitudinal studies, and qualitative research involving mobile apps, wearable trackers, or school-based digital programs. Particular attention was paid to systematic reviews published post-2020 to capture recent technological shifts. Data extraction focused on intervention characteristics, study design, and outcomes related to the holistic movement paradigm , specifically MVPA, step counts, sedentary time, and sleep - as well as psychosocial well-being and adherence. A narrative synthesis was employed to highlight patterns of effectiveness, identify active Behavior Change Techniques (BCTs), and examine barriers to implementation in educational environments.

3. Results

3.1. Effects of Mobile Apps, Gamified Platforms, and Exergames on Physical Activity

Analysis of included systematic reviews reveals a statistical distinction between outcomes related to physical fitness and those related to habitual physical activity. A 2024 review reported that mHealth interventions produced “small-to-large” statistically significant effects on specific fitness parameters, including agility, muscle strength, and cardiopulmonary endurance [1]. However, quantitative synthesis regarding habitual daily activity yielded mixed results. Another 2024 meta-analysis identified a significant increase in daily step counts in eHealth intervention groups (Mean Difference: +593.46 steps/day), while the analysis for Moderate-to-Vigorous Physical Activity (MVPA) showed no significant gain across subgroups, with some analyses indicating a mean difference of -1.99 min/day compared to controls [5].

Regarding engagement mechanisms, a 2025 analysis identified specific Behavior Change Techniques (BCTs) associated with higher efficacy in digital interventions. Programs incorporating Goal Setting (BCT 1.1), Action Planning (BCT 1.4), Self-Monitoring (BCT 2.3), and Instruction on how to perform the behavior (BCT 4.1) resulted in greater behavioral changes than those utilizing passive tracking alone [14]. A 2017 large-scale analysis indicated that social competition features generated measurable spikes in walking activity, though these increases were temporally linked to the duration of specific challenges [19].

Longitudinal data on adherence consistently demonstrated a decline over time. Multiple studies reported that user engagement peaked during the first 4 to 8 weeks, followed by a significant reduction in usage frequency [7, 15]. In the context of Augmented Reality (AR) games, a 2021 review observed age-dependent variations: while children aged 5-6 reported sustained enjoyment, motivation in older children (aged 7-8) declined rapidly once the novelty faded and game content did not evolve [16]. Similarly, systematic reviews of Active Video Games confirmed that while they induced energy expenditure equivalent to moderate-intensity exercise [9, 20], sustained participation beyond 12 weeks was rare without updates to game mechanics [14].

While mobile and gamified tools successfully initiate engagement and improve physical competence through instructional content, their capacity to sustain habitual behavior change is limited by the rapid decay of extrinsic motivation once the novelty effect dissipates.

3.2. Impact of Wearable Devices and School-Based Digital Programs

Interventions integrating wearable devices into school settings produced the most robust statistical improvements in movement behaviors. Comparative analysis indicates that structural school-based programs achieved higher adherence rates than home-based or hybrid models [8, 10]. The "Super Quinas" project (2024), a representative structural intervention involving 12 weeks of digital monitoring and extra-curricular activity, reported significant differences between groups. The intervention group demonstrated an increase of approximately 18 minutes of MVPA per day compared to controls [25].

In terms of the 24-hour movement paradigm, digital interventions showed high efficacy in displacing sedentary time. Meta-analytic data reported a mean reduction in overall sedentary behavior of 33.12 min/day and a reduction in recreational screen time of 31.48 min/day [5]. Structural interventions achieved even higher reductions; the "Super Quinas" trial recorded a decrease in sedentary time of approximately 44 minutes per day in the intervention group [25]. Additionally, significant secondary outcomes were observed regarding sleep, with intervention participants achieving an increase in sleep duration of 17 minutes per night [25].

Implementation reviews identified specific facilitators and barriers. Forrest et al. (2025) found that "digital homework", where active tasks are assigned by teachers and verified via wearables, was effective in extending school-based activity goals into the home environment [11]. Furthermore, technology-enhanced "active breaks" in classrooms were associated with improvements in academic metrics, specifically time-on-task and concentration [11, 17]. However, reported barriers to implementation included technical connectivity issues and varying levels of digital literacy among teaching staff, which negatively impacted program fidelity in under-resourced settings [12, 21].

Interventions embedded in the school environment demonstrated superior efficacy compared to home-based models, leveraging structural routines and teacher accountability to drive significant improvements in MVPA, sedentary time reduction, and sleep duration.

3.3. Psychosocial Outcomes and Well-Being

Quantitative assessments of digital health interventions indicated positive shifts in psychosocial outcomes. A 2024 meta-analysis reported statistically significant improvements in self-efficacy regarding physical activity among children using eHealth tools [26]. Furthermore, an umbrella review of meta-analyses found consistent improvements in Executive Function (EF), specifically in the domains of inhibition and working memory, attributed to the dual-task nature of exergames [17].

The literature identifies a specific "dose-response" relationship for mental health benefits within these interventions. Andermo et al. (2020) reported that school-related physical activity interventions were most effective in reducing anxiety and depression when they consisted of moderate-intensity aerobic exercise performed 3 or more times per week for 15-60 minutes [12]. UNICEF data further described a U-shaped relationship between digital engagement and mental well-being, where "moderate use" was associated with higher well-being scores compared to "no use" or "excessive use" [28].

Social engagement metrics revealed that adolescents responded more strongly to competitive features (peer comparison) than younger children [13, 20]. However, attrition data indicated that technical friction played a significant role in disengagement; barriers such as syncing errors and complex user interfaces were frequently cited reasons for withdrawal from home-based components of the interventions [18]. Consistent with physical activity outcomes, psychosocial benefits were maintained longer in multi-component interventions that included human support (e.g., teacher or parent feedback) alongside digital monitoring [5, 11].

Digital health interventions yield measurable psychosocial benefits, including enhanced self-efficacy and executive function, provided that usage remains within a "moderate" range and is supported by social or human interaction to prevent isolation.

3.4. Implementation Fidelity, Socioeconomic Disparities, and Intervention Characteristics

Analysis of intervention feasibility reveals a distinct socioeconomic gradient in effectiveness, often described in the literature as the "Inverse Care Law." Systematic reviews observed that school-based physical activity interventions frequently yielded the smallest effect sizes in populations with the highest baseline risks, largely due to implementation barriers in under-resourced environments [10]. Reviews focusing on the "digital divide" identified that barriers have shifted from simple lack of access (having a device) to disparities in digital literacy and connectivity [21, 29]. In feasibility studies of social-network-based interventions, technical friction, such as device syncing failures, software incompatibility, and inconsistent broadband access, was cited as a primary cause for participant dropout, significantly reducing intervention fidelity [18].

Furthermore, intervention effectiveness was statistically moderated by the intensity of technical support and the duration of the program. Teacher-led implementation was found to be highly sensitive to "burden"; programs requiring extensive technical troubleshooting by educators showed lower compliance rates compared to "plug-and-play" automated systems or those with dedicated external technical staff [22]. Regarding duration, meta-regression analyses indicated an inverse relationship between intervention length and effect size. Studies with durations shorter than 12 weeks consistently reported larger effect sizes for physical activity outcomes compared to those extending beyond six months, quantitatively confirming the decay of engagement over time [1]. These findings indicate that while digital tools are scalable in theory, their real-world efficacy is statistically correlated with the digital infrastructure, the level of human support provided, and the temporal scope of the intervention. These findings underscore the importance of providing adequate technical support and designing interventions that are adaptable to varying socioeconomic contexts, ensuring that digital health tools can achieve their intended impact across diverse school populations

To support the narrative synthesis, key quantitative and qualitative patterns across the included interventions are summarized in Table 1. The table highlights the primary domains affected by digital health tools, physical fitness, MVPA, sedentary behavior, sleep, motivational processes, and equity considerations, illustrating the variability in effectiveness across settings and technologies. These consolidated findings provide an overview of where digital interventions demonstrate the strongest impact and where limitations remain evident.

Domain	**Core Findings (Shortened)**	**Representative Evidence**
Physical Fitness Outcomes	Improvements in agility, strength, balance, endurance; strongest effects in structured or feedback-based programs.	[1], [3], [4]
Moderate-to-Vigorous Physical Activity (MVPA)	Small increases; digital tools mainly raise step counts/light activity unless supported by adults.	[2], [7], [14]

Sedentary Behavior Reduction	Sedentary time decreases (~30 min/day); active digital tasks replace passive screen time.	[5], [10]
Sleep and Circadian Rhythm	Select interventions improve sleep duration and timing.	[25]
School-Based Hybrid Programs	Most sustainable effects; school structure supports compliance and monitoring.	[8], [10], [11]
Gamification and Motivation	Motivation improves short-term; adherence drops after 4–8 weeks without evolving challenges.	[16], [17], [20]
Equity and Implementation Fidelity	Outcomes vary based on digital literacy and infrastructure; low-resource groups show weaker effects.	[18], [19], [21], [29]

Table 1. Summary of Key Findings from Digital Health Interventions

Given the central role of behavioral mechanisms in shaping intervention outcomes, Table 2 presents a structured overview of the Behavior Change Techniques (BCTs) most frequently employed in the analyzed studies. The table outlines how these techniques were operationalized, their relative effectiveness, and the strength of evidence supporting each. This framework helps clarify why certain interventions succeed while others produce only short-term or marginal effects.

Behavior Change Technique (BCT)	**Description / Example**	**Effectiveness**	**Evidence**
Goal Setting (1.1)	Daily/weekly activity goals (steps, MVPA).	Effective only with added monitoring and supervision.	[2], [7]
Action Planning (1.4)	Scheduled activity prompts; structured routines.	Improves adherence; still underused.	[14], [6]

Self-Monitoring (2.3)	Wearable tracking of activity/sleep.	High initial engagement; insufficient alone for habit formation.	[3], [4]
Feedback on Behavior (2.2)	Personalized notifications and progress bars.	Increases light activity but not MVPA.	[5], [7]
Instruction via Demonstration (4.1)	Video modeling, guided tutorials.	Strongest for improving physical fitness skills.	[1], [8]
Social Comparison (6.2)	Rankings, leaderboards, team challenges.	Highly effective for adolescents.	[13], [20]
Rewards / Gamification (10.1)	Badges, levels, points.	Drives early motivation; short-lived without progression.	[16], [17]
Environmental Restructuring (12.1)	School integration, digital homework.	Most effective overall; enhances long-term compliance.	[10], [11]

Table 2. Most Frequently Used Behavior Change Techniques (BCTs) in Digital Interventions

4. Discussion

The synthesis of current evidence suggests that while digital health interventions offer scalable mechanisms for health promotion, their impact is heterogeneous and heavily dependent on intervention design and setting. The findings from this review can be analyzed through four primary thematic threads: the divergence between physical capacity and habitual behavior, the impact on the 24-hour movement paradigm, the necessity of structural integration, and the critical implications for practice.

4.1. The Divergence Between Physical Capacity and Habitual Behavior

A nuanced bifurcation characterizes the effectiveness of mHealth and wearable interventions. Evidence indicates that these tools function effectively as instructional supports, driving measurable improvements in physical fitness parameters such as agility, muscle strength, and cardiopulmonary endurance [1]. However, the translation of these physiological gains into sustained Moderate-to-Vigorous Physical Activity (MVPA) is inconsistent. The disparity between significant increases in step counts (+593 steps/day) and the lack of significant change in MVPA suggests that digital tools currently act as scaffolds for competence, teaching children how to move via video modeling (BCT 4.1), rather than independent drivers of lifestyle transformation. Without human supervision, the automated prompts provided by apps appear sufficient to nudge low-intensity behaviors but often lack the potency to push children across the physiological threshold into vigorous activity [5]. This limitation is likely mechanistic; while apps can successfully operationalize Goal Setting (BCT 1.1), they lack the capacity for environmental restructuring (BCT 12.5), they cannot physically alter the user's surroundings to facilitate spontaneous play in the same way a playground or structured PE class does [14]. Consequently, digital tools are best understood as educational instruments that build physical literacy, rather than autonomous generators of high-intensity exercise.

4.2. Impact on the 24-Hour Movement Paradigm

When analyzed through the broader lens of 24-hour movement behaviors, digital interventions demonstrate consistent clinical utility in the displacement of sedentary time. Systematic reviews report reductions in sedentary behavior averaging over 30 minutes per day [5]. This phenomenon can be interpreted as a form of "digital displacement," where active screen time (exergaming, tracking) successfully competes with and replaces passive screen time (television, social media scrolling). From a metabolic perspective, this substitution is clinically significant; reducing prolonged sedentary bouts improves glucose regulation and vascular health, even if the displaced time does not reach the intensity of MVPA. Furthermore, structural interventions such as the "Super Quinas" project have documented objective increases in sleep duration [25]. This indicates that the primary value of digital health tools may lie in their ability to regulate the circadian balance between rest, light activity, and sleep. By structuring the day with digital checkpoints, these interventions help establish a healthier 24-hour rhythm, minimizing the chaotic, unstructured time that often leads to sleep deprivation and excessive screen consumption [11, 27].

4.3. The Necessity of Structural Integration and Social Context

Sustainability of behavior change remains the primary challenge, with engagement typically declining after an initial 4-to-8-week period due to the erosion of the "novelty effect" [7, 15]. This trajectory is particularly evident in Augmented Reality (AR) interventions. The observation that motivation in older children (aged 7–8) declines more rapidly than in younger groups suggests that as cognitive demands increase, the initial visual appeal of AR becomes insufficient to maintain interest without evolving gameplay complexity [16]. To mitigate this "adherence cliff," successful interventions must transition users from extrinsic gamification (points, badges) to intrinsic motivation (mastery, enjoyment). The review identifies that this transition is significantly more likely when digital tools are embedded in "phygital" (physical-digital) ecosystems within schools. In these environments, technology provides the objective data, but the school provides the accountability and social reinforcement necessary for persistence [8, 10]. Social components, such as peer comparison and leaderboards, function as potent motivators for adolescents by leveraging their developmental need for social validation, whereas standalone home use often leads to isolation and attrition [20, 26].

However, structural integration is not a panacea; its success is mediated by the "burden" placed on educators. Implementation data reveals that high-fidelity outcomes are contingent upon "plug-and-play" systems that minimize technical friction. Interventions requiring extensive technical troubleshooting by teachers show significantly lower compliance rates compared to automated systems or those supported by external staff [22]. Thus, while the school environment provides necessary accountability and social reinforcement, the technology itself must be seamless to avoid overwhelming the educational infrastructure and to prevent dropout caused by device syncing failures or software incompatibility [18].

4.4. Implications for Practice and Policy

Translating these findings into practice requires a strategic change for policymakers, educators, and parents. From a policy perspective, the evidence supports updating physical education curricula to include "digital literacy for health," moving beyond sports proficiency to include data interpretation and self-monitoring skills.

- For Teachers: Digital tools should not be viewed as replacements for physical education but as complementary instruments for "digital homework." Assigning active tasks tracked via wearables bridges the gap between school instruction and home behavior [11]. However, implementation must rely on "plug-and-play" systems to minimize teacher burden [22].
- For Parents: The findings suggest a focus on "moderate use." Parents should be encouraged to support digital health tools that promote social connection or active play

(exergames), while avoiding the trap of excessive surveillance which can undermine the child's intrinsic motivation.

From an ethical perspective, the integration of wearables in education demands a rights-based approach. Schools must ensure that biometric data collection serves the purpose of educational empowerment and self-regulation, avoiding its use for surveillance or punitive grading [22]. Finally, to address the "Inverse Care Law," implementation strategies should prioritize "lowest common denominator" technologies. Relying on high-end consumer wearables or continuous broadband access risks alienating low-income populations; instead, scalable programs should utilize accessible solutions like pedometers or SMS-based interventions to ensure that digital health bridges, rather than widens, existing socioeconomic disparities [29].

4.5. Limitations of the Evidence Base

The interpretation of these findings must be tempered by significant methodological constraints. A primary limitation is measurement heterogeneity; a persistent discrepancy exists between self-reported data and objective accelerometry, with self-reports consistently yielding larger effect sizes. This suggests a significant perception bias among participants, who may overestimate their activity levels when using digital trackers [3]. Furthermore, the temporal validity of the evidence is limited. Meta-regression analyses confirm an inverse relationship between intervention duration and effect size, with studies extending beyond 12 weeks consistently reporting diminished outcomes compared to shorter trials [1]. There is a paucity of longitudinal data extending beyond six months, leaving the long-term durability of these behavioral changes largely unknown [8]. Additionally, selection bias remains prevalent; many studies recruit volunteers from well-resourced environments or provide devices free of charge, potentially obscuring the real-world barriers faced by low-income populations with lower digital literacy [21]. Finally, the potential for publication bias suggests that interventions showing no effect or negative engagement are underrepresented in the literature, possibly skewing the perceived efficacy of digital health solutions. Future research must prioritize long-term, equitable, and objectively measured trials to fully understand the potential of these tools.

Taken together, the evidence suggests that digital health interventions should be understood less as isolated technological solutions and more as components of broader ecological systems shaping children's daily behaviors. Their success depends on whether they are embedded within supportive social structures, particularly schools, that can provide accountability, routine, and opportunities for peer-based motivation. At the same time, current research remains limited by short follow-up periods, inconsistent measurement strategies, and a persistent socioeconomic gradient in both access and effectiveness. Future studies must therefore prioritize longer-term evaluations, standardized accelerometry-based outcomes, and targeted strategies to minimize digital inequities that disproportionately disadvantage vulnerable populations. Only by addressing these structural and methodological gaps can digital interventions reach their full potential as sustainable tools for improving movement behaviors and overall well-being in school-aged children.

5. Conclusions

This comprehensive narrative review indicates that digital health interventions, specifically mobile applications, wearable activity trackers, and exergames, offer a promising and scalable strategy to modulate the 24-hour movement behaviors of school-aged children. However, the evidence suggests that these tools should not be viewed as autonomous solutions capable of reversing the inactivity crisis in isolation. While digital tools successfully instruct users on how to improve physical fitness parameters and effectively displace passive screen time, achieving clinically significant reductions in sedentary behavior of approximately 33 minutes per day [5], their ability to independently drive sustained increases in habitual Moderate-to-Vigorous Physical Activity (MVPA) remains inconsistent.

A definitive finding of this review is the critical role of the environmental setting and implementation simplicity. Interventions integrated into structural school programs demonstrated superior adherence and more robust outcomes compared to standalone home-based models, provided they utilized "plug-and-play" technologies that minimized teacher burden [22]. As evidenced by the "Super Quinas" project, the efficacy of digital monitoring is amplified when it acts as a component of a "phygital" ecosystem, supported by mentorship and peer interaction [25]. This structure appears necessary to mitigate the "novelty effect," preventing the rapid decline in engagement typically observed after the initial 4-to-8-week period of gamified interaction [7, 16].

Despite these benefits, the scaling of pediatric digital health faces significant hurdles. The implementation of these technologies is threatened by the "Inverse Care Law," where the "digital divide" in connectivity and literacy risks excluding the populations most in need of health promotion [10, 21]. Furthermore, while psychosocial benefits such as increased self-efficacy and improved sleep duration (+17 minutes/night) are evident [12, 25], the ethical implications of biometric surveillance in schools require the adoption of a rights-based approach to data privacy [22].

Future research must prioritize longitudinal studies extending beyond six months to evaluate strategies for sustaining motivation after the initial 12-week window, given the established decay in effect size over time [1]. There is also a pressing need for implementation science to identify how schools can adopt cost-effective, low-tech solutions that bridge the socioeconomic gap. Ultimately, the successful digitalization of health promotion depends on creating hybrid environments where technology serves to facilitate, rather than automate, the development of lifelong healthy habits.

Disclosure

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All authors have read and agreed with the published version of the manuscript.

Funding statement

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Acknowledgements

Not applicable.

Conflict of interest

The authors declare no conflict of interest.

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