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Behavioral Change Through Serious Gaming Approaches for Childhood Obesity Interventions

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Abstract. Childhood obesity is a significant public health issue that can lead to a variety of physical and mental health implications. Serious games offer an innovative approach to address this challenge by reinforcing behaviors through interactive components. In this work, we explore the potential of serious games as a tool for facilitating behavior change in interventions to address childhood obesity. This paper presents the design approach of three serious games that aims to promote healthy habits in younger populations and tackle childhood obesity. Based on a systematic review, key factors influencing childhood obesity are identified. Protective factors include regular physical activity, a healthy diet and family meals. Risk factors include excessive screen time, unhealthy eating habits and consumption of processed foods and sugary drinks. The results of these studies served as a foundation for the design of the serious games, while the identified educational objectives were translated into game elements. Those three serious games approaches can be used to complement clinical monitoring for a comprehensive approach to the problem.

Keywords. Childhood obesity, Serious games, Behavior change, Public health, Intervention strategies.

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1. Introduction

Childhood obesity has become a critical public health challenge in the 21st century, with statistics showing that one-third of children in the WHO European Region are either overweight or obese [1]. The root causes of this health crisis are multifaceted, encompassing excessive food consumption, insufficient physical activity, diets rich in unhealthy fats, sugars, and salt, coupled with increasingly sedentary lifestyles. Recently, the use of software technology has emerged as a promising solution to encourage children and their families to adopt healthier lifestyle choices [2]. In that frame, the engagement of children in serious games has shown to improve their food skills and nutrition knowledge through interactive game play which in turn leads to healthier eating behaviours during childhood and beyond [3].

Serious games are increasingly adopted as educational tools for promoting good health-related behaviors and addressing and obesity prevention in children. They can also propose solutions to barriers or provide extra motivational arguments for behavioral change by acknowledging reality [2]. Numerous recent works investigate the use of gamification methods for this purpose, focusing on younger population with excellent results. DigesTower focused on promoting a healthier life and preventing childhood obesity [4]. NutritionBuddy is a game designed to make obese children more aware of the importance of well-balanced foods [5]. The ENDORSE platform developed a variety of mini-games in the form of educational and action missions to promote effective behavioral lifestyle changes in overweight/obese children [6]. Nevertheless, existing serious games implementations often fail to fully encompass the clinical outcomes of interventions against childhood overweight/obesity. According [7]serious games show significant positive effects on increasing physical activity (SMD = 0.61) but have limited impact on body composition (SMD = -0.26, non-significant) and dietary habits (SMD = 0.05, non-significant) in children and adolescents.

This work presents the design and development of serious games targeting behavioral change interventions for childhood obesity prevention. The games integrate evidence-based strategies including goal-setting for healthy lifestyle habits, family participation, and positive reinforcement mechanisms to promote sustainable behavioral changes in children's dietary and physical activity patterns.

The rest of this paper is structured as follows: Section II outlines key behavioral guidelines for effective obesity interventions in children. Section III presents the three serious games developed for this study, detailing their objectives and mechanics. Finally, Section IV concludes the paper.

2. Evidence-based behavioural modification for the prevention of childhood obesity

The role of diet in children's body weight status has been studied in terms of food and food group intake [8], as well as adherence to dietary patterns (e.g., Mediterranean diet, Western diet) [9] and meal patterns (e.g., eating breakfast, having dinner meals, frequency and type of snacking) [10], with the available data highlighting a significant impact on overweight/obesity risk and related markers. In relation to foods and food groups, a higher intake of sugar-sweetened beverages and fast foods has been consistently associ-

ated with increased odds of overweight/obesity, whereas less evidence exists for refined grains and meat/meat products [8].Overall, a higher diet quality has been associated with lower risk of overweight/obesity in children and adolescents [11]. Regarding meal patterns, regular consumption of breakfast and family meals is associated with lower body mass index and reduced odds of overweight/obesity in children, whereas meal skipping (primarily breakfast) may be a detrimental factor [12].

In children, regular physical activity has been associated with improvements in physical fitness, cardiometabolic indices, bone health, cognitive outcomes and mental health [13]. With regard to body weight status, epidemiological data have consistently revealed an inverse association between engagement in physical activity (especially moderate-to-vigorous) and various adiposity indices [14], as well as a detrimental impact of sedentary time (most importantly recreational screen time) on body weight status [15], in children's cohorts.

3. Intervention with Serious Games

This section outlines the methodology and development of the proposed Serious Games. In table 1 we present of the features of the individual apps. The age-specific design considers both cognitive development and increasing autonomy in food choices, with younger children focusing on basic nutrition concepts while older children engage with more complex decision-making scenarios.

Table 1. Comparison of Game Features

Feature	Food Ninja	Food Quiz	Food Treasure
Target Age	6-12 years	8-16 years	8-14 years
Learning Focus	Food categorization	Health knowledge	Active learning
Game Mechanics	Tapping/scrolling	Multiple-choice	AR exploration
Social Elements	Individual play	Family assistance	Parent-child interaction
Physical Activity	None	None	Required
Difficulty	Speed & categories	Question complexity	Customizable
Technology	Basic touchscreen	Basic device	Smartphone/Tablet
Environment	Indoor screen	Indoor screen	Indoor/Outdoor
Reinforcement	Points & levels	Question aids	Discovery rewards

Food Ninja A scrolling-based game focused on meal pattern education (figure 1). Players identify and select moving food items from specific categories, with points awarded for correct choices. Game progression features increasingly complex food categories and faster scrolling speeds.

Educational objectives: The game aims to enhance: food identification within nutrient categories, understanding of food groups' roles in balanced diets, critical decision-making through timed gameplay, and interactive learning of age-appropriate nutrition concepts.

Food Quiz is an interactive experience with progressively difficult questions across various categories, including meal patterns, physical activity, dietary patterns, nutrition basics, and healthy lifestyle choices (figure 2). The game's core mechanics involve answering multiple-choice questions that increase in complexity as players advance. To en-

hance the gameplay and provide strategic elements, Food Quiz incorporates aids, such as a 50/50 option that eliminates two incorrect answers, or the option to ask a family member for assistance.

Educational objectives: The structure of the game allows important health concepts to be taught such as health and nutrition literacy, awareness of the importance of physical activity, better understanding of healthy eating and dietary patterns, and encouraging family discussions about health issues. The progressive difficulty and use of aids help maintain player engagement while providing a sense of accomplishment as they advance through the game.

Food Treasure is an AR game integrating physical activity, family engagement, and nutrition education (figure 3). Parents or teachers hide QR codes or food items in a designated area. Children search and scan items with their mobile devices, receiving nutritional information and viewing 3D food projections through AR.

Educational objectives: The game promotes active nutrition learning, reduces sedentary screen time, and encourages family interaction. Its flexible design suits both home and school environments, using AR technology to create an engaging educational experience.

Figure 1. Food Ninja screen

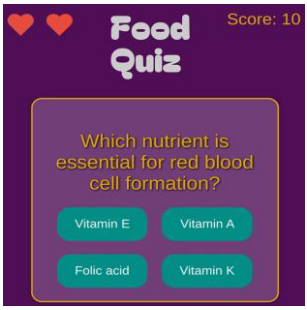

Figure 2. Food Quiz screen

Figure 3. Food Treasure screen

4. Conclusions and Future Scope

This paper presents a conceptual framework of serious games as an innovative tool for promoting behavior change in childhood obesity interventions. A suite of three serious games was proposed, designed to improve children's nutrition knowledge, dietary behavior, and overall food skills by incorporating goal setting, social support, and positive reinforcement. While existing research demonstrates the potential of serious games in improving nutritional knowledge and dietary behavior, this paper focuses on the conceptual framework and implementation approaches of our proposed suite. We describe the theoretical foundations, design considerations, and technical implementation of these applications. We acknowledge the current limitation in empirical validation of user engagement and effectiveness, future work will address this through comprehensive user studies measuring both quantitative engagement metrics and learning outcomes via pre- and post-intervention assessments. We also recognise that the effectiveness of our apps may vary significantly depending on the gender or family situation of the user, and therefore future adaptations may be necessary to better serve diverse user groups

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References

[1] World Health Organization, et al. WHO European Childhood Obesity Surveillance Initiative (COSI), report on the fifth round of data collection, 2018–2020. 2020.
[2] Lamas S, Rebelo S, da Costa S, Sousa H, Zagalo N, Pinto E. The influence of serious games in the promotion of healthy diet and physical activity: a systematic review. Nutrients. 2023;15(6):1399.
[3] Weiland A, Reiband N, Schäffeler N, Zurstiege G, Giel KE, Zipfel S, Mack I. A serious game for the prevention of obesity in school children – impact of parent's involvement: a randomized controlled trial. Life. 2022;12(6):779.
[4] Dias JD, Mekaro MS, Lu JKC, Otsuka JL, Fonseca LMM, Zem-Mascarenhas SH. Serious game development as a strategy for health promotion and tackling childhood obesity. Rev Latino-Am Enfermagem. 2016;24:e2759.
[5] Michael S, Katrakazas P, Petronoulou O, Anastasiou A, Iliopoulou D, Koutsouris DD. Nutritionbuddy: a childhood obesity serious game. In: 2018 Second World Conference on Smart Trends in Systems, Security and Sustainability (WorldS4). IEEE; 2018. p. 5–8.
[6] Zarkogianni K, Chatzidaki E, Polychronaki N, Kalafatis E, Nicolaides NC, Voutetakis A, et al. The ENDORSE feasibility study: exploring the use of m-health, artificial intelligence and serious games for the management of childhood obesity. Nutrients. 2023;15(6):1451.
[7] Liu M, Guan X, Guo X, He Y, Liu Z, Ni S, Wu Y. Impact of serious games on body composition, physical activity, and dietary change in children and adolescents: a systematic review and meta-analysis of randomized controlled trials. Nutrients. 2024;16(9).
[8] Jakobsen DD, Brader L, Bruun JM. Association between food, beverages and overweight/obesity in children and adolescents—a systematic review and meta-analysis of observational studies. Nutrients. 2023;15(3):764.
[9] Liberali R, Kupek E, de Assis MAA. Dietary patterns and childhood obesity risk: a systematic review. Child Obes. 2020;16(2):70–85.
[10] Dallacker M, Hertwig R, Mata J. The frequency of family meals and nutritional health in children: a meta-analysis. Obes Rev. 2018;19(5):638–53.
[11] Zheng X, Wang H, Wu H. Association between diet quality scores and risk of overweight and obesity in children and adolescents. BMC Pediatr. 2023;23(1):169.
[12] Saltaouras G, Kyrkili A, Bathrellou E, Georgoulis M, Yannakoulia M, Bountziouka V, et al. Associations between meal patterns and risk of overweight/obesity in children and adolescents in western countries: a systematic review of longitudinal studies and randomised controlled trials. Children. 2024;11(9):1100.
[13] DiPietro L, Buchner DM, Marquez DX, Pate RR, Pescatello LS, Whitt-Glover MC. New scientific basis for the 2018 US physical activity guidelines. J Sport Health Sci. 2019;8(3):197.
[14] Bourdier P, Simon C, Bessesen DH, Blanc S, Bergouignan A. The role of physical activity in the regulation of body weight: the overlooked contribution of light physical activity and sedentary behaviors. Obes Rev. 2023;24(2):e13528.
[15] Biddle SJH, García Bengoechea E, Wiesner G. Sedentary behaviour and adiposity in youth: a systematic review of reviews and analysis of causality. Int J Behav Nutr Phys Act. 2017;14(1):43.