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아동비만 예방을 위한 스마트폰 어플리케이션 프로토타입 개발: 개발 근거 및 실행가능성 연구 설계

김혜랑[1,2], 강재헌[3], 박현아[3], 조수현[4], 전소혜[5], 정지혜[6], 성은주[1]

[1]성균관대학교 의과대학 강북삼성병원 가정의학과, [2]성균관대학교 의과대학 의과학연구소,[3]인제대학교 의과대학 서울백병원 가정의학과,[4]중앙대학교 의과대학 중앙대학교병원 가정의학과, [5]한국기계전기전자시험연구원,[6]인제대학교 임상영양연구소

Development of a Smartphone Application Prototype for Child Obesity Prevention: Rationale and Study Design of Acceptability and Feasibility Tests

Hyerang Kim[1,2], Jae-Heon Kang[3], Hyn Ah Park[3], Soo Hyun Cho[4], Sohye Jeon[5], Ji-hye Jung[6], Eunju Sung[1]

[1]Department of Family Medicine, Kangbuk Samsung Hospital, Sungkyunkwan University School of Medicine, Seoul, Korea
[2]Medical Research Center, Sungkyunkwan University School of Medicine, Seoul, Korea
[3]Department of Family Medicine, Seoul Paik Hospital, Inje University College of Medicine, Seoul, Korea
[4]Department of Family Medicine, Chung-Ang University Hospital, Chung-Ang University College of Medicine, Seoul, Korea
[5]Korea Testing Certification, Seoul, Korea
[6]Institute for Clinical Nutrition, Inje University, Seoul, Korea

Background: There have been many efforts to rectify lifestyles that contribute to obesity using a variety of methodologies in heterogeneous settings, but effective and sustainable interventions that are suitable for children are still needed. We developed a smartphone application called "HAPPY ME" for guiding health behavior decisions, which employs gamification and self-monitoring strategies. The aim of this paper is to outline the rationale and methods for the development and feasibility test of "HAPPY ME".
Methods: The study consisted of two phases: 1) description of theory-based conceptual framework and rationales for smartphone application development and 2) outline of a pre- and post-test design in 4th-6th grade of healthy elementary school students for 4 weeks. The students will be delivered missions or messages on a daily basis, which is to stretch the knowledge and skills for action. They will simultaneously be engaged in self-monitoring their eating and physical activities to clear daily quests. To measure acceptability and feasibility we will monitor usability, compliance, and satisfaction for a 4-week study period and evaluate the intervention effects on self-efficacy, readiness, and intention to engage in healthy behavior.
Conclusions: The results of the feasibility study will show whether the smartphone application "HAPPY ME" for children is acceptable, as well as if it is usable and feasible for self-directed health management. The results will provide preliminary evidence of the effectiveness of smartphone application-supported child behavioral modification for child obesity prevention and management.
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■ Corresponding author : **Eunju Sung, MD, PhD**
Department of Family Medicine, Kangbuk Samsung Hospital, Sungkyunkwan University School of Medicine. 29 Saemunan-ro, Jongno-gu, Seoul 03181, Korea
Tel: +82-2-2001-5138, Fax: +82-2-757-0436
E-mail: eunjusung68@gmail.com

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INTRODUCTION

In recent years, children being overweight or obese has become one of the major concerns in the public health sector worldwide, including Korea. The prevalence and severity of overweight and obese school-aged children in Korea has increased almost tenfold over the last 20 years,[1)] and an estimated 14.3% of school-aged children were

overweight or obese in 2011.[2] The importance of early assessment and intervention of potential and substantial risk factors for child obesity has been emphasized in light of its deleterious health consequences. Despite the increasing number of behavioral interventions for obesity prevention and management in children,[3] it is still uncertain what the most effective and efficient components of these interventions are and what the most acceptable and sustainable strategies are for childhood.

Smartphones have recently become part of contemporary culture in children. It is common for children to start using smartphones at 10-12 years old, and 81% of children aged 8-18 years use them.[4] It is reported that Korea reached a smartphone penetration rate of 65% among school-aged children in 2013, which increased 13 times from 6% in 2010.[5] The broad reach of smartphones and the prosperity of the multimedia industry have gained enough attention to facilitate the engagement of children and therefore be a potentially powerful means for children's health management. Given the features of portability, accessibility, and adaptability, smartphone-delivered interventions may provide a more effective strategy in modifying a range of obesity-related health behaviors, specifically diet and physical activity. Previous research with adults has found that technology-based interventions are an acceptable and effective method for obesity management by delivering health information, providing self-monitoring tools or programs, and interacting *via* automatic feedback systems.[6,7] Moreover, interventions using smartphone applications have been considered to overcome many of the barriers of conventional offline obesity management interventions in children, including constraining high dropout rates accompanied by low attendance to education sessions, lack of interest, unwillingness to engage in face-to-face counseling or interviewing, and sometimes large burdens for accompanying parents.[8] Interventions using smartphone applications can provide a more effective and acceptable means of child obesity management, allowing the participants an interesting, easily-accessible, self-facilitated intervention using the interactive and playful features of the smartphone.[9]

Despite the potential advantages of smartphone application-supported strategies to provide effective and acceptable support, it is hard to find evidence of the acceptability and effectiveness of technology-based interventions specifically targeting obesity management in school-aged children. As the first step in establishing an evidence base around the use of smartphone applications in child obesity prevention and management, therefore, we developed "HAPPY ME", a smartphone application for guiding health behavior decisions using gamification and self-monitoring strategies. We plan to conduct a preliminary study to test the acceptability and feasibility of this application in child obesity prevention and management.

METHODS

1. Overview of study design

The aim of this paper is to describe the rationale and developmental procedure of a smartphone application for child obesity prevention and management and also present a study protocol for a feasibility test specifically targeting school-aged children. This study was designed as one of the sub-components of the project "Development of Integrative Platform based on Bio Technology and Information Technology (BT-IT) for the Prevention and Management of Obesity in Children and Youth" granted by the Ministry of Science, Information-Communication Technology and Future Planning, Korea (NRF-2013M3C8A2075911). The study consisted of two phases: 1) design and development of the smartphone application "HAPPY ME" and 2) study protocol for preliminary test of the prototype of "HAPPY ME" for acceptability and feasibility.

2. Design and development of "HAPPY ME"

1) Theoretical framework

The conceptual background for "HAPPY ME" development was Csikszentmihalyi's flow theory and Keller's attention, relevance, confidence, and satisfaction (ARCS) model of motivational design.[10,11]

Csikszentmihalyi's flow theory posited that "flow is the subjective experience of engaging just-manageable challenges by tackling a series of goals, continuously processing feedback about progress, and adjusting action based on this feedback"[10]. Flow is completely focused motivation that is promoted by feelings of competence and efficacy in harnessing a feeling of spontaneous joy while performing a task. Motivation and immersion are essential

prerequisites to elicit and sustain engagement in the process of the activity. Based on the conceptual framework of this theory, gamification has been functionally infused in the development of the smartphone application in order to enhance the delivery of educational content with enjoyment. The functional content for gamification was structured based on the important key conditions of flow theory, including: 1) a clear set of goals, 2) clear and immediate feedback, and 3) a balance between perceived challenges and perceived skills.

Keller's ARCS model of motivational design was developed to supplement the learning process with motivation and consists of four main areas: 1) attention, which initiates motivation for learners, 2) relevance, which is established by using language and examples that the learners are familiar with, 3) confidence, which focuses on establishing positive expectations for achieving success among learners, and 4) satisfaction, which is achieved by providing positive feedback on an achievement or a reward for a learning experience.[11] From a design perspective, educational practices are embedded in the gamification at various steps in a literacy- and visual-friendly manner in order to keep children's attention and facilitate their engagement in behavioral modification.

2) Gamification

Gamification is the concept of applying game mechanics and dynamics to non-game contexts to make people more motivated and engaged in solving problems. Game mechanics are functional elements in gamification, including a leaderboard, points, badges, levels, and challenges or quests.[12] Game dynamics are related to the individual's reactions to satisfy fundamental needs and desires, including the desire for achievement, altruism, competition, rewards, and self-expression.[13] The combination of game mechanics and dynamics creates a motivating, emotional, and entertaining interaction, driving the users' engagement and participation and stimulating them to move the action forward to achieve goals. It can provide the knowledge and skills necessary to accomplish tasks and facilitate the development of problem-solving strategies. These gaming elements can be translated into a game for the health education sector by providing the opportunity for authentic practice in realistic contexts. Learning and behavioral change through playing a well-designed game takes advantage of the many potential benefits of self-help in health management, which facilitates self-directed and self-explored engagement, development of self-concepts and self-efficacy, and therapeutic communication and social support. The most remarkable contribution of playful gaming elements and ease of use is maintaining engagement and ensuring adherence to the learning and training of desirable health behaviors through the players' full involvement and enjoyment in the game.

Gamification has been studied and applied with mobile and web applications to encourage the participants to engage in decision-making for desired behaviors in the health sector, including smoking cessation,[14] medication adherence,[15] self-management for chronic disease,[16] physical activity engagement[17] and dietary decision-making.[18] Gamification has also been recognized as a very practical tool for taking advantage of health care in children and adolescents.[19] However, using technology for education or health management in children is still a topic under debate due to the potential harmful side effects of media addiction or smartphone addiction. Technology-based interventions for child health management are just in the beginning stages of development, and thus there is little evidence of their potential benefits for child health outcomes. Indeed, designing technology-based health interventions, especially those that use gaming elements, for children is complicated, and the success depends on how well the gaming elements incorporate therapeutic or educational content and how well the balance between adherence and addiction can be maintained. Therefore, the design and development of a technology-based child health intervention requires an understanding of the subjects' developmental traits and the determinants of their behavior. We took this into consideration in the design and development of our smartphone application for child obesity prevention and management, "HAPPY ME". The strategies we used were as follows: 1) using points/badges and levels as rewards for completing quests, 2) using closed social networking services with friends, 3) providing practical examples of diet, physical activity and socio-emotional support, 4) setting time limits for each quest completion, 5) setting opening and closing times for use of the application as 7 a.m. and 10 p.m., and 6) allowing communication and monitoring through interaction with parents.

3) "HAPPY ME" design

"HAPPY ME" is an interactive system that primarily uses a gamification and self-monitoring modality as a means to influence decision making for behavioral change for obesity prevention and management in school-aged children. The design was inspired by social cognitive theory (SCT), which addresses dynamic and reciprocal interaction of personal, behavioral, and environmental factors as determinants of behavior.[20] A principle concept in SCT is self-efficacy, a person's belief in his or her ability to perform a specific behavior successfully, which is considered to be a core determinant of health behavior change. Key conceptual elements of SCT include reciprocal determinism, behavioral capability, observational learning, reinforcements, and expectations. "HAPPY ME" was designed to aid healthy behavior adoption by incorporating gaming elements into these theoretical concepts.

"HAPPY ME" consists mainly of nine quests that address healthy diets, physical activity and exercise, socio-emotional support, and obesity-related knowledge. Six quests are available to the user from the beginning, and three more quests are available when the user successfully completes quests on a daily basis and gets to a certain level by earning experience points. The first page displays the six quests that are available, and the user can select one of them. For example, the user can start the quest that addresses exercise by clicking the corresponding button. When the user opens the quest, the message, "ten-minute stretching for healthy body" appears with a "start" button. When the "start" button is clicked, a simulation video of the stretching exercise is displayed with a stopwatch on the board. After ten minutes, a message that reads "success" pop up and some experience points are given as a reward. If the user exits the page before the ten minutes are up, a message that reads "incomplete" appears. Each quest is randomly updated on a daily basis. Experience points and badges are given as rewards for the completion of each quest. As users earn experience points, they can get to higher levels.

Closed social networking services allow all users who participate in "HAPPY ME" to be ranked on a scoreboard so users can compare their own ranking to that of their friends in real time. Badges are given as additional rewards to users who achieve a certain number of experience points or reach certain levels. In addition, physical activity is automatically recorded and displayed as a daily step count *via* a pre-installed pedometer on the application. The immediate feedback system provides the amount of calories expended in accordance with the step count and also displays a comparison with the recommended calorie intake. Experience points are given as a reward for meeting step count goals. Students are encouraged to record their dietary intake and physical activity as much as they can. Self-monitoring of dietary intake and physical activity is optional because manual recording methods are apparently labor-intensive and burdensome for such an age group, which can reduce the adherence to the application. Rewards are given for tracking dietary intake and physical activity in order to incentivize users.

4) Intervention content

The intervention areas on which "HAPPY ME" focuses are diet, physical activity, and socio-emotional support. These areas have been suggested as key elements in child obesity management.[21] The key messages for each area are based on national policy and expert recommendations for healthy lifestyle in children.[22-24] Key messages for healthy eating are focused on eating fruits and vegetables every day, eating two servings or more of low-fat dairy every day, eating breakfast every day, opting for an appropriate portion size, drinking more water than sugar-sweetened beverages, and choosing healthy snacks over instant and fast food. These messages are taken from the Dietary Guidelines for Healthy Eating in Children.[22] Two key messages for physical activity are suggested that are consistent with the Dietary Guidelines for Healthy Eating in Children[23] and the Physical Activity Guide for Koreans[24]: engage in one hour or more of active play and limit screen time to less than two hours. The quests for socio-emotional support also include missions for social skill development and lifestyle habit change. The quests for action are displayed with pictures or videos with examples or simulations to ensure the user's attention and confidence in learning and practice. Each message in these topics is randomly provided, with quests at first and then requests to respond to missions on a daily basis. According to the response and success rate, the messages are designed to automatically reorganize in order to reinforce behavioral change.

Five or six questions per daily quest are provided to

stretch the user's knowledge and skills for action. The questions cover educational information such as food and diet, physical activity and exercise, behavioral acceptance, social skills and healthy relationships, and general information about health and obesity. Research members of the child obesity prevention and management project developed the pool of key messages and questions, and they consulted an advisory committee consisting of experts on child education, behavioral science, psychology, physical education, and nutrition.

3. Acceptability and feasibility test of prototype "HAPPY ME"

1) Setting and participants

This study employs a school-based pre- and post-test design aimed at improving healthy behavior for obesity prevention and management. Elementary school students from fourth to sixth grade who use smartphones will be recruited from two schools. The participants will include those 1) whose weight ranges from underweight to obese, 2) who are healthy without systematic or metabolic disease conditions, 3) who are capable of downloading and operating the smartphone application, 4) who have not been involved in any behavioral modification programs in the past 6 months, and 5) whose parents give permission for them to participate.

2) Study procedure

A newsletter will be sent to potential participants' parents in the recruited schools. The newsletter will include the purpose of the study, method and duration, features of the applied smartphone application, information that will be collected, and a written consent form. The consent form will be obtained from dyads of parents or legal guardians and students. After collecting consent forms, the research staff will telephone the parents who permit their children to participate in the study, describe this study in further detail, and obtain verbal consent. Children's current health status and medical history will be determined through the telephone interview with the parents.

Enrolled students will participate in the 4-week trial of the prototype "HAPPY ME". In advance of "HAPPY ME" installation, smartphone use, determined by time and frequency, of all participants will be measured for a run-in period of 1 week to get baseline data. Changes in smartphone use within-group will be analyzed to determine the potential impact of encouragement to use the newly installed application on the general use of smartphones in children – whether use of the smartphone will be acceptable for child health interventions, considering concerns over the negative effects of smartphone use.

The participants will be instructed to install the "HAPPY ME" application on their own smartphones and to create an account for login with general information such as age, sex, current body weight, and height. They will then be informed of the practical features of the application by research staff. This study was approved by the institutional review board of I University College of Medicine (IRB No. IIT-2014-080).

4. Outcome measures

The rate of parents' agreement to let their children participate will be addressed. The usage and compliance of "HAPPY ME" will be monitored throughout the whole period of the trial by keeping an access log of participant's activity on the application. The collected data will be summarized on a daily and weekly basis. The access log will be analyzed for an estimation of the retention rate and success of the quests as primary outcomes in accordance with aim of this feasibility study.

As the secondary outcomes, current dietary behavior and physical activity, readiness and intention to engage in behavioral modification, perceptions, knowledge and self-efficacy for healthy diet and physical activity will be assessed using a constructed survey questionnaire in a face-to-face interview with all participants before and after the study. The changes in the magnitude of readiness, intention, behavior, and psychological variables measured before and after the trial will be evaluated in order to find the short-term effects of the intervention on health behavior decisions. The step count automatically collected by the pedometer will be used as the objective indicator to verify actual behavioral change in effect. Dietary intake and physical activity, which users are encouraged to record but given the option not to, will be used to assess users' commitment to self-management. Satisfaction with the application will also be assessed at the end of the study.

DISCUSSION

Many smartphone applications for health management are currently available, as the need for dynamicity of electronic communication technologies in the health sector is growing. Interactive smartphone applications can offer an unprecedented opportunity for individualized and intensive treatment approaches by providing timely information, immediate access, social support, and real-time feedback on health behavior decisions. The need for an innovative system to facilitate children's engagement in self-management is also growing. Despite the growing adoption of technology-based interventions for disease management and health promotion even in children or youth, systematic evaluations for acceptability and feasibility of such technologies are limited.[25] Moreover, few of the applications currently being used employ approaches with expert-recommended strategies and behavioral targets to assist healthy behavior in children.[26] Some applications in use create confusion or misconceptions for the users because of the limited and fragmentary information provided to them. The design and application of smartphone-support strategies is more complicated and challenging for health behavior researchers, mobile application developers, and health promotion practitioners when the aim is child obesity management. Focusing on enjoyment with excessive game mechanics can lead children to indulge in excessive smartphone use rather than achieve the desired results through purposeful action. A poor design fails to meet the children's expectations and create satisfaction, and is not sufficient to motivate them by delivering persuasive content. Even though an application may be designed well and have a sound context, additional effort is required to monitor and guide users to ensure safe access and appropriate use of other functions on the smartphone.

This paper describes the rationale and methodology of the acceptability and feasibility test of intervention delivery using the smartphone application that was developed specifically for aiding behavioral decisions related to child obesity prevention and management. "HAPPY ME" was designed to provide an interactive and practical tool to increase children's awareness, knowledge, and self-efficacy related to healthy behavior for obesity prevention and management. Important aspects of the design of "HAPPY ME" are as follows. First, it targets multiple behavioral changes, which is considered more acceptable and valuable to the users because it reduces the burden to find other supplemental applications or materials.[26] Second, it typically uses game mechanics and dynamics to deliver informative content, which has been suggested as an effective way to make the users engage into purposive actions[22,27] and to increase motivation and adherence to the application. It is known that encouraging smartphone use and adapting game elements have potential adverse effects, such as overindulgence, in child health care interventions. Therefore, we constrain the use of the application to a certain number of quests per day. However, the functionalities for self-monitoring of dietary intake and physical activity are available even when the quest limit has been reached for the day, and rewards are offered for commitment to tracking this behavior. The application is designed to only be available from 7 a.m. to 10 p.m., so as to not disturb the children's bedtime. Smartphone use during class is generally prohibited by school regulations in Korea. The protocol for this feasibility test will follow these regulations and will not interrupt the children's schoolwork.

Notwithstanding the positive aspects, concerns about the negative effects of mobile technology-supported strategies are being raised. Increased access to smartphones may increase obsessive use and addiction, which can create harmful consequences for physical and psychological health outcomes.[28] There is a concern that the increased use of smartphones may take the place of active play and promote sedentary behavior, which has been increasingly studied as a determinant of childhood obesity.[29,30] Therefore, careful consideration should be given to issues of smartphone-supported child obesity interventions. Parental involvement has been suggested as one of the most important elements in child obesity management using smartphone applications, allowing the parents to participate with the child and support the child's achievements.[26] The third cachet of this application is that parental participation is required to complete one of the six daily quests, which includes an element such as "discussion of vegetables and fruits which are available" or "to make a promise to exercise together with parents". Incorporating parents in the activities of the application allows the parents to monitor their child's adherence to the activities with the application, and thus possibly encourage the child more. It

can be helpful to make the home environment more supportive of the child obesity intervention as well.

Lastly, multidisciplinary work across the areas of child education, behavioral science, medicine, nutrition, physical activity, psychology, and intellectual technology science have shaped the development of the application and the planned empirical test of the application. The principles and strategies used in "HAPPY ME" can be translated to general health promotion projects for children and youth.

The results of this acceptability and feasibility test are expected to provide preliminary evidence of whether a smartphone-supported intervention is acceptable and appropriate for child health promotion as well as obesity management. Based on the insights from the preliminary evaluation, advanced usability features of the prototype will be incorporated into the comprehensive service platform for school-based obesity prevention and management that can involve parents or primary caregivers, school teachers, and community health service providers in next stage of this project. Future research is warranted to examine the sustainability of health interventions delivered via these technologies and the capacity for long-term health outcome maintenance.

요 약

연구배경: 비만의 예방과 관리를 위한 다양한 생활습관 중재 연구가 진행되고 있으나, 아동의 성장기적 발달특성을 고려한 효과적인 중재방법 개발이 여전히 요구되고 있다. 본 연구에서 생활습관 교정을 통한 아동의 비만 관리를 위해 게이미피케이션(gamification)과 자기관찰(self-monitoring) 전략을 기반으로 한 스마트폰 어플리케이션 "HAPPY ME" 개발하였다. 본 연구의 목적은 아동비만 관리를 위한 스마트폰 어플리케이션 개발의 타당성 및 실행가능성 평가를 위해 고안된 연구방법을 제시하고자 함이다.

방법: 본 연구는 1) 스마트폰 어플리케이션 개발을 위한 이론-기반 개념적 틀과 타당성, 2) 초등학교 4-6학년을 대상으로 한 사전-사후 연구방법에 대해 기술하였다. 연구기간 동안 스마트폰 어플리케이션을 통해 식생활과 신체활동 증진과 관련된 실제적인 지식과 기술을 포함한 정보메세지를 대상자들에게 매일 1회 제공하며, 자기관찰 및 건강증진 퀘스트 수행을 격려한다. 연구 종료 시 "HAPPY ME"에 대한 대상자들의 수용성 및 실행가능성을 평가하기 위한 어플리케이션 이용 및 만족도에 대한 조사를 실시하고, 건강행위 증진에 대한 자기효능감과 행위변화단계(stage of behavioral change)를 평가하고자 한다.

결론: 본 연구 결과를 통해 아동 비만 예방 및 관리를 위해 개발된 스마트폰 어플리케이션의 타당성 및 수용성, 아동의 자기관리를 통한 건강증진 행위 개발 도구로서의 적합성에 대한 근거를 제시할 수 있을 것으로 사료된다. 또한, 본 연구 결과는 아동의 비만 예방 및 관리를 목적으로 한스마트폰 어플리케이션 기반 아동의 생활습관 중재의 효과 평가를 위한 기초자료로 활용될 것으로 기대된다.

중심 단어: 행동화, 아동 비만, 게이미피케이션, 스마트폰 어플리케이션

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