대한지역사회영양학회지 27(4): 296~308, 2022
Korean J Community Nutr 27(4): 296~308, 2022
https://doi.org/10.5720/kjcn.2022.27.4.296
ISSN 1226-0983 (print) / 2287-1624 (on-line)

RESEARCH ARTICLE

Check for updates

RE-AIM 프레임워크를 이용한 프로그램 평가: 체계적 고찰과 어린이 대상 건강증진 프로그램 평가

이지은[1] · 심재은[2] · 김기랑[3] · 강재헌[4] · 황지윤[5]†

[1]상명대학교 대학원 외식영양학과, 대학원생, [2] 대전대학교 식품영양학과, 교수, [3]단국대학교 식품영양학과, 교수, [4]성균관대학교 의과대학 강북삼성병원 가정의학과, 교수, [5]상명대학교 식품영양학전공

Program Evaluation using the RE-AIM Framework: A Systematic Review and Application to a Pilot Health Promotion Program for Children

Ji-Eun Lee[1], Jae Eun Shim[2], Kirang Kim[3], Jae-Heon Kang[4], Ji-Yun Hwang[5] †

[1]Graduate student, Department of Food service Management and Nutrition, Sangmyung University, Korea
[2]Professor, Department of Food and Nutrition, Daejeon University, Korea
[3]Professor, Department of Food Science and Nutrition, Dankook University, Korea
[4]Professor, Department of Family Medicine, Kangbuk Samaung Hospital, School of Medicine, Sungkyunkwan University, Korea
[5]Professor, Major of Foodservice Management and Nutrition, Sangmyung University, Korea

†Corresponding author
Ji-Yun Hwang
Major of Foodservice Management and Nutrition, Sangmyung University, 20 Hongjimun-2-gil, Jongno-gu, Seoul 03016, Korea

Tel: +82-2-781-7521
Fax: +82-2-2287-0104
E-mail: jiyunhk@smu.ac.kr

Acknowledgments
This work was supported by the Bio & Medical Technology Development Program of the National Research Foundation (civil research project for solving social problems through the National Research Foundation of Korea (NRF)) and funded by the Ministry of Science, ICT & Future Planning (Grant No. 2013M3C8A2A01078464, 2014M3C8A2A01070970, NRF-2020R1A2C1011675).

ORCID
Ji-Eun Lee: https://orcid.org/0000-0003-4044-9358
Jea Eun Shim: https://orcid.org/0000-0001-8458-9112
Kirang Kim: https://orcid.org/0000-0003-3054-8758
Jae-Heon Kang: https://orcid.org/0000-0002-5209-0824
Ji-Yun Hwang: https://orcid.org/0000-0003-4003-1293

Received: June 15, 2022
Revised: July 29, 2022
Accepted: August 08, 2022

ABSTRACT

Objectives: This study aimed to develop evaluation criteria for the elementary-school-based health promotion program using the RE-AIM framework and to examine their feasibility.

Methods: Previous evaluation studies on health interventions for elementary-school students using the RE-AIM framework were reviewed systematically to identify appropriate evaluation criteria. A diet and physical activity intervention based on the transtheoretical model was implemented in a pilot study using the "Happy Me" application. The feasibility of using the RE-AIM framework to evaluate it was examined.

Results: The review yielded the following evaluation criteria: "reach," the ratio of participants out of the total target population; "efficacy/effectiveness," the difference in outcomes between the intervention and control groups, or between a pre- and post-test; "adoption," the rate of use of the program and participation in the next stage of the program; "implementation," the progress on the program components; "maintenance," the participants' and teachers' intention to continue using the program. The pilot study reached 76.6% of the targeted population. The intake of sugar-sweetened beverages decreased ($P < 0.0001$), and the duration of walking increased ($P < 0.0001$). Other indicators could not be evaluated; therefore, potential indicators were suggested.

Conclusions: This study produced feasible evaluation criteria for elementary-school-based health promotion using the RE-AIM framework. Nevertheless, the feasibility needs to be validated with a broader range of studies and long-term interventions.

KEY WORDS childhood obesity, health education, school health promotion, mobile applications, feasibility studies

Introduction

Childhood obesity is a health problem that cannot be overlooked because it is increasing worldwide [1]. In 2013, almost a quarter of children in developed countries and more than 10% in developing countries were overweight or obese based on the body mass index (BMI) [2]. Children with obesity are likely to remain obese in adulthood [3, 4]. They are more at risk of developing adult health problems, such as type 2 diabetes, heart disease, stroke, various types of cancer, and osteoarthritis [5-7]. The dietary and physical activity behaviors of children are affected by many social factors, and schools play a vital role by establishing a secure and cooperative environment with policies and practices to support healthy behaviors [8].

To carry out an intervention program effectively, there is a need for a systematic and scientific method to evaluate the effects of the program objectively on various levels [9, 10]. The RE-AIM framework developed by Glasgow et al. has been used to assess the overall health impact of health promotion programs [11, 12]. The RE-AIM framework aims to assess the effectiveness of the health promotion program and seek more efficient resource allocation in the future with reference to five dimensions: reach, efficacy, adoption, implementation, and maintenance [11]. According to a systematic review [13] of interventions focused on applying the RE-AIM framework, 26 out of the 71 articles published from 1999 to December 2010 pertained to physical activity and obesity; only two were conducted in the school setting. Thus, few studies on physical activity and nutrition intervention in a school setting have been evaluated using the RE-AIM framework.

Mobile phones and the transtheoretical model (TTM) allow for more systematic and effective implementation of intervention programs. Intervention programs using mobile phones have the advantage that service users can easily receive tailored information anytime, anywhere [14]. Mobile-based approaches are beneficial for implementing successful interventions on eating habits and physical activity [15]. The TTM, developed by Prochaska et al. [16], has been used in intervention studies to assess various behavioral changes, enabling tailored education at the stage of behavioral change [17]. Mobile technology or TTM have been applied to various interventions in adults, but limited studies have used the same with children [18]. In addition, few studies have applied new technology and the TTM simultaneously [19].

This study developed feasible evaluation criteria of the RE-AIM framework for application to an elementary-school-based health promotion program. First, potential evaluation criteria were proposed with an analysis of previous studies that evaluated the elementary-school-based health promotion program using the RE-AIM framework. Second, the feasibility of the RE-AIM framework was evaluated using the authors' elementary-school-based pilot health promotion program.

Subjects and Methods

1. Selection of studies for systematic review

Domestic and international studies were searched to examine the application of the RE-AIM framework for evaluating health promotion programs. Fig. 1 presents the selection process. A literature search was conducted using four databases (RISS, Koreamed, PubMed, and ScienceDirect), using the following search keywords: child, nutrition education, physical activity education, health intervention, nutrition intervention, diet intervention, and physical activity intervention. The literature search process was iterative and was conducted using various combinations of keywords, using the "AND" function in the search options.

Thus, 120 studies were identified from international databases. No domestic studies evaluating the effects of nutrition, physical activity, and eating habits on elementary-school children using the RE-AIM framework were found. After excluding duplicate studies, 62 studies were selected initially. The abstracts of the selected studies were screened, and the final four intervention studies on elementary school children were selected (Fig. 1).

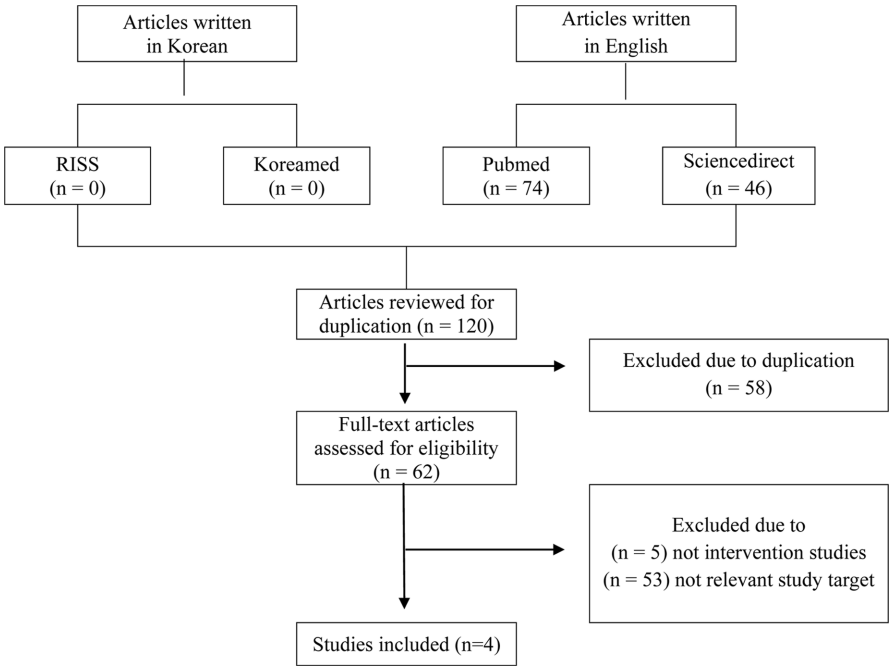

Fig. 1. Flow diagram of the selection process of intervention studies

2. Subjects and methods of the pilot study

A pilot study was conducted to assess the feasibility of an elementary-school-based health promotion program. The pilot study was conducted as a non-randomized controlled trial of an intervention on a healthy diet and physical activity using the "Happy Me" mobile application developed as a tailored mobile service for the prevention and management of childhood obesity [20, 21]. The subjects were 5th to 6th-grade students from four elementary schools in Gimpo City and Incheon City. The four research schools were assigned as representative schools in each region by the Gimpo Office of Education Support and the Incheon Metropolitan City Office of Education. Parents of the participating students received an informed consent form explaining the nature and procedure of the study. The study was approved by the Inje University Seoul Paik Hospital Institutional Review Board (IIT-2015-070). Of the 989 students, 166 who did not provide written informed consent to participate in the study and 37 who did not participate in the pre- or post-tests were excluded. Of the 786 participants remaining, 558 students used the mobile application aimed at obesity prevention and management (intervention group), whereas 228 students followed the regular curriculum (control group) for 12 weeks from August 20, 2015, to November 20, 2015. Both groups received one session of offline education on the nutrition and physical activity. The measures used in the pre- and post-tests of the study included eating habits (i.e., frequency of intake of breakfast, vegetables, fruit, sugar-sweetened beverages, fast food, instant food, snacks, and late-night snacks), physical activity (i.e., frequency of engaging in physical activities that make it difficult to breathe, intense physical activities, mild physical activities, and strengthening exercise per day; the number of days on which one walked for more than 10 minutes (per week); the duration of walking in a day), screen time, physical measurements (i.e., height, weight, BMI, waist circumference, and hip circumference), and results of the Physical Activity Promotion System (PAPS; i.e., cardiopulmonary endurance, flexibility, power, and strength).

Results

1. Systematic review to identify evaluation criteria used in the RE-AIM framework

Four studies [22-25] were selected based on the screening criteria (Table 1). Two studies involved physical activity

Table 1. Summary of the selected studies

Reference (publication year)	Intervention factor	Subjects	Study design	Intervention duration
Collard DCM et al. (2010)	Physical activity	Primary-school students aged 10 ~ 12 years (n = 2,210); IG[1] (20 schools, n = 1,117) versus CG[2] (20 schools, n = 1,091)	CRCT[3]; Intervention using the "iPlay[4] program"	Two school years
Janssen M et al. (2013)	Physical activity	Primary-school students aged 6 ~ 12 years (n = 2,280); IG (4 schools, n = 1,155) versus CG (4 schools, n = 1,125)	RCT[5]; Intervention using The "PLAY grounds program"	One school year (10 months)
Dunton GF et al. (2014)	Nutrition	Program evaluation sample: 50 third-grade classrooms in California; IG (28 classrooms, n = 651) versus CG (22 classrooms, n = 496); Dissemination sample: 7,359 teachers who ordered the program materials and 195,245 students who participated in the program during the 2010 ~ 2011 school year	RCT; Health belief model and social cognitive theory; Intervention using "The SMC[6] program"	10 weeks
Larsen A et al. (2015)	Nutrition	Program evaluation sample: 47 fourth-grade classrooms in California; IG (27 classrooms, n = 971) versus CG (20 classrooms, n = 742); Dissemination sample: 4,821 fourth-grade classrooms (n = 152,065) that used the program materials during the 2011 ~ 2012 school year	RCT; Health belief model and social cognitive theory; Intervention using "The Nutrition Pathfinders program"	4 ~ 10 weeks

1) Intervention group, 2) Control group, 3) Cluster randomized controlled trial, 4) Injury Prevention Lessons Affecting Youth, 5) Randomized controlled trial, 6) Shaping Up My Choices

intervention [22, 23], and two involved nutrition intervention [24, 25] for elementary school students aged 6 ~ 12 years. The sample sizes ranged from 1,147 to 2,280. There were three randomized controlled trials (RCT) with parallel groups [23-25] and one cluster randomized controlled trial (CRCT) [22]. In two studies, two different samples were used: the dissemination sample (to evaluate Reach, Adoption, and Maintenance) and the program evaluation sample (to assess Efficacy/Effectiveness and Implementation) [24, 25]. The dissemination sample consisted of all classrooms that ordered the program and the students who participated in the program. The program evaluation sample for the RCT was recruited from local public elementary schools. Table 2 summarizes the results of evaluating these studies using the RE-AIM framework.

1) Reach

This review was conducted on a specific target population (i.e., elementary-school students). The baseline sample sizes of the reviewed studies ranged from 1,147 to 2,280 (median = 1,837.5) participants. All studies reported the age (range = 6 to 12 years) and sex of the participants. The participation rate was reported in all studies, and it ranged from 33% to 99.9%.

2) Efficacy/Effectiveness

All reviewed studies included measures of nutrition knowledge, self-efficacy, outcome expectations, intake of foods, or outcomes related to physical activity. The nutrition knowledge variables (reported knowledge about food groups, main nutrients, nutrient functions, breakfast choices, snack choices, and dinner choices) were measured in two studies [24, 25]. Both reported statistically significant improvements in the intervention group with reference to all nutrition knowledge variables compared to the control group. Self-efficacy and outcome expectations were measured in the two studies [24, 25], and both reported significant improvements in the intervention group compared with the control group. The intake of foods was measured in two studies [24, 25], and both reported statistically significant improvements in some food groups (i.e., vegetables, low-nutrient high-energy foods, sugar-sweetened beverages) in the intervention group as compared with the control group. The outcomes related to physical activity were measured in the two studies [22, 23], one of which reported significant improvements in energy expenditure during recess in the intervention group compared to the control group [23].

3) Adoption

At the organizational level, all the studies specified the location of the intervention as the school. The rate at which the schools adopted the intervention program was reported in all studies, ranging from 9% to 66.7%. The “Adoption” rate was calculated as the rate of schools that agreed to participate in the program [22, 23] or the rate at which the classrooms ordered the program [24, 25].

4) Implementation

All the reviewed studies described the intervention duration, which ranged from four weeks to two school years. Fidelity of implementation was reported as follows: 96% of the teachers distributed all newsletters; 71% of the teachers taught the exercises most of the time; 28% of the students and 55% of the parents had read all the newsletters [22]; 71.4% of the program elements were implemented successfully [23]; 100% or 88.9% of the teachers in the evaluation sample implemented all the lessons [24, 25].

5) Maintenance

All reviewed studies described their maintenance standards. Three of the studies examined whether the teachers wanted the program to be a standard practice in their curriculum or whether they wanted to re-order the program materials during the subsequent school year [22-25]. The other study examined how well the program elements were maintained at the 18-month follow-up [23].

Table 2. Evaluation results of the selected studies using the RE-AIM framework

Reference (Publication year)	Reach	Efficacy/Effectiveness	Adoption	Implementation	Maintenance
Collard DCM et al. (2010)	Participation rate = 99.9% (2,208 out of the 2,210 students who were invited to participate in the program)	Injury incidence density per 1,000 hours of physical activity (not statistically significant); Injury severity (not statistically significant)	Some of the schools (9%) were willing to participate in the program (45 out of the 480 schools invited for participation)	Most of the teachers (96%) distributed all eight newsletters; Some of the teachers (71%) taught the exercises most of the time; Some of the students (28%) had read all the newsletters; Some of the parents (55%) had read all the newsletters	Some of the teachers (52%) indicated that the program would become a standard practice in their curriculum routine
Janssen M et al. (2013)	Participation rate = 60.7% (464 students were defined as physically inactive out of 765 students who completed the PA questionnaire)	Energy expenditure during the recess for the intervention group was significantly different (IG[1]: 0.105 ± 0.01 kcal/kg/min, CG[2]: 0.074 ± 0.01 kcal/kg/min, $P < 0.01$)	Some of the schools (66.7%) were willing to participate in the program (10 out of 15 schools invited for participation); Some of the schools (80%) started the actual preparation of the program (4 out of 5 schools in the IG[1])	Some of the program (71.4%) elements were successfully implemented (5 out of 7 program elements)	Follow-up at 18 months, 60% of the program elements were completely maintained (3 out of 5 program elements)
Dunton GF et al. (2014)	Participation rate = 42% (195,245 out of 461,974 third-grade students in California during the 2010 ~ 2011 school year)	Nutrition knowledge variables ($P < 0.01$), self-efficacy ($P < 0.01$), outcome expectations ($P < 0.01$), intake of vegetables ($P < 0.10$), and low-nutrient high-energy foods ($P < 0.01$) were significantly different from pre- to post-survey.	Some of all third-grade classrooms (39%) ordered the program in 2010 ~ 2011 (7,359 out of 19,000 third-grade classrooms across all public elementary schools in California that year)	All of the intervention teachers in the evaluation sample implemented all the lessons	Some of all third-grade classroom teachers (37%) re-ordered the program materials during the subsequent school year (2,723 out of 7,359 third-grade classroom teachers who ordered the program materials)
Larsen A et al. (2015)	Participation rate = 33% (152,065 out of 462,403 fourth-grade students in California during the 2011 ~ 2012 school year)	Nutrition knowledge variables ($P < 0.001$), self-efficacy ($P < 0.05$), outcome expectations ($P < 0.001$), intake of low-nutrient high-density foods ($P < 0.05$), and sugar-sweetened beverages ($P < 0.05$) were significantly different between the IG[1] and CG[2].	Some of all fourth-grade classrooms (26%) ordered the program in 2011 ~ 2012. (4,821 out of 18,500 fourth-grade classrooms across all public elementary schools in California that year)	Some of the teachers (88.9%) completed all seven lessons (24 out of 27 teachers who were in the IG[1]); 58.5% of all students completed the homework (568 out of 971 students who were in the IG[1])	Some of all fourth-grade classroom teachers (41%) re-ordered the program materials during the subsequent school year (1,977 of 4,821 fourth-grade classroom teachers who ordered the program materials)

1) Intervention group; 2) Control group

2. RE-AIM framework-based evaluation of an elementary-school-based pilot health promotion program

Before evaluating the feasibility of the RE-AIM framework, criteria for evaluating the intervention with a mobile application and the TTM were developed (Table 3). The feasibility of this evaluation system using the RE-AIM framework was assessed by evaluating the individual level of "reach" and "efficacy/effectiveness" of a pilot study involving intervention in healthy eating habits and physical activity (Table 4).

1) Reach

The schools (n = 4) invited to participate in the pilot study consisted of 989 students in Grades 5 and 6. The study population consisted of 786 students at the start; 759 students completed the post-test after the 12-week intervention. The "Reach" of the target population (four elementary schools in Gimpo City and Incheon City) was 76.7%.

2) Efficacy/Effectiveness

Efficacy/Effectiveness was assessed through pre- and post-tests on the eating habits, physical activity, screen time, physical measurements, and the PAPS. Among the changes in food intake frequency, in the intervention group, the intake frequency of

Table 3. Suggested evaluation criteria in each dimension of the RE-AIM framework for the intervention programs using a mobile application based on the transtheoretical model

Dimension	Criteria
Reach	*Individual level*
	1. Size of the target population that participated in the program
	2. Number of people who were willing to participate
	3. Number of people who downloaded the application
Efficacy/Effectiveness	*Individual level*
	1. Changes in knowledge, cognition, and attitude before and after program implementation
	2. Difference between the intervention and control groups
	3. Judging the existence of confidence pertaining to the challenge
	4. Changes in health condition before and after program implementation
	5. Changes in food intake before and after program implementation
	6. Changes in physical activity before and after program implementation
	7. Changes in the behavioral stage according to the TTM[1]
	8. Judging the difficulty level or lack of convenience of application usage
Adoption	*Individual level*
	1. Number of participants who used the application
	Organizational level
	1. Number of schools that adopted the use of the application
Implementation	*Individual level*
	1. Number of participants who initially logged onto the application
	2. Number of participants who started taking the nutrition and physical activity challenges on the application
	3. Number of participants who completed the nutrition and physical activity challenges
	Organizational level
	1. Number of teachers who successfully implemented the program elements
Maintenance	*Individual level*
	1. Number of people who continued to use the application after six months
	Organizational level
	1. Number of schools that intended to extend the use of the application to routine practice

1) Transtheoretical model

Table 4. Evaluation of the impact of the intervention using the mobile application "Happy Me" using the RE-AIM framework

Dimension	Definition	Criteria	Evaluation
Reach	Participation rate	all 5th and 6th-grade students from four elementary schools in the cities of Gimpo and Incheon (n = 989); participants who provided consent to participate in the study (n = 786); participants who completed the post-survey assessment after the 12-week intervention (n = 759)	76.7% (= 759/989*100)
		Rate of schools that were willing to participate in the cities of Gimpo and Incheon	Assigned by the Office of Education; not applicable for this study
Efficacy/Effectiveness	Knowledge/Cognition /Attitude	Changes in knowledge, perception, and attitudes regarding healthy eating habits and physical activities	Suggested to include in the evaluation index in future
	Self-efficacy	"Judging the existence of confidence regarding a challenge" with reference to the algorithm in the application	There are data, but not sufficient for establishing an assessment standard
	Change in the TTM[1)] stage	Number of people whose TTM[3)] stage changed with reference to food intake and physical activity (rate of people who advanced to the next level vs. rate of people who reverted to a lower level)	There are data, but not sufficient for establishing an assessment standard
	Changes in food intake	Frequency of eating breakfast (days/week)	In the intervention group: 2.3 ± 2.6 (pre) versus 1.6 ± 1.5 (post), $P = 0.0014$
		Frequency of eating vegetables (times/week)	No significant changes
		Frequency of eating fruit (times/week)	No significant changes
		Frequency of drinking sugar-sweetened beverages (times/week)	In the intervention group: 2.3 ± 2.6 (pre) versus 1.6 ± 1.5 (post), $P < 0.0001$; In the control group: 2.5 ± 3.1 (pre) versus 2.0 ± 2.3 (post); Between groups $P = 0.0286$
		Frequency of eating fast food (times/week)	No significant changes
		Frequency of eating instant food (times/week)	No significant changes
		Frequency of eating snacks (times/week)	No significant changes
		Frequency of late-night snacking (times/week)	In the intervention group: 2.3 ± 2.6 (pre) versus 1.6 ± 1.5 (post), $P = 0.0026$

Table 4. continued

Dimension	Definition	Criteria	Evaluation
Efficacy/Effectiveness	Changes in health condition	Frequency of physical activities reaching VO_2max (days/week)	No significant changes
		Frequency of intense physical activities (days/week)	No significant changes
		Frequency of mild physical activities (days/week)	No significant changes
		Frequency of strengthening exercise (days/week)	No significant changes
		Frequency of walking for more than 10 minutes in a day (days/week)	No significant changes
		Duration of walking (minutes/day)	In the intervention group: 74.2 ± 89.9 (pre) versus 95.2 ± 105.1 (post), $P < 0.0001$; In the control group: 68.2 ± 69.2 (pre) versus 66.1 ± 62.6 (post); Between groups $P = 0.0064$
	Potential and unintended negative effects	Difficult or inconvenient to use application	Need to include additional videos on proper motion during exercising, a manual for the "Happy Me" application, and factors that attract interest
		Weekday screen time (minutes/day) Weekend screen time (minutes/day)	Weekend screen time (min/a day) in the intervention group: 157.5 ± 100.8 (pre) versus 166.5 ± 96.6 (post), $P = 0.0021$
	Availability of the application	Numbers of downloads and log-ins	-
	Satisfaction with the application	Satisfaction with the application	Not applicable
Adoption[2)]	Rate of future adoption	Responsibility of students or schools that are willing to use "Happy Me" in the future	Not applicable
Implementation[2)]	Rate of improvement in knowledge	Number of people on each TTM stage before and after intervention	Not applicable
	Rate of adoption of the application	Number of participants who initially logged on to the application	Not applicable
Maintenance[2)]	Maintenance	Rate of people who showed positive changes in food intake and duration of exercise after six months	Not applicable

1) Transtheoretical model; 2) not measured in this pilot study, 3) Based on the TTM, the stages of subjects were determined by their status, decision to make behavioral changes, and self-confidence in behavioral changes [41].

sugar-sweetened beverages decreased from 2.3 ± 2.6 times/week to 1.6 ± 1.5 times/week after intervention ($P < 0.0001$). The magnitude of the effect was larger in the intervention group than in the control group ($P < 0.0286$). The duration of walking increased from 74.2 ± 89.9 minutes/day to 95.2 ± 105.1 minutes/day in the intervention group, owing to the changes in exercise time ($P < 0.0001$). The increase in walking duration in a day was larger in the intervention group than the control group ($P = 0.0064$). Such changes were not observed in the control group. Changes in the TTM stages and self-efficacy were expected to be evaluated by the item, "Are you confident in your ability to accept the challenge" and "change in the TTM stages related to food intake and physical activity" according to the mobile application used. However, these data had a large number of instances of selection of food groups (i.e., vegetables, fruits, sugar-sweetened beverages, fast food, instant food, snacks, and late-night snacks) and acceptance of challenges. Additional reference criteria for the evaluation, such as the most important challenge and the challenge with which the participant is most confident, are required to reflect the "Efficacy" of the intervention. In addition, the changes in knowledge, perception, and attitudes regarding healthy eating habits and physical activities, and availability of and satisfaction with the application were suggested to be included in the evaluation criteria in a future study.

3) Adoption, Implementation, and Maintenance

These dimensions of the RE-AIM framework did not apply to the measurement tools of the pilot study. Therefore, the following potential indicators are suggested for use in future studies: "Adoption" could be assessed based on the proportion of schools or students who are willing to continue using the "Happy Me" application in the future, the proportion of students who have gained knowledge and have achieved their goals through the application could be used as an indicator of "Implementation," and "Maintenance" could be assessed based on the proportion of students who exhibited a positive change in their food intake and health condition after six months.

Discussion

This study aimed to identify evaluation criteria used in the RE-AIM framework using a systematic review and evaluated the feasibility of the RE-AIM framework using an elementary-school-based pilot health promotion program. The systematic review revealed no studies in Korea evaluating the effectiveness of health promotion programs for elementary-school students using the RE-AIM framework. Thus, four international studies were selected [22-25]. In the four studies selected, "Reach" was assessed by the rate of participation in the program out of the eligible population. "Efficacy" was assessed based on the pre- and post-test outcomes for the intervention group and control groups. "Adoption" was assessed by the usage rate of the program and the participation rate in the next stage of the program; "Implementation" was assessed by the progress of the program components and lessons. "Maintenance" was assessed by the rate of participants and teachers who responded positively to the program and intended to continue to use it. The feasibility of the RE-AIM framework was examined by applying it to evaluate a pilot study based on the evaluation components identified from the review. Students (n = 989) from Grades 5 and 6 from four elementary schools in Gimpo City and Incheon City were intervened for 12 weeks using the "Happy Me" application developed as a customized mobile service for the prevention and management of childhood obesity. The results of the intervention were evaluated using the RE-AIM framework. Reach and Efficacy could be evaluated, but Adoption, Implementation, and Maintenance could not be assessed in the pilot study. Accordingly, assessment indicators, such as future participation rate, knowledge improvement rate, and availability of or satisfaction with the application, are suggested for future studies.

Previous studies used the RE-AIM framework in the evaluation phase, planning the intervention, and reviewing the literature on health intervention [9, 26, 27]. On the other hand, only one Korean study that used the RE-AIM framework to evaluate an alcohol education program for university students was found [28]. In this study, the RE-AIM framework was used to develop

an evaluation plan in the development stage. Reach was assessed with reference to the rate of students who had received alcohol education. Efficacy was evaluated by the changes in awareness, knowledge, attitude, and skills pertaining to moderate drinking. Adoption was analyzed by the rate of schools that adopted the alcohol education program. Implementation was examined by the degree of change in the educated students' knowledge and utilization of skills and whether the staff followed the instructional guidelines. Maintenance was determined by whether the students' moderate drinking practice lasted longer than six months and whether alcohol education was included as a regular component of the curriculum.

In previous studies [22-25], the RE-AIM framework was used to evaluate the effects of the nutrition and physical activity intervention in elementary-school students in the United States and the Netherlands. On the other hand, in the present study, the pilot study involved sending messages using a mobile application as an intervention based on the TTM. Mobile intervention is highly accessible and cost-effective and can provide personalized information [29-34]. Additionally, the TTM is the most promising model for promoting behavioral changes associated with healthy lifestyle habits [35].

Similar to the intervention method used in this study, three studies used a mobile application and the TTM simultaneously [36-38]. One of these, in a study conducted in Australia, messages developed using the TTM were sent to participants for 12 weeks via their mobile phones [38]. The study was similar to the present study in the contents and intervention period. The intervention group received eight mobile messages, one email, five personal coaching calls, a dietary brochure, and other materials through the mobile application and website every week. By contrast, the control group received four mobile messages and a printed dietary and physical activity guideline only. The pre- and post-online surveys showed that after 12 weeks, the intervention group had a lower weight, higher daily intake of vegetables, and lower intake of sweet beverages and instant food than the control group. Furthermore, the total amount of physical activity in the intervention group increased by 252.2 MET-minutes per week, and the frequency increased by 1.3 days per week. Patridge et al.[38] reported a greater magnitude of changes in the intake frequency of vegetables and instant food than those observed in the present study. These differences are because the target population and the intervention factors in the two studies were different. The target population of the present study was 5th and 6th-grade elementary school students, while that by Patridge et al.[38] was 18- to 35-year-old young adults with a high risk of weight gain and overweight. In addition to providing messages using the mobile application, Patridge et al. also provided information through personal coaching calls and a dietary brochure [38].

The limitations of the present study are as follows. First, the mobile intervention had several advantages, but it was difficult to assess the Maintenance aspect because a longer intervention period indicated a lower participation rate [39]. Second, although the 12-week period was sufficient for obesity intervention, further research is required because several school-based prevention and management programs demand long-term intervention [40]. Third, because this study evaluated the results of the pilot study using the RE-AIM framework, it is necessary to reevaluate the same in an expanded study in the future. Fourth, the pilot study did not include a dietary intake measurement tool in the pre- and post-test. To evaluate the efficacy in future studies, the dietary intake needs to be assessed in detail using methods such as the 24-hour recall. Nevertheless, this study was meaningful because it was the first to evaluate the feasibility of the RE-AIM framework through a systematic review of elementary-school-based intervention studies. In addition, the effects of intervention with a mobile application and TTM were similar to those of previous studies, suggesting that these methods have the potential for effective intervention.

Conclusions

In this study, only some of the five dimensions of the RE-AIM framework were evaluated because of the limitations of the measurement tools. According to a systemic review of the RE-AIM framework, most studies using the RE-AIM framework indicated Reach and Efficacy. On the other hand, only a few addressed Adoption, Implementation, and Maintenance. In the future, more effective program evaluation and dissemination will be possible if the evaluation criteria are selected by considering all five dimensions of the RE-AIM framework at the planning stage of the intervention program.

References

1. Ogden CL, Carroll MD, Curtin LR, Lamb MM, Flegal KM. Prevalence of high body mass index in US children and adolescents, 2007-2008. J Am Med Assoc 2010; 303(3): 242-249.
2. Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: A systematic analysis for the global burden of disease study 2013. Lancet 2014; 384(9945): 766-781.
3. Freedman DS, Kettel L, Serdula MK, Dietz WH, Srinivasan SR, Berenson GS. The relation of childhood BMI to adult adiposity: The Bogalusa Heart Study. Pediatrics 2005; 115(1): 22-27.
4. Freedman D, Wang J, Thornton JC, Mei Z, Sopher AB, Pierson RN et al. Classification of body fatness by body mass index-for-age categories among children. Arch Pediatr Adolesc Med 2009; 163(9): 805-811.
5. Benjamin RM. The Surgeon General's vision for a healthy and fit nation. Public Health Rep 2010; 125(4): 514-515.
6. Nader PR, O'Brien M, Houts R, Bradley R, Belsky J, Crosnoe R et al. Identifying risk for obesity in early childhood. Pediatrics 2006; 118(3): e594-e601.
7. Biro FM, Wien M. Childhood obesity and adult morbidities. Am J Clin Nutr 2010; 91(5): 1499S-1505S.
8. Centers for Disease Control and Prevention (CDC). School health guidelines to promote healthy eating and physical activity. Morb Mortal Wkly Rep 2011; 60(RR-5): 1.
9. De Bourdeaudhuij I, Van Cauwenberghe E, Spittaels H, Oppert, JM, Rostami C, Brug J et al. School-based interventions promoting both physical activity and healthy eating in Europe: A systematic review within the HOPE project. Obes Rev 2011; 12(3): 205-216.
10. Van Cauwenberghe E, Maes L, Spittaels H, van Lenthe FJ, Brug J, Oppert JM et al. Effectiveness of school-based interventions in Europe to promote healthy nutrition in children and adolescents: Systematic review of published and 'grey'literature. Br J Nutr 2010; 103(6): 781-797.
11. Glasgow RE, Vogt TM, Boles SM. Evaluating the public health impact of health promotion interventions: The RE-AIM framework. Am J Public Health 1999; 89(9): 1322-1327.
12. Glasgow RE, Klesges LM, Dzewaltowski DA, Estabrooks PA, Vogt TM. Evaluating the impact of health promotion programs: Using the RE-AIM framework to form summary measures for decision making involving complex issues. Health Educ Res 2006; 21(5): 688-694.
13. Gaglio B, Shoup JA, Glasgow RE. The RE-AIM framework: A systematic review of use over time. Am J Public Health 2013; 103(6): e38-e46.
14. Kim YA. Our Class Revolution: Current situation of smart learning and development plan (OR2011-02-7). Seoul: Korean Educational Development Institute; 2011.
15. Turner-McGrievy GM, Beets MW, Moore JB, Kaczynski AT, Barr-Anderson DJ, Tate DF. Comparison of traditional versus mobile app self-monitoring of physical activity and dietary intake among overweight adults participating in an mHealth weight loss program. J Am Med Inform Assoc 2013; 20(3): 513-518.
16. Prochaska JO, DiClemente CC, Norcross JC. In search of how people change: Applications to addictive behaviors. Am Psychol 1992; 47(9): 1102-1114.
17. Prochaska JO, Redding CA, Evers KE. The transtheoretical model and stages of change. In: Glanz K, Rimer BK, Viswanath K, editors. Health behavior and health education. San Francisco (CA): John Wiley & Sons; 2008. p. 97-122.
18. Carvalho de Menezes M, Bedeschi LB, Santos LC, Lopes AC. Interventions directed at eating habits and physical activity using the Transtheoretical Model: A systematic review. Nutr Hosp 2016; 33(5): 1194-1204.
19. Partridge SR, McGeechan K, Hebden L, Balestracci K, Wong AT, Denney-Wilson E et al. Effectiveness of a mHealth lifestyle program with telephone support (TXT2BFiT) to prevent unhealthy weight gain in young adults: Randomized controlled trial. JMIR Mhealth Uhealth 2015; 3(2): e66.
20. Jung JH, Jeon SH, Bae HJ, Cho YG, Hur YI, Sung EJ et al. Development of a smartphone application for 4th-6th grade elementary students aimed to prevent childhood obesity. Korean J Obes 2016; 25(2): 99-104.
21. Kim K, Kang J, Park HA, Cho SH, Jeon S, Jung J et al. Development of a smartphone application prototype for child obesity prevention: rationale and study design of acceptability and feasibility tests. Korean J Health Promot 2015; 15(4): 194-201
22. Collard DC, Chinapaw MJ, Verhagen EA, Van Mechelen W. Process evaluation of a school based physical activity related injury prevention programme using the RE-AIM framework. BMC pediatrics 2010; 10(1): 86.
23. Janssen M, Toussaint HM, Van Mechelen W, Verhagen EA. Translating the PLAYgrounds program into practice: A process evaluation using the RE-AIM framework. J Sci Med Sport 2013; 16(3): 211-216.
24. Dunton GF, Liao Y, Grana R, Lagloire R, Riggs N, Chou CP et al. State-wide dissemination of a school-based nutrition education programme: A RE-AIM (Reach, Efficacy, Adoption, Implementation, Maintenance) analysis. Public Health Nutr 2014; 17(2): 422-430.
25. Larsen AL, Robertson T, Dunton G. RE-AIM analysis of a randomized school-based nutrition intervention among fourth-grade classrooms in California. Transl Behav Med 2015; 5(3): 315-326.

26. De Meij JS, Chinapaw MJ, Kremers SP, Jurg ME, Van Mechelen W. Promoting physical activity in children: The stepwise development of the primary school-based JUMP-in intervention applying the RE-AIM evaluation framework. Br J Sports Med 2010; 44(12): 879-887.
27. Wozniak L, Rees S, Soprovich A, Al Sayah F, Johnson ST, Majumdar SR et al. Applying the RE-AIM framework to the Alberta's Caring for Diabetes Project: A protocol for a comprehensive evaluation of primary care quality improvement interventions. BMJ open 2012; 2(5): e002099.
28. Kim HK, Kim M, Lee EH, Kwon EJ, Cho HI. Development of "Drink smart" alcohol education program for university students: Application of the intervention mapping and transtheoretical model. Korean J Health Educ Promot 2011; 28(5): 145-160.
29. Woolford SJ, Clark SJ, Strecher VJ, Resnicow K. Tailored mobile phone text messages as an adjunct to obesity treatment for adolescents. J Telemed Telecare 2010; 16(8): 458-461.
30. Burke LE, Styn MA, Sereika SM, Conroy MB, Ye L, Granz K et al. Using mHealth technology to enhance self-monitoring for weight loss: A randomized trial. Am J Prev Med 2012; 43(1): 20-26.
31. De Niet J, Timman R, Bauer S, van den Akker E, de Klerk C, Kordy H et al. Short message service reduces dropout in childhood obesity treatment: A randomized controlled trial. Health Psychol 2012; 31(6): 797-805.
32. Turner-McGrievy GM, Beets MW, Moore JB, Kaczynski AT, Barr-Anderson DJ, Tate DF. Comparison of traditional versus mobile app self-monitoring of physical activity and dietary intake among overweight adults participating in an mHealth weight loss program. J Am Med Inform Assoc 2013; 20(3): 513-518.
33. Kim JW, Lee EJ. Current status of dietary education applications (App) as a smart education material. J Korean Pract Arts Educ 2013; 26(4): 81-110.
34. Woolford SJ, Clark SJ, Strecher VJ, Resnicow K. Tailored mobile phone text messages as an adjunct to obesity treatment for adolescents. J Telemed Telecare 2010; 6(8): 458-461.
35. Andrés A, Gómez J, Saldaña C. The transtheoretical model and obesity: A bibliometric study. Scientometrics 2007; 73(3): 289-301.
36. Kim HH, Seo HJ. HealthTWITTER initiative: Design of a social networking service based tailored application for diabetes self-management. Healthc Inform Res 2014; 20(3): 226-230.
37. Lee MK, Park HA, Yun YH, Chang YJ. Development and formative evaluation of a web-based self-management exercise and diet intervention program with tailored motivation and action planning for cancer survivors. JMIR Res Protoc 2013; 2(1): e11.
38. Partridge SR, McGeechan K, Hebden L, Balestracci K, Wong AT, Denney-Wilson E et al. Effectiveness of a mHealth lifestyle program with telephone support (TXT2BFiT) to prevent unhealthy weight gain in young adults: Randomized controlled trial. JMIR Mhealth Uhealth 2015; 3(2): e66.
39. Steinberg DM, Levine EL, Askew S, Foley P, Bennett GG. Daily text messaging for weight control among racial and ethnic minority women: Randomized controlled pilot study. J Med Internet Res 2013; 15(11): e244.
40. Shaya FT, Flores D, Gbarayor CM, Wang J. School-based obesity interventions: A literature review. J Sch Health 2008; 78(4): 189-196.
41. Lee JE, Lee DE, Kim K, Shim JE, Sung E, Kang JH et al. Development of tailored nutrition information messages based on the transtheoretical model for smartphone application of an obesity prevention and management program for elementary-school students. Nutr Res Pract 2017; 11(3): 247-256.