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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

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BACKGROUND/OBJECTIVES: Easy access to intervention and support for certain behaviors is important for obesity prevention and management. The available technology such as smartphone applications can be used for intervention regarding healthy food choices for obesity prevention and management in elementary-school students. The transtheoretical model (TTM) is comprised of stages and processes of change and can be adopted to tailored education for behavioral change. This study aims to develop TTM-based nutrition contents for mobile applications intended to change eating behaviors related to weight gain in young children.
SUBJECTS/METHODS: A synthesized algorithm for tailored nutrition messages was developed according to the intake status of six food groups (vegetables, fruits, sugar-sweetened beverages, fast food and instant food, snacks, and late-night snacks), decision to make dietary behavioral changes, and self-confidence in dietary behavioral changes. The messages in this study were developed from December 2014 to April 2015. After the validity evaluation of the contents through expert consultation, tailored nutrition information messages and educational contents were developed based on the TTM.
RESULTS: Based on the TTM, stages of subjects are determined by their current intake status, decision to make dietary behavioral changes, and self-confidence in dietary behavioral changes. Three versions of tailored nutrition messages at each TTM stage were developed so as to not send the same messages for three weeks at most, and visual materials such as figures and tables were developed to provide additional nutritional information. Finally, 3,276 tailored nutrition messages and 60 nutrition contents for applications were developed.
CONCLUSIONS: Smartphone applications may be an innovative medium to deliver interventions for eating behavior changes directly to individuals with favorable cost-effectiveness. In addition, using the TTM for tailored nutrition education for healthy eating is an effective approach.

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INTRODUCTION

The economic burden attributable to obesity and its related diseases was estimated at approximately 1,363 billion Korean Won [1]. Since about 50% of obese children will become obese adults [2], reducing childhood obesity has substantial economic benefits. Unlike genetic factors, lifestyle risk factors such as eating habits are modifiable risk factors [3]. Therefore, a greater emphasis on keeping children healthy is needed, rather than treatment [4]. In this regard, promoting healthy diets with nutrition education to children is critical and effective for obesity prevention.

Previous studies have shown that utilization of electrical devices is a practical, cost-efficient, and reliable method for health care [5]. The use of mobile phones enables healthcare providers to send personalized messages to users, who receive tailored information in any place at any time easily [6]. Mobile-based approaches have been reported in successful interventions for eating habits and physical activity [7-9]. Since children and adolescents are familiar with the use of smart devices

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[10,11], new technology may be fully applied to these age groups for educational purposes.

The transtheoretical model (TTM) developed by Prochaska *et al*. [12] is comprised of stages and processes of change. Since, this theoretical model can be adopted for tailored education for behavioral change [13,14], it has been applied to manage and change behaviors related to physical activity intervention [15-17], smoking cessation [18,19], drinking cessation [20], and game addiction intervention [21] for adolescents, adults, and older adults; however, it has not been as extensively applied in respect of children. A recent systematic review [22] has shown that there have been 28 intervention studies directed at eating behaviors using the TTM that reported positive results for reduction of fat intake, an increase in the intake of fruits and vegetables, and increases in physical activity. Based on a systematic review of mobile-based interventions of health behavior change [23], 12 studies have reported positive results of changing eating habits (10 from 38 secondary outcomes related to eating habits out of 54 studies, and 2 from 13 primary outcomes related to diet out of 27 studies). Mobile technology or the TTM has been applied to a wide range of interventions in adults, but limited studies have been done on children [22,23]. In addition, there have been few studies that applied both new technology and the TTM [24-26]. Thus, this study aimed to develop TTM-based tailored nutrition information messages for a mobile-based obesity management program application for elementary-school students.

SUBJECTS AND METHODS

Development of tailored nutrition message algorithm

A synthesized algorithm for tailored nutrition messages was developed in accordance with the intake levels of six food items and stages of behavioral change in the TTM, according to presence/absence of intention and self-confidence in behavioral change. First, subjects' daily (vegetables, fruits, sugar-sweetened beverages, fast food and instant food, and snacks) or weekly (late-night snacks) intake levels are evaluated. Target eating behaviors were selected based on evaluation components of the Nutrition Quotient (NQ) of South Korea [27], national dietary guidelines for children [28], a previous study [29], and results from Korean National Health and Nutrition Examination Surveys [30]. Subjects are supposed to set goals of intake levels every week. The ultimate goals of weekly intake levels for each food group are as follows: vegetables ≥ 5 times a day, fruits ≥ twice a day; and no intake of sugar-sweetened beverages, fast food & instant food, and snacks and late-night snacks (Table 1). The intake level goal for the following one week is set based on the current intake level. Subjects need to move one step forward compared to their current intake level if it is less than the ultimate goal.

Examples of the categorized algorithm for tailored nutrition messages about vegetable intake are shown in Table 2 and Fig. 1. Examples of all stage (Fig. 2), first criterion (Fig. 3), and second criterion (Fig. 4) are also shown. For example, if a subject did not eat any vegetables, the intake level is Ⅰ. Subsequently, if he or she did not decide to make dietary behavioral changes and did not have self-confidence in behavioral changes, he or she is categorized into the precontemplation stage. That is, he or she will receive tailored nutrition message 'Ⅰ_TTM1' for the next following week (Table 2).

Table 1. Intake level goals for moving on to the next stage of the TTM according to current intake status

Food group	Current intake status		Goals of intake level[1)]
	Intake frequency per week, days	Intake frequency per day, times	
Vegetables	Never		≥ 1 per day
	1-3	1-2	≥ 3 per day
		3-4	≥ 5 per day
		≥ 5	≥ 5 per day
	4-5	1-2	≥ 3 per day
		3-4	≥ 5 per day
		≥ 5	≥ 5 per day
	6-7	1-2	≥ 3 per day
		3-4	≥ 5 per day
		≥ 5	Maintaining
Fruits	Never		≥ 1 per day
	1-3	1	≥ 2 per day
		≥ 2	≥ 2 per day
	4-5	1	≥ 2 per day
		≥ 2	≥ 2 per day
	6-7	1	≥ 2 per day
		≥ 2	Maintaining
Sugar-sweetened beverages, fast food & instant food, and snacks	Never		Maintaining
	1-3	1	Never
		≥ 2	≤ 1 per day
	4-5	1	< 1 per day & ≤ 3 per week
		≥ 2	≤ 1 per day
	6-7	1	< 1 per day & ≤ 5 per week
		≥ 2	≤ 1 per day
Late-night snacks	Never[2)]		Maintaining
	1-3 per week[2)]		Never
	4-5 per week[2)]		≤ 3 per week
	6-7 per week[2)]		≤ 5 per week

TTM: the transtheoretical model

[1)] The goals of intake level for the following one week are set based on the current intake level. Subjects need to move one step forward compared to the current intake level if it is less than the ultimate goal. The ultimate goals of weekly intake levels for each food group are: vegetables ≥ 5 times a day; fruits ≥ twice a day; no intake of sugar-sweetened beverages, fast food and instant food, snacks, and late-night snacks

[2)] Intake frequency of late-night snacks is measured only weekly.

Expert consultation

Tailored nutrition messages were developed from December 2014 to April 2015. Three consecutive expert consultations were performed, in addition to face and content validity by five university professors majored in nutrition. This study was approved by the Sangmyung University Institutional Bioethics Review Board (SMUIBRB : BE2015-2).

Finalized tailored nutrition messages

After establishing face validity and evaluation of nutrition education contents for messages through the expert consultation,

Table 2. An example of a synthesized algorithm according to criteria: categorization of tailored nutrition messages for vegetable intake

1st criterion		2nd criterion			Subject categorization[1)]
Current intake status	Intake level	Decision to make dietary behavioral changes	Self-confidence in dietary behavioral changes	Stages of behavioral change in TTM	
Never	I	Y	Y	Preparation	I_TTM3
			N	Contemplation	I_TTM2
		N	Y	Contemplation	I_TTM2
			N	Precontemplation	I_TTM1
1-3 days per week & 1-2 times per day	II	Y	Y	Preparation	II_TTM3
			N	Contemplation	II_TTM2
		N	Y	Contemplation	II_TTM2
			N	Precontemplation	II_TTM1
1-3 days per week & 3-4 times per day	III	Y	Y	Preparation	III_TTM3
			N	Contemplation	III_TTM2
		N	Y	Contemplation	III_TTM2
			N	Precontemplation	III_TTM1
1-3 days per week & ≥ 5 times per day	IV	Y	Y	Preparation	IV_TTM3
			N	Contemplation	IV_TTM2
		N	Y	Contemplation	IV_TTM2
			N	Precontemplation	IV_TTM1
4-5 days per week & 1-2 times per day	V	Y	Y	Preparation	V_TTM3
			N	Contemplation	V_TTM2
		N	Y	Contemplation	V_TTM2
			N	Precontemplation	V_TTM1
4-5 days per week & 3-4 times per day	VI	Y	Y	Preparation	VI_TTM3
			N	Contemplation	VI_TTM2
		N	Y	Contemplation	VI_TTM2
			N	Precontemplation	VI_TTM1
4-5 days per week & ≥ 5 times per day	VII	Y	Y	Preparation	VII_TTM3
			N	Contemplation	VII_TTM2
		N	Y	Contemplation	VII_TTM2
			N	Precontemplation	VII_TTM1
6-7 days per week & 1-2 times per day	VIII	Y	Y	Preparation	VIII_TTM3
			N	Contemplation	VIII_TTM2
		N	Y	Contemplation	VIII_TTM2
			N	Precontemplation	VIII_TTM1
6-7 days per week & 3-4 times per day	IX	Y	Y	Preparation	IX_TTM3
			N	Contemplation	IX_TTM2
		N	Y	Contemplation	IX_TTM2
			N	Precontemplation	IX_TTM1
6-7 days per week & ≥ 5 times per day	X	Y	Y	Action	X_TTM4
		Y	N	Preparation	X_TTM3

TTM, transtheoretical model; Y, yes; N, no
[1)] Categorization of tailored nutrition messages according to the 1st and 2nd criterion

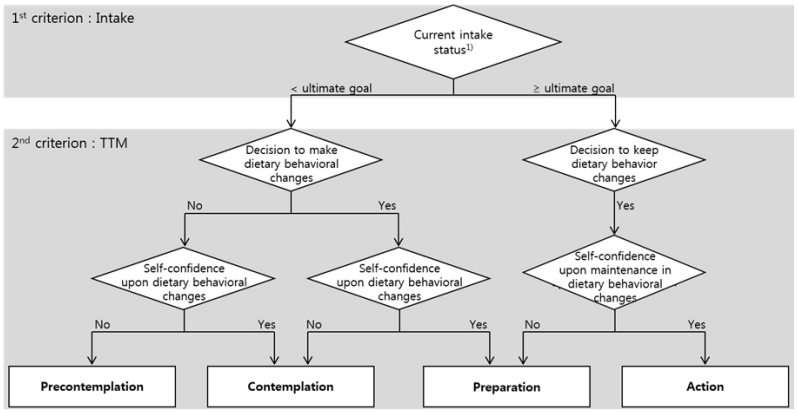

Fig. 1. A logic model for categorization of tailored nutrition messages. [1)] The number of current intake status: 10 for vegetables; 7 for fruits, sugar-sweetened beverages, fast food & instant food; 4 for late-night snacks

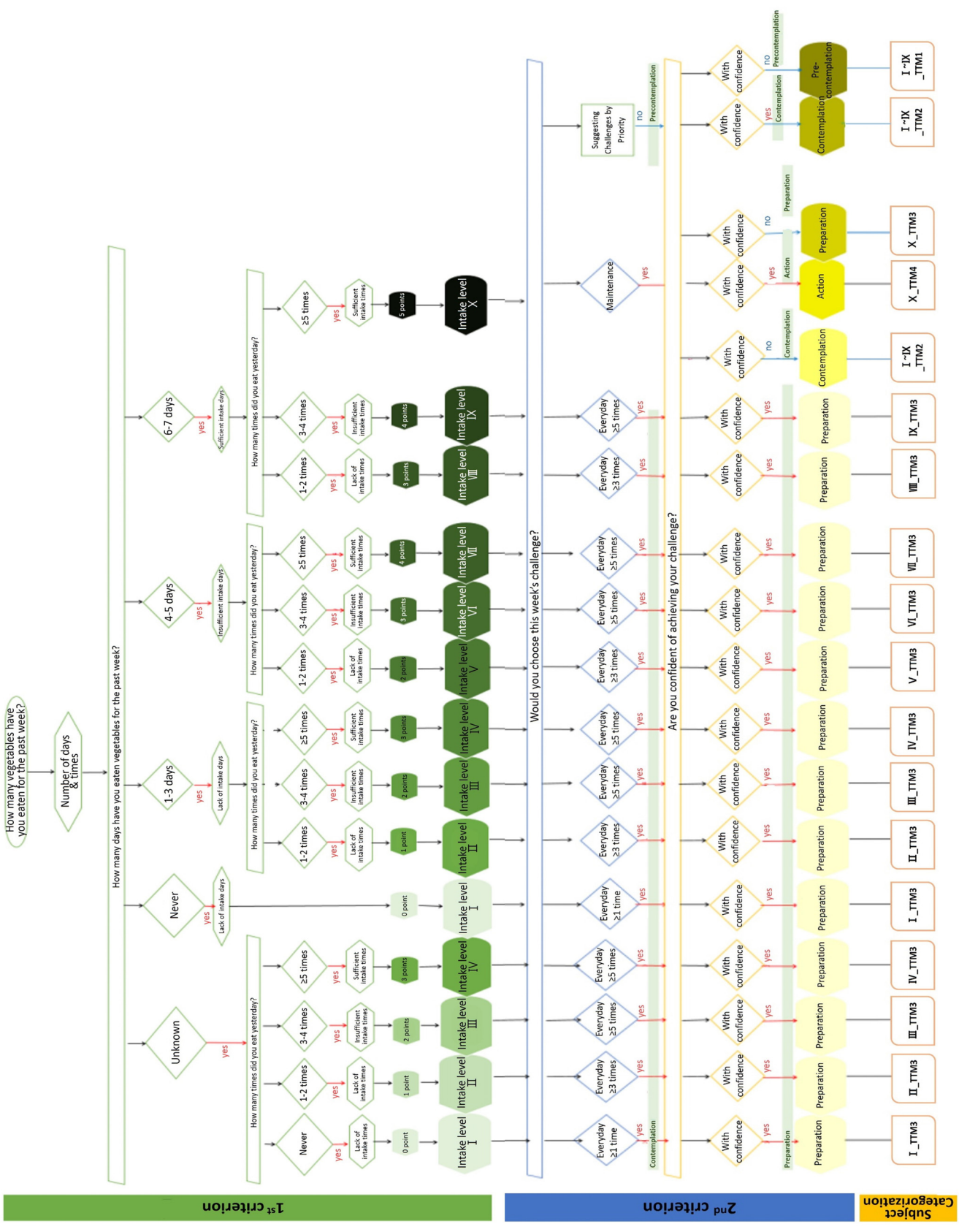

Fig. 2. An example of a categorized algorithm: vegetable intake

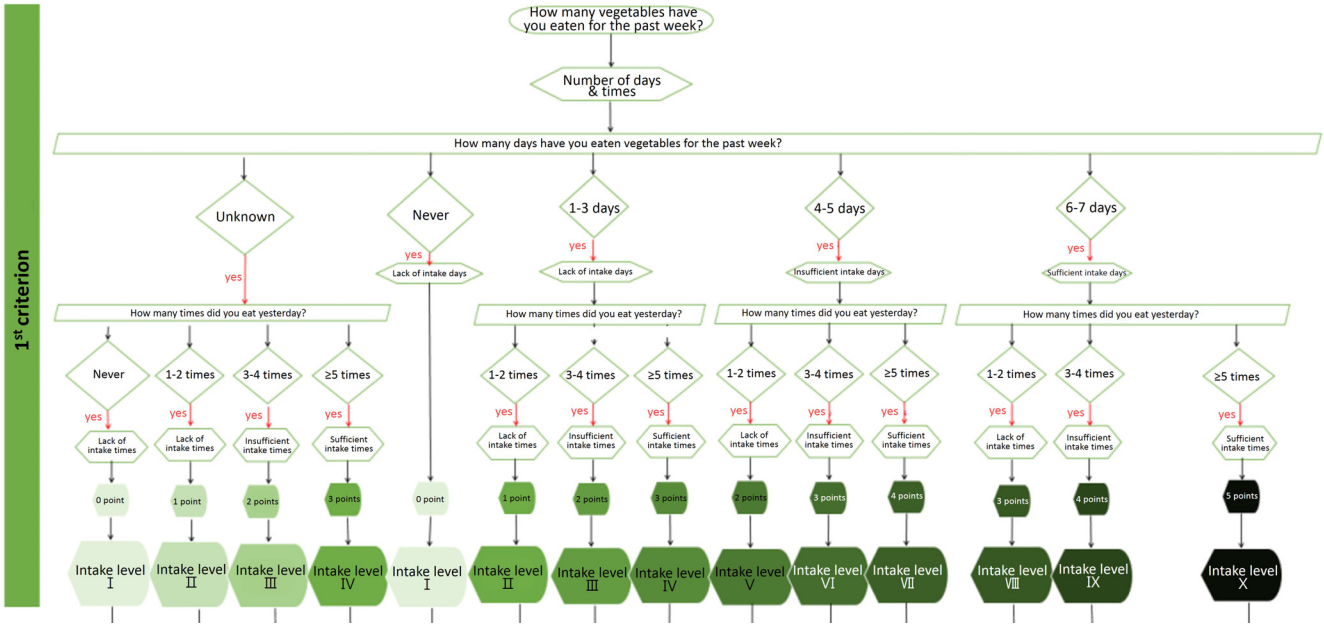

Fig. 3. An example of a categorized algorithm for the first criterion: vegetable intake

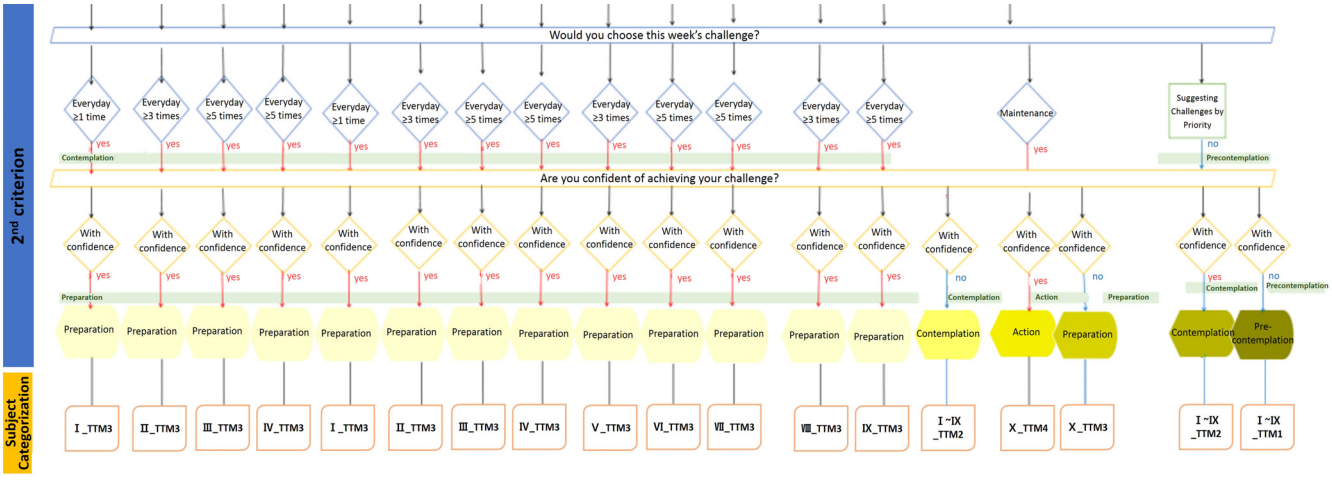

Fig. 4. An example of a categorized algorithm for the second criterion and subject categorization: vegetable intake

TTM-based tailored nutrition messages were developed for "Happy me", an application consisting of a child obesity prevention and management program. The TTM is currently one of the most promising models in understanding and promoting behavioral changes associated with healthy lifestyle habits [31]. A proof-reading was done for the tailored nutrition messages by elementary-school teachers and experts in the Korean language.

RESULTS

Development of tailored nutrition message algorithm

Based on the TTM, stages of subjects are determined by their current intake status, decision to make dietary behavioral changes, and self-confidence in dietary behavioral changes. Message categories according to stages of dietary behavioral change for the TTM are shown in Table 3.

Subjects in the precontemplation stage have no intention to change behaviors in the near future [12]. Tailored nutrition messages for this stage contain information on the benefits or risks of food intake, consciousness raising, and environmental reevaluation. Environmental reevaluation helps subjects recognize their current intake level and the positive effects they would have by changing behaviors.

Subjects in the contemplation stage are aware of a problem and the need to overcome it, but have not yet decided a commitment to take action [12]. Self-reevaluation allows them to realize healthy eating is important and to intend to start healthy dietary behaviors.

Subjects in the preparation stage are intending to make dietary behavioral changes in the next month and have not successfully taken behavioral changes in the past year [12]. In order to induce behavioral changes by giving them confidence

Table 3. Message categories according to stages of dietary behavioral change for the transtheoretical model

Stage of TTM	Message categories
Precontemplation	Information (benefit)
	Information (risk)
	Consciousness raising
	Environmental reevaluation
Contemplation	Information (benefit)
	Information (risk)
	Self-reevaluation
	Portion size
	Suggestion of how to eat
Preparation	Information (benefit)
	Information (risk)
	Self liberation
	Boosting self-confidence (implanting self-confidence)
	Making a promise
	Suggestion of how to eat
Action	Suggestion of how to eat
	Recipe
	Social support
	Reinforcement management
	Counterconditioning/stimulus control
	Recommended intake
	Portion size

TTM: the transtheoretical model

in taking action, tailored nutrition messages for this stage include self-liberation, boosting self-confidence, making a promise, suggestion of how to eat, and advanced nutrition information.

Subjects in the action stage modify their behaviors, experiences, or environments because they know what the risks are if they do not change behaviors [12]. Tailored nutrition messages for this stage contain suggestions of how to eat, social supports, reinforcement management, and counterconditioning.

Expert consultation

Expert consultation was made regarding the number of messages needed to be developed based on the TTM stages and for contents of tailored nutrition messages. Visual materials like figures and tables connected to tailored nutrition messages were additionally developed because nutrition messages need to have a limited number of words due to the nature of a mobile phone (Fig. 5). Each step-by-step message needs to be provided daily within one week. In the case that subjects stay on the same intake goal and in the same stage for three consecutive weeks, tailored nutrition messages for each TTM stage were further developed in three versions in order to not send the same messages for three weeks at most.

Table 4. The number of tailored nutrition messages

Food intake items		Number
Vegetables	$[(9^{1)} \times 4^{2)})+(1^{3)} \times 2^{4)})] \times 7^{5)} \times 3^{6)}$	798
Fruits	$[(6^{1)} \times 4^{2)})+(1^{3)} \times 2^{4)})] \times 7^{5)} \times 3^{6)}$	546
Sugar-sweetened beverages	$[(6^{1)} \times 4^{2)})+(1^{3)} \times 2^{4)})] \times 7^{5)} \times 3^{6)}$	546
Fast food & instant food	$[(6^{1)} \times 4^{2)})+(1^{3)} \times 2^{4)})] \times 7^{5)} \times 3^{6)}$	546
Snacks	$[(6^{1)} \times 4^{2)})+(1^{3)} \times 2^{4)})] \times 7^{5)} \times 3^{6)}$	546
Late-night snacks	$[(3^{1)} \times 4^{2)})+(1^{3)} \times 2^{4)})] \times 7^{5)} \times 3^{6)}$	294
Total		3,276

[1] The number of stages of current intake status except for the stage of current intake = ultimate goal
[2] The number of stages of the transtheoretical model except for the stage of current intake = ultimate goal
In this study, contemplation was divided into two according to the existence of self-confidence toward behavioral change. Thus, subjects were categorized into precontemplation, contemplation without self-confidence, contemplation with self-confidence, preparation, and action stages.
[3] A stage of current intake status = ultimate goal
[4] The number of stages of the transtheoretical model (preparation and action)
[5] Days per week
[6] The number of weekly tailored nutrition message versions

Finalized tailored nutrition messages

Based on the TTM, this study has developed an intervention program for children to promote healthy growth. In order to ensure objective and accurate nutrition information, the sources were collected from the Korea Food and Drug Administration, the Ministry of Health and Welfare, the Ministry of Agriculture, the Food and Rural Affairs, the Korea Health Promotion Foundation, the Seoul Metropolitan Office of Education, and community health centers of each region. Elementary-school textbooks and university-level nutrition books were also reviewed. After assessing and sorting the collected nutrition information, tailored messages were programmed to be sent to subjects in accordance with categories defined by criteria. Finally, 3,276 tailored nutrition messages and 60 nutrition contents for application were developed (Table 4).

First of all, according to the ultimate goals of intake level, there are nine intake levels for vegetables; six for fruits, sugar-sweetened beverages, and fast food & instant food; and three for late- night

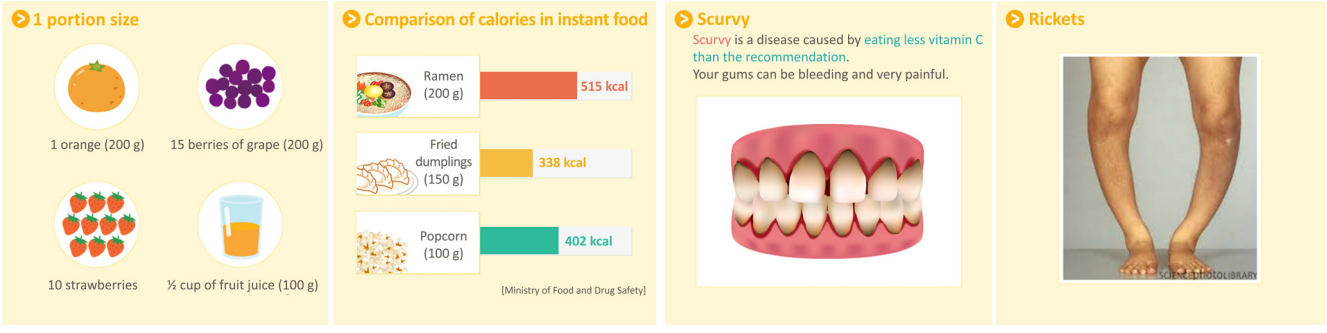

Fig. 5. Visual materials related to tailored nutrition messages

Table 5. An example of daily messages according to stages of dietary behavioral change for the transtheoretical model: vegetable intake

Stages of TTM	Categories	Daily message examples
Precontemplation	Information (benefit)	Vegetables have lots of dietary fiber that enhances active intestinal mobility. No worries about your intestinal health!
	Consciousness raising	Why should we eat vegetables more than five times a day? Think about health advantages. (Example) Vegetables have lots of dietary fiber that enhance active intestinal mobility. No worries about your intestinal health!
	Environmental reevaluation	How can we eat vegetables more than five times a day? (Example) Try making sandwiches or a salad with vegetables or you can make a unique recipe of your own!
Contemplation	Information (benefit)	Since vitamin A in carrots is a fat-soluble vitamin, stir-frying is an effective way to eat carrots for vitamin A absorption.
	Self-reevaluation	Why do we have difficulties with eating vegetables more than five times a day? Let's think about potential barriers. (Example) It would be too tedious to eat raw vegetables only.
	Portion size	Eating vegetables $\geq$ 5 times a day is good for your health. Let's find out how much vegetables you need to eat each time: a dish of bean sprouts (70 g), seasoned spinach (70 g), 1/3 of a cucumber (70 g), 1/3 of a carrot (70 g).
Preparation	Self-liberation	Why don't you make a plan for eating vegetables? (Example) How about eating vegetables for refreshment?
	Boosting self-confidence	Let's think about the first plan by yourself. Make this promise to yourself, and keep it.
	Making a promise	Commit yourself to eating vegetables.
	Suggestion of how to eat	At home, people often blend vegetables, because it is convenient to eat. However, note that eating whole-blended is far better than drinking expressed juice only.
Action	Suggestion of how to eat	When you eat out, try to choose dishes with vegetables. (Example) Bibimbap, rice with many vegetable side-dishes, or rice and condiments wrapped in leaves of lettuce.
	Social support	Do you feel it is difficult to eat vegetables more than five times a day? Let's eat vegetables with your families and friends!
	Reinforcement management	Is it going well? If and when you couldn't fulfill it today, no worries. You will do better tomorrow.
	Counterconditioning/ stimulus control	How about eating dried sweet potatoes, steamed potatoes, or raw cucumber for refreshments, instead of having snacks like crackers? They are delicious, and also good for your health!
Nutrition information contents	Portion size	Children between 6-11 years of age are recommended to eat vegetables more than five times a day. Then, let's find out how much amount of vegetables we should eat per time: a dish of bean sprouts (70 g), seasoned spinach (70 g), 1/3 of a cucumber (70 g), 1/3 of a carrot (70 g).
	Classification of phytochemicals and its effects according to color.	Red-lycopene in tomato: delayed aging process, DNA's fitness, vascular health, immunity improvement.
		Green-lutein and isoflavone in chives, spinach, cabbage, broccoli: healthy cells, eye health, improving cholesterol levels, delay aging process, lower blood pressure, pulmonary function sufficiency.
		Yellow-β-carotene and hesperidin in carrot, sweet potato, and pumpkin: growth and development and eye health.
		White-allicin in onion, white mushrooms, and garlic: fitness of cardiovascular and circulatory systems, adequate cholesterol level, healthy heart, delayed aging process.
		Purple-antocyanin in black bean and eggplant: healthy arteries, healthy heart, improving cognitive competence, antioxidants.

TTM: the transtheoretical model

snacks. According to the TTM, subjects are categorized into the precontemplation, contemplation without self-confidence, contemplation with self-confidence, preparation, and action stages; thereby the contemplation stage is divided into two stages according to the existence of self-confidence towards behavioral change in this study. After categorizing subjects, tailored nutrition messages are provided for each stage. If the current intake status of subjects meets the ultimate goal of intake level, subjects will be placed in either the preparation or the action stage, depending on the current level of self-efficacy. The tailored nutrition messages for each stage were developed in three versions so as to not to deliver the same messages for three consecutive weeks. Messages were developed to be clear and understandable so that the subject could recognize his or her problem and the importance of behavioral change. Examples of the tailored nutrition messages for vegetables are in Table 5.

Tailored nutrition messages for subjects in the precontemplation stage were composed of information on benefit or risks of food intake, consciousness raising, and environmental reevaluation such as "Vegetables have lots of dietary fiber that enhance active intestinal mobility. No worries about your intestinal health!". In the contemplation stage, messages were about information on benefit or risk of food intake, self-reevaluation, and portion size. An example of self-reevaluation is "Why do we have difficulties with eating vegetables more than five times a day? Let's think about potential barriers. (Example) It would be too tedious to eat raw vegetables only". In the preparation stage, messages were composed of contents about self-liberation and boosting self- confidence, making a promise, and suggestions of how to eat such as "Let's think about the first plan made by yourself. Make this promise to yourself, and keep it" and "Commit yourself to eating vegetables". Because subjects in the action stage are already practicing, they are given tailored nutrition messages about suggestions of how to eat, recipes, social support, reinforcement management, counterconditioning, recommended intake, and portion size. An example of reinforcement manage-

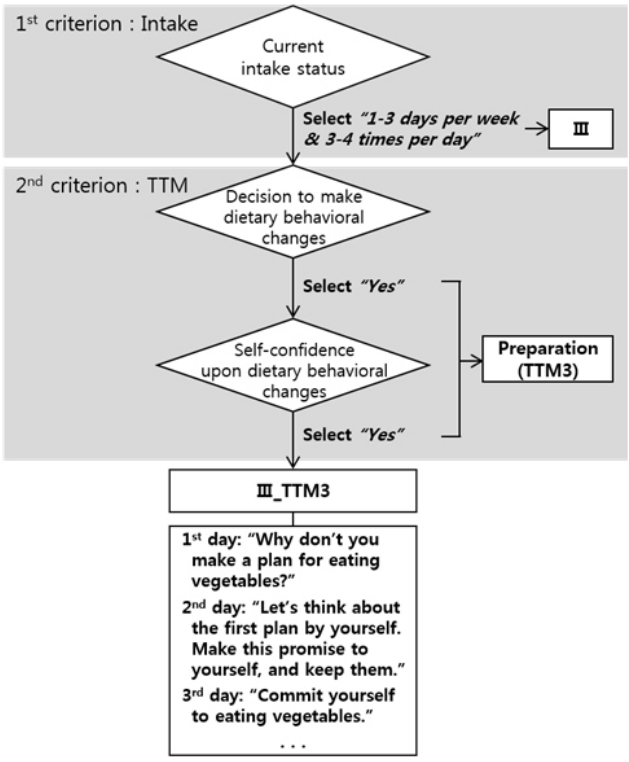

Fig. 6. An example of the tailoring process: vegetable intake

ment is "Is it going well? If and when you couldn't fulfill it today, no worries. You will do better tomorrow".

For example, if a subject consumed vegetables 3-4 times a day for 1-3 days a week during the past week, the intake level is set to III. Then, if the subject decided to make dietary behavioral changes and answered that he or she has self-confidence in behavioral changes, the subject will be categorized into the preparation stage. The subject will receive tailored nutrition messages corresponding to 'III_TTM3' (Fig. 6) for the following week.

DISCUSSION

In order to improve eating habits, this study used the TTM, an effective model for behavioral change, and mobile-based applications to deliver tailored nutrition education according to the stage of behavioral change. Dietary intervention was composed of six intake components: vegetables, fruits, sugar-sweetened beverages, fast food & instant food, snacks, and late-night snacks. Subjects were categorized by their current intake status, decision to make dietary behavioral changes, and self-confidence upon dietary behavioral changes. A total of 3,276 tailored nutrition messages and 60 nutrition contents were developed for a mobile application.

The TTM is one of the most effective theoretical models for health promotion interventions [31]. In two studies on tailored physical activity and nutrition education intervention based on the TTM in obese adults, body weight and calorie intake were significantly reduced and energy expenditure was increased [32,33]. Many studies using the TTM for dietary behavioral modification have been mostly conducted on adults and limited studies have been conducted on children, especially in school settings. Based on the results of previous studies on adults [32,33], the TTM is also considered a feasible and effective model for intervention studies in children.

A mobile-based application had great accessibility to allow subjects to commit to consistent behavioral changes without temporal and spatial constraints [6]. Several studies have investigated the advantages of the use of mobile phone for obesity prevention and management in adults [7,9], adolescents [34], and children [8]. Two mobile-based intervention studies in obese adults have shown that self-monitoring and feedback on physical activity and eating habits via mobile phone significantly decreased Body mass index (BMI) and energy intake in the intervention group [7,9]. Tailored text messages about eating habits and screen time were sent via mobile phone to obese adolescents aged 12-18 years subjects for 90 days [34]. Subjects were enthusiastic and responded that tailored messages such as the most popular messages about meal suggestions and recipe ideas helped them maintain a healthy diet and focus on weight management. Tailored feedback text messages about exercise, eating habits, and emotional well-being were provided to obese children aged 7-12 years for 38 weeks [8]. Dropout rates of the intervention group were 3.25 times less than the control group, although no difference existed in BMI decrease between the two groups. Previous studies based on the TTM using mobile phones have focused on subjects in the preparation and action stages, while our study tried to cover subjects from the precontemplation to action stages.

These incompatible results may be attributable to differences in the targeted populations. Most studies using tailored messages about eating habits have dealt with an overweight or obese population, who already knew their current weight status and had thought about behavioral modification in the preparation or action stage [7-9,34]. However, the target population of this study were all students in elementary schools and the goal of the study was to promote healthy eating for prevention and management of childhood overweight and obesity. In this regard, target-specific differences in the study goals should be considered.

Recently, several intervention studies have been based on the TTM using mobile devices. In an intervention using mobile application developed for the SNS-based self-management of diabetic patients, subjects were categorized based on the TTM stages through an evaluation algorithm for current exercise practices [24]. Unlike our study, this study has only used the TTM for subject categorization, not for the delivery of tailored messages. There have been two other studies that have used the TTM to categorize subjects for providing tailored messages and showed positive results. In a web-based self-management diet and exercise intervention, program contents were developed according to the TTM stages and the program had 90% participation rates after 12 weeks in pilot study [25]. In a 12-week intervention study for diet and exercise, text messages based on the TTM have resulted in an increase in body weight loss and vegetable intake compared to the control group [26]. The two studies [25,26] were similar to our study in study methods

of tailored messages based on the TTM for dietary behavioral changes. However, the study populations of these studies were cancer survivors and adults, whereas ours were elementary-school children. These intervention studies based on the TTM using mobile devices have been effective in cancer survivors and adults.

Smartphone application may be an innovative medium to deliver interventions for eating behavior changes directly to individuals with favorable cost-effectiveness. In addition, the TTM enables study providers and recipients to send and receive tailored nutrition messages, respectively. This study is meaningful in that it is the first study in Korea to develop tailored nutrition messages for children's healthy eating habits based on the TTM using mobile devices in school settings. However, the developed messages still need to be further validated and evaluated in real settings by future studies. The developed tailored nutrition messages in this study are expected to help children not only in addressing their obesity but also in maintaining a healthy diet in an easy and interesting way.

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