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Research Article

Development and Evaluation of a Mobile Web-based Food Allergy and Anaphylaxis Management Educational Program for Parents of School-aged Children with Food Allergy: A Randomized Controlled Trial

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SUMMARY

Purpose: This study aimed to develop a mobile web-based food allergy (FA) and anaphylaxis management educational program for parents of school-aged children with food allergies and evaluate its effectiveness.

Methods: A mobile program was developed based on a web-based teaching-learning system model. Its effectiveness was subsequently evaluated using a parallel, randomized controlled pre- and post-test design. This study included 73 parents of school-aged children with food allergies. These parents were randomly assigned to either the experimental (n = 37) or control (n = 36) groups. The experimental group participated in a 2-week mobile web-based educational program that covered major topics in FA and anaphylaxis management. These topics included an understanding of food allergies and anaphylaxis, learning techniques for using an epinephrine auto-injector, and developing an emergency action plan. An educational booklet was provided to the control group. Participants completed a pre-test and two post-test questionnaires to evaluate the impact of the program. The assessment tools were the Food Allergy Knowledge Test, Food Allergy Self-Efficacy for Parents, and Food Management and Adaptation Scale. The data were analyzed using descriptive statistics, a test of homogeneity for the pre-test, an independent t-test, and repeated measures ANOVA.

Results: The experimental group experienced greater improvement in the knowledge of FA (post-intervention $t = 14.51$, $p < .001$; 2 weeks post-intervention, $t = 16.15$, $p < .001$), FA self-efficacy (post-intervention $t = 77.99$, $p < .001$; 2 weeks post-intervention, $t = 76.09$, $p < .001$), and practice behavior in FA management (post-intervention $t = 28.10$, $p < .001$; 2 weeks post-intervention, $t = 27.98$, $p < .001$) after web-based FA education.

Conclusion: This study revealed improvements in the knowledge, self-efficacy, and practice behaviors of parents regarding FA and anaphylaxis management. Therefore, the mobile web-based educational program can contribute to the effective management of food allergies and anaphylaxis for parents of school-aged children. CRIS registration: KCT0007491.

Introduction

Food allergy (FA) is an abnormal immune response of the body to otherwise harmless food. FA reactions mediated by immunoglobulin E (IgE) can cause hives, breathing difficulties, and gastrointestinal symptoms. Furthermore, FA symptoms can range from mild to severe, and in rare cases, lead to anaphylaxis, which is potentially fatal [1–4]. There is an increasing number of these severe and potentially life-threatening allergic reactions (anaphylaxis) in children [5–9].

FA is estimated to affect 2–10% of the population, with higher rates among school-aged children than among adults [6,7]. In South Korea, the prevalence of diagnosed FA in school-aged children was 4.6%, 5.2%, 6.4%, 5.5%, and 6.6% in 1995, 2000, 2005, 2008, and 2012, respectively [8,9]. The prevalence of immediate-type FA among school-aged children was found to be 5.3%, with hen's egg, cow's milk, peanuts, tree nuts, wheat, and seafood as the leading causes of this reaction [2,10,11]. With the increasing prevalence of FA over the

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last two decades, the care of school-aged children with life-threatening allergies has become a major challenge for parents. Moreover, food-induced anaphylaxis data revealed that 30% of anaphylactic reactions occur in schools [12].

There is no known cure for FA. Therefore, strict avoidance of food allergens and early recognition and management of allergic reactions are important measures for the prevention of serious health consequences [9,13]. Childhood FA has a wide-ranging effect on parental quality of life; it creates a burden for meal preparation, social activity limitations due to dietary restrictions, anxiety over unintentional exposure, fear of leaving the child in the care of others, and life-threatening allergic reactions [14,15]. Although FA and food-induced anaphylaxis practice guidelines with comprehensive education have been proposed for parents, parents often experience a high degree of anxiety when their child is diagnosed with FA. Parents also report a fear of handing over the main responsibility for allergen avoidance to their children [14].

School-aged children require care that promotes a healthy lifestyle and well-being, including a positive sense of self and the ability to cope with stressful situations [15]. Parents are an essential resource for children to manage their health and behavior. Thus, parenting knowledge, attitudes, and practices are associated with positive parent–child interactions and healthy development in children [16]. Although the risk of anaphylaxis is low, it can occur after the consumption of certain foods at home, school, and in public places. In South Korea, 74.7% of life-threatening allergies among school-aged children are related to food-induced anaphylaxis [9]. Therefore, parents and caregivers should be aware of FA management, the risk of life-threatening allergies, and timely responses [17]. In this context, various interventions have been developed worldwide to evaluate the effectiveness of improving FA management and supporting the quality of life for families [17]. Some interventions designed to improve parental knowledge and self-efficacy in managing and coping with FA management enhance their ability to respond more effectively to their child's risk-related episodes and promote allergy management throughout their daily lives [18]. These studies improve parental knowledge and confidence in allergy management. However, they require actual allergy management practices (e.g., label reading, cross-contamination, and auto-injector administration) that may not be available in all treatment settings. To establish actual management practices, education should encourage voluntary reporting and practice through ongoing interactive online learning rather than in a single course [18]. In addition, interventions are diverse and have yet to achieve the desired effect on different outcome measures. Therefore, the optimal format, as well as evidence-based content and a combination of intervention components, requires further investigation [14].

In South Korea, increasing interest in FA and anaphylaxis has led to extensive research on their mechanism, diagnosis, and treatment [12]. However, developing evidence-based guidelines, including standard educational protocols that can improve both the quality of care and patient outcomes, is equally critical [19]. In response, the South Korea Center for Disease Control and Prevention (KCDC) has published and distributed guidelines for the management of food allergies and anaphylactic reactions in preschools, schools, and public places in accordance with evidence-based research since 2013 [20]. These guidelines seek to effectively provide care to children with known FA and enable the recognition of symptoms of allergic reactions in both diagnosed and undiagnosed children to foster timely responses to emergency needs [21]. Previous studies have demonstrated the necessity of developing a parent education program that facilitates the communication of practical information and uses credible educational resources to support effective allergy management [18,22]. Because parents of children with food allergies tend to make childcare and school decisions based on their knowledge [22], they need an educational program that follows evidence-based guidelines to make informed decisions about school and social activities [23].

There has been an increase in the number of parents working fulltime in recent years, making face-to-face education challenging [24]. Online learning interventions provide an opportunity to facilitate distance education [25]. Most of these methods use an internet-connected network that enables regular and reliable availability of information and offers learner-centered interventions using audio, video, and text to communicate with learners [26,27]. This can help create a collaborative and interactive nursing intervention environment where learners can be engaged, provide immediate feedback, and ask questions [28]. In addition, online learning interventions are more cost-effective than traditional lectures and can maintain anonymity and privacy [29].

This study aimed to develop and verify the effectiveness of a mobile web-based FA and anaphylaxis management educational program for parents. The educational content, both for the experimental group that participated in the online learning program and the control group that received a booklet, is based on KCDC guidelines. The study hypothesis was as follows: the parents who participated in the intervention (online learning group) would have increased knowledge, self-efficacy, and improved practice behavior compared to that in the control group (booklet distribution group).

Methods

Study design

This study describes the development process of a mobile web-based FA and anaphylaxis management educational program. Furthermore, it evaluates the effectiveness of online learning among parents of school-aged children with food allergies using a parallel, randomized controlled pre- and post-test design. This study was registered at cris.nih.go.kr (KCT0007491).

Development process of a mobile web-based FA and anaphylaxis management educational program.

In this study, a mobile web-based educational program was developed based on Jung's [30] web-based teaching-learning system model. The five-stage process involved analysis, design, development, application, and evaluation. In the first stage, we analyzed the KCDC guidelines, literature, user needs assessment, and conducted expert interviews. In the design stage, we established learning objectives, educational content, and user-friendly web design. We collaborated with web development experts for mobile web-based program development during the third stage. In the application and evaluation stages, an operating web server was created, evaluation by an expert and a user were performed, and the mobile web-based educational program was modified and updated accordingly.

Evaluating the mobile web-based FA and anaphylaxis management educational program.

Setting and samples

A total of 73 participants (experimental group, 37; control group, 36) were included in this study. Parents of school-aged children with FA from the Atopy Education Information Center in South Korea were invited to participate in the study. The inclusion criteria were as follows: (1) parents of children who had been diagnosed with FA, who voluntarily agreed to participate; (2) parents of children between 6 and 12 years of age; and (3) parents who could access the internet through desktop computers, tablets, or mobile devices.

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The sample size needed for repeated-measures analysis of variance (ANOVA) was calculated using G*Power 3.1 [31]. A total sample size of 44 participants (22 in each group) was required for a significance level (α) of .05, power of .95, medium effect size (f^2) of 0.25, correlation among repeated measures of .05, and two groups across the three measurements. We used an effect size of 0.25 based on a prior study [28], wherein the medium effect size of a web-based educational program and a power of .95 were used to obtain a larger sample that supports the hypothesis. Considering the drop-off rate, we recruited 80 participants and randomly assigned them to the experimental and control groups, with 40 participants in each group. A research assistant, who was not involved in the study, independently conducted randomization using an allocation program (www.randomizer.org). The participants were placed into the experimental and control groups using an opaque sealed envelope. Participants were blinded to the allocation to prevent the discovery of their assigned study group. After excluding participants who were not involved in the program ($n = 2$) or had incomplete data for the post-test ($n = 5$), data from 73 participants (37 experimental and 36 control) were included in the final analysis (Figure 1).

Ethical consideration

This study was approved by the Institutional Review Board of S University, South Korea (IRB N0:2-7001793-AB-N-0120180V80HR). Participants received information on the eligibility criteria, purpose, and procedures of the study. Furthermore, eligible participants signed informed consent and were assured of confidentiality. Participants could also voluntarily withdraw without any adverse consequences. All participants were provided a small compensation (a skin moisturizing kit). After collecting the post-test data, access to the mobile web-based educational program was provided to participants in the control group.

Measurements

FA knowledge, self-efficacy, and practice behavior in FA management were assessed using questionnaires. The questionnaires were translated by an English translator using a translation and back-translation procedure following permission from the author. The content was verified by three pediatric allergists, three nursing professors, one nurse, and one dietitian. The content validity index (CVI) was calculated using the proportion of items, where experts gave three or four points on a four-point scale (four points for 'very appropriate' and one point for 'not at all appropriate') [32]. When the CVI was .80 or higher, it was determined that the content validity was secured [32].

FA knowledge

FA knowledge was assessed using the Food Allergy Knowledge Test (FAKT) developed by Hahn [33]. Four items with CVI scores

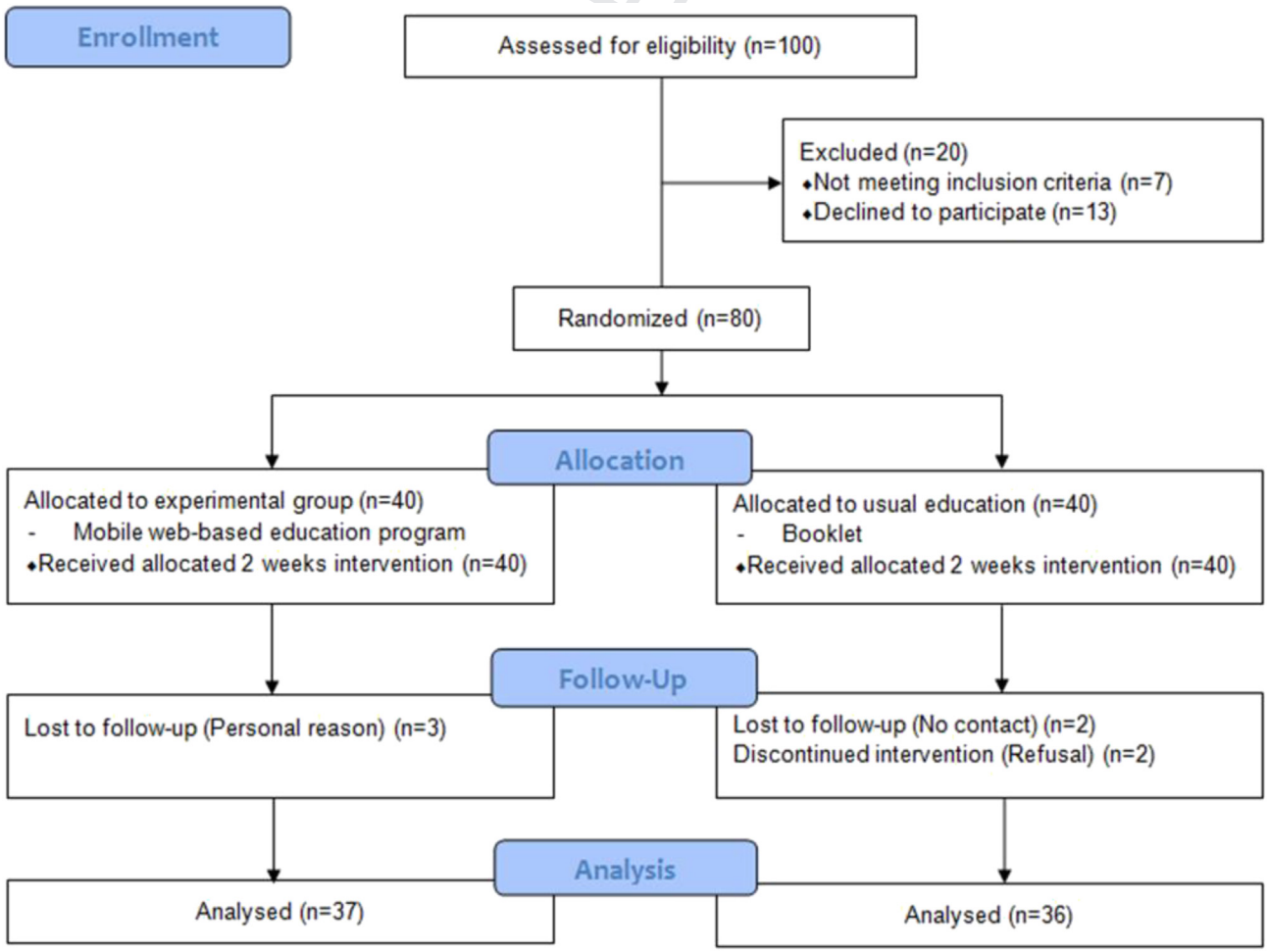

Figure 1. Participant flowchart.

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lower than .80 were eliminated in the FA knowledge scale. This tool consists of 53 questions that address the following: food avoidance (7), knowledge of FA (6), using an EpiPen (13), understanding anaphylactic shock (4), and symptoms (23). "One" point was given for a correct answer and "zero" for an incorrect or unknown answer. The maximum total score is 53 points, with a higher score indicating higher FA knowledge. A previous study reported its initial development with a Cronbach's α of .86 [33]. In this study, the Cronbach's α was .95. We obtained permission from the author to use FAKT.

Self-efficacy in FA management

Self-efficacy in FA management was assessed using the Food Allergy Self-Efficacy for Parents (FASE-P), which was developed by Knibb et al. [34]. This tool consists of 22 items: six on managing social activities, seven on precaution and prevention, three on allergy treatment, three on food allergen identification, and three on seeking information about FA. CVI values for each item ranged from .88 to 1.00. Moreover, questions were rated on a 10-Likert scale (0 = not at all to 10 = very much so). The total maximum score was 220 points, with higher scores indicating higher self-efficacy confidence. In a previous similar study, the Cronbach's α was .88 [34]. The reliability of the instrument was indicated by a Cronbach's α of .97. We obtained permission from the author to use FASE-P.

Practice behavior in FA management

Practice behavior in FA management was assessed using the Food Management and Adaptation Scale (FAMAS). This tool was developed by Klinnet et al. [35] and consists of 11 items: 10 on FA management and 1 on balanced integration. Each item had a CVI value ranging from .88 to 1.00. Questions were rated on a nine-Likert scale (one = *not at all* to nine = *very much so*). The maximum total score was 99 points, with a higher score indicating more positive practice behavior. In a previous study, Cronbach's α ranged from .91 to .98 [35]. Here, Cronbach's α was .95. Permission to use this tool was obtained from the authors.

Data collection and procedure

Measurements were performed at baseline, post-intervention, and 2 weeks post-intervention at the Atopy Education Information Center, S city. Data from the pre-test were collected from patients who visited the center, met the selection criteria, and signed an informed consent form agreeing to participate in the study. To prevent contamination, control group data were collected from October to November 2018, and experimental data were collected from November to December 2018. To protect the personal information of participants, members were granted access by the researcher as a program system administrator when registering on the site. After approval, security was maintained to prevent the exposure of personal information and content. A questionnaire was allotted by a researcher for assessment, whereas the pre- and post-tests were conducted by a researcher who was unaware of the group assignment. The researcher monitored learning history after registering to check the learning process of the experimental group.

For the control group, a small booklet titled "Food allergy and anaphylaxis management" was created and distributed. A mobile text message was sent to remind participants to read the booklet twice a week for 2 weeks. Next, a follow-up survey was conducted immediately post-intervention (booklet distribution) and 2 weeks post-intervention. A previous study showed that the 2-week intervention period of transformation into practice was related to knowledge and self-efficacy [36].

For the experimental group, the mobile web-based educational program for FA and anaphylaxis management was delivered for 2 weeks, five times per week, for approximately 45 min/day (Table 1). The experimental group could access the website and listen to the lecture any time during the 2 weeks.

Statistical analyses

All statistical analyses were performed using SPSS (version 21.0; IBM Corp., Armonk, NY, USA). The general characteristics of participants were calculated using the frequency, percentage, mean, and standard deviation. The between-group homogeneity of the dependent variables was analyzed using the Chi-square, Fisher's exact, and independent t-tests. Moreover, FA knowledge, self-efficacy, and practice behavior in the FA management of the intervention time or between groups were analyzed using repeated-measures ANOVA and independent t-test. Five incomplete data points were excluded from the analysis. Therefore, there were no missing values. The assumptions of normality and homogeneity of variance for the study variables were checked for normality (skewness, 0.89−2.22; kurtosis, 1.58−4.31), Leven's statistics for homogeneity of variance in FA knowledge (0.55, $p = .460$), self-efficacy (2.89, $p = .093$), and practice behavior (0.00, $p = .991$). Finally, the Greenhouse–Geisser value was used because the assumption of sphericity was not met (FA knowledge: W of Mauchly = 0.12, $p < .001$; self-efficacy: W = 0.02, $p < .001$; practice behavior: W = 0.07, $p < .001$).

Results

Development of a mobile web-based FA and anaphylaxis management educational program

We reviewed the KCDC guidelines to determine the recommended curriculum and educational content. To discuss educational program needs and preferences of parents, we conducted focus group discussions through semi-structured interviews with parents of school-aged children, who have previously been diagnosed with FA and have been administered an epinephrine auto-injector. Interviews were conducted with FA experts, including a dietitian, two nurses, and two allergists. In addition, the scope and content of the learning material contained on the website were evaluated in relation to FA-related information available on the Ministry of Food and Drug Safety website. Integration of the findings from this stage helped us plan the content of the educational program. The survey revealed that the desired educational content included four main topics: understanding FA, anaphylaxis, techniques for using an epinephrine auto-injector, and emergency action plans.

Two web designers and the researcher designed the webpages during the design stage. There were four headings on the main screen: FA, anaphylaxis, epinephrine auto-injector, and emergency action plan. FA-related website links were also provided to access additional information. To create a user-friendly website, a responsive web design (RWD) that gives every user a flawless online experience was implemented [29]. The menus were well-positioned on the top left corner of the site to help users identify the educational content. Icons designed to enhance the aesthetic appeal of educational content, as well as updated information and notification services, were provided in real time to enable users to regularly interact with the content.

In the development stage, the interactive mobile web educational program was developed through a storyboard that provided details of an entire website to make lessons more meaningful and interesting. The curriculum consisted of 4 sessions (themes) and 23

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Table 1 *The Contents of Mobile Web-based Food Allergy Management Education Program.*

Session/theme	Day	Program contents	Time (min)	Method
1. Food allergy general knowledge and management	1	Program instruction	5	Online lecture (PPT, audio, video)
		The comparison of food allergy, food intolerance, and food poisoning/Review/Quiz & feed back	10/2/3	Formative evaluation
		The signs and symptoms of an allergic reaction and risk factors/Review/Quiz & feed back	10/2/3	
		Q & A and discussion	10	Online participation (webinar)
	2	Food allergen according to age (preschool, elementary, high school level)/Review/Quiz & feed back	10/2/5	Online lecture (PPT, audio, video) Formative evaluation
		Know which food allergens commonly cross-react/Review/Quiz & feed back	10/2/5	
		Q & A and discussion	15	Online participation (webinar)
	3	Prevalence of food allergy according to age/Review/Quiz & feed back	5/2/3	Online lecture (PPT, audio, video) Formative evaluation
		The relationship between atopic dermatitis and food allergy/Review/Quiz & feed back	5/2/3	
		The importance of diagnosis and the principles of treatment/Review/Quiz & feed back	/2/3	
		Q & A and discussion	15	Online participation (webinar)
	4	Be aware of food avoidance, food cross-contamination, food label/Review/Quiz & feed back	6/2/3	Online lecture (PPT, audio, video) Formative evaluation
		How to prepare safe meals/Review/Quiz & feed back	6/2/3	
		Cookware and kitchenware quality management/Review/Quiz & feed back	6/2/3	
		Q & A and discussion	15	Online participation (webinar)
	5	Well-balanced diet through a nutritious alternative/Review/Quiz & feed back	10/2/3	Online lecture (PPT, audio, video) Formative evaluation
		Coordinate local community support (home, playgroup, schools)/Review/Quiz & feed back	10/2/3	
		Q & A and discussion	15	Online participation (webinar)
2. Anaphylaxis general knowledge and management	6	Understanding the mechanisms of anaphylaxis/Review/Quiz & feed back	10/2/3	Online lecture (PPT, audio, video) Formative evaluation
		Identify precipitating causes initiate relevant investigations/Review/Quiz & feed back	10/2/3	
		The critical signs and symptoms suggestive of anaphylaxis/Review/Quiz & feed back	15	
		Q & A and discussion	15	Online participation (webinar)
	7	The common and uncommon foods that trigger hypersensitivity reactions/Review/Quiz & feed back	5/2/3	Online lecture (PPT, audio, video) Formative evaluation
		Management and treatment/Review/Quiz & feed back	6/2/3	
		The importance of prescription epinephrine auto-injectors and how to use correctly /Review/Quiz & feed back	7/2/3	
		Q & A and discussion	15	Online participation (webinar)
	8	How to undertake emergency management of anaphylaxis/Review/Quiz & feed back	5/2/3	Online lecture (PPT, audio, video) Formative evaluation
		Considerations and management for eating out, social activities, daily life/Review/Quiz & feed back	5/2/3	
		Prevention and precaution at home and in schools/Review/Quiz & feed back	6/2/3	
		Q & A and discussion	15	Online participation (webinar)
3. Epinephrine auto-injector	9	How to properly use and practice epinephrine auto-injector in the event of a severe allergic reaction/Review/Quiz & feed back	17/5/3	Online lecture (PPT, audio, video) Formative evaluation
		Q & A and discussion	20	Online participation (webinar)/ demonstration
4. Anaphylaxis emergency action	10	Information on steps to take during and after an allergic emergency/Review/Quiz & feed back	17/5/3	Online lecture (PPT, audio, video) Formative evaluation
		Q & A and discussion	20	Online participation (webinar)/demonstration

topics (Table 1). The duration of each session was approximately 30 min through teaching–learning materials (PowerPoint, audio, or video), which offered the main lecture on the topic (Table 1). The review, quiz, and feedback with 1:1 coaching were provided for 5 min at the end of each topic to encourage continuity of learning. The interactive online discussion held through a webinar lasted for approximately 10–15 min. This discussion was held to enhance the ability of users to understand educational content. Before the class, the program information and schedule were shown on the bulletin board. To support autonomous learning, a question-and-answer (Q&A) session was conducted through the website and mobile text. A total of 86 storyboards were converted to a booklet PDF format that was uploaded on the website.

During the application stage, the mobile web-based educational program, termed "Food allergy & Anaphylaxis management," was implemented in the experimental group after validation by seven experts. The criteria for evaluating the educational curriculum included its comprehensiveness, alignment with the standard, consistency with objectives, relevance, efficacy, effectiveness, reliability, impact, and sustainability. The results for evaluating the website (1~4 points) were accuracy (4 points), objectivity (4 points), currency (4 points), authority (3.8 points), and coverage

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(3.6 points). All parents, who completed the mobile web-based educational program, reported on system efficacy (3.9 points), system convenience (3.8 points), design (3.8 points), reliability of information (3.8 points), and usefulness of information (3.8 points).

Effectiveness of the mobile web-based intervention

Participant characteristics and homogeneity tests

A total of 73 parents of children with FA participated in this study, with 37 parents randomized to the experimental group and 36 to the control group. As indicated in Table 2, no significant differences in characteristics were found between the two groups. The mean age of participants was 38.00 ± 0.11 years in the experimental group and 37.81 ± 1.37 years in the control group. In both groups, most participants were mothers (experimental group, 83.3%; control group, 75.0%). The children included 42 boys (57.5%) and 31 girls (42.5%) with FA. The mean age of children whose parents were assigned to the experimental group was 8.73 ± 2.19 years, whereas that of children whose parents were assigned to the control group was 8.08 ± 2.35 years. The products most frequently responsible for reactions were milk (experimental group, 54.1%; control group, 38.9%), eggs (experimental group, 21.6%; control group, 22.2%), nuts (experimental group, 10.8%; control group, 19.4%), wheat (experimental group, 10.8%; control group, 16.7%), and shellfish (experimental group, 2.8%; control group, 2.8%). In the homogeneity test, no significant differences were found in FA knowledge ($t = -0.84$, $p = .405$), self-efficacy ($t = -0.51$, $p = .610$), and practice behavior in FA management ($t = -1.41$, $p = .163$) between the two groups at baseline.

Hypothesis verification

FA knowledge: A significant difference was found in the interaction between the groups and time (time: $F = 576.73$, $p < .001$; groups: $F = 68.97$, $p < .001$, time by group: $F = 124.63$, $p < .001$) (Table 3) (Figure 2A). The mean and estimated mean are the same when rounded to the third digit after the decimal point. Therefore, the estimated mean is not indicated in Table 3. The experimental group showed significantly greater improvement in knowledge scores than by the control group both at the post-intervention ($t = 14.81$, $p < .001$) and 2-week follow-up ($t = 16.15$, $p < .001$). The mean scores for FA knowledge from baseline to post-intervention and 2-week follow-ups were 13.05, 49.73, and 49.16, respectively, in the experimental group and 15.25, 30.89, and 26.41 in the control group. The FA knowledge scores were significantly different between the post-intervention and 2-week follow-up in both the experimental ($t = 3.60$, $p = .001$) and control groups ($t = 9.24$, $p < .001$). These results support our hypothesis.

Self-efficacy in FA management: A significant difference was found in the interaction between the groups and time (time: $F = 7308.92$, $p < .001$; groups: $F = 166.74$, $p < .001$, time by group: $F = 625.21$, $p < .001$) (Table 3; Figure 2B). The experimental group showed significantly greater improvement in self-efficacy scores than the control group at both the post-intervention ($t = 18.64$, $p < .001$) and 2-week follow-up ($t = 18.38$, $p < .001$). In the experimental group, the mean scores for self-efficacy from baseline to post-intervention and 2-week follow-ups were 2.55, 8.24, and 8.21, respectively. In contrast, these scores were 2.62, 5.72, and 5.73 in the control group. The self-efficacy scores were significantly different between the post-intervention and 2-week follow-up in the experimental group ($t = 3.90$, $p < .001$), but there was no significant difference in the control group ($t = -1.22$, $p = .230$). These results support our hypothesis.

Practice behavior in FA management: A significant difference was found in the interaction between the groups and time (time: $F = 5411.80$, $p < .001$; groups: $F = 386.53$, $p < .001$, time by group: $F = 1285.84$, $p < .001$) (Table 3; Figure 2C). The experimental group showed significantly greater improvement in practice behavior scores than the control group at both the post-intervention

Table 2 *Homogeneity Test of General Characteristic between Experimental and Control Groups at Baseline (N = 73).*

Characteristics		Categories	Total (n = 73)	Exp. (n = 37)	Cont. (n = 36)	x^2 or t	*P*
			n (%)	n (%)	n (%)		
Parents	Age (M± SD)			38.00 ± 0.11	37.81 ± 1.37	0.67	.506
	Gender	Women	58 (79.5)	31 (83.8)	27 (75.0)	0.86	.353
		Men	15 (20.5)	6 (16.2)	9 (25.0)		
	Education	≤ High school	12 (16.4)	7 (18.9)	5 (13.9)	0.37	.562
		≥ college	61 (83.6)	30 (81.1)	31 (86.1)		
	Work	Two-income family	29 (39.7)	14 (37.8)	15 (41.7)	0.11	.74
		Single-income family	44 (60.3)	23 (62.2)	21 (58.3)		
	Education experience	Yes	9 (12.3)	5 (13.5)	4 (11.1		.999†
	of food allergy	No	64 (87.7)	32 (86.5)	32 (88.8)		
Child	Age (M± SD)			8.73 ± 2.19	8.08 ± 2.35	1.21	.230
	Gender	Boy	31 (42.5)	18 (48.6)	13 (36.1)	1.17	.279
		Girl	42 (57.5)	19 (51.4)	23 (63.9)		
	Allergen(s)	Egg	16 (21.9)	8 (21.6)	8 (22.2)	2.26	.687
		Peanuts	11 (15.1)	4 (10.8)	7 (19.4)		
		Wheat	10 (13.7)	4 (10.8)	6 (16.7)		
		Shellfish	2 (2.7)	1 (2.8)	1 (2.8)		
		Milk	34 (46.6)	20 (54.1)	14 (38.9)		
	Symptoms	Urticaria	50 (65.8)	26 (70.3)	24 (66.7)	4.67	.457
		Diarrhea	9 (1.3)	6 (16.2)	3 (8.3)		
		Lip swelling	11 (16.4)	4 (10.8)	7 (19.4)		
		Difficulty breathing	5 (8.3)	2 (5.4)	3 (8.4)		
	History of anaphylaxis	Yes	7 (9.6)	4 (10.8)	3 (8.3)	0.13	.719
		No	66 (90.4)	33 (89.2)	33 (91.7)		
	History of epinephrine	Yes	2 (28.3)	1 (25.0)	1 (33.3)	0.06	.809
	injection	No	5 (71.4)	3 (75.0)	2 (66.7)		
	History of emergency	Yes	7 (9.6)	4 (10.8)	3 (8.3)	0.13	.719
	department visit	No	66 (90.4)	33 (89.2)	33 (91.7)		

Note: Exp. = experimental group; Cont. = control group; M±SD = mean standard deviation.
†Fisher's exact test.

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Table 3 *Comparison of Knowledge, Self-efficacy, and Practice Behavior between Experimental and Control Group (N = 73).*

Variable	Pre-test	Post-test 1	Post-test 2	Post 1-pre	Post 2-pre	Post 2-post 1	Sources	F(*p*)
	M[a] ± SD (SE)	M[a] ± SD (SE)	M[a] ± SD (SE)	t(*p*)	t(*p*)	t(*p*)		
Knowledge								
Exp. (n = 37)	13.05 ± 11.79 (1.84)	49.73 ± 1.56 (0.88)	49.16 ± 1.70 (0.98)	19.64 (<.001)	19.48 (<.001)	3.60 (.001)	Time	576.73 (<.001)
Cont. (n = 36)	15.25 ± 10.60 (1.87)	30.89 ± 7.47 (0.89)	26.42 ± 8.28 (0.99)	16.9 (<.001)	15.08 (<.001)	9.24 (<.001)	Group	68.97 (<.001)
t(*p*)		14.81 (<.001)	16.15 (<.001)				Time × Group	124.63 (<.001)
Self-efficacy								
Exp. (n = 37)	2.55 ± 0.55 (0.10)	8.24 ± 0.51 (0.10)	8.21 ± 0.52 (0.10)	77.99 (<.001)	76.09 (<.001)	3.90 (<.001)	Time	7308.92 (<.001)
Cont. (n = 36)	2.62 ± 0.63 (0.10)	5.72 ± 0.64 (0.10)	5.73 ± 0.63 (0.10)	42.90 (<.001)	44.33 (<.001)	−1.22 (.230)	Group	166.748 (<.001)
t(*p*)		18.64 (<.001)	18.38 (<.001)				Time × Group	625.21 (<.001)
Practice behavior								
Exp. (n = 37)	2.38 ± .61 (0.09)	8.27 ± .50 (0.09)	8.27 ± .50 (0.09)	72.26 (<.001)	72.26 (<.001)	.00 (.999)	Time	5411.80 (<.001)
Cont. (n = 36)	2.56 ± .52 (0.10)	4.60 ± .61 (0.09)	4.59 ± .62 (0.09)	30.28 (<.001)	28.68. (<.001)	.92 (.373)	Group	386.53 (<.001)
t(*p*)		28.10 (<.001)	27.98 (<.001)				Time × Group	1285.84 (<.001)

Note: Exp. = experimental group; Cont. = control group; FA = food allergy; M±SD = mean standard deviation; SE = standard error.
[a] Estimated mean and mean are the same when rounded to the third digit after the decimal point.

(t = 28.10, $p < .001$) and 2-week follow-ups (t = 27.98, $p < .001$). The mean scores for practice behavior from baseline to post-intervention and 2-week follow-ups were 2.38, 8.27, and 8.27, respectively, in the experimental group and 2.56, 4.60, and 4.59 in the control group. The practice behavior scores in both the experimental group (t = 0.00, $p = .999$) and the control group (t = 0.92, $p = 0.373$) did not show significant differences between the post-intervention and 2-week follow-up. These results support our hypothesis.

Discussion

Development of a mobile web-based FA and anaphylaxis management educational program

School-aged children with FA and their parents have first-hand experience with allergic reactions and should be involved in school decisions [37]. Web-enabled devices, such as smartphones, tablets, and laptops, have evolved into essential tools for education, communication, and information [26]. The findings of this study suggest that online learning is more effective than open lectures for the self-management of FA [35]. This evaluation of online learning content showed that RWD, offering a seamless experience on any device, has been recommended because all users have access to all digital devices [29]. RWD enables the design of sites for different device types, making maintenance easier over time for learners. However, communication and human contact between learners and educators are difficult to facilitate [38]. Therefore, effective development of educational methods requires the design of online discussions that offer a tool through which learners can actively participate in a more meaningful manner than in face-to-face instructional teaching [27]. The participants acknowledged that the learning process was improved by reflecting on their knowledge and establishing learning strategies with practice through 1:1 coaching and online discussion. However, some participants were not motivated to practice. Therefore, adding coaching to promote self-reflection and facilitate encouragement may be helpful in future educational programs.

In this study, online course time was approximately 45 min as a relative learning time for promoting the development of the parental awareness program to care for children with food allergies [36]. In a previous study, learners were able to learn various educational strategies and skills through repetition and effective communication [28]. Therefore, the online learning program in this study emphasizes competency reinforcement and problem-solving ability through repetition. It provided effective online communication approaches, such as quizzes and feedback, update and notification services, and Q & A sessions. Repetition in learning, both direct and indirect, is thought to influence the ability of participants to identify the problem and practice the best solutions in their social activities.

Effectiveness of the mobile web-based intervention

Parenting knowledge, self-efficacy, and practice behavior are associated with positive parent–child interactions and healthy development of school-aged children [39]. The study showed that a mobile web-based intervention significantly improved parental knowledge, self-efficacy, and practice behavior regarding FA and anaphylaxis management compared to the control group [40]. This finding is consistent with those of other studies [28], which showed that an educational intervention positively influenced practice behavior, along with the level of parent knowledge and self-efficacy. These results indicate that mobile web-based education and online learning can improve the practice behavior of

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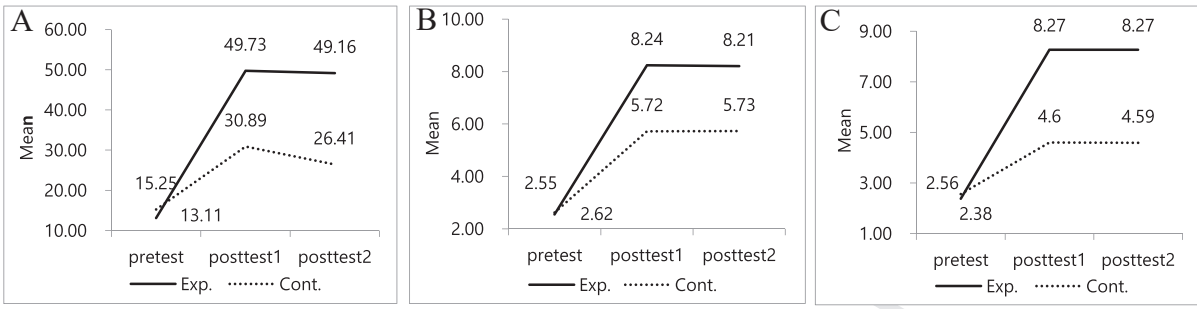

Figure 2. The effects of mobile web-based educational program on knowledge, self-efficacy, and practice behavior from baseline to follow-up. (A) The effects of mobile web-based program on knowledge. (B) The effects of mobile web-based program on self-efficacy. (C) The effects of mobile web-based program on practice behavior Q12

parents. This suggests that online learning platforms are suitable for people with limited time.

In this study, the knowledge of FA management in the experimental group was significantly higher than that in the control group after a 2-week intervention. This supports the suggestion that online education is more beneficial than traditional face-to-face education [41]. Our findings demonstrate the necessity of considering the impact of variables, such as participant characteristics and educational topics, on the effectiveness of the educational method when approaching learning design [23]. We designed the FA management and anaphylaxis management curriculum based on guidelines, which comprised an initial assessment of parental needs and preferences via focus groups, criteria established by the KCDC, and drafting via expert interviews and website surveys. The topics of the education module that were determined to be key for successful management included FA epidemiology, clinical manifestations, diagnosis and treatment, food avoidance, symptoms, epinephrine auto-injector, anaphylaxis, emergencies, labeling, and accidental exposure prevention. The module was also designed as an RWD with screens optimized for a wide variety of devices that use the internet, from mobile devices to desktops. Therefore, accessibility and utilization enabled participation in training without interruption.

There was a statistically significant increase in the self-efficacy score in FA and anaphylaxis management of the experimental group compared to that of the control group. Web-based self-management significantly increased self-efficacy in FA management education compared to face-to-face learning [36]. However, no significant difference was observed in self-efficacy between online-based FA management school nurse education and face-to-face intervention [42]. Repeated education and encouragement are required to improve self-efficacy in education [33]. Therefore, parents were instructed to participate in a 25-min online lesson with attractive teaching materials (PowerPoint, audio, and video) to motivate self-efficacy. Moreover, a 5-min review, quiz, and feedback (1:1 coaching) encouraged in-depth knowledge. The educational material could be accessed with no or limited restrictions at any time to promote greater confidence in the parents' ability to respond effectively. Most parents reported spending over 1 h connecting to the program every day via internet-connected devices during the online intervention.

Practice behavior in FA management in the experimental group showed a significant difference in scores compared to that in the control group after the mobile web-based intervention. This result, although obtained from a single-group study design, partially supports the finding of a previous study. The practice behavior of adolescents aged 13–17 years, who were diagnosed with FA and prescribed an epinephrine auto-injector, was significantly increased after the intervention compared to that before the intervention. In that study, the researchers set up the action and timeframe in which they measured practice behavior [43]. Here, we used a questionnaire to measure the willingness to change attitude and behavior with confidence in practice, rather than frequency and rate recording. As some parents of school-going children are not aware of their responsibility for childcare, a network that supports communication and feedback and promotes cooperation between the school and healthcare providers is necessary [44]. In this study, online interventions directed at parents addressed behavior change by sharing information about target problem-solving skills through online discussions, Q&A, and individual feedback. In particular, interactive online discussions (webinars) influenced user motivation to gain confidence in childcare and encouraged more time to reflect on and contribute to thoughtful interactions. However, some participants expressed that their interactive communication was insufficient. Therefore, future programs should be developed to enhance their own practices with confidence as a learning strategy.

In this study, the experimental group showed significantly improved knowledge, self-efficacy, and practice behavior in FA and anaphylaxis management compared to that by the control group, indicating the effectiveness of mobile web-based education. This could contribute to the creation of FA and anaphylaxis management in schools, healthcare facilities, and the public. Further, it could be achieved by developing more dynamic, interesting, and interactive mobile web-based learning content and establishing an online educational platform for the parents of school-aged children. In addition, the collaboration between parents, schools, and healthcare providers can facilitate better communication and foster similar expectations. Therefore, assessing the effectiveness of FA management for schools and clinical nurses is suggested.

The FA knowledge and self-efficacy of the 2-week follow-up were significantly decreased compared to the post-intervention. It is essential to help parents maintain continuity of learning that ultimately improves practice behavior at a high risk of life-threatening allergies. It is not easy to maintain the continuity of learning with time, owing to decreased memory activation. Therefore, repetitive learning is vital for the enhancement and sustenance of education effects over a long time [45]. However, previous studies did not confirm the continuity of learning related to the subject of this study. As cognitive knowledge and self-efficacy are significant factors influencing practice behavior [15], ensuring continuity of learning with available resources is imperative. Therefore, exploring the effect of educational resources and the interval of repetitive learning on sustaining the continuity of FA and anaphylaxis management education is necessary in the future.

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Limitation

This study has some limitations. First, our sample population comprised parents who had basic internet and computer knowledge, with most children already being treated by an allergist. Therefore, the participants were likely to be more knowledgeable about FA than the general population. Second, because practice behavior in FA management was identified based on the subjective reports of participants in this study, the degree of FA management should be measured and compared with objective indicators in the future.

Conclusion

The mobile web-based FA and anaphylaxis management educational program improved parental knowledge, self-efficacy, and practice behavior regarding FA and anaphylaxis management after program completion. The curriculum consisted of 4 sessions (themes) and 23 topics. During the sessions, teaching–learning materials (PowerPoint, audio, and video), interactive online discussions (webinar), quizzes, and feedback (1:1 coaching) were utilized. Update and notification services were provided after the lesson to encourage continuity of learning. In addition, a Q&A session was conducted via a website and mobile text to support autonomous learning. This program can be used to deepen the knowledge of parents and improve self-efficacy and practice behaviors regarding FA and anaphylactic management. Therefore, the results of this study provide an innovative and important contribution to learner-centered education, which can be achieved by extending nursing care. To demonstrate the effectiveness of the mobile web-based educational program for several participants in various settings, long-term follow-up studies in different clinical settings are recommended.

Conflict of interest

The authors declare no conflict of interest

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