Effects of Mobile Application on Self-Efficacy, Eating Behavior, and Physical Activity in Metabolic Syndrome Patients

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Abstract. Metabolic syndrome is typically managed by treating each component of cardio-metabolic risk factors separately. Mobile applications have the critical role in health services, such as for metabolic syndrome patients' improvement in self-management behaviour. This study intended to determine the effect of exercise and diet application on the self-efficacy, eating behaviour, and physical activity of metabolic syndrome patients. This study employed a quasi-experimental pretest and post-test control group design with a total sample of 72 participants divided into two groups: booklet and mobile application. Self-efficacy, eating behaviour, and physical activity were measured before and after the intervention was administered to both groups. The results showed that the experimental group, which used educational videos and mobile applications, achieved significant results on the variables of self-efficacy regarding nutritional behaviour ($p < 0.001$), exercise self-efficacy ($p = 0.029$), and physical activity ($p < 0.001$), according to the results of the Wilcoxon test. Meanwhile, there was no significant change in the variable of eating behaviour ($p = 0.248$). The results of the Mann-Whitney test reveal a significant difference ($p < 0.001$) for the variables of self-efficacy for nutritional behaviour, exercise self-efficacy, and physical activity. In contrast, there were no significant differences between the groups in terms of eating behaviour ($p = 0.542$). The mobile application of diet and physical activity affects the self-efficacy and physical activity of patients with metabolic syndrome.

Keywords: Eating Behaviour, Metabolic Syndrome, Mobile Application, Physical Activity, Self-Efficacy

1 Introduction

Metabolic syndrome (MetS) is characterized by a combination of cardio-metabolic risk factors, including hypertension, abdominal and visceral obesity, elevated triglyceride levels, insulin resistance or impaired glucose tolerance, and low High-Density Lipoprotein Cholesterol (HDL-C) levels. According to the International Diabetes

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Federation (IDF) criteria 2006, a person with metabolic syndrome is defined as central obesity with two factors: hypertension, increased blood sugar, low HDL-C levels, and increased triglyceride levels [1]. Studies have shown that metabolic syndrome increases the risk of cardiovascular disease by twofold and type 2 diabetes mellitus by fivefold. Globally, it is estimated that around 25% of the population has metabolic syndrome, with a higher prevalence in older age groups. In Asian countries such as Indonesia (21.6%), China (24.2%), Korea (31.3%), Taiwan (32.8%), and India (33.5%), relatively high prevalence rates of metabolic syndrome have been recorded [2].

Metabolic syndrome is linked to obesity and a sedentary lifestyle. The primary approach to preventing and managing metabolic syndrome is a healthy lifestyle, which includes regular physical activity and a balanced diet [3]. Lifestyle modifications can effectively reduce metabolic risk factors both clinically and economically. According to the prevalence of metabolic syndrome can be reduced twofold by combining dietary intervention and routine physical activity, compared to metformin and placebo pharmacotherapy groups [4]. A diet emphasising a combination of macronutrients, particularly a low-carbohydrate diet and increased fibre, vegetables, fruit, and reduced fat, can reduce metabolic risk factors [5]. Physical activity is an important factor in self-management of metabolic syndrome. Engaging in regular physical activity may lower the risk of metabolic syndrome by up to four times. In addition, maintaining approximately 150 minutes of exercise per week may help reduce the severity of the condition [6].

Metabolic syndrome is typically managed by treating each component of cardio-metabolic risk factors separately by recommending lifestyle changes and pharmacological and surgical approaches, such as bariatric surgery, if required [7]. Personalised and group-based intervention programs tend to be difficult to address the large demand of the metabolic syndrome population. The program includes multi-session education, direct supervision, and door-to-door intervention. These programs are difficult to implement because they require a lot of committed resources [8]. E-health technology can enhance intervention quality, which refers to using information and communication technology to improve health care [9].

An intervention that nurses can use to help manage the behaviour of metabolic syndrome patients is using e-health technology such as mobile applications. Mobile applications play an important role in many aspects of human life, including health services [8]. Mobile applications can assist in diagnosis and prevention and provide advice related to health problems. Mobile applications can positively affect patient health and the relationship between health workers and patients [9].

Mobile applications have the potential to modify self-management behaviour in patients with metabolic syndrome. Self-management in health care makes it easier for users to manage their health data independently to prevent chronic diseases [10]. Self-efficacy is a crucial cognitive factor in changing health behaviour. Apps designed to manage metabolic syndrome can enhance healthy lifestyle behaviours, including reducing weight and body mass index, increasing physical activity, and improving self-efficacy for exercise [9]. In this study, diet and exercise app is used for self-management of metabolic syndrome patients. Accordingly, this study sought to

examine how exercise and dietary interventions influence self-efficacy, eating behaviour, and physical activity among patients with metabolic syndrome.

2 Methods

This quasi-experimental study employs a control group and a pre-and post-test design. The study employed simple random assignment to allocate participants to each group. Two out of the 13 hamlets in Merjosari Urban Village were selected. The study was conducted from August 2023 to October 2023. The required sample size was calculated using the Lemeshow formula, with an additional 10% allowance for potential loss to follow-up and participant dropout. Based on this calculation, 72 participants were included in the required sample. The research protocol was approved by the Health Study Ethics Committee, Faculty of Health Sciences, Brawijaya University (No. 5458/UN10.F17.10.4/TU/2023) and was conducted in accordance with the principles outlined in the Declaration of Helsinki.

In each selected hamlet, patients with metabolic syndrome who met the inclusion criteria received the same intervention to reduce confounding factors. The study's inclusion criteria were as follows: 1) participants had to be aged 18 years or older; 2) had an Android-based smartphone; 3) participants enrolled in the Chronic Disease Management Program; and 4) had metabolic syndrome, as indicated by the presence of three markers: a fasting blood glucose level of ≥ 5.6 mmol/L (≥ 100 mg/dL), central obesity defined as a waist circumference exceeding 80 cm in women and 90 cm in men, and blood pressure of ≥ 130 mmHg systolic or ≥ 85 mmHg diastolic (12). The criteria for exclusion from the study are: 1) contraindications to physical activity or walking; 2) health problems such as cognitive, visual, or mental disorders that interfere with the use of a smartphone; and 3) unwillingness to sign the informed consent form.

The study involved providing health education to two groups. The control group received booklets, while the experimental group received videos and the FITA application. The product validation test results for booklets and health education videos are valid, with an average score of 86.15% and 89.1%, respectively [11]. The FITA Application product validation test results indicate that this application has received a Grade A (Excellent) rating, with an average score of 91.75% [12]. Results were measured after four weeks. Self-efficacy regarding nutritional behavior was calculated using the Self-Efficacy Questionnaire Regarding Nutritional Behavior. The instrument's stability was measured by retesting at two-week intervals ($p < 0.001$, Interclass Coefficient = 0.924) [13]. Self-efficacy for exercise was calculated using the Self-efficacy for Exercise Scale (SEE-C). The Self-Efficacy for Exercise Scale (SEE-C) showed satisfactory construct validity and internal consistency, with a Cronbach's alpha value of 0.75 [9]. Eating behaviour was assessed using the Dutch Eating Behavior Questionnaire (DEBQ). The instrument demonstrated adequate reliability across all items, with Cronbach's alpha values of ≥ 0.70, while the Spearman correlation coefficients were also acceptable (rho > 0.30; $p < 0.05$) [14]. Physical activity was evaluated using the Global Physical Activity Questionnaire (GPAQ). Changes in self-

efficacy, eating behaviour, and physical activity between the control and experimental groups were examined using the Wilcoxon test. Differences in baseline characteristics between the two groups were assessed using the Mann-Whitney and Chi-Square tests. The study flow is illustrated in Fig. 1.

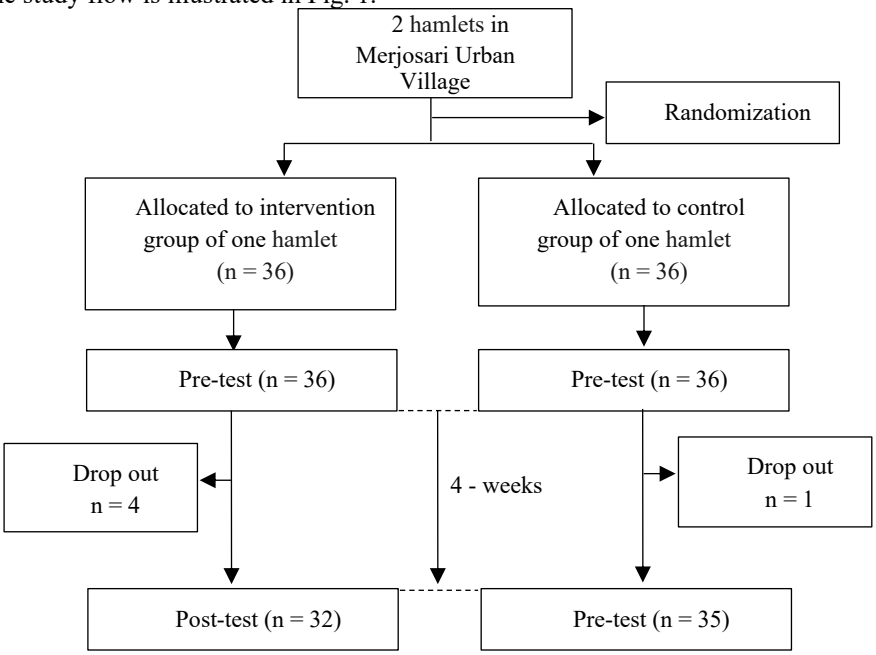


Fig. 1. Flow Chart of Recruitment, Randomization, and Participation of Metabolic Syndrome in Each Group

3 Results

A baseline survey was administered to participants in both the control and experimental groups. The control group received a book on metabolic syndrome and completed four post-surveys, while the experimental group received an educational video about metabolic syndrome and a mobile app-based self-management intervention and completed five post-surveys. The intervention lasted for four weeks, and follow-up was conducted by health cadres using the Whatsapp group. The questionnaire comprises general characteristics, exercise self-efficacy, nutritional behaviour self-efficacy, eating behaviour, physical activity, application function, and usability. Physiological indicators for metabolic syndrome patients, including blood pressure, waist circumference, and blood sugar measurements, were collected by an enumerator.

Table 1. Participant Characteristics

Participant Characteristics	Control Group n = 35		Experimental group n = 32		*p*
	n	%	n	%	
Age					< 0.001
Early Adulthood (26-35 years)	1	2.9	5	15.6	
Late Adulthood (36-45 years)	3	8.6	15	46.9	
Early Elderly (46-55 years)	6	17.1	8	25.0	
Late Elderly (56-65 years)	10	28.6	4	12.	
Seniors (> 65 years old)	15	42.9	0	0	
Sex					0.619
Man	3	8.6	3	9.4	
Woman	32	91.4	29	90.6	
Education					< 0.001
Elementary School	24	68.6	3	9.4	
Junior High School	8	22.9	6	18.8	
Senior High School	3	8.6	16	50.0	
College	0	0	7	21.9	
Marital status					0.015
Marry	26	74.3	26	81.3	
Single	0	0	4	12.5	
Widow	9	25.7	2	6.3	
Work					0.186
Homemaker	24	68.6	14	43.8	
Self-employed	8	22.9	12	37.5	
Private	3	8.6	5	15.6	
Civil servants	0	0	1	3.1	
Residence status					0.253
Living alone	5	14.3	2	6.3	
Living with family	30	85.7	30	93.8	
Pretest					
Central obesity					0.909
Men central obesity (> 90 cm)	3	8.6	3	9.4	
Women central obesity (> 80 cm)	32	91.4	29	90.6	
Blood pressure					0.228
Pre hypertension (SBP: 120-139 mmHg or DBP: 80-89 mmHg)	13	37.1	14	43.8	
Grade 1 hypertension (SBP: 140-159 mmHg or DBP: 90-99 mmHg)	10	28.6	13	40.6	
Grade 2 hypertension (SBP: ≥ 160 mmHg or DBP: ≥ 100 mmHg)	12	34.3	5	15.6	
Fasting blood sugar					0.273
Pre diabetes (100-125 mg/dL)	27	77.1	28	87.5	
Diabetes (≥ 126 mg/dL)	8	22.9	4	12.5	
Post-test					
Central obesity					0.909
Central obesity in men (> 90 cm)	3	8.6	3	9.4	
Central obesity in women (> 80 cm)	32	91.4	29	90.6	
Blood pressure					< 0.001
Normal (SBP: < 120 mmHg and DBP: < 80 mmHg)	0	0	6	18.8	
Pre hypertension	14	40	18	56.3	

Participant Characteristics	Control Group n = 35		Experimental group n = 32		*p*
	n	%	n	%	
(SBP: 120-139 mmHg or DBP: 80-89 mmHg)					
Grade 1 hypertension	14	40	6	18.8	
(SBP: 140-159 mmHg or DBP: 90-99 mmHg)					
Grade 2 hypertension					
(SBP: ≥ 160 mmHg or DBP: ≥ 100 mmHg)	7	20	2	6.3	
Fasting blood sugar					0.007
Normal (79-99 mg/dL)	0	0	5	15.6	
Pre diabetes (100-125 mg/dL)	30	85.7	26	81.3	
Diabetes (≥ 126 mg/dL)	5	14.3	1	3.1	

Note: n, sample size; SBP, Systolic Blood Pressure; DBP, Diastolic Blood Pressure

The participants' characteristics are summarized in Table 1. Of the 72 participants initially enrolled, 67 completed the study, as four participants withdrew from the experimental group and one from the control group. The majority of participants in both groups were female, married, homemakers, and living with families. No differences were observed at baseline, except for age, education, marital status, blood pressure, and blood sugar at post-test (95% CI). Correlation tests were carried out to ensure the strength of the relationship between each significant demographic factor and the variable of interest. The test results showed a weak correlation, so it did not interfere with the research findings (correlation range from -0,353 to 0,361).

Table 2. Self-Efficacy Regarding Nutritional Behavior in Metabolic Syndrome Patients

Self-Efficacy Regarding Nutritional Behavior	Control Group				Experimental group			
	Pretest		Posttest		Pretest		Posttest	
	f(x)	%	f(x)	%	f(x)	%	f(x)	%
Low Self-efficacy	14	40%	19	54.3%	23	71.9%	6	18.8%
High Self-efficacy	21	60%	16	45.7%	9	28.1%	26	81.3%
Total	35	100%	35	100%	32	100%	32	100%
Wilcoxon test	p = 0.166				p = < 0.001			
Mann Whitney test	p = < 0.001							

Table 2 describes the self-efficacy regarding nutrition behaviour before and after health education was given to metabolic syndrome patients. Self-efficacy in the control group is not different ($p = 0.166$, 95% CI). On the contrary, the experimental group faces differences pre-post self-efficacy ($p < 0.001$, 95% CI). Significant differences in self-efficacy regarding nutrition behaviour exist between application and booklet groups ($p < 0.001$, 95% CI).

Table 3. Self-Efficacy for Exercise in Metabolic Syndrome Patients

Self-Efficacy for Exercise	Control Group		Experimental group	
	Pretest	**Posttest**	**Pretest**	**Posttest**

	f(x)	%	f(x)	%	f(x)	%	f(x)	%
Low Self-efficacy	15	42.9%	19	54.3%	16	50%	7	21.9%
High Self-efficacy	20	57.1%	16	45.7%	16	50%	25	78.1%
Total	35	100%	35	100%	32	100%	32	100%
Wilcoxon test		p = 0.317				p = 0.029		
Mann Whitney test				p = < 0.001				

Table 3 describes the self-efficacy for exercise before and after health education was given to metabolic syndrome patients. No significant change in self-efficacy was observed within the control group (p = 0.317, 95% CI). In contrast, the application group demonstrated a significant pre-post improvement in self-efficacy (p = 0.029, 95% CI). A significant difference in exercise self-efficacy was also found between participants receiving the application and those using the booklet (p < 0.001, 95% CI). These findings indicate that the application was more effective than the booklet in improving self-efficacy related to nutrition and exercise behaviour.

Table 4. Eating Behavior in Metabolic Syndrome Patients

Eating Behavior	**Control Group**				**Experimental group**			
	Pretest		**Posttest**		**Pretest**		**Posttest**	
	f(x)	**%**	**f(x)**	**%**	**f(x)**	**%**	**f(x)**	**%**
Unhealthy eating behavior	19	54.3%	19	54.3%	15	46.9%	11	34.4%
Healthy eating behavior	16	45.7%	16	45.7%	17	53.1%	21	65.6%
Total	35	100%	35	100%	32	100%	32	100%
Wilcoxon test		p = 1.000				p = 0.248		
Mann Whitney test				p = 0.542				

Table 4 presents the eating behaviour of patients with metabolic syndrome before and after the health education intervention. No significant change in eating behaviour was observed in the control group (p = 1.000, 95% CI) or the experimental group (p = 0.248, 95% CI). Furthermore, the comparison between the booklet and application groups revealed no significant difference in eating behaviour (p = 0.542, 95% CI). These findings suggest that health education had little impact on changing the eating behaviour of patients with metabolic syndrome.

Table 5. Physical Activity in Metabolic Syndrome Patients

Physical activity	**Control Group**				**Experimental group**			
	Pretest		**Posttest**		**Pretest**		**Posttest**	
	f(x)	**%**	**f(x)**	**%**	**f(x)**	**%**	**f(x)**	**%**
Light physical activity	7	20%	12	34.3%	8	25%	0	0%
Moderate physical activity	28	80%	15	42.9%	24	75%	10	31.3%
Vigorous physical activity	0	0%	8	22.9%	0	0%	22	68.8%
Total	35	100%	35	100%	32	100%	32	100%

Wilcoxon test	p = 0.124	p = < 0.001
Mann Whitney test	p = < 0.001	

Table 5 describes the physical activity of metabolic syndrome patients before and after receiving health education. Booklets have no impact on increasing physical activity scores ($p = 0.124$, 95% CI), while the mobile application has an impact on increasing physical activity scores in metabolic syndrome patients ($p < 0.001$, 95% CI). A significant difference in physical activity was observed between the application and booklet groups ($p < 0.001$, 95% CI). The findings indicate that the application produced a greater improvement in physical activity among patients with metabolic syndrome than the booklet.

Table 6. SUS Score Results on the FITA Application

Grade	***SUS Score***	**F(x)**	**%**
A (Excellent)	≥ 80.3	9	28.1%
B (Good)	≥ 74 and < 80.3	19	59.4%
C (*Ok*)	≥ 68 and < 74	4	12.5%
Total		32	100%
Mean SUS Score		78.44	

The System Usability Scale (SUS) measures user satisfaction or acceptance of an application. The FITA Application received an average SUS Score of 78.44, corresponding to a Grade B (Good) on the Likert scale. When evaluated for specific usability aspects, the FITA application demonstrated good usability values in terms of learnability, efficiency, memorability, errors, and satisfaction. Table 6 presents the overall SUS Score results for the FITA Application.

4 Discussion

The use of printed educational materials, including leaflets, was not associated with an improvement in self-efficacy related to nutritional behaviour. In contrast, mobile applications have been shown to enhance healthy eating self-efficacy among patients with metabolic syndrome [15]. Wong et al. (2022) also found that participants who received health education through a mobile application experienced greater improvements in exercise self-efficacy scores than those in the control and booklet groups. Thus, delivering information on metabolic syndrome and its management through a mobile application may help strengthen patients' self-efficacy in managing their condition [16].

The theory of planned behaviour suggests that beliefs about factors that can facilitate or hinder behavioural performance can influence self-efficacy. The low self-efficacy of metabolic syndrome patients can be affected by the low intensity of intervention, lack of significant changes in the home environment to change behaviour, and low individual intention/involvement to make behaviour changes [17]. In the booklet group

of this study, most targets did not ask many questions regarding the learning material. If the target individual does not ask many questions, health workers tend not to repeat the information provided, assuming the client already understands it. Providing learning feedback is necessary to help target individuals understand the effort required to achieve their goals [18].

Metabolic syndrome patients can lead a healthy lifestyle if they have confidence that proper self-management can control their health condition and remain stable, obtain benefits, and minimise costs. Metabolic syndrome patients have the confidence to carry out appropriate diet and physical activity management because they have high self-efficacy [10]. Individuals who have high self-efficacy will be able to overcome the difficulties they experience to adopt a healthy lifestyle. Meanwhile, individuals with low self-efficacy tend to give up quickly if they cannot adapt, have no hope, and experience failure [18].

Mobile applications may contribute to improving self-efficacy among patients with metabolic syndrome. Self-efficacy related to health plays an important role in encouraging behavioural change and supporting the adoption of a healthy lifestyle. In patients with metabolic syndrome, higher self-efficacy has been associated with healthier behaviours, particularly in dietary management and engagement in physical activity. Therefore, strengthening self-efficacy is important to encourage application users to actively participate in efforts to maintain a healthy lifestyle [10]. Patients with metabolic syndrome can use various application features to achieve their goals. Mobile applications can help individuals monitor their progress in implementing healthy eating patterns and exercising regularly, based on the guidance provided in the application, thereby increasing their self-efficacy. Self-efficacy sources can also come from individuals with similar conditions who have successfully implemented healthy behaviours [19].

Palacios et al. (2018) found no difference in dietary behaviour between the group given the application and the diet recommendation sheet. Print media has several weaknesses, including a limited scope of information, lack of durability, and the risk of being lost quickly [20]. According to the theory of planned behaviour, three factors influence an individual's behaviour: normative, control, and behavioural beliefs [17]. However, mobile applications have not been successful in changing users' nutritional attitudes, as individual attitudes are the primary predictor of daily behaviour [20].

Patients with metabolic syndrome need to consider both the negative and positive impacts of their attitudes to determine their actual behaviour. Insufficient knowledge may lead individuals to be unaware of vulnerable health conditions. Therefore, it is crucial to possess adequate knowledge to increase awareness [21]. Metabolic syndrome patients need knowledge of lifestyle management, such as a healthy diet to change behaviour. The recommended diet is a low carbohydrate, low fat, and high intake of fruit, vegetables, and fibre [20].

Mobile applications may not be effective in changing eating behaviour over a long period due to potential boredom for users. Users must use the app regularly to obtain changes in eating behaviour. Additionally, internet connectivity and manual data entry can pose obstacles for metabolic syndrome patients attempting to change their eating habits. Therefore, the development of mobile applications should involve relevant

stakeholders, information technology professionals, and health workers to ensure that the resulting technology meets the needs of its intended users [22].

Earlier research has shown a significant improvement in physical activity scores among participants who used the application. Wong et al. (2021) also reported a significant difference in physical activity between participants who received the application and those who received the booklet. Adults with insufficient physical activity have been reported to have nearly twice the risk of developing metabolic syndrome compared with those who perform moderate-intensity physical activity for at least 150 minutes per week [23]. Several factors may affect physical activity levels, including behaviour modification, self-efficacy, employment status, age, and sex. Changing physical activity requires support from the environment, health workers, and family, as well as health education [24]

The use of mobile applications has been shown to increase the activity of metabolic syndrome patients and can also be helpful for monitoring, recording, and analysing health data [8]. Age is a factor that affects technology use, with older individuals opting for traditional health education methods such as lectures, leaflets, or booklets to achieve their health behaviour goals. The data shows that younger users engaged in physical activity more frequently than older participants, as demonstrated by a greater increase in physical activity scores among younger users of the application [25]. Users generally prefer applications that are free, easy to use, and can train and motivate them. The interaction between different features of mobile applications is crucial for technology-based health interventions [25].

This study offers several strengths. It examined the role of a mobile application in supporting exercise and dietary interventions among patients with metabolic syndrome living in urban areas of Indonesia. The findings also indicated that the FITA application demonstrated moderate user acceptability and was considered feasible for use. FITA application can be applied to improve health status, diet interventions, and physical activity independently. We found that the FITA application is efficacious in improving self-efficacy. Intensive use of the FITA application can increase health behavior related to physical activity. Community nurses in Dinoyo Community Health Center can use FITA application as a health promotion tool for managing metabolic syndrome.

Several limitations should be considered when interpreting the findings of this study. First, the relatively short intervention period and limited sample size may restrict the generalisability of the results. The lack of public interest in participating due to the inability to use mobile applications and busy work. Several participants dropped out after follow-up for one month. The extension of study duration affected insufficient sample requirements for this study. Second, the participants were only recruited from urban areas in Merjosari Urban Village, Malang, Indonesia. Third, users of other mobile operating systems, such as Windows, iOS, and BlackBerry, cannot use the Android-based FITA application.

5 Conclusion

The findings indicate that mobile applications can improve self-efficacy and physical activity among patients with metabolic syndrome. These results support the potential use of mobile applications as an approach to facilitate healthy lifestyle management in this population. Further research is needed to assess the long-term effects of mobile application-based interventions.

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