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Effects of Walking Promotion Using Smart Mobile Activity Meter on Changes in Metabolic Health

RESEARCH

SU KYOUNG LEE
MYUNG-GWAN KIM
YUMI OH
DONGJIN KIM
MINSU KIM
SUNYOUNG YANG
HYUN WOOK HAN

*Author affiliations can be found in the back matter of this article

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CORRESPONDING AUTHORS:

Hyun Wook Han

Department of Biomedical Informatics, Graduate School of Medicine, CHA University, Seongnam 13488, South Korea; Institute for Biomedical Informatics, Graduate School of Medicine, CHA University, Seongnam 13488, South Korea

stepano7@gmail.com

SunYoung Yang

Digital Healthcare Team, Healthcare Innovation Center, Korea Health Promotion Institute, Seoul, South Korea; Department of Health Convergence, Ewha Womans University, Seoul, South Korea

syyang@khepi.or.kr

ABSTRACT

Background: Regular physical exercise can increase insulin sensitivity, improve good cholesterol levels, reduce body weight, and ameliorate cardiovascular risk factors. Over the past decade, e-health technologies using mobile applications were proven to be an effective delivery method for educational interventions. No e-health tools were designated specifically for patients with metabolic syndrome.

Methods: Final analysis subjects were 7,234 as a result of excluding cases with missing values according to the variables used. We mediated the subjects to walk in advance, 3 months, and 6 months through smart mobile health care, and the level of improvement in the metabolic syndrome index was repeatedly measured. RM ANOVA & Path analysis & Sobel test was conducted to determine whether there was a mediating effect.

Results: Subjects who practiced walking for up to 3 months tended to use smart mobile health care devices better for 6 months, and the walking practice rate increased. This confirmed that there was a significant partial mediating effect as a result of the Sobel test. after 6 months, WC and TG decrease.

Conclusion: It was found that the more programs that provide advice and interventions on physical activity through smart mobile healthcare devices were used, the more helpful it was to promote walking exercise practice.

KEYWORDS:
Metabolic Syndrome Index; Mobile Healthcare; Walk; Meditation Effect; Public Health Program

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BACKGROUND

Patients with metabolic syndrome (MetS) are more likely to develop diabetes, pre-diabetes, cardiovascular disease, and stroke if left untreated (Wong et al., 2021). If obese, these patients do little physical exercise or have poor blood sugar control, further increasing the risk of cardiovascular disease and stroke (Wong et al., 2020). It is very important to make lifestyle modifications such as staying physically active and performing regular exercise (*The benefits of physical activity*, 2022). Regular physical exercise can increase insulin sensitivity, improve good cholesterol levels (HDL), and reduce blood pressure, weight, and cardiovascular risk factors (*The benefits of physical activity*, 2022; Pettman et al., 2008; Vetter et al., 2011).

Previous studies have reported a variety of lifestyle interventions, including educational programs including educational sessions and counseling, on-the-job training interventions, and athletic supervision on MetS management (Chang et al., 2016; Kim et al., 2011; Nanri et al., 2012; Oh et al., 2015). However, most previous studies are only transferable to a limited number of patients as high labor resources are required (Zhang et al., 2016).

Mobile health (mHealth) technology using apps and wearable devices is becoming increasingly popular as it allows patients to monitor their health status (Kim et al., 2022). Previous studies have reported the great potential of the Internet and mobile phone-based mHealth educational interventions to support patients with chronic conditions and promote disease self-management (Petrella et al., 2014; Wong et al., 2018). Over the past decade, e-health technologies using mobile applications (apps) have proven to be an effective delivery method for educational interventions (Jahangiry et al., 2017; Khaylis et al., 2010; Liebreich et al., 2009; *Scaling for Impact: Second Innovation Forum in the WHO Western Pacific Region, Manila, Philippines (hybrid meeting)*, 2022).

Recent evidence suggests that smartphone apps can increase physical activity over a short period of time (up to 3 months) (Wong et al., 2021). Facilitation of physical activity (PA) in adults has shown evidence for an effect of mHealth on increasing PA (Milne-Ives et al., 2020). Most health-related behaviors, such as a balanced diet and regular exercise, can lead to significant improvements if sustained through motivation (Lee et al., 2020; Sequi-Dominguez et al., 2020). However, most e-health tools are web-based platforms or apps designed for the general public, not specifically for MetS patients (Wong et al., 2021). Furthermore, little change in behavior may occur due to a lack of continuous self-monitoring or individualized feedback on outcomes (Spring et al., 2013). There is a need to design, tailor and evaluate highly interactive mobile apps that further increase physical activity in patients with specific health problems such as MetS.

It is necessary to prove how efficiently the factors related to metabolic syndrome were improved by remotely identifying the health behaviors of subjects and intervening through a health management program using a smart mobile phone. Additionally, more empirical studies are needed to investigate the mediating effect of mobile application use on increased physical activity, as most available studies only examine the effects of eHealth interventions/programs and general care (Azar et al., 2016; Jahangiry et al., 2017; Petrella et al., 2014).

Therefore, this empirical study was conducted, and the purpose of this study is to verify how much physical activity intervention through a smart mobile healthcare app increases physical activity and improves health status of patients with metabolic syndrome and make suggestions for the development of the smart mobile healthcare field.

METHODS

STUDY DESIGN

This was a multicenter retrospective and single-arm study with a pretest-posttest design. Data from the Korean National Mobile Healthcare Program in 2018. Model of study design is following the Figure 1.

All participants who completed the 24-week program in 2018 were included in the study. The primary outcome was the proportion of participants with one or more improved risk factors, which translates into the overall impact of the program. The secondary outcome was the improvement rate and change in the mean value of each risk factor.

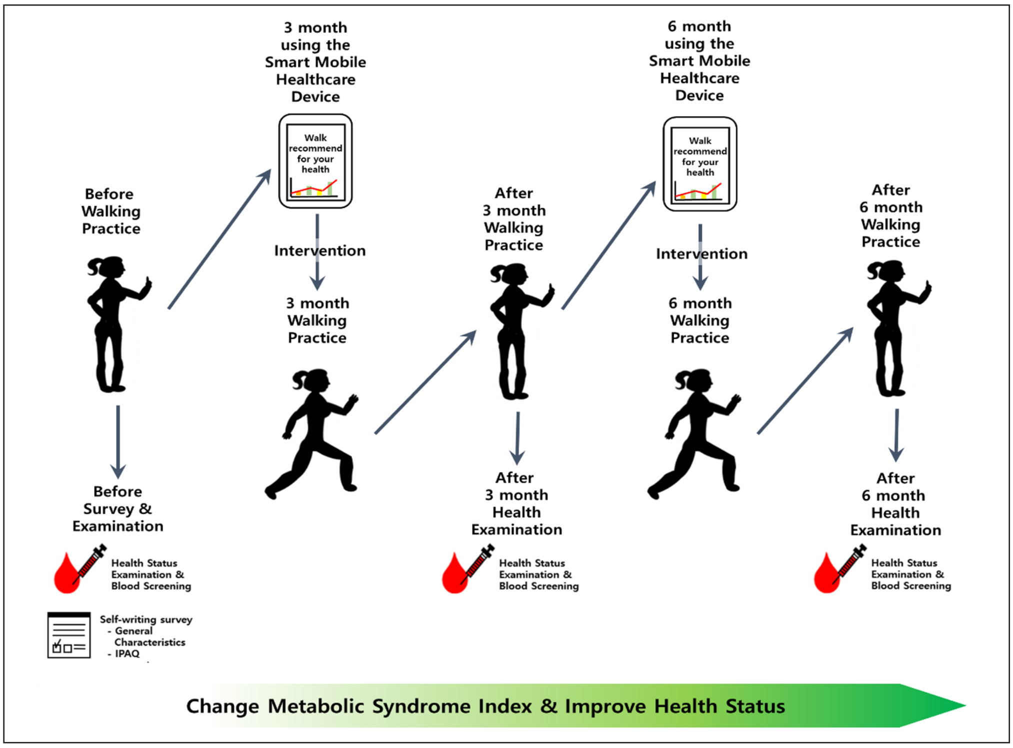

Figure 1 Model of Study Design for Smart Mobile Healthcare & Walking Practice.

KOREAN NATIONAL MOBILE HEALTHCARE PROGRAM

This program was a public health initiative operated by the Health Promotion and Development Institute targeting chronic disease prevention. It was developed by a committee composed of medical as well as information and communication technology experts through referring various references (Hofer et al., 2015; Huzooree et al., 2019; Juen et al., 2015; Thanuja & Balakrishnan, 2013). The main characteristic of the program was the addition of mobile healthcare to the existing face-to-face consultation program. It consisted of three visits to Public Health Centers (on registration day, after 3 month and after 6 month) and mobile healthcare in daily life for 6 months week.

When visiting a Public Health Centers, participants received a health examination, completed a questionnaire, and underwent face-to-face consultations. The examination consists of (1) anthropometric measurements of height, weight, waist circumference (WC) and body mass index (BMI); (2) BP measurement; and (3) blood tests for FBG, TG, and HDL-C by point-of-care or laboratory testing. The questionnaire consisted of basic demographics and health behaviors such as smoking, consuming alcohol, physical activity and exercise, and nutrition. The consultation was conducted by nurses, nutritionists, and exercise specialists for each topic. Through the consultation, (1) nurses aimed to help participants quit smoking and consuming alcohol and improve metabolic syndrome risk factors; (2) nutritionists aimed to help participants eat according to their energy standards based on gender and age, and, if obese, lose 5–10% of their body weight within 6 months; and (3) exercise specialists aimed to help participants exercise for at least 2.5 to 3 hours per week. Although consultations have such basic goals in common, they are tailored to the participant at the discretion of the expert.

On the day of registration, participants are provided with a mobile app. and an activity tracker, and are instructed to participate in the program, including using the mobile service. In the mobile app, meal, exercise, step count, weight, BP, blood sugar, and body composition can be recorded; step count is recorded automatically from the activity tracker while accessing the app.

The 2018 programs recruited participants at PHCs from April 2018 to December 2018. The eligibility criteria for participants were as follows: (1) 18 years or older, (2) smartphone user, and (3) having at least one of the following metabolic syndrome risk factors according to Adult Treatment Panel III criteria (*Dietary Reference Intakes for Koreans. 8th ed*, 2015) and definition of central obesity tailored to Koreans (*The Physical Activity Guide for Koreans* 2013): (i) systolic BP (SBP) ≥ 130 mmHg or diastolic BP (DBP) ≥ 85 mmHg; (ii) FBG ≥ 100 mg/dL; (iii) TG ≥ 150 mg/dL;

(iv) HDL- C < 40 mg/dL in men or < 50 mg/dL in women; and (v) WC ≥ 90 cm in men or ≥ 85 cm in women. Those who had been diagnosed with hypertension, diabetes, or hyperlipidemia, or had been taking drugs for these conditions were excluded.

DATASET CLEANING & FINAL ANALYSIS SUBJECTS

In the dataset with a total of 8,713 cases, the final analysis subjects were 7,234 as a result of excluding cases with missing values according to the variables used.

AIM OF THE STUDY

Among the datasets of the Korean National mobile healthcare program, this study focused on changes in metabolic syndrome index according to walking practice. And grasp the mediate effect of smart mobile healthcare devices.

STATISTICAL ANALYSIS

Statistical significance was set at two tailed $p < .05$. Statistical analyses were performed using R version 4.2.1 (David P. Swan, 2012). A chi-square test was used to determine the general characteristics of walking practice. And by the same analysis method, it was checked whether metabolic syndrome-related variables changed 3 months before and 6 months after intervention depending on whether smart mobile healthcare was involved. Corresponding sample t-test and repeated measures ANOVA were conducted on the changes in metabolic syndrome index according to walking practice and time, and how many mobile devices were used to mediate physical activity. Path analysis was performed through the 'lavaan' package ("Executive Summary of The Third Report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, And Treatment of High Blood Cholesterol In Adults (Adult Treatment Panel III)," 2001) in R to determine how much walking practice increased depending on how much smart mobile health care app was used and how much the metabolic syndrome index decreased. In addition, the Sobel test (D'Agostino et al., 2008) was conducted to determine whether there was a mediating effect.

RESULTS

GENERAL CHARACTERISTICS OF THE WALK PRACTICE

The total number of subjects was 7,234. Among them, 2,422 people (33.5%) practiced walking before the program, 3,565 people (49.3%) who practiced walking after 3 months of the program, and 3,657 people who practiced walking after 6 months of the program (Table 1).

According to gender, 35.0% of the 2,422 walking practitioners and 32.4% of women were different before the program started ($p < .05$). And 3 months after the program, the number of walking practitioners increased to 3,565 people (49.3%), and the walking practice rate according to gender was equal to 49.6% for men and 49.1% for women($p > .05$). 6 months after the program, the number of walking practitioners increased to 3,657 (50.6%), and it was that 51.7% of men and 49.7% of women still practice walking equally without any gender differences ($p > .05$).

According to age, there was no difference in the total walking practice rate of 2,422 people (33.5%) in the dictionary, 32.7% in 20–39 years and 33.9% in 40–59 years($p > .05$). After 3 months of the program, among the 3,565 people who practiced walking, 47.2% of those aged 20–39 and 50.3% of those aged 40–59 showed a higher rate of walking among those aged 40–59 ($p < .05$). And even after 6 months, 20 out of 3,657 people –39 years old 47.6%, 40–59 years old 52.6%, 40–59 years old walking practice rate was higher ($p < .01$).

According to the educational level, before starting the program, 46.5% of subjects with education below middle school practiced walking the most, and 38.0% of subjects with high school level had 32.3% of subjects with university level or higher. There was a difference in the order of 28.8% among subjects with education level($p < .001$). The rate of walking practice 3 months after the program was started was highest among those at the high school level 53.9%, at the junior high level or lower level 51.3%, at the university level 47.9%, and at the graduate school level or higher 47.3% ($p < .001$). The rate of walking practice 6 months after the program was started was highest in high school level subjects 55.6%, followed by middle school level or lower level 51.4%, university level 48.8%, and graduate school level or higher level 50.3% (p < .001).

UNIT: N (%)				
VARIABLE	**PRE WALK PRACTICE**	**POST 1 WALK PRACTICE**	**POST 2 WALK PRACTICE**	**TOTAL**
Sex				
Male	1,075 (35.0) *	1,525 (49.6)	1,591 (51.7)	3,075 (100.0)
Female	1,347 (32.4)	2,040 (49.1)	2,066 (49.7)	4,159 (100.0)
Age				
20–39	770 (32.7)	1,112 (47.2) *	1.121 (47.6) **	2,354 (100.0)
40–59	1,652 (33.9)	2,453 (50.3)	2,536 (52.6)	4,880 (100.0)
Education Level				
≥Graduate School	210 (28.8) ***	344 (47.3) ***	366 (50.3) ***	728 (100.0)
College	1,529 (32.3)	2,272 (47.9)	2,315 (48.8)	4,740 (100.0)
High School	617 (38.0)	876 (53.9)	903 (55.6)	1,624 (100.0)
≤Middle School	66 (46.5)	73 (51.3)	73 (51.4)	142 (100.0)
Occupation				
Non-Physical Occupation	1,569 (31.3) ***	2,390 (47.7) ***	2,454 (49.0) ***	5,013 (100.0)
Physical Occupation	273 (39.4)	366 (52.8)	369 (53.2)	693 (100.0)
Student	40 (51.3)	57 (73.1)	53 (67.9)	78 (100.0)
Housewife	475 (36.3)	667 (51.0)	693 (53.0)	1,308 (100.0)
Inoccupation	65 (45.8)	85 (59.9)	88 (62.0)	142 (100.0)
Total	2,422 (33.5)	3,565 (49.3)	3,657 (50.6)	7,234 (100.0)

Table 1 General Characteristics of the Walk Practice.

a) Walk practice: ≥5 day/1 week, ≥30 minutes/1 time
b) Pre: Before smart mobile walk practice, Post 1: 3 month smart mobile walk practice, Post 2:6 month smart mobile walk practice, e) Chi-Square Test, e) * $p < .05$, ** $p < .01$, *** $p < .001$.

The rate of walking practice according to occupation was highest for students before starting the program at 51.3%, followed by inoccupation at 45.8%, physical occupation group at 39.4, housewife at 36.3%, and non-physical occupation group at 31.3% ($p < .001$). And the walking practice rate after 3 months of the program was the highest for students 73.1%, followed by inoccupation 59.9%, physical occupation group 52.8%, housewife 51.0%, and non-physical occupation group 47.7% ($p < .001$). After 6 months of the program, the walking practice rate was the highest for students 67.9%, inoccupation 62.0%, physical occupation group 53.2%, housewife 56.0%, and non-physical occupation group 49.0% in that order ($p < .001$).

GENERAL CHARACTERISTICS OF THE USE MOBILE DEVICE

Independent t-test & ANOVA were performed to test the difference between the average of smart mobile device use days for 3 months and the average smart mobile device use days for 6 months according to general characteristics (Table 2).

There was no difference in the use of smart mobile devices according to gender and education level for 3 months and 6 months, respectively.

According to age, the number of days of using smart mobile devices for 3 months was 20–39 years old, 32.18 days, and 40–59 years old 35.51 days, and the number of days of using smart mobile devices was high among those in their 40s or older. The number of days of use in 6 months was 39.24 days for 20–39 years old and 46.96 days for 40–59 years old, the number of days using the device was the most among those in their 40s or older ($p < .001$).

According to occupation, the number of days of using smart mobile devices for 3 months was 35.85 days for housewives, 34.70 days for physical occupations, 34.19 days for non-physical occupations, 31.13 days for those without a job, and 30.01 days for students ($p < .001$). The number of days used during 6 months was the most at 46.89 by housewives, 45.29 days in the physical occupation group, 43.99 days in the non-physical occupation group, 38.33 days in the non-job group, and 36.69 days in the student group ($p < .001$).

CHANGE METABOLIC SYNDROME RELATE VARIABLE OF THE WALK PRACTICE

A chi-square test was performed to determine whether there were changes in metabolic syndrome-related variables according to whether walking was practiced or not (Table 3).

Before the smart mobile healthcare program, there was no difference in HT, WC, and FBS according to whether walking was practiced ($p > .05$). Before the smart mobile healthcare program, there was no difference in HT, WC, and FBS according to whether walking was practiced. As for the subjects who practiced walking before the program, 60.0% of the normal group and 40.0% of the abnormal group had TG ($p < .01$)., and 68.7% of the normal group and 31.3% of the abnormal group had HDL-Cholesterol ($p < .01$).

When walking was practiced for 3 months through the smart mobile healthcare program, there was still no difference in HT ($p > .05$) and FBS ($p > .05$). Also, in the case of HDL-C, there was no difference in walking practice according to the program ($p > .05$). For the subjects in the group evaluated that they practiced walking for 3 months through the program, the WC was 40.4% in the normal group, an 9.6%p increase in the normal group compared to before the program ($p < .001$). In the case of TG, the normal group was 67.0%, which increased by 7.0%p ($p < .001$). When walking was practiced for 6 months through the smart mobile healthcare program, there was still no difference in HT, FBS, and HDL-C. For the subjects in the group evaluated to have practiced walking for 6 months through the program, the WC was 44.4% in the normal group, an increase of 13.6%p in the normal group compared to before the program ($p < .001$). In the case of TG, the normal group was 68.5, which increased by 8.5%p ($p < .01$).

UNIT: M ± SD		
VARIABLE	**3 MONTHS USE MOBILE DEVICE**	**6 MONTHS USE MOBILE DEVICE**
Sex		
Male	34.20 ± 14.89	44.27 ± 23.10
Female	34.60 ± 15.04	44.56 ± 23.47
Age		
20–39	32.18 ± 15.16***	39.24 ± 23.63***
40–59	35.51 ± 14.76	46.96 ± 22.74
Education Level		
≥Graduate School	34.36 ± 14.86	44.17 ± 23.10
College	34.91 ± 15.11	45.62 ± 23.69
High School	32.40 ± 17.37	42.24 ± 26.47
≤Middle School	28.84 ± 17.50	38.28 ± 26.58
Occupation		
Non-Physical Occupation	34.19 ± 14.87***	43.99 ± 23.19***
Physical Occupation	34.70 ± 15.44	45.29 ± 23.88
Student	30.01 ± 15.53	36.69 ± 24.09
Housewife	35.85 ± 14.83	46.89 ± 23.05
Inoccupation	31.13 ± 16.11	38.33 ± 24.38

Table 2 General Characteristics of the Use Mobile Device.

* $p < .05$, ** $p < .01$, *** $p < .001$.

CHANGE METABOLIC SYNDROME INDEX OF THE WALK PRACTICE

In order to understand how detailed and average the continuous values of the metabolic syndrome indicators according to walking practice were varied, repeated measures ANOVA was performed, followed by the Bonferroni test as a post hoc test for each time point (Table 4).

As a result, the average SBP decreased from 126.03 before the program to an average of 121.94 after 3 months, and showed an average of 122.19 after 6 months. was found to be maintained ($p < .001$).

In the case of DBP, the average of 81.17 before the program decreased to an average of 78.42 after 3 months, and an average of 78.74 after 6 months. was found to be maintained ($p < .001$).

In the case of WC, an average of 88.52 before the program decreased to an average of 96.73 after 3 months, and an average of 86.15 after 6 months. It was found that WC decreased even more than months ago ($p < .001$).

In the case of FBS, an average of 95.67 before the program decreased to an average of 94.09 after 3 months, and an average of 93.80 after 6 months. It was found that FBS decreased more than a month ago ($p < .001$).

In the case of TG, an average of 154.22 before the program decreased to an average of 142.79 after 3 months, and an average of 142.97 after 6 months. appeared to remain in a decreasing state ($p < .001$).

In the case of HDL-C, the average was 52.86 before the program, then the average was 52.71 after 3 months, and the average was 53.85 after 6 months. HDL-C was found to increase ($p < .001$).

In addition, the average number of days that subjects used the device for smart mobile health care up to 3 months in advance was 34.43 days, and the average number of days of using the device from 3 months to 6 months was 44.45 days ($p < .001$).

UNIT: N (%)						
VARIABLE	PRE WALK PRACTICE		POST 1 WALK PRACTICE		POST 2 WALK PRACTICE	
	YES	NO	YES	NO	YES	NO
HT						
Abnormal	1,080 (44.6)	2,047 (42.5)	1,052 (29.5)	1,049 (28.6)	954 (26.1)	928 (25.9)
Normal	1,342 (55.4)	2,765 (57.5)	2,513 (70.5)	2,620 (71.4()	2,703 (73.9)	2,649 (74.1)
WC						
Abnormal	1,675 (69.2)	3,419 (71.1)	2,124 (59.6) ***	2,358 (64.3)	2,033 (55.6) ***	2,168 (60.6)
Normal	747 (30.8)	1,393 (28.9)	1,441 (40.4)	1,311 (35.7)	1,624 (44.4)	1,409 (39.4)
FBS						
Abnormal	790 (32.6)	1,498 (30.9)	892 (25.0)	848 (23.1)	782 (21.4)	774 (21.6)
Normal	1,632 (67.4)	3,323 (69.1)	2,673 (75.0)	2,821 (76.9)	2,875 (78.6)	2,803 (78.4)
TG						
Abnormal	968 (40.0) **	2,102 (43.7)	1,175 (33.0) ***	1,375 (37.5)	1,153 (31.5) **	1,238 (34.6)
Normal	1,454 (60.0)	2,710 (56.3)	2,930 (67.0)	2,294 (62.5)	2,504 (68.5)	2,339 (65.4)
HDL-C						
Abnormal	759 (31.3) **	1,415 (29.4)	831 (23.3)	884 (24.1)	713 (19.5)	721 (20.2)
Normal	1,663 (68.7)	3,397 (70.6)	2,734 (76.7)	2,785 (75.9)	2,944 (80.5)	2,856 (79.8)
Total	2,422 (100.0)	4,812 (100.0)	3,565 (100.0)	3,669 (100.0)	3,657 (100.0)	3,577 (100.0)

Table 3 Change Metabolic Syndrome relate Variable of the Walk Practice.

Walk practice: ≥5 day/1 week, ≥30 minutes/1 time, HT: Hypertension, SBP: Systole Blood Pressure, DBP: Diastole Blood Pressure, WC: Wais Circumference, FBS: Fasting Blood Sugar, TG: Triglyceride, HDL-C: High-Density Lipoproteins Cholesterol Metabolic Syndrome relate Variables Abnormal Value (HT: SBP ≥130 or DBP ≥85, WC: Male ≥90, Female ≥80, FBS: ≥100, TG: ≥150 HDL-C: Male <40, Female <50), b) Pre: Before smart mobile walk practice, Post 1: 3 month smart mobile walk practice, Post 2:6 month smart mobile walk practice, e) Chi-Square Test, e) * $p < .05$, ** $p < .01$, *** $p < .001$.

THE EFFECT OF PROMOTING WALKING EXERCISE BY USING SMART MOBILE ACTIVITY METER ON CHANGES IN METABOLIC SYNDROME INDEX: PATHWAY MODEL & MEDIATION EFFECT

Through path model analysis and sobel test, the mediating effect of walking measurement and intervention through smart mobile health care device and the improvement effect of metabolic syndrome index were investigated (Figure 2).

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UNIT: M±SD				
VARIABLE	**PRE[A] WALK PRACTICE**	**POST 1[B] WALK PRACTICE**	**POST 2[C] WALK PRACTICE**	***P* (BONFERRONI)**
SBP	126.03 ± 13.44	121.94 ± 12.92	122.19 ± 12.72	<.001 (a > b, c)
DBP	81.17 ± 10.32	78.42 ± 9.86	78.74 ± 9.83	<.001 (a > b, c)
WC	88.52 ± 9.58	86.73 ± 9.35	86.15 ± 9.38	<.001 (a > b > c)
FBS	95.67 ± 12.41	94.09 ± 11.18	93.80 ± 11.24	<.001 (a > b >c)
TG	154.22 ± 86.28	142.79 ± 77.66	142.97 ± 76.71	<.001 (a > b, c)
HDL-C	52.86 ± 13.10	52.71 ± 11.81	53.85 ± 11.65	<.001 (a, b < c)
MSI	2.16 ± 1.10	1.74 ± 1.17	1.59 ± 1.16	<.001 (a > b > c)
Use Mobile Device †		**3 Month Use**	**6 Month Use**	***p***
		34.43 ± 14.97	44.45 ± 23.31	<.001

Table 4 Change Metabolic Syndrome Index of the Walk Practice.

a) SBP: Systole Blood Pressure, DBP: Diastole Blood Pressure, WC: Waist Circumference, FBS: Fasting Blood Sugar, TG: Triglyceride, HDL-C: High-Density Lipoproteins Cholesterol, MSI: Metabolic Syndrome Index Abnormal Value (HT: SBP ≥130 or DBP ≥85, WC: Male ≥90, Female ≥80, FBS: ≥100, TG: ≥150 HDL-C: Male <40, Female <50), b) Repeated Measured ANOVA (Post-hoc: Bonferroni), † Paired t-Test & Repeated Measured ANOVA (Post-hoc: Bonferroni) + 3 & 6 month Use Mobile Device Covariance, c) M: Mean, SD: Standard Deviation, d) Pre: Measured Before smart mobile walk practice, Post 1: Measured after 3 month smart mobile walk practice, Post 2: Measured after 6 month smart mobile walk practice, e) * $p < .05$, ** $p < .01$, *** $p < .001$.

It was found that the TG decreased by B = –4.419 ($p < 0.05$) in subjects who practiced walking in advance. And the more people practiced walking, the more they tended to be better at using smart mobile healthcare devices for 3 months by B = 1.686 ($p < 0.01$), and it was found that the walking practice rate up to 3 months later increased by B = .328 ($p < 0.001$). In addition, it was found that the more the smart mobile health care device was used for 3 months, the more the walking practice rate after 3 months increased by B = .004 ($p < 0.01$). This confirmed that there was a significant partial mediating effect as a result of the Sobel test (z = 3.032, $p < .01$). And because of this, after 3 months, WC decreased by B = –.327($p < 0.001$), TG decreased by B = –6.682 ($p < 0.001$), and HDL-C increased by B = .730 ($p < 0.001$),, indicating an improvement in metabolic syndrome index.

Subjects who practiced walking for up to 3 months tended to use smart mobile health care device better by B = 9.506 ($p < 0.001$) for 6 months, and the walking practice rate up to +month increased by B = .404 ($p < 0.001$) more significantly. appeared to do In addition, it was found practice rate up to 6 months later increased by B = .001 ($p < 0.001$). This confirmed that there was a significant partial mediating effect as a result of the Sobel test (z = 15.113, $p < .001$). And because of this, after 6 months, WC decreased by B = –.423 ($p < 0.001$), and TG decreased by B = –4.709 ($p < 0.01$), showing the improvement effect of metabolic syndrome index. that the more the smart mobile healthcare device was used during June, the more the walking

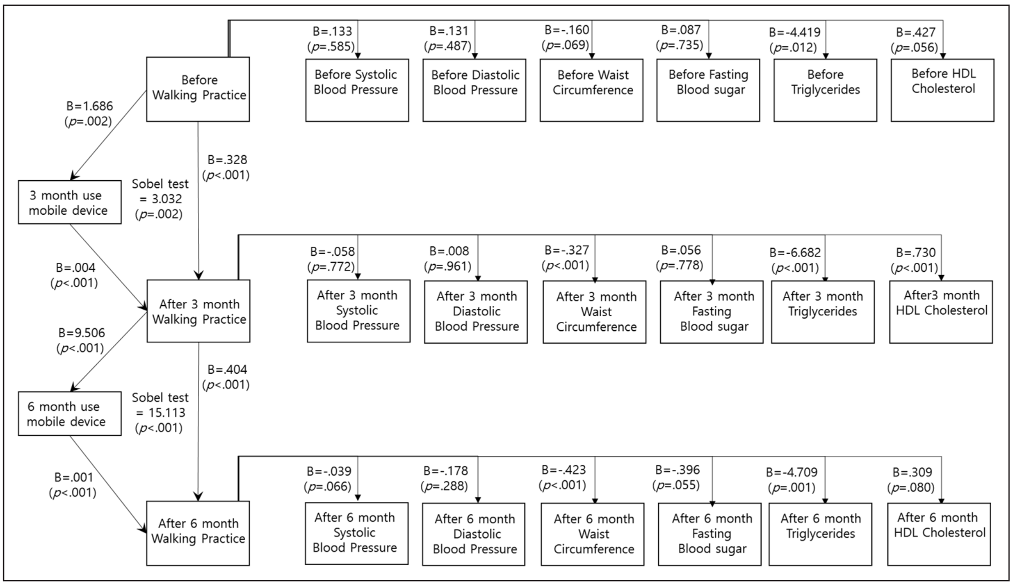

Figure 2 The effect of walking promoting using smart mobile activity meter on changes in metabolic profiles. The Sobel test was used to evaluate the mediation effects of walking exercise promotion on changes in metabolic profiles.

DISCUSSION

In this study, as a result of examining the mediating effect of the walking practice rate measurement and intervention through the smart mobile healthcare device and the improvement effect of the metabolic syndrome index, it was confirmed that the use of the smart healthcare device significantly increased the walking practice rate. It was found that there was a significant partial mediating effect on the increase in walking practice rate when using smart devices for more than 3 months. In addition, it was confirmed that subjects who exercised walking for up to 3 months maintained the use of smart healthcare devices for 6 months better, and when using smart devices for 6 months, there was a significant partial mediating effect on the increase in the walking practice rate. Accordingly, there was a clear change in the improvement of the metabolic syndrome index. In other words, the wearable device app itself was found to be effective in improving metabolic syndrome indicators such as SBP, DBP WC, FBS, TG, and HDL-C. Adding a mobile app along with a wearable device to the intervention improves metabolic syndrome indices by increasing walking practice rates. In particular, the improvement effect of waist circumference and triglyceride was very clear.

This result is consistent with a previous cohort study using mobile apps and wearable devices, and increased PA not only lowered blood pressure through significant weight loss, but also reduced the risk of type 2 diabetes (Fukuoka et al., 2015). Additionally, studies that measured step count and activity level showed significant reductions in weight and BMI in older adults (Suboc et al., 2014), and interventions that provided feedback to participants via a website, along with education and self-management, were more likely to result in PA than the group that received only the activity meter (Rowley et al., 2019). The results and feedback through the wearable device and mobile app in this study were similar to those of the group that maintained walking for more than 6 months, showing improved health outcomes. In addition, Schraplau et al (Schraplau et al., 2021) reported that a preventive effect could be achieved by combining a mobile diagnostic approach with an intervention program that includes lifestyle monitoring through wearables and mobile applications, especially nutrition and exercise programs that can be easily integrated into daily routines. These results are attributed to the importance of additional education on metabolic syndrome, normal baseline, correct eating habits, and increased activity (Kim et al., 2022).

To the best of our knowledge, this is one of the few studies that analyzed the effect of mHealth devices on PA facilitation in healthy general population with metabolic syndrome risk factors in Korea. Wearable devices can promote health behavior change, but their successful use and potential health benefits depend more on the design of an engagement strategy than on the nature of the technology (Patel et al., 2012). Here, the need for individual encouragement, competition and collaboration, and effective feedback related to human behavior is emphasized (Kim et al., 2022). In this study, personalized knowledge and information provided through mobile notifications and apps acted as a major factor in preventing MetS by continuously maintaining the recommended PAs presented by guidelines in Korea and the United States. Increased PA is well known to prevent or delay the onset of heart disease, diabetes and other chronic diseases (Jang et al., 2018). Therefore, it cannot be overemphasized that raising PA in groups with at least one major risk factor is considered a priority for disease prevention.

It is hoped that this study will be used as a policy basis contributing to disease prevention and public health promotion by increasing access to intervention programs through smart mobile healthcare for those who have difficulty paying attention to walking exercise.

LIMITATIONS

Data were collected and analyzed based on the effects of smart mobile health care on physical activity, so it was not possible to grasp the results of controlling the variables for eating habits and nutrients.

CONCLUSIONS

It was found that the more programs that provide advice and interventions on physical activity through smart mobile health care devices were used, the more helpful it was to promote walking exercise practice.

DATA ACCESSIBILITY STATEMENT

The authors shared data from the Korea Institute for Health Promotion's 2018 nationwide mobile health care program. Therefore, the data sets generated and/or analyzed during the current study are not publicly available due to [the reason the data was not made public]. However, it can be used by the corresponding author upon a reasonable request to the Korea Health Promotion Institute (https://www.khealth.or.kr/eps).

ETHICS AND CONSENT

This study was approved by the institutional review board of the CHA Bundang medical center (CHAMC 2021 04 053), We confirms that all experiments were performed in accordance with relevant named guidelines and regulations. We were confirms that informed consent was obtained from all participants and their legal guardians.

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

Conceptualization: SKL and MGK. Data curation: MGK, SKL, YO, DJK, SYY, and MSK. Formal analysis: MGK and SKL. Methodology: SKL and MGK. Supervision: HWH. Writing – original draft: SKL and MGK. Writing – review & editing: SKL, SYY, and HWH.

Su Kyoung Lee and Myung-Gwan Kim are authors equally contribute, hence co 1st author.

AUTHOR INFORMATION

Correspondence and requests for materials should be addressed to Hyun Wook Han.

AUTHOR AFFILIATIONS

Su Kyoung Lee orcid.org/0000-0002-9582-4402
Department of Biomedical Informatics, Graduate School of Medicine, CHA University, Seongnam 13488, South Korea; Institute for Biomedical Informatics, Graduate School of Medicine, CHA University, Seongnam 13488, South Korea

Myung-Gwan Kim orcid.org/0000-0002-6649-4715
Department of Biomedical Informatics, Graduate School of Medicine, CHA University, Seongnam 13488, South Korea; Institute for Biomedical Informatics, Graduate School of Medicine, CHA University, Seongnam 13488, South Korea

Yumi Oh orcid.org/0000-0003-2003-8690
Department of Health Policy Research and Evaluation, Korea Health Promotion Institute, Seoul, Republic of Korea

DongJin Kim orcid.org/0000-0003-4074-5544
Digital Healthcare Team, Healthcare Innovation Center, Korea Health Promotion Institute, Seoul, South Korea

MinSu Kim orcid.org/0000-0003-3624-1757
Strategic and Planning Team, Department of Strategic and Planning, Korea Health Promotion Institute, Seoul, Republic of Korea

SunYoung Yang orcid.org/0000-0001-6660-1632
Digital Healthcare Team, Healthcare Innovation Center, Korea Health Promotion Institute, Seoul, South Korea; Department of Health Convergence, Ewha Womans University , Seoul, South Korea

Hyun Wook Han orcid.org/0000-0002-6918-5694
Department of Biomedical Informatics, Graduate School of Medicine, CHA University, Seongnam 13488, South Korea; Institute for Biomedical Informatics, Graduate School of Medicine, CHA University, Seongnam 13488, South Korea

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