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Mobile health, physical activity, and obesity

Subanalysis of a randomized controlled trial

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Abstract

Background: Recent studies on physical activity were analyzed by randomizing participants into either the intervention or control group. It is necessary to classify each intervention and control groups according to physical activity using the International Physical Activity Questionnaire (IPAQ).

Methods: This was a pilot project for SmartCare Services. The intervention group received obesity management services using a smartphone for 24 weeks, while the control group did not receive the interventions. Six anthropometric indices were analyzed: weight, body mass index (BMI), waist circumference, body fat, systolic blood pressure (SBP), and diastolic blood pressure (DBP). Five laboratory tests, including fasting blood sugar (FBS), glycosylated hemoglobin (HbA1c), high-density lipoprotein cholesterol (HDL-C), total cholesterol (TC), and triglycerides (TGs), were also assessed. The final 324 participants were categorized using the IPAQ questionnaire, and anthropometric indices and laboratory tests were analyzed for within-group and between-group changes from baseline to final visit.

Results: Statistically significant decreases in the intervention group compared with the control group were observed in terms of insufficient activity (IA) (-1.6 ± 3.03 vs -0.1 ± 1.94 kg) and moderate activity (MA) (-2.5 ± 3.81 vs -0.3 ± 2.24 kg) for weight, IA (-0.7 ± 1.14 vs -0.2 ± 0.93 kg/m^2) and MA (-0.9 ± 1.30 vs -0.2 ± 0.86 kg/m^2) for BMI, and health-enhancing physical activity (HEPA) (-1.6 ± 3.69% vs -0.1 ± 3.15%) for body fat. For HbA1c, HEPA in the intervention group showed significant decreases (-0.2 ± 0.67 vs 0.0 ± 0.34 mg/dL) compared with the control group.

Conclusion: Anthropometric indices and laboratory test results were improved in the smartphone-based intervention group. Especially, improvement of metabolic components in the group with more active physical activity was remarkable.

Abbreviations: FBS = fasting blood sugar, HbA1c = glycosylated hemoglobin, HDL-C = high-density lipoprotein cholesterol, HEPA = health-enhancing physical activity, hsCRP = high-sensitivity C-reactive protein, IA = insufficient activity, LDL-C = low-density lipoprotein cholesterol, MA = moderate activity, MET = Metabolic Equivalent of Task, TC = total cholesterol, TG = triglyceride.

Keywords: e-health, IPAQ, metabolic syndrome, mobile health, obesity, physical activity, telemonitoring

1. Introduction

Dietary changes and sedentary lifestyles caused the surge in obesity rates.[1,2] There is a growing awareness that it is necessary to monitor obesity and overweight regularly because major diseases are associated with cardiovascular disease, type II diabetes, and cancers.[3,4] Biomarkers are representative indices for managing obesity. These include weight, body mass index (BMI), waist circumference, hip circumference, and waist-to-hip ratio.[5] Blood chemistry components used to measure obesity include fasting blood sugar (FBS), glycosylated hemoglobin (HbA1c), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), total cholesterol (TC), triglyceride (TG), and high-sensitivity C-reactive protein (hsCRP).[6] The use of mobile health (m-health) programs recently increased because they are effective means of managing obesity.[7] It was estimated that there are 4.77 billion mobile phone users globally in 2017. This number is expected to increase to 5.07 billion people by 2019, comprising 67% of the population.[7] The use of m-health was recognized as a suitable method for health management because of its high distribution rate.[8–10] Studies conducted on physical activity, dietary intake, and self-measurement monitoring in m-health users have shown that it is more effective than traditional obesity treatments such as food-exercise diary or self-monitoring, and so on.[11–14] A study conducted in young adults in the Sydney, Australia, from November 2012 to July 2014 measured weight, dietary intake, and utilized International Physical Activity Questionnaires (IPAQs) for measuring physical activity.[15] As a result of this study, personalized dietitians coaching using the mobile phone app improved the weight, dietary intake, and physical activity

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more than the control group who only received only 4 text messages and printed dietary and physical activity guidelines without an access to mobile phone apps. However, this study only analyzed the physical activity between an intervention group and a control group. And, there has been research showing that obesity is associated with blood markers such as lipid according to physical activity.[16] So, our study assumed that there will be average differences in biomarkers and blood chemistry indices depending on the participant's category. This study aims to classify each intervention group and control group as categories using IPAQ and to analyze within-group changes and differences in biomarkers and blood chemistry indices in detail. Finally, this study is a follow-up of the study by Oh et al[17] using subanalysis conducted after analyzing the difference between intervention and control groups in terms of body weight and BMI.

2. Materials and methods

This study was a national pilot project for SmartCare Services and aimed to analyze the impact of m-health usage by dividing participants into 2 groups: an intervention group that received obesity management service using a smartphone for 24 weeks and a control group that did not.

2.1. Participants and study period

This study was conducted in Seoul National University and Yonsei University (Clinical Trials GOV NCT01344811). It was a multicenter, randomized, parallel, interventional, and open-label trial. Participants were selected from outpatients who have the ability to use a smartphone and were being treated for metabolic syndrome at 2 university medical schools. Participants who completed the study using SmartCare services from March 9, 2011, to April 3, 2013, were selected for final analysis. The Institutional Review Board of Seoul National University Hospital approved this study (IRB number: h-1009-095-333).

The selection criteria to participate are as follows:

(1) Adult male/female patients over 20 years old who are able to visit hospitals;
(2) BMI $\geq$ 25 kg/m^2;
(3) The patient who has metabolic syndrome (3 or more elements among 5 elements of metabolic syndrome listed as follows):
   (a) Waist circumference $\geq$90 cm in men and $\geq$80 cm in women,
   (b) Hypertriglyceridemia (TG $\geq$150 mg/dL),
   (c) HDL-C $<$40 mg/dL in men and $<$50 mg/dL in women,
   (d) Hypertension (blood pressure $\geq$130/85 mm Hg or taking antihypertensive medication), and
   (e) Hyperglycemia [fasting plasma glucose (FPG) $\geq$100 mg/dL or taking antidiabetic medication].

2.2. SmartCare program for intervention subject

Figure 1 shows the SmartCare services provision program. Participants were chosen on the basis of eligibility criteria. Participants were evaluated for their suitability according to the general descriptions and participant selection criteria, and they then filled out the application and consent form. The consent form included the purpose of the study, the method of retention and disposal of the data after the clinical trial, and the protection of personal information through the anonymity and coding of the subject. All the contents were described by the nurse in advance, and the procedure for direct signing of participant was proceeded. Participants in the intervention group were provided with smartphones equipped with the SmartCare application and a Bioimpedance Analyzer via Bluetooth (Modal: InBody IH-U070B, Manufacturer: Biospace Inc., South Korea, www.inbody.com) to facilitate telemonitoring. Measurement data were transmitted to the SmartCare system through smartphones when participants measured their weight using the medical device. After, Health reports were automatically created based on the personal health information of participants according to the clinical decision support system (CDSS) algorithm function of the SmartCare system. Health managers (i.e., nurses, nutritionists, and exercise prescribers) provided prevention, consultation, and educational services remotely to participants based on these reports. Information on measurement results were transmitted to participants using messages or weekly emails. They also underwent a health promotion program, which included a health status survey, progress management, and monthly status evaluations. A personalized health report was also sent once a month. All participants visited the hospital at least once every 2 months and consulted a physician.[18]

2.3. Data collection

SmartCare Services were analyzed by dividing the participants into 2 groups: an intervention group that received obesity management services using a smartphone for 24 weeks and a control group that did not use a smartphone. Demographic information from the subjects (i.e., age, gender, smoking status, drinking habits, etc) were investigated and recorded during screening. Weight, BMI, waist circumference, body fat percentage, SBP, and DBP comprised the biomarkers included in analysis indices. Blood chemistry tests included FBS, HbA1c, HDL-C, TC, and TG. Changes in each index were defined as change from initial hospital visit (baseline) to final hospital visit (24 weeks).

Biomarkers were measured during 3 hospital visits (initial visit, week 12 intermediate visit, and final visit) over a 6-month period. Nurses calculated BMI as weight (kg)/height^2 (m^2) using height and weight measurements. Body fat mass was measured using a body fat analyzer and waist circumference was measured using a tape measure, with participants standing with their feet 25 to 30 cm apart, ensuring even weight distribution. SBP and DBP were measured on both sides of the left and right arms using a standard sphygmomanometer after a 5-minute stabilization period. The average blood pressure was then calculated. Five types of blood chemistry tests were performed on blood samples collected after 10 hours of fasting.

2.4. IPAQ questionnaire

The IPAQ is a questionnaire that includes a comprehensive range of physical activities and was reported to be appropriate for individuals 18 years and older.[19] The IPAQ was used for assessing the physical activity of subjects during the final visit. All activities, such as leisure time, indoor activities, outdoor activities, work-related activities, and traffic-related activities, were included. Information on activity frequency and duration were recorded on the basis of the last 7 days of walking and moderate and intense physical activities.

Physical activity scores were defined for the IPAQ short as follows[20]:

(1) Continuous score
   (a) Walking MET-minutes/week = 3.3 $\times$ walking minutes and walking days at work;

Figure 1. Procedure diagram for the SmartCare program.

(b) Moderate MET-minutes/week = 4.0 × moderate-intensity minutes and moderate days at work;
(c) Vigorous MET-minutes/week = 8.0 × Vigorous intensity minutes × vigorous-intensity days at work.
* MET = Metabolic Equivalent of Task

(2) Categorical score
(a) Category 1 (low physical activity level):
Participants who did not meet the criteria for categories 2 or 3 were put in this category.
(b) Category 2 (moderate physical activity level):
At least 20 minutes of vigorous-intensity activity per day for 3 or more days per week or at least 30 minutes of moderate-intensity activity per day for 5 or more days per week or 5 or more days of any combination of walking, moderate-intensity or vigorous-intensity activities achieving a minimum total physical activity of at least 600 MET minutes/week.
(c) Category 3 (high physical activity level):
Vigorous-intensity activity for at least 3 days achieving a minimum total physical activity of at least 1500 MET-minutes/week or 5 or more days of any combination of walking, moderate-intensity, or vigorous-intensity activities achieving a minimum total physical activity of at least 3000 MET-minutes/week.

2.5. Statistical analysis

Biomarkers and blood chemistry indices were analyzed using within-group changes and between-group differences.

Data collection and analysis were performed based on the assumption that the intervention group will exhibit greater effects because of their use of SmartCare.

(1) SPSS WIN 19.0 (SPSS Inc., Chicago, IL, USA) program was used to analyze the results.
(2) Evaluation groups were classified depending on the level of physical activity.
The level of physical activity was assessed using the IPAQ submitted by the participant at 24 weeks to determine the level of physical activity. Physical activity was classified as HEPA, MA, and IA. The control group was classified into IA (n = 53), MA (n = 27), and HEPA (n = 67) and the

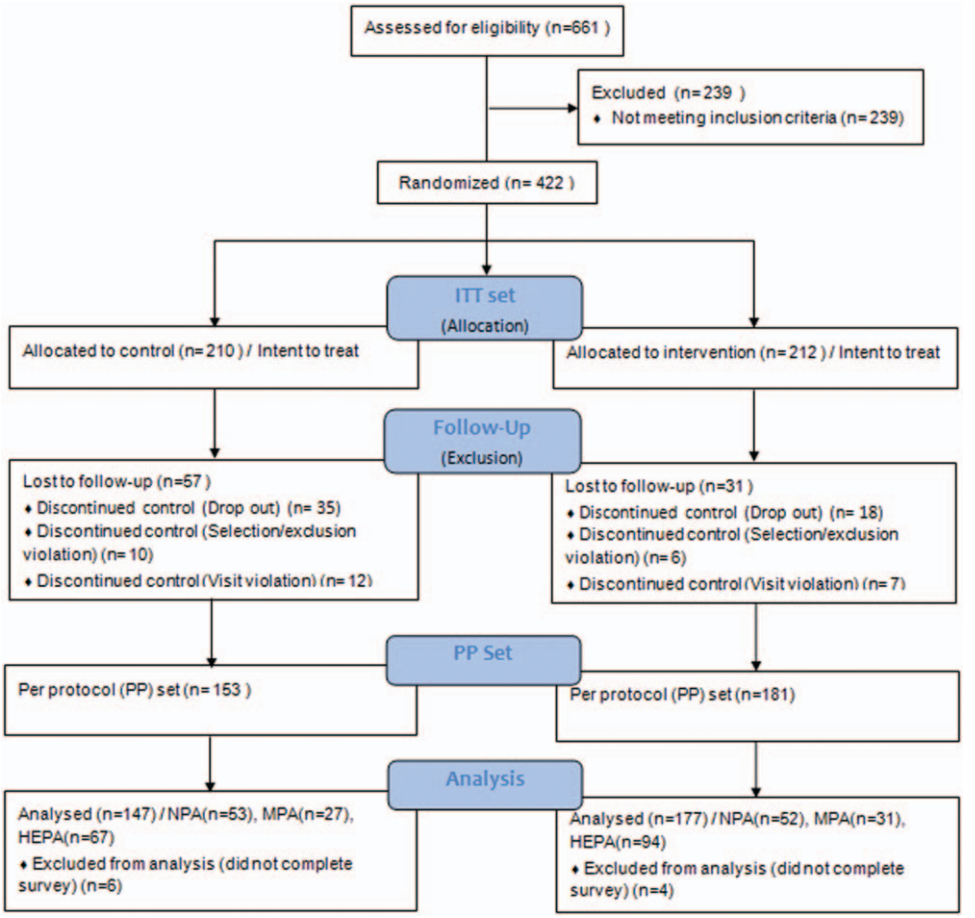

Figure 2. Disposition of study subjects.

intervention group was classified into IA (n = 52 people), MA (n = 31), and HEPA (n = 94) for the analysis of change of obesity indices according to physical activity.

(3) A Chi-square test was performed on demographic characteristics to identify the differences between technical analysis and measurement level groups.
(4) Analysis of variance (ANOVA) was performed to test for any differences in physical activity between groups.
(5) The pair *t* test was used to analyze differences between baseline and endpoint.
(6) Analysis of covariance (ANCOVA) was used to analyze indices between groups in terms of the differences from baseline to endpoint. Covariance was adjusted for ages and the degree of education, which showed differences in demographic characteristics and baseline.
(7) A power analysis was conducted using G power software (http://www.psycho. uni-duesseldorf.de/abteilungen/aap/gpower3). This showed an effect size of 0.05 with power 0.910 for a sample size of 213 participants.

All significance levels were analyzed based on a Cronbach alpha value of 0.05.

3. Results

3.1. Baseline characteristics of participants

A total of 661 participants was screened for the study. Two hundred thirty-nine participants failed to meet the inclusion criteria. Four hundred twenty-two participants were randomized into groups and data were analyzed through an intent-to-treat (ITT) analysis. Two hundred ten participants were randomized into the control group and 212 participants were randomized into the intervention group. Among the 422 participants initially randomized, 324 participants (control group: 147, intervention group: 177) were available for the per-protocol analysis (Figs. 2 and 3).

Demographic characteristics included gender, age, education, smoking status, alcohol consumption, hospital (Seoul National University or Yonsei University), and categories by the physical activity.

No statistically significant differences were found in terms of gender, smoking status, alcohol consumption, hospital, and physical activity level. However, statistically significant differences in ages and education were found, as summarized in Table 1.

3.2. Differences in metabolic components according to physical activity type

Table 2 summarizes changes within groups and differences between groups according to biomarkers.

The intervention group was found to have decreased IA (-1.6 ± 3.03 kg), decreased MA (-2.5 ± 3.81 kg), and decreased HEPA (-2.6 ± 3.91 kg) as a result of changes in weight. These changes were statistically significant.

Changes in BMI in the control group resulted in IA, MA, and HEPA changes that were not statistically significant. IA decreased (-0.7 ± 1.14 kg/m^2), MA decreased (-0.9 ± 1.30 kg/m^2), and

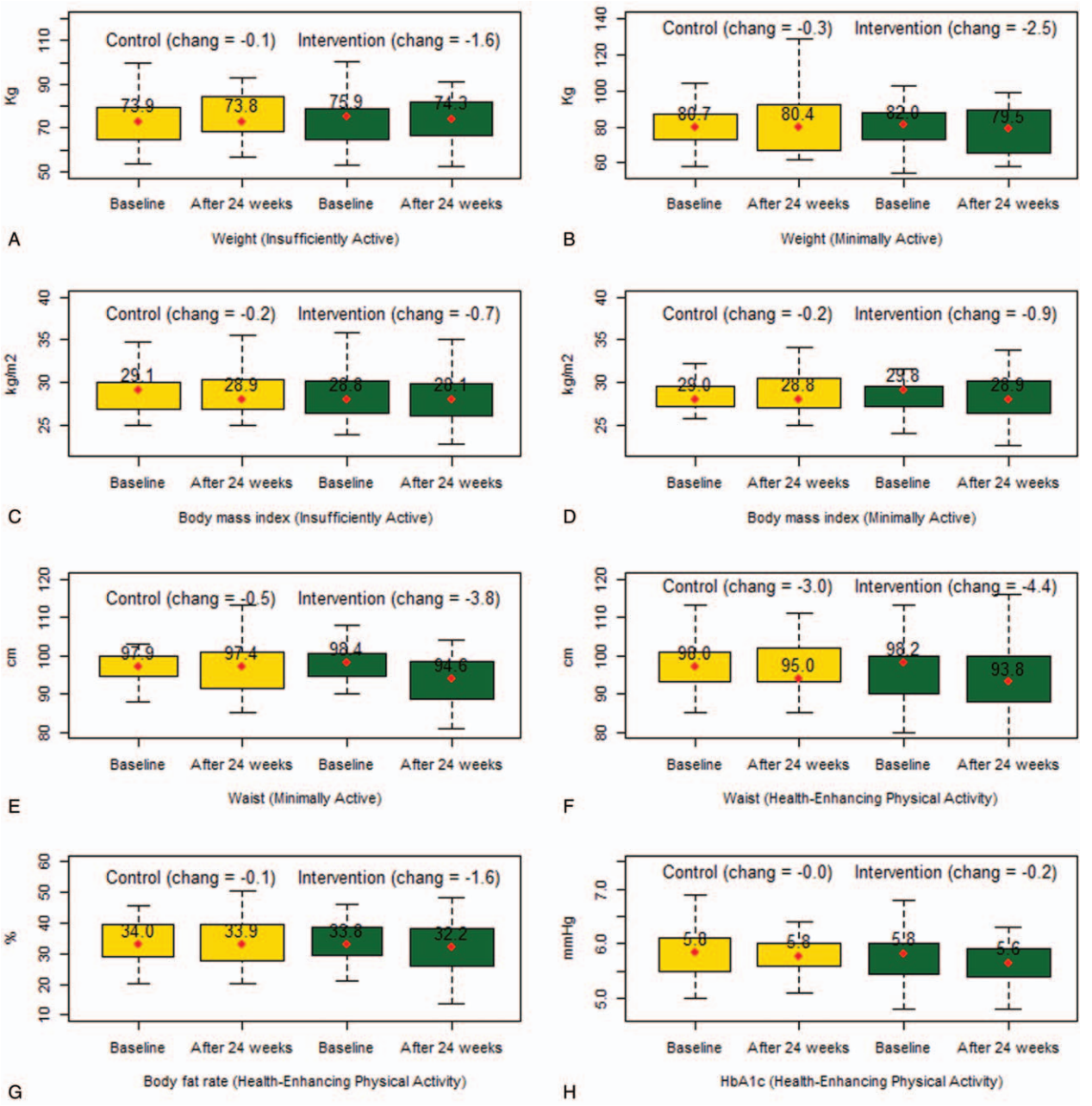

Figure 3. Indicators with significant differences between groups of 6 biomarkers and 5 blood chemistry markers over 6 months.

HEPA decreased ($-1.0 \pm 1.44\,kg/m^2$) in the intervention group. These changes were statistically significant.

Waist analysis was conducted in the intervention group; there were decreases in MA (-3.8 ± 5.78 cm) and in HEPA (-4.4 ± 4.75 cm), which proved to be statistically significant.

Body fat percentage analysis in the intervention group revealed statistically significant decreases in HEPA by $-1.6 \pm 3.69\%$.

SBP analysis was conducted to determine changes in groups. Statistically significant changes were found in the intervention group, wherein IA decreased by -6.2 ± 14.66 mm Hg, MA decreased by -5.7 ± 11.27 mm Hg, and HEPA decreased by -7.0 ± 13.50 mm Hg. Between-group analysis showed that the differences between IA, MA, and HEPA in the control and intervention groups were not statistically significant.

DBP analysis showed statistically significant changes in groups. IA decreased by -3.5 ± 10.45 mm Hg and HEPA decreased by -2.5 ± 10.79 mm Hg in the intervention group. The differences in IA, MA, and HEPA in the control and intervention groups were not statistically significant as shown by between-group analyses.

Table 3 summarizes changes within groups and differences between groups according to levels of physical activity and blood chemistry.

In the intervention group, HEPA increased by 4.0 ± 7.76 mg/dL as a result of HDL-C. The increase in HEPA was statistically significant. The differences in IA, MA, and HEPA in the control and intervention groups were not statistically significant.

TC analysis revealed statistically significant changes in intervention group where IA decreased by -2.8 ± 29.83 mg/dL,

Table 1

Characteristics of the subjects (N = 324).

Variables	Control (n = 147)	Intervention (n = 177)	P*
	N (%)		
Gender			
Male	65 (42.5)	88 (57.5)	.371
Female	82 (48.0)	89 (52.0)	
Age, y			
19–44	51 (39.5)	78 (60.5)	.003
44–64	63 (43.2)	83 (56.8)	
≥65	33 (67.3)	16 (32.7)	
Education			
Elementary	19 (82.6)	4 (17.4)	.003
Middle school	11 (64.7)	6 (35.3)	
High school	46 (46.9)	52 (53.1)	
≥University	70 (33.8)	113 (61.7)	
Others	1 (33.3)	2 (66.7)	
Smoking			
Smoker	20 (43.5)	26 (56.5)	.212
Nonsmoking	115 (47.7)	126 (52.3)	
Past smoker	12 (32.4)	25 (67.6)	
Drinking alcohol			
Drinker	67 (41.1)	96 (58.9)	.121
Nondrinking	80 (49.7)	81 (50.3)	
Hospital			
S	75 (45.7)	89 (54.3)	.912
Y	72 (45.0)	88 (55.0)	
Categories by the physical activity			
Category 1 (Inactive, not 2 or 3)	53 (50.5)	52 (49.5)	.358
Category 2 (Minimally active, 600> MET-min/week)	27 (46.6)	31 (53.4)	
Category 3 (Health enhancing physical activity, 3000> MET-min/week)	67 (41.6)	94 (58.4)	

BMI = body mass index, BP = blood pressure, DBP = diastolic blood pressure, S = Seoul National University, SBP = systolic blood pressure, Y = Yonsei University.

* Chi-square test.

MA increased by 7.7 ± 27.99 mg/dL, and HEPA decreased by −5.1 ± 23.74 mg/dL in the intervention group. Between-groups analyses showed nonstatistically significant differences between IA, MA, and HEPA in the control and intervention groups.

The intervention group had statistically significant decreases in HEPA (−52.3 ± 78.19 mg/dL) as shown using TG analysis. The differences between IA, MA, and HEPA in the control and intervention groups were not statistically significant.

FBS analysis revealed statistically significant decreases in IA (−4.7 ± 11.51 mg/dL), MA (−2.1 ± 10.32 mg/dL), and HEPA (−3.1 ± 12.04 mg/dL) in the intervention group. The differences between IA, MA, and HEPA in the control and intervention groups were not statistically significant.

HbA1c analysis of within-group changes revealed statistically significant decreases in IA (−0.1 ± 0.22 mg/dL) and HEPA (−0.2 ± 0.67 mg/dL).

4. Discussion

This study is a subgroup analysis of the study by Oh et al,[17] which examined the effectiveness of m-health in intervention and control groups. This study adds to the current literature by its analyses of the changes in obesity indices and the difference between groups depending on physical activity levels. The differences between groups were analyzed through data provided by 6 types of biomarkers and 5 components of blood chemistry. Changes from baseline to the final visit were assessed.

The intervention group showed statistically significant decreases in biomarkers and blood chemistry indices compared with the control group. Biomarker results were similar to the difference analysis results between the 2 groups. However, the intervention group showed greater decreases in HEPA after conducting a special analysis.

Changes in blood chemistry indices between groups showed no statistically significant differences in FBS, HDL, TC, and TG based on IPAQ analyses. However, the intervention group had statistically significant decreases in HEPA (−0.2 ± 0.67 vs −0.0 ± 0.34 mg/dL) compared with the control group ($P < .05$).

The results of analysis adequately showed the relationship between obesity and HbA1c.

It was expected that physical activity levels of the participants in the intervention group would not differ from the control group. However, participants in the intervention group had higher levels of HEPA than the control group. This suggests that there was greater compliance with the SmartCare services in the intervention group than the control group. These results suggest that increased use of SmartCare services is associated with a decrease in obesity rates.

Older participants experienced difficulties with using the provided devices. Installation and instructions were provided again through revisits, if the participant is unable to operate devices or if the internet was unavailable. New devices were issued to participants having difficulty with device usage or who lost their devices. This resulted in interruptions in BP measurements. A number of participants asked for additional devices to enable them to measure their BP during extended travel or while in their workplaces. However, they were advised that the experiment was limited to home measurement only.

The study had several limitations. First, tools such as activity trackers would have enabled a more objective classification standard. Second, measurements of insulin resistance were not conducted. Insulin resistance is involved in the pathogenesis of metabolic syndrome. Third, the acceptance of u-health care services could have been determined by counselors. As this is a possible factor affecting remote obesity health care, the quality of counselors who provide care is important. Fourth, there is no measurement of physical activity at the beginning of the study. Therefore, physical activity before the study could not be compared with baseline. In spite of these limitations, this study is the first study to classify obesity groups as categories using the IPAQ and to analyze biomarkers and blood chemistry indices.

5. Conclusion

This study compared and analyzed changes in biomarkers and blood chemistry indices between the intervention group and control group based on the IPAQ. The study also aimed to assess the difference in the index changes between each group.

The intervention group showed larger decreases in biomarkers and blood chemistry indices than the control group. Changes in biomarkers were not significantly different from the results of the difference analysis between the intervention group and the control group. It was confirmed that the intervention group exhibited greater changes in HEPA. In addition, HbA1c showed

Table 2

According to levels of physical activities in biomarkers, changes within groups, and difference between groups.

		Control group (n = 147)			Intervention group (n = 177)			Difference between groups†		
Variable	Month	IA (n = 53) Mean ± SD	MA (n = 27) Mean ± SD	HEPA (n = 67) Mean ± SD	IA (n = 52) Mean ± SD	MA (n = 31) Mean ± SD	HEPA (n = 94) Mean ± SD	IA *P*	MA *P*	HEPA *P*
Weight, kg	Baseline	73.9 ± 12.02	80.7 ± 11.56	79.4 ± 14.73	75.9 ± 9.59	82.0 ± 18.32	81.7 ± 13.64			
	24 wks	73.8 ± 12.39	80.4 ± 11.75	77.9 ± 14.20	74.3 ± 10.07	79.5 ± 19.10	79.1 ± 13.96			
	change*	−0.1 ± 1.94	−0.3 ± 2.24	−1.5 ± 3.12	−1.6 ± 3.03	−2.5 ± 3.81	−2.6 ± 3.91	.001	.011	.052
	P‡	.642	.498	<.001	<.001	.001	<.001			
BMI, kg/m^2	Baseline	29.1 ± 3.10	29.0 ± 2.46	29.8 ± 7.12	28.8 ± 2.72	29.8 ± 4.39	29.3 ± 2.90			
	24 wks	28.9 ± 3.27	28.8 ± 2.49	28.5 ± 2.61	28.1 ± 3.14	28.9 ± 4.76	28.3 ± 3.16			
	change*	−0.2 ± 0.93	−0.2 ± 0.86	−1.3 ± 6.70	−0.7 ± 1.14	−0.9 ± 1.30	−1.0 ± 1.44	.004	.010	.642
	P‡	.147	.452	.106	<.001	.001	<.001			
Waist, cm	Baseline	95.3 ± 13.46	97.9 ± 5.92	98.0 ± 8.35	96.3 ± 6.42	98.4 ± 10.83	98.2 ± 7.78			
	24 wks	95.3 ± 7.31	97.4 ± 7.44	95.0 ± 8.28	107.2 ± 103.28	94.6 ± 11.28	93.8 ± 8.65			
	change*	0.0 ± 13.24	−0.5 ± 2.93	−3.0 ± 4.08	10.9 ± 103.88	−3.8 ± 5.78	−4.4 ± 4.75	.424	.019	.035
	P‡	1.000	.366	<.001	.452	.001	<.001			
Body fat (%)	Baseline	36.6 ± 5.67	33.2 ± 6.56	34.0 ± 6.22	35.2 ± 6.51	34.1 ± 7.09	33.8 ± 7.31			
	24 wks	37.4 ± 6.06	33.4 ± 7.16	33.9 ± 6.04	35.0 ± 7.64	34.0 ± 8.04	32.2 ± 8.04			
	change*	0.8 ± 2.51	0.2 ± 2.30	−0.1 ± 3.15	−0.2 ± 4.10	−0.1 ± 2.59	−1.6 ± 3.69	.078	.572	.003
	P‡	.023	.661	.905	.659	.847	<.001			
SBP, mm Hg	Baseline	135.5 ± 15.55	135.1 ± 9.73	138.0 ± 13.80	137.7 ± 14.50	135.9 ± 15.30	139.0 ± 15.24			
	24 wks	134.8 ± 14.30	131.2 ± 13.03	133.2 ± 12.87	131.5 ± 11.64	130.2 ± 14.08	132.0 ± 14.86			
	change*	−0.7 ± 15.17	−3.90 ± 12.25	−4.8 ± 11.73	−6.2 ± 14.66	−5.7 ± 11.27	−7.0 ± 13.50	.175	.513	.670
	P‡	.753	.105	.001	.004	.008	<.001			
DBP, mm Hg	Baseline	82.2 ± 11.57	84.2 ± 8.83	84.0 ± 9.45	85.4 ± 11.57	83.8 ± 8.94	83.9 ± 12.57			
	24 wks	83.3 ± 9.95	81.5 ± 7.92	82.6 ± 8.99	81.9 ± 10.85	81.4 ± 10.30	81.4 ± 10.85			
	change*	1.1 ± 11.98	−2.7 ± 7.61	−1.4 ± 9.05	−3.5 ± 10.45	−2.4 ± 7.89	−2.5 ± 10.79	.051	.997	.704
	P‡	.524	.073	.224	.020	.098	.026			

BMI = body mass index, DBP = diastolic blood pressure, HEPA = health-enhancing physical activity, IA = insufficiently active, MA = minimally active, SBP = systolic blood pressure, SD = standard deviation.

* Change W24 = week 24–baseline.

† ANCOVA using the site and baseline weight as covariates.

‡ Paired *t* test.

Table 3

According to types of physical activities in blood chemistry, changes of within groups, and difference of between groups.

		Control group (n = 147)			Intervention group (n = 177)			Difference between groups†		
Variable	Month	IA (n = 53) Mean ± SD	MA (n = 27) Mean ± SD	HEPA (n = 67) Mean ± SD	IA (n = 52) Mean ± SD	MA (n = 31) Mean ± SD	HEPA (n = 94) Mean ± SD	IA *P*	MA *P*	HEPA *P*
FBS, mg/dL	Baseline	103.7 ± 17.65	98.1 ± 13.79	102.9 ± 15.36	98.5 ± 10.29	98.4 ± 11.81	102.4 ± 13.61			
	24 wks	97.9 ± 14.23	101.3 ± 20.87	99.9 ± 13.61	93.8 ± 9.18	96.3 ± 11.13	99.3 ± 11.99			
	change*	−5.8 ± 15.92	3.2 ± 21.90	−3.0 ± 13.82	−4.7 ± 11.51	−2.1 ± 10.32	−3.1 ± 12.04	.807	.293	.973
	P‡	.004	.422	.015	.005	.001	<.001			
HbA1c, mg/dL	Baseline	6.0 ± 0.45	5.8 ± 0.29	5.8 ± 0.42	5.8 ± 0.35	5.9 ± 0.47	5.8 ± 0.41			
	24 wks	5.8 ± 0.38	5.7 ± 0.31	5.8 ± 0.49	5.7 ± 0.37	5.7 ± 0.41	5.6 ± 0.42			
	change*	−0.2 ± 0.27	−0.1 ± 0.17	0.0 ± 0.34	−0.1 ± 0.22	−0.2 ± 0.38	−0.2 ± 0.67	.415	.124	.041
	P‡	.010	.462	.082	.005	.282	.016			
HDL-C, mg/dL	Baseline	47.1 ± 10.48	46.7 ± 12.73	48.0 ± 12.64	45.0 ± 7.31	44.6 ± 7.01	46.0 ± 10.33			
	24 wks	50.6 ± 9.82	48.0 ± 12.02	50.4 ± 12.71	48.4 ± 10.00	49.0 ± 10.11	50.0 ± 12.20			
	change*	3.5 ± 8.32	1.3 ± 8.49	2.4 ± 7.85	3.4 ± 8.37	4.4 ± 6.63	4.0 ± 7.76	.760	.091	.172
	P‡	.929	.444	.958	.497	.134	.039			
TC, mg/dL	Baseline	190.6 ± 33.44	184.7 ± 31.94	189.2 ± 37.08	190.3 ± 32.13	179.4 ± 27.99	191.6 ± 36.01			
	24 weeks	190.9 ± 31.74	179.7 ± 28.83	189.0 ± 30.29	187.5 ± 32.07	187.1 ± 29.87	186.5 ± 33.32			
	change*	0.3 ± 24.44	−5.0 ± 33.15	−0.2 ± 32.41	−2.8 ± 29.83	7.7 ± 27.99	−5.1 ± 23.74	.454	.125	.219
	P‡	<.001	.568	.093	<.001	.041	.001			
TG, mg/dL	Baseline	164.7 ± 84.86	191.3 ± 79.08	185.7 ± 129.47	163.3 ± 85.02	163.0 ± 104.84	212.5 ± 239.16			
	24 wks	145.9 ± 87.92	167.9 ± 78.04	149.1 ± 79.91	141.1 ± 83.47	141.5 ± 76.28	160.2 ± 207.55			
	change*	−18.8 ± 67.05	−23.4 ± 90.66	−36.6 ± 119.37	−22.2 ± 85.63	−21.5 ± 107.88	−52.3 ± 78.19	.700	.866	.397
	P‡	.046	.192	.014	.067	.276	<.001			

FBS = fasting blood sugar, HbA1c = hemoglobin A1c, HDL-C = high-density lipoprotein cholesterol, HEPA = health-enhancing physical activity, IA = insufficiently active, MA = minimally active, SD = standard deviation, TC = total cholesterol, TG = triglyceride.

* Change W24=week 24–baseline.

† ANCOVA using the site and baseline weight as covariates.

‡ Paired *t* test.

statistically significant larger decreases in HEPA in the intervention group than the control group. These results suggest that HBA1c should be considered as an important index that shows the relationship of blood chemistry indices and obesity.

Technologies such as m-Health are becoming more common and increasingly recognized as effective obesity management services. In addition to the development of technology, various obesity management indices such as biomarkers and blood chemistry indices should be further studied to improve the effectiveness of obesity management.

Author contributions

Chang Hee Lee, Ga-Hye Yi, Bumjo Oh designed and conducted the study. Chang Hee Lee, Bumjo Oh interpreted the results, and Booyoon Cheung, Ga-Hye Yi helped write the manuscript. Chang Hee Lee, Bumjo Oh helped obtain funding, analyzed the data. Yun Hwan Oh provided methodological support. Booyoon Cheung edited the manuscript. All authors read and approved the final manuscript.

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