Original Paper

Mobile-Based Comprehensive Weight Reduction Program of the Workplace (Health-On): Development and a Pilot Study

Abstract

Background: There is growing interest in mobile technology for obesity management. Despite the known effectiveness of workplace-based weight loss programs, there are few studies of smartphone-delivered intervention.

Objective: Development and verification of an integrated and personalized mobile technology-based weight control program, optimized for workplaces.

Method: A weight reduction algorithm was developed for calorie prescription, continuous monitoring, periodic feedback and re-evaluation, goal re-setting, and offline intervention with behavior-changing strategies. 30 obese volunteers (BMI ≥25kg/m2) participated in a 12-week Health-On pilot program. The primary outcome was weight reduction, and secondary outcomes were improved anthropometric measures, metabolic profiles, and fat CT measures, all assessed pre- and post-intervention.

Results: Health-On incorporated proprietary algorithms and several strategies intended to maximize adherence, using compatible online and offline interventions. The median body weight of the 30 participants decreased from 81.3kg (Interquatile range (IQR)77.1-87.8) before intervention to 76.6kg (IQR70.8-79.5) after the 12week intervention period($p<0.001$). The metabolic profiles and fat measures (blood pressure, HbA1c, total cholesterol, triglyceride, HDL, LDL, ALT, visceral and subcutaneous adipose tissue; $p<0.05$) also improved significantly.

Conclusions: These findings indicate that Health-On is an effective weight loss program, easily implemented in workplaces.

Keywords: weight loss programs; smartphone; workplaces; weight reduction algorithm

Introduction

Obesity is a major global health problem [1], the cause of increased morbidity and mortality, and significant health-care resources are expended on managing and preventing obesity and associated complications [2-5]. Of the options for the treatment of obesity, lifestyle interventions are the most effective, more so than drug therapy and surgery [6]. Central to obesity lifestyle interventions are two principles: negative calorie balance, and maintenance of the negativity. For physicians, a clinic setting of fragmentary visits and short consultations makes individualized feedback and instruction problematic. For patients, a daily food intake/physical activity diary is intrusive, and recollections unreliable [7].

There is growing interest in lifestyle interventions using smart devices [8], and they can be effective tools to combat obesity, helping to overcome the limitations of current interventions. Most smart devices already can measure users' physical activities and can synchronize applications.

Workplace lifestyle interventions are known to be effective for weight reduction, increased productivity, and in reducing financial burdens on employees [9-11]. Employee numbers will be fairly constant over the intervention period, and employer-provided resources (cafeteria, fitness center), messengers, and periodic health checkup services can be incorporated into the interventions. Additionally, considering the features of mobile health applications (e.g. real-time lifestyle monitoring and participant interactivity), workplaces are highly suitable for integrated intervention via mobile technology. Despite these advantages, mobile-based interventions in practice are rare.

Against this background, we developed a comprehensive mobile app (Health-On) and embarked on a pilot study to verify its workplace feasibility and effectiveness.

Methods

Development of the Health-On Application

Health-On is a program that combines online devices (mobile app and smart watch) and offline interventional resources (cafeteria, fitness center, peer support) (Figure 1). Researchers first developed the Health-On smartphone App using the Android SDK (SDK r20.0.3) [12].

Figure 1. Main pages.

To accommodate the first principle, negative calorie balance, we developed an equation to calculate total energy expenditure (TEE) and an algorithm to prescribe diet and physical activities. For the second principle, negativity maintenance, we created a daily diet/physical activities tracker and applied behavior change strategies.

Equation for Calculating an estimation of Total Energy Expenditure (TEE)

To identify the calorie consumption/expenditure negative balance, we must calculate total energy expenditure (TEE) and maintain a TEE greater than calorie intake. TEE is obtained by summating resting metabolic rate (RMR), the thermic effect of activity (TEA) and the thermogenic effect of food (TEF). We chose the predictive Cunningham equation for measuring RMR as it is an accurate formula for estimating RMR using fat-free mass and is close to measured values in Korea [13,14]. For measuring TEA, we used The International Physical Activity Questionnaire Short Form (IPAQ-SF) [15,16].

However, IPAQ-SF does not include calories expended in daily activities, e.g. showering or speaking. Thus, we estimated calorie expenditure from these to be 10% of RMR, on the premise that obese participants are sedentary [17]. TEF was assumed to be 10% of RMR+TEA [18].

TEE can be expressed as follows:

TEE=RMR+TEA(①+②)+TEF, where ①=kcal consumption from IPAQ-SF and ②=kcal consumption not included in the IPAQ-SF (for example, walking <10 minutes and other daily activities).

This equation was used to maintain the negative calorie balance between dietary intake and physical activities.

Diet and Physical Activity Prescription Algorithm

Following accepted guidelines [19], we set a recommended goal of a 7% baseline body weight loss over 12 weeks, divided into 3.0%, 2.5% and 1.5% targets for each four-week period. We assumed that a 7,000 kcal expenditure is needed to lose 1kg of fat [20], Subjects themselves determined how many negative calories they needed from their control variables, e.g. how much they should cut down on eating or how much they should increase physical activity to achieve their weight reduction goals. Then, the algorithm suggested the goals of daily calories from dietary intake necessary to achieve weight loss. These goals and variables were adjusted periodically to reflect weight change during the process. To achieve safe weight reduction, we set quantitative parameters of a minimum of 1,200 kcal per day for women and 1,500 for men [19].

Convenient Method of Tracking Daily Diet and Physical Activity

Diet

Dietary intake could be entered in the app either by inputs on a pre-entered menu or inputting using the search option.

Pre-entered Inputs

We applied various methods to minimize user effort in keying in calories. First, the workplace cafeteria daily menu nutritional data were entered into the app. Additionally, menus of restaurants nearby the workplace were entered. Menus that were frequently entered by app users were also pre-entered, thereby automatically appearing in the app.

Input by search

We embedded Canpro4.0 and FanTasy (Food and Nutrition Database System) databases [21,22]. When users consumed foods not on the pre-entered menu, they could search in the app. The typical Korean diet was provided in an easy-to-search -select and -enter list. Meals not on the list could be entered directly by the user.

Physical Activity

Physical activity could be entered in the app either by automatic input or manually.

Automatic input

Health-On enabled connectivity with an activity tracker, e.g. a smart watch, to measure usual physical activity. The collected data (expended calories and step count) were automatically sent every hour to the app via Bluetooth®, and made available to users.

Manual input

The app enables entry of type, strength, and frequency and duration of aerobic exercise, strength exercise, and common sports, as activity is difficult to measure while using fitness equipment or doing aquatic exercise. This type of user-provided information was calculated and automatically converted into expended calories based on user weight [23].

Behavior Change Strategies

This program contains several strategies for encouraging behavior change that are effective for weight reduction [24]. We modified these strategies for mobile technology applicability (e.g. individualized tailored feedback based on personal life-log and ranking). We used resources available in the workplace, e.g. the cafeteria and fitness center, in order to optimize advantages and maximize effectiveness [25].

Health Age

Health-On can calculate health age from basic health information. We had previously found that a web-based health risk appraisal (factoring in health age) can be effective for ascertaining health risks and motivating lifestyle modifications [26], and we adjusted this tool for our purposes.

Health Information

A team of nurses, nutritionists and exercise trainers devised educational material with diet and physical activity tips. This information was provided in the app daily to improve exercise and dietary habits, and ensure effective weight loss. Additionally, counseling with a nutritionist and an exercise trainer was made available through social networks.

Feedback on the Life-log

We developed feedback for self-monitoring and self-reflection on periodic results. Each day, calorie intake was compared with the goal, and goal achievement provided an incentive for further progress. A nutritionist provided feedback on participants' dietary intake records. An exercise supervisor gave feedback based on comparisons between burnt calories and exercise targets. Feedback was delivered via a pop-up.

History Query

With the history query function, users could monitor their health examination results pre- and post-program, weekly changes in body composition and measurements, and weekly dietary and exercise performance.

Competition
Good-natured competition, a useful weight loss motivation method, was introduced for promoting Health-On continuous usage. Health-On automatically adds users' friends from contact lists, enabling competition for achievement scores or step counts.

Ranking
The achievement score was based on the 7.0% weight loss success or failure compared with the starting weight+proximity to monthly goals+dietary input frequency/activity tracker usage.

Step counts
The cumulative number of steps over a period of time, recorded on the activity tracker's pedometer, was used to calculate rankings.

Health-On Program Pilot Study

Study Population
The primary purpose of this study was to evaluate the effect and safety of the Health-on weight loss program. In April 2012, an announcement targeting SK telecom workers in a workplace about the recruitment of people with BMI of more than 25kg/m^2, who were willing to control diet and exercise for weight loss had been made on the intranet.

Exclusion Criteria
We exclude anyone from the recruited members ① who had answered at least one 'yes' to the questionnaires of Physical Activity Readiness Questionnaire(PAR-Q)[27] and their eligibility to this study was judged ineligible after counseling, ② who had answered 'yes' on the eating disorder survey that were judged ineligible for this study after counseling with a doctor, ③ who had SBP ≥160mmHg or DBP 100 ≥mmHg, fasting blood sugar ≥ 160mg/dl, triglyceride≥500mg/dl, LDL-cholesterol ≥190mg/dl and judged ineligible after counseling with a doctor due to identification of more than one abnormality, ④ who were obese and had received any pharmacological, procedural, or surgical treatment within a month, ⑤ who had undergone a drastic weight change (more than 10% of body weight) within a month, ⑥ who had suffered from or received a procedure due to severe illness such as myocardial infarction, stroke, cancer-related disorders, and hip surgery, ⑦ who had been suffering from thyroid disease, ⑧and who were judged by the researcher as ineligible to participate. 30 people were finally recruited for this study.

Measurements
Anthropometric data (height, weight, percentage of body fat measured by Inbody® 720), fasting blood samples and CT scans were collected via questionnaire. Data were collected twice, before and after the 12-week intervention. Participants provided written informed consent and the Institutional Review Board approved the protocol.

Abdominal adipose tissue mass was estimated using cross-sectional images obtained by a standardized and validated CT technique [28]. Participants were examined in the supine position with a 16-detector row CT scanner (Somatom Sensation 16; Siemens Medical Solutions, Forchheim, Germany). A single umbilicus level 5mm slice image was obtained. The total abdominal adipose tissue area (TAT: subcutaneous adipose tissue (SAT) area+VAT) was calculated using specialized software (Rapidia 2.8; Infinitt, Seoul, Korea) with the attenuation values within a range of −250 to −50 Hounsfield Units. We used VAT≥100cm^2 as the criterion for visceral obesity [29].

Intervention

Based on these health indicators, weight reduction goals and target net kcals were individually determined through the Health-on algorithm.

For the first four weeks, a 600-700 kcal breakfast was provided to create a habit of not skipping breakfast. Participants were encouraged to join GX (Group eXercise) once a week at the company gym. Participants were able to check goal achievement by taking Inbody® measurements regularly.

A specialist sent review data (Life Style Guide) every fortnight, and personal contact was scheduled after the initial health check-up, when checking monthly goals, and during a post-study follow-up.

Outcomes

The primary outcome of the study was the change in weight of participants before and after the program. We also measured the change in percentage of body fat(%), lean body mass(kg), waist circumference(cm), serum triglyceride (TG), high-density lipoprotein cholesterol(HDL-C), low-density lipoprotein cholesterol (LDL-C), non-HDL cholesterol, systolic and diastolic BP (mmHg), fasting plasma glucose (FPG) (mg/dL), and visceral fat as the secondary outcomes.

Statistics

The continuous demographic variable and the baseline variable were summarized using descriptive statistics (means with standard deviations and medians with ranges). The categorical demography characteristics were summarized by frequency distribution and percentages. Comparison of the differences between pre- and post-study outcomes was done with a Wilcoxon signed rank test.

All analyses were conducted using STATA v12.1 for Windows, with a p value <0.05 used to indicate statistically significant differences (StatCorp. Houston, TX).

Results

The interventions discussed in methods (above) are incorporated into the app.

Health-On App (Online Intervention)

Health-On has four theme pages: main, diet, physical activity, and challenge and ranking. Each page allows users to easily see their achievements and to maximize user convenience and app effectiveness with a simple user interface (UI). The theme icons are on the tab menu, making movements between pages smooth and convenient (Figure2-Figure5).

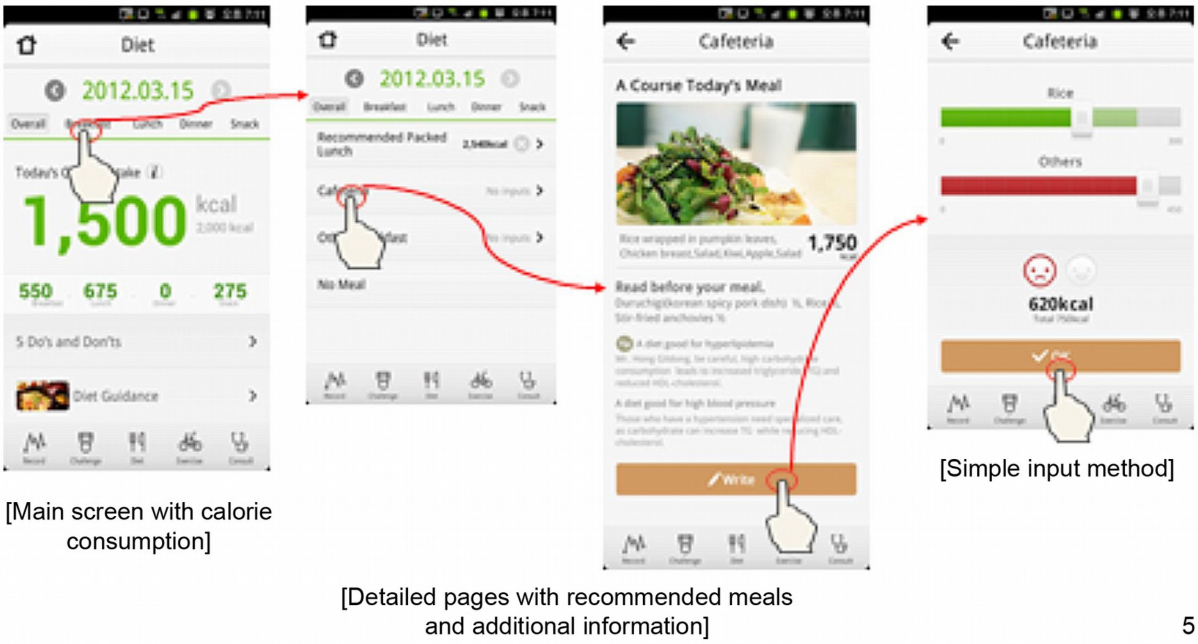

Figure 2. Diet pages.

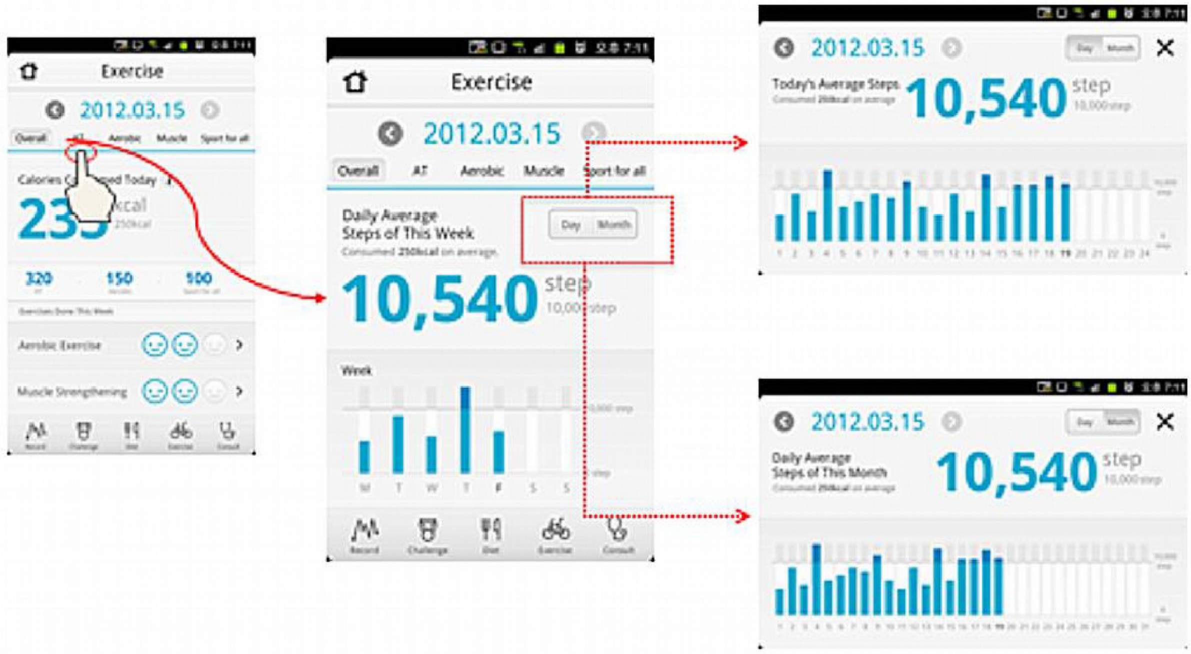

Figure 3. Physical activity pages: activity tracker.

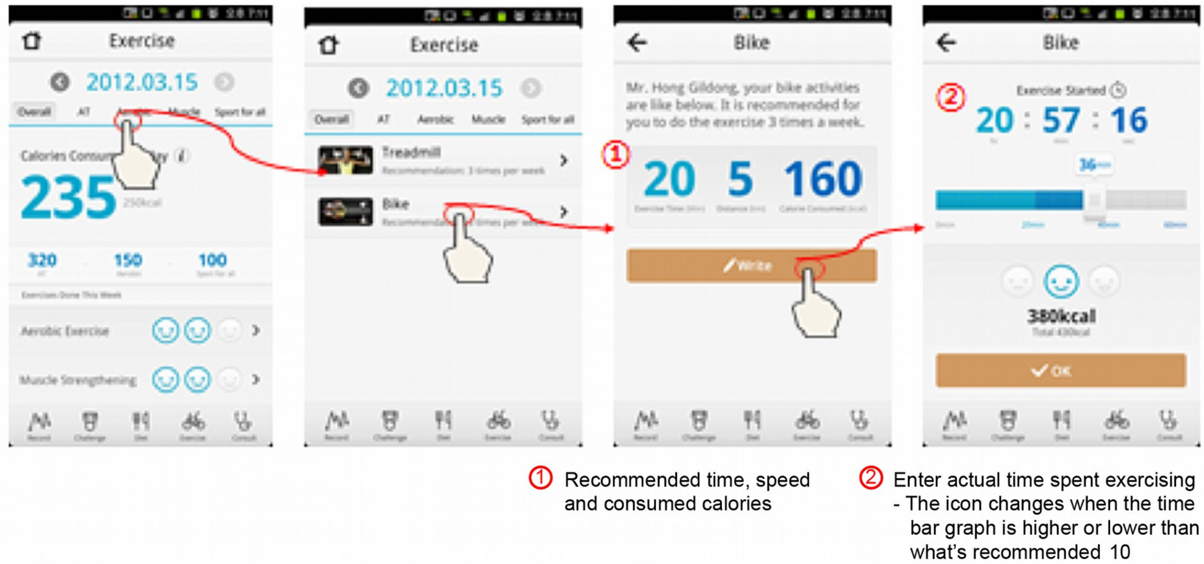

Figure 4. Physical activity pages: aerobic exercise.

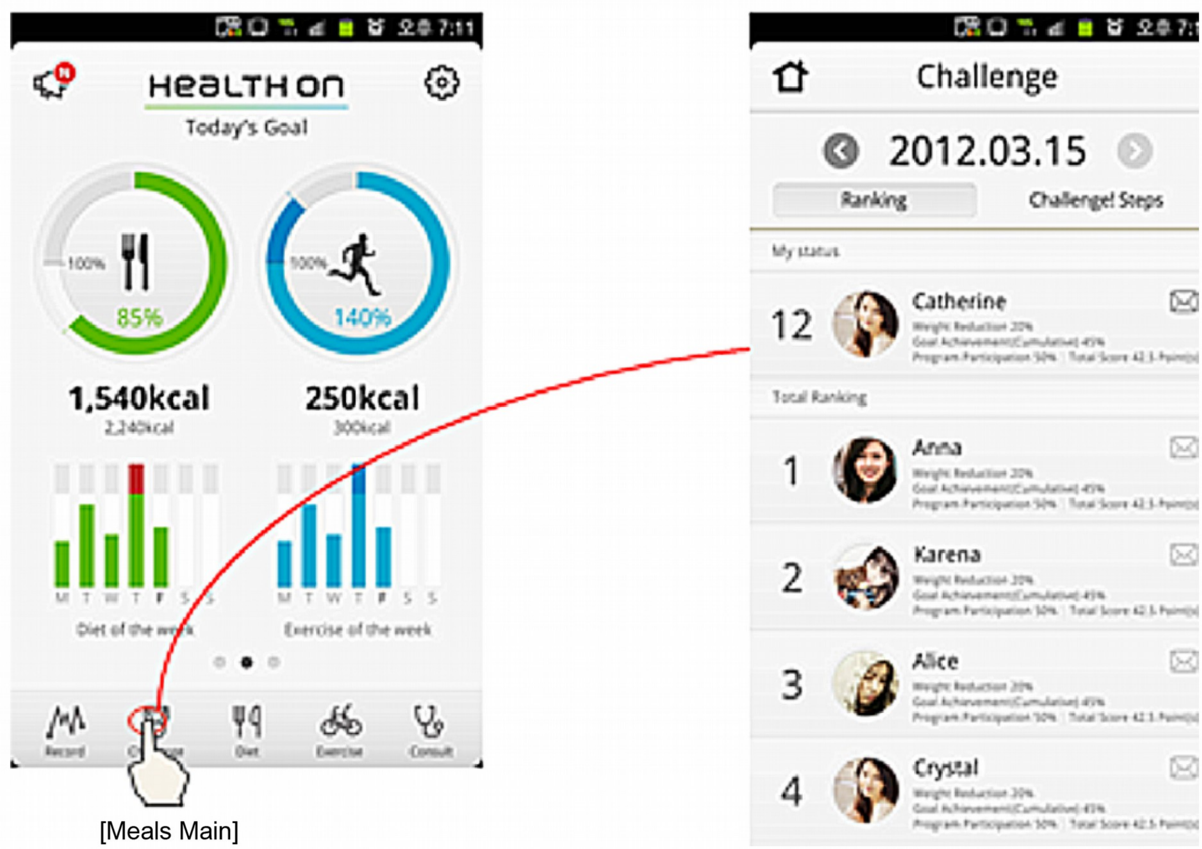

Figure 5. Challenge and ranking pages.

Offline Intervention

Recommended face-to-face components in Internet-delivered weight reduction interventions are included; this increases intervention use and effectiveness [30]. Therefore, the offline intervention for Health-On enables nurses, nutritionists and exercise trainers to inspect goal achievements and provide periodic feedback.

Pilot Study

Table 1. shows the baseline characteristics of the participants. Median age was 39 (IQR35-42), and 28(93.3%) were male. Nine people (30%) had an education level above Master's degree and the remainder were college graduates, suggesting a relatively high level of education.

Table 1. Baseline characteristics of study participants (n=30)

Variable	Median(IQR)	
Age	39	(35-42)
Male sex, n (%)	28.0	(93.3)
Academic background		
Bachelor's degree	21	(70.0)
graduate degrees or higher	9	(30.0)
Current smoker, n (%)	11	(36.7)
Drinking frequency per a week, days	1.0	(1.0-2.0)
Anthropometry		
height, cm	170.4	(166.5-173.0)
weight, kg	81.3	(77.1-87.8)
Waist circumference, cm	96.8	(93.0-102.5)
BMI, kg/m^2	28.0	(27.2-30.3)
Bioimpedance measurement		
LBM, kg	55.4	(51.6-58.3)
Body Fat, %	28.2	(25.5-30.8)
Metabolic Profile		
Systolic BP, mmHg	128	(118-132)
Diastolic BP, mmHg	75	(70-81)
Fasting plasma glucose, mg/dl	92	(87-98)
HbA1c, mg/dl	5.6	(5.5-5.8)
Total cholesterol, mg/dl	205	(174-228)
Triglyceride, mg/dl	159	(108-214)
HDL-cholesterol, mg/dl	45.5	(37.0-53.0)
LDL-cholesterol, mg/dl	131.5	(97.0-155.0)
non-HDL cholesterol, mg/dl	154	(129-195)
AST, IU/L	24	(19-31)
ALT, IU/L	30.5	(18-59)
Fat CT		
CT_fat ratio	0.64	(0.50-0.94)
Visceral fat, mm^2	140.5	(110.4-192.9)
Subcutaenous fat, mm^2	224.3	(184.0-292.8)

Data are expressed as median (IQR) or number (%) of study participants unless otherwise indicated.
Abbreviation: IQR, Interquartile range, BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).

The median of variables were, weight 81.3kg (IQR77.1-87.7), abdominal circumference 96.3cm (IQR93.0-102.5), and BMI 28.0 (IQR27.2-30.3).

Visceral fat and subcutaneous fat were measured by the Fat CT, with medians being 140.5 cm^2 (IQR110.4-192.9) and 224.3 cm^2 (IQR184.0-292.8) respectively.

Changes in anthropometric and metabolic profiles between pre- and post-intervention are shown in Table 2. The medians of weight, WC, BMI, LBM and body fat percentage reduced significantly, as did most of the metabolic profiles, especially HbA1c and non-HDL cholesterols. The changes in visceral fat and subcutaneous fat were statistically significant.

Table 2. Comparison of Outcomes before and after Health-On program (n=30)

	Baseline		Final		Difference		*P**
	Median(IQR)		Median(IQR)		Median(IQR)		
Anthropometric measurement							
Weight, kg	81.3	(77.1-87.8)	76.6	(70.8-79.5)	-6.2	(-8.4--3.9)	<0.001
Waist circumference, cm	96.8	(93.0-102.5)	88	(84.5-95.0)	-9.2	(-11--5.5)	<0.001
BMI, kg/m^2	28.0	(27.2-30.3)	25.7	(24.6-28.0)	-2.2	(-3.4--1.5)	<0.001
bioimpedance measurement							
LBM, kg	55.4	(51.6-58.3)	54.0	(51.2-57.1)	-1.0	(-2.1--0.3)	0.003
Body Fat, %	28.2	(25.5-30.8)	24.1	(20.9-27.6)	-4.65	(-6.5--1.8)	<0.001
Metabolic Profile							
SBP, mmHg	128	(118-132)	121	(107-127)	-5.5	(-14--2)	0.002
DBP, mmHg	75	(70-81)	70	(63-82)	-4	(-10-2)	0.084
Fasting plasma glucose, mg/dl	92	(87-98)	90	(86-99)	-1.5	(-8-3)	0.381
HbA1c, mg/dl	5.6	(5.5-5.8)	5.4	(5.2-5.6)	-0.2	(-0.4--0.1)	<0.001
Total cholesterol, mg/dl	205	(174-228)	185	(158-198)	-15.5	(-31--7)	0.001
Triglyceride, mg/dl	159	(108-214)	89	(57-124)	-63	(-113--25)	<0.001
HDL-cholesterol, mg/dl	45.5	(37.0-53.0)	51	(43-62)	6.5	(1-10)	0.007
LDL-cholesterol, mg/dl	131.5	(97.0-155.0)	107.5	(88-125)	-17.5	(-31--3)	0.001
non-HDL cholesterol, mg/dl	154	(129-195)	126.5	(107-145)	-21.5	(-36--11)	<0.001
AST, IU/L	24	(19-31)	22.5	(17-32)	-1.5	(-9-4)	0.229
ALT, IU/L	30.5	(18-59)	20.5	(16-30)	-5	(-28-1)	0.006
Fat CT							
CT_fat ratio	0.64	(0.50-0.94)	0.63	(0.4-0.92)	-0.05	(-0.19-0.06)	0.092
Visceral fat, cm^2	140.5	(110.4-192.9)	95.6	(732.4-133.0)	-39.4	(-60.3--16.3)	<0.001
Subcutaenous fat, cm^2	224.3	(184.0-292.8)	165.0	(117.3-237.9)	-56.4	(-77.0--20.6)	<0.001

Data are expressed as median (IQR) or number (%) of study participants unless otherwise indicated.
*Wilcoxon signed-rank test

Abbreviation: IQR, Interquartile range, LBM, LBM Lean Body Mass, SBP, Systolic Blood Pressure, DBP, Diastolic Blood Pressure, BMI, Body Mass Index (calculated as weight in kilograms divided by height in meters squared).

Discussion

Principal Results

The purpose of this study was to develop and verify a comprehensive mobile-based workplace weight reduction program.

Health-On has several strengths compared with other weight reduction apps. Although there are more than 10,000 such apps, a recent review reported that many have insufficient evidence-based content vis-a-vis U.S. government diet and exercise recommendations [30,31]. Health-On incorporates a scientifically-evidenced algorithm for estimating negative calorie balance and behavioral strategies established as effective for weight management. Additionally, requiring people to complete pre-program health questionnaires, enabled avoidance of participants with health risks. Therefore, Health-On can minimize possible adverse effects, often neglected by other apps.

We created a more convenient method of keying in data. As noted in previous self-monitoring studies, the less intrusive the tool, the higher the rate of adherence [32]. We devised several convenient ways to improve user adherence by collecting data on dietary intake and physical activities. The accuracy and sustainability of keeping a food diary is important, so we endeavored to create a user-friendly and non-intrusive UI. Instead of the food-diary method, we installed a volume bar for pre-entered diet fields so people can more conveniently record food consumption. This significantly relieves the onerous task of name-searching, and certainly increases adherence to and sustainability of the program compared to a paper food diary. As for monitoring physical activities, the entry method is more convenient than the paper diary technique that most other apps require. A better approach, such as activity tracking via wearable devices and auto-synchronizing data via Bluetooth®, can improve program adherence and compensate for participant self-reporting limitations. Furthermore, physical activities can be quantified and evaluated more accurately.

This program incorporated clinically-proven effective behavior-change strategies for facilitating weight loss, changes in diet and exercise, and preventing relapse [20,24,32,33]. It is known that if, when deciding the target weight loss, users' diet-exercise preferences are reflected on the target, greater success will result [34]. Furthermore, Health-On enables patients to monitor their lifestyles through an everyday life-log, and allows professionals to provide feedback and educational information. Behavioral changes are promoted through self-monitoring, education, feedback, and competition.

This comprehensive approach combines interventional components that have the strongest effect on obesity (e.g. healthy meals) and workplace wellness [10,35]. Most apps do not integrate diet, physical activity and behavior-change strategies [10,36].

Workplace weight management is a highly effective approach to intervention [3,11,19], and Health-On is the first-ever mobile-based workplace intervention that maximizes the advantages and suitability of workplace lifestyle interventions. Effective population-based weight management is feasible in workplaces, from which supplementary benefits flow, e.g. increased productivity, lower absenteeism and reduced medical costs [3,10,11,19].

In a meta-analytic review, Verweij et al. [37] analyzed the effectiveness of workplace interventions targeting physical activity and/or dietary behavior on outcomes. That study delivered moderate quality evidence that workplace physical activity and dietary behavior interventions significantly reduce body weight (nine studies; mean difference -1.19kg [95% CI -1.64 to -0.74] [38]. These studies did not use mobile intervention. After the 12-week Health-On program, improvements in anthropometry, bioimpedance measures, metabolic profile and visceral fat were considerable. It is possible that reduction in body weight can be greater when mobile intervention is added to conventional interventions [37].

During calorie restriction, muscle wasting prevention is important, because muscles play an important role in improving metabolic profiles and reducing insulin resistance [39]. Nevertheless, without the simultaneous modification of diet and physical activity, losing weight with a low-calorie diet alone might reduce fat and also fat-free mass [40]. It may superficially seem like a significant reduction in weight, but resisting metabolic rate and insulin sensitivity would become lower due to a reduction in muscle mass, thus resulting in the tendency of weight re-gain [40]. This study was characterized with a body fat reduction -4.65% (median difference (MD)) (IQR -6.5 to -1.8), and a decrease in muscle mass 1.0kg(MD) (IQR -2.1 to -0.3). By preventing muscle loss that could generally occur with a lower calorie diet, it could be concluded that there had been an ideal weight loss achievement with decreased tendency to long-term weight re-gain.

Interestingly, there was a significant reduction in visceral fat levels despite the short intervention period. Accumulation of visceral adipose tissue is a clinically important marker as it increases insulin resistance to induce metabolic syndrome and heightens cardiovascular risks, so the results of this study demonstrate that Health-on is effective in managing obesity and lowering the cardiovascular disease risks [41].

Through the reduction in obesity rates in workers, as many studies results previously showed, improved productivity and reduced absent rates, thus reduction in expenses could be expected from employer [42-44].

Limitations

This study has several limitations, namely:

Health-On was developed on an energy balance equation, which was based on scientific evidence such as Cunningham's equation, which estimates RMR indirectly [45]. Metabolic rate and calorie expenditure are assumed, not determined through individual differences such as genetic susceptibility to obesity.

IPAQ-SF is the desired instrument to measure physical activities, but it considers those within the previous seven days. There can be differences between daily calorie expenditure calculated from IPAQ-SF and the actual level of physical activity. Although we attempted to compensate for these shortcomings with activity trackers, discrepancies could occur [46].

Despite the short period of this Health-on study, weight reduction was substantial. However, the persistence of weight reduction was unpredictable. Thus, further research for post-program body weight changes and management is indicated.

Conclusions

Health-On is a promising workplace intervention tool, which can be used in similar environments, e.g. schools and the military, with minimal modifications. The results of this study could form a base for designing randomized clinical trials for comparison with conventional weight loss programs. Henceforth, future research should focus on the additional benefits and longitudinal effects of this program.

Acknowledgement

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Conflict of Interest

Authors have no potential conflicts of interest to disclose.

Abbreviations

IPAQ-SF: The International Physical Activity Questionnaire Short Form
IQR: Interquatile range
RMR: Resting metabolic rate
TEA: Thermic effect of activity
TEE: Total energy expenditure

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Figure Legends

Figure 1. Main pages
Figure 2. Diet pages
Figure 3. Physical activity pages: activity tracker
Figure 4. Physical activity pages: aerobic exercise
Figure 5. Challenge and ranking pages