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Lifestyle intervention using Internet of Things (IoT) for the elderly: A study protocol for a randomized control trial (the BEST-LIFE study)

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ABSTRACT

Modification of lifestyle habits, including diet and physical activity, is essential for the prevention and control of type 2 diabetes mellitus (T2DM) in elderly patients. However, individualized treatment is more critical for the elderly than for general patients. This study aimed to determine lifestyle interventions that resulted in lowering hemoglobin A_{1c} (HbA_{1c}) in Japanese pre- and early diabetic elderly subjects. The BEST-LIFE trial is an ongoing, open-label, 6-month, randomized (1:1) parallel group trial. Subjects with HbA_{1c} of ≥5.6%—randomly assigned to the intervention or control group —use wearable monitoring devices loaded with Internet of things (IoT) systems that aids them with self-management and obtaining monthly remote health guidance from a public health nurse. The primary outcome is changes in HbA_{1c} after a 6-month intervention relative to the baseline values. The secondary outcome is the change of behavior modification stages. The background, rationale, and study design of this trial are also presented. One hundred forty-five subjects have already been enrolled in this lifestyle intervention program, which will end in 2019. The BEST-LIFE trial will provide new evidence regarding the effectiveness and safety of our program on lowering HbA_{1c} in elderly subjects with T2DM. It will also investigate whether information communication technology tools and monitoring devices loaded with IoT can support health care in elderly subjects. The trial registration number is UMIN-CTR: UMIN 000023356.

Keywords: behavior modification, elderly, internet of things, lifestyle intervention, type 2 diabetes

INTRODUCTION

The prevalence of type 2 diabetes mellitus (T2DM) is gradually increasing,[1] and its ratio has increased due to the aging population.[2] Since the clinical characteristics of diabetes in elderly patients are specific,[3] proper understanding of the individual's functional capacity, comorbidity,

etc., is necessary to prevent and treat T2DM in these patient groups without the onset of adverse events.[4] Even in elderly patients, improvement of lifestyle habits such as dietary and exercise therapy is known to be effective in preventing and controlling T2DM.[4]

Since 2014, we have been collaborating with Toyota City Hall in conducting a project aimed at extending the healthy life expectancy of people who have retired from Toyota Motor Corporation (Toyota Health Navigator Club; THNC). The elderly population is generally defined as people aged 65 and over. The majority of its members consequently were elderly. In this project, a new system was developed to promote healthy behaviors by uploading previous records associated with their health conditions, including annual health screening results, to a cloud-based platform. These records were then converted into graphical data that could be accessed by the subjects by logging into their personal page ("My Page"). Moreover, we have developed a function that enables subjects to view a chart of their daily records of their activity meters, body weight (BW), and blood pressure (BP) via their My Page. From their My Page, subjects can receive personalized advice that is automatically delivered along with the programmed messages.

Although it is well known that a healthy lifestyle is essential in controlling T2DM, behavior modification is often difficult.[5] Cradock *et al.* previously reviewed that four important factors, i.e., "instruction on how to perform a behavior," "action planning," "goal setting," and "feedback and monitoring," were fundamental for the success of behavior modification techniques.[5] Accordingly, an original system was developed that utilizes wearable monitoring devices loaded with Internet of things (IoT) and facilitates remote health guidance by the public health nurse to cover these four factors.

However, the results were obtained based on an empirical project, and the scientific evidence on the effectiveness of the intervention remains unclear. Thus, the BEST-LIFE study has been implemented to clarify whether lifestyle interventions using our system could achieve the purpose of our project, i.e., prevent and control lifestyle-related diseases. In this ongoing randomized controlled study, we will evaluate the effectiveness of an exercise program as a lifestyle intervention using self-management in Japanese pre- and early- diabetic elderly individuals in the BEST-LIFE trial (the Diabetic control and BEhavior modification STage: LIFEstyle intervention using the IoT devices in senior citizens).

METHODS

Trial Design

The BEST-LIFE study is an open-label, 6-month, randomized (1:1) parallel group trial to evaluate the changes of hemoglobin A_{1c} (HbA_{1c}) and compare the structural lifestyle intervention with the usual self-care in early diabetic and pre-diabetic elderly subjects. The trial was registered in the Japanese University Hospital Medical Information Network Clinical Trials Registry (UMIN-CTR: UMIN 000023356). The protocol of the study was approved by the ethical committee of Nagoya University Graduate School of Medicine (No. 2016-0209). All patients provide written informed consent to participate in this trial.

Study Subjects

Totally, 583 of the 832 registered subjects took the annual systematic health screenings organized by THNC in November 2016. Of these individuals, 283 with HbA_{1c} levels of ≥5.6% were extracted and invited via invitation letters.

Inclusion criteria of the BEST-LIFE study are individuals with (1) HbA_{1c} levels of ≥5.6% analyzed during the health screening checkup sponsored by the THNC and (2) any age* and sex.

Subjects are excluded from this study if they are (1) individuals receiving outpatient treatment for diabetes or other diseases and who are prohibited by their attending physician to practice exercise therapy and 2) those who are determined as unsuitable based on their systematic health screening results. *Because the members of the THNC were already retired that nearly equaled elderly, we did not create the additional age limit.

Registration and Randomization

Since May 2017, we have been recruiting subjects enrolled to the current randomized trial. After obtaining informed consents and explaining this trial, subjects are enrolled via a Web-based registration and follow-up system organized by the Center for Advanced Medical and Clinical Research of the Nagoya University Hospital. The system automatically evaluates the eligibility of each patient and randomly assigns patients to the intervention or control group. The allocation ratio is 1:1, and a dynamic allocation strategy using a minimization method is used. The stratifying factors for randomization are age (<70 or ≥70 years old), sex, HbA_{1c} levels (<6.5% or ≥6.5%), and behavior modification stages (indifference and interested, preparatory, or execution and maintenance phase).

Intervention

Patients in the intervention group were provided with smartphones (Kyocera S301, Kyoto, Japan) programmed with the study-specific application, Bluetooth-enabled activity trackers (TOSHIBA Actiband WERAM1100, Tokyo, Japan), Bluetooth-enabled BP monitors (A&D UA-851PBT-C, Tokyo, Japan), and Bluetooth-enabled BW scales (A&D UC-411PBT-C). The measurements recorded in the activity meters, BW scales, and sphygmomanometer will be automatically collected and stored via the Internet. A movie filming a model of optimal exercise will be weekly delivered via "My Page." The movie will be changed to step-up/step-down depending on his/her amount of physical activity in the previous week. Lifestyle guidance was provided by a public health nurse (call center) via a telephone call once a month, and concomitantly, each participant's behavior modification stage was surveyed. Figure 1 shows the study's flowchart.

Clinical Data Collection

The subjects will be subjected to a systematic medical checkup, including blood sampling and testing similar to the annual health checkup 6 months after starting the trial. We will collect laboratory data on HbA_{1c}, total cholesterol, triglyceride, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, serum creatinine, uric acid, blood sugar (fasting), and hemoglobin levels determined at the clinical chemistry facility of Oriental Clinic Med. Corp. (Nagoya, Japan). We will also measure the height, BW, systolic BP (SBP), and diastolic BP (DBP) at baseline and after 6 months.

Assessment of Physical Activity and Stage of Health Behavior

The number of daily steps will be extracted from the uploaded data. Physical activity is assessed using the original physical activity score (PAS) that is defined according to the algorithm: daily physical activity score = [(score of exercise strength) × (score of duration) × (score of frequency)] × (number of times/day). Each score is determined using the score of exercise strength corresponding with 1, 10, 100, and 1000 to 3–3.9, 4–5.4, 5.5–6.9, and >7 metabolic equivalents (METs), respectively; the score of duration corresponds with 1, 10, and 100 to 10–29, 30–64, and >65 min, respectively; and the frequency on 1, 10, and 20 corresponds to once–twice, 3–4 times, >5 times per week, respectively.

The subjects' previous health checkup results and information regarding their lifestyle habits
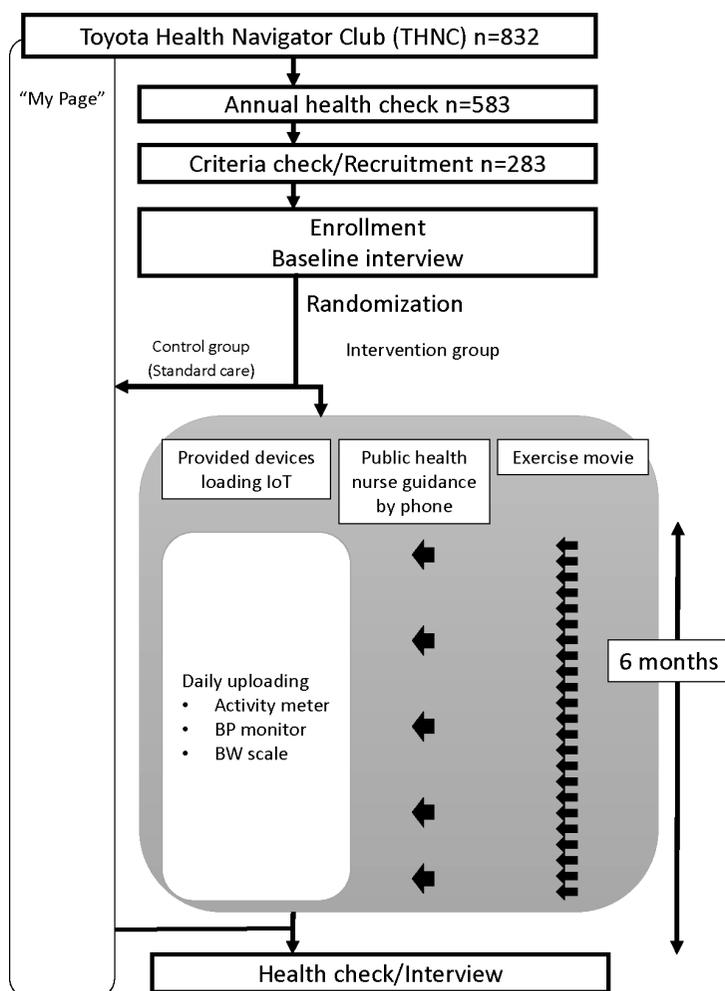
Fig. 1 Flowchart of the current trial

such as diet contents, smoking habits, and amount of physical exercise will be collected through a subject interview, and the database will be created. We grade the stages of health behavior (SHB) using a self-administered questionnaire at the baseline and after 6 months. Regarding the habit of regular physical exercise, the healthy dietary habit, and smoking cessation, they should check the box with the following statements: (1) You have no intention to change the behavior (Pre-contemplation), (2) You acknowledge an intention to change the behavior (Contemplation), (3) You actively plan to change the behavior (Determination), (4) You will change the behavior but within 6 months only (Action), (5) You sustain the behavior change for at least 6 months (Maintenance).

End-Points

The primary end-point is the change in HbA_{1c} from baseline to 6 months. The secondary end-points are the change in SHB, BP, and BW. Furthermore, as an exploratory study, indicators

associated with the variations of HbA$_{1c}$ levels such as daily steps and PAS in the intervention group will be investigated. In the initial version of the study protocol, the primary end-point was the change in behavior modification stages. The primary end-point was changed from SHB to HbA$_{1c}$ modification after the approval from the ethical committee on June 14, 2017, because the majority of SHB already belonged to the action and maintenance stage.

Sample Size

According to the findings of the previous studies that examined the effects of lifestyle modification on diabetes control,[6] improvement in HbA$_{1c}$ levels after intervention has been reportedly showing a standard deviation of approximately 0.5%. Assuming that a ≥0.25% improvement in HbA$_{1c}$ level is considered clinically significant, improvement in HbA$_{1c}$ levels of the intervention group will be expected to be >0.25% compared to that of the control group in this trial.

A total of ≥126 cases, including at least 63 cases per group, are required under the following conditions: a significance level of 0.05 (on both sides) and a power of 80%. As some cases may be deemed as unsuitable for evaluation, we aim to accumulate a total of 140 cases, with 70 cases per group.

Statistical Analysis

To evaluate the primary outcome, the amount of HbA$_{1c}$ will be compared between the treatment groups based on an analysis of covariance using the baseline HbA$_{1c}$, sex, and age as covariates.

Regarding the behavior modification stages as secondary end-points, comparisons will be performed between the intervention and control groups to estimate the effects on the behavior modification stages. Regarding the percentage of patients with a behavior modification stage at the execution or maintenance phase 6 months after the intervention, the groups will be compared using the Pearson's chi-square test. Furthermore, based on the logistic regression used as the outcome variable, the percentage of patients with a behavior modification stage at the execution or maintenance phase 6 months after the intervention and the odds ratio of reaching the execution/ maintenance phase will be calculated to estimate the effects of the intervention on the behavior modification stage. Sex, age, baseline HbA$_{1c}$ levels, and baseline behavior modification stages will be considered as covariates. To complement the results of the aforementioned analyses, the association between the behavior modification stage and the existence or absence of intervention will be examined by performing an extended Mantel test using the following layers: sex, age (<70 or ≥70 years), baseline HbA$_{1c}$ levels measured (<6.5% or ≥6.5%), and baseline behavior modification stages.

The changes in BP and BW as secondary end-points will be compared between the treatment groups based on the analysis of covariance using the baseline BP and BW, sex, and age as covariates, respectively.

Regarding the daily steps and PAS in the intervention group, during the intervention period, based on the differences between the baseline HbA$_{1c}$ levels and those 6 months after intervention, the intervention group will be divided into two subgroups at the median value. After divided into two groups according to the median value of delta HbA$_{1c}$ levels, a linear mixed model will be used to determine at what time in the observation period the differences in the device data occurred between the groups with a good degree of improved HbA$_{1c}$ levels and the other groups. Similarly, BP and BW will also be analyzed, and their amount of variation will be assessed.

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RESULTS

From May 28 to 30, 2017, a total of 145 subjects were enrolled: 72 in the intervention group and 73 in the control group. The enrollment completed. To date (September 2017), only three subjects have refused to participate in the study. The intervention period will end on November 2017. The study will end in 2019.

DISCUSSION

This study aimed to clarify whether lifestyle interventions, especially increased physical activity, could decrease HbA_{1c} levels in Japanese pre- and early diabetic elderly subjects in the RCT design. This is one of the first RCTs evaluating the self-management program to promote health behaviors using the wearable monitoring devices loaded with IoT and a remote health guidance.

According to the 2016 American Diabetes Association (ADA)'s standards of medical care in diabetes, adults with diabetes should perform at least 150 min of aerobic exercises for 3 days per week with no more than 2 consecutive days without exercise.[7] The randomized control study conducted by The Diabetes Prevention Program Research Group in the USA showed that lifestyle interventions, including diet and exercise were more effective in preventing the development of type 2 diabetes than metformin, a commonly prescribed medicine for T2DM.[8] Interestingly, ≥60-year-old subjects in the lifestyle intervention groups had notably greater reduction in diabetes incidence than the younger subjects.[8] However, "aging" alone is susceptibility to impair physical function, diabetes accelerates the reduction in muscle mass, strength, and function, and leads to sarcopenia and frailty.[9,10] Moreover, limitations in physical function are already prevalent among elderly people with pre-diabetes.[11] Although T2DM is generally closely associated with obesity, an inverse linear relationship was observed between age at the time of T2DM diagnosis and body mass index.[12] Thus, in non-obese elderly patients, alternative caution should be exerted to prevent contradictory effects of dietary therapy, such as excessive caloric restriction that may lead to malnutrition or decreased skeletal muscle mass. Moreover, both young and adult onset of T2DM had a high risk of cardiovascular diseases,[12] which has rapidly increased in Japan.[13] The benefits of healthy lifestyle modification are also established in patients with T2DM at high risk of cardiovascular disease, where physical activity is recommended and not contraindicated.[14] Thus, a reasonable menu appropriate for each individual should be created to achieve the goal without adverse events. Aerobic exercises should be prescribed for better glycemic control whenever possible, and muscle strength training (isometric) exercises, so-called resistance exercise, may be safe and preferable to help maintain the skeletal muscle mass and increase basal metabolism.[15] One of the special characteristics of our program is to use the wearable monitoring system loaded with IoT for accurate monitoring.

Another special characteristic is using the remote health guidance given by the public health nurse during planning of routine to prevent overuse injury, or for the early detection of complications such as a heart attack. A remote guidance via a telephone call could be cost-effective and less time-consuming for the participant. Moreover, it might be encouraging and motivating for the retirees to regain appropriate and detailed advice from expert public health nurses, which they received while at work. Furthermore, we deliver a weekly movie for individually specific optimal exercise via the "My Page."

The BEST-LIFE trial is a randomized controlled study to evaluate the effectiveness and safety of an exercise program as a lifestyle intervention using the wearable monitoring system loaded with IoT and the remote health guidance by the public health nurse in Japanese pre- and early

diabetic elderly subjects. Although further studies are needed, this study will provide evidence of effective and safe healthy lifestyle intervention tool in elderly subjects with diabetes. Moreover, continuous healthy lifestyle practices in elderly pre- and early diabetic patients will contribute to good glycemic control and reduce the risks for frailty and sarcopenia, leading to healthy life expectancy extensions.

CONFLICT OF INTEREST

There are no conflicts of interest to declare.

ACKNOWLEDGMENTS

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