The Effects of an 18-Month Walking Habit Intervention on Reducing the Medical Costs of Diabetes, Hypertension, and Hyperlipidemia—A Prospective Study

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Abstract Chronic diseases such as diabetes, hypertension, and hyperlipidemia increase the medical costs for middle-aged and elderly people, thus requiring preventive intervention. Monitoring, maintaining, or increasing the number of steps walked per day could be expected to effectively reduce medical costs. We evaluated the medical costs for chronic diseases after the implementation of a step count monitoring system with an information communication technology that we hypothesized would efficiently decrease medical costs. We enrolled 342 subjects in the intervention group. An additional 1,025 subjects were selected as controls by matching with the intervention group for age, gender, and total medical costs accumulated in the year prior to the study. The subjects in the intervention group were provided with pedometers that were used with reading devices stationed throughout the city. The duration of the intervention was 18 months. The subjects were given health points based on their activity performance improvements such as the number of steps they walked. The medical costs for the 18 months before and after the intervention were compared. The effect of cost reduction was evaluated by comparing the percent increase in medical cost from before to after intervention between the control group and the intervention group. The step counts for the first three months and the last three months of the intervention period were assessed, and the results showed that an average step count of 8000 steps was maintained throughout the intervention period. Assuming that the control group showed a natural increase in medical costs, the results suggest that the natural increase in medical costs was suppressed in the intervention group during the intervention period as a result of using the pedometer technology and health points. Therefore, we found that encouraging the participants to proactively participate in walking was an effective strategy.

Keywords: walking, medical costs, chronic diseases, step counting technology by information communication technology.

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1. Introduction

Chronic diseases such as diabetes, hypertension, and hyperlipidemia increase medical costs for middle-aged and elderly people. Chronic diseases also contribute to the development of multiple chronic disorders [1]. While hyperlipidemia and hypertension further increase such risks, improvement of these conditions has been shown to lower overall risks [2–5]. Interventions involving physical activity were found to reduce the progression toward insulin resistance. However, most interventions were carried out in select groups such as groups of people with impaired glucose tolerance [6]. Data from cohort studies that use questionnaires to measure physical activity strongly support the independent role of physical activity [7].

In recent studies, moderate exercises such as walking have been shown to decrease the risk of type 2 diabetes and coronary heart disease [7–10]. Assessing walking in terms of gait speed is a well established physical function measure that predicts adverse health outcomes and mortality [11, 12]. A decline in gait speed may be an ear-
ly cause of decline in physical function, development of disability, and loss of independence, which are associated with poorer survival in older adults [13].

A structured combination of physical exercise and lifestyle improvement is necessary for the prevention, improvement, and management of chronic disorders. However, previous studies have found that it is challenging to clearly analyze the effect of interventions for chronic diseases on cost-effectiveness and cost-utility [14, 15]. These interventions often impose a stringent or moderately stringent control of blood pressure and sugar levels in patients with chronic disorders [16]. However, interventions that encourage proactive, enjoyable participation from subjects are not considered. Further, the changes in medical costs and physical function in patients with diabetes, hypertension, and hyperlipidemia, or a combination of these have not been fully evaluated to date.

For patients with such diseases, supporting exercise may be effective in improving physical function and reducing medical costs. For instance, walking can be easily carried out in daily life. With the development of convenient means of transportation (such as cars), it is necessary for people to consciously develop a walking habit for disease management and to reduce future disease risk.

Nowadays, the number of steps an individual takes can be easily monitored using a pedometer. In addition, Internet-based interventions to change behavior can be widely disseminated at a relatively low cost. In a previous study on an Internet-mediated walking program using a pedometer, the researchers found that adding online community features did not increase average daily step counts [17]. Other previous studies used a financial incentive of USD 100 and a lottery incentive program, but financial incentives offered through a pedometer did not result in older adults walking more [18, 19].

Furthermore, most interventions spanned less than 24 weeks [20]. No studies gathered daily steps over a long period to examine the effect of walking on medical costs. Therefore, in this study, we aimed to examine the effect of walking on medical costs in middle-aged and elderly people by developing and using a pedometer and recording system that was able to monitor participants’ number of steps.

In this study, the environment for active participation was prepared by providing participants with health points as incentives to proactively involve themselves in activities. We hypothesized that the pedometer and recording system using information communication technology (ICT) efficiently reduces the medical costs of chronic diseases.

2. Methods

2.1 Subjects

This project was carried out by combining the city health promotion activity and our research. The population of the city is approximately 73,000 people and is positioned as a big commuter town. Subjects were recruited by the city’s public relations department through public advertisements. Disposition of the subjects is shown in Fig. 1. All subjects were capable of walking without assistance.

![Fig. 1](image_url) Disposition of study subjects.
The exclusion criteria were as follows: those who died during the intervention period, those who did not participate in all examinations, and those who could not walk independently at the time of intervention.

The analysis was performed for 18 months from October 2015 to March 2017, and medical costs were analyzed from April 2014 to March 2017.

The sample size was calculated from the total population of the municipality, selecting those aged 41 to 72 years and covered by National Health Insurance (n = 12,566), upon stratification by age, gender, whether the subject participated in physical evaluations over the past two years, and total medical costs in the year prior to the study. A sample size required for a 5% tolerance and a confidence interval of 95% with an effect size of 0.2 was calculated to be 393 people.

Finally, the intervention group consisted of 342 individuals and the control group of 1,025.

The National Health Insurance is community-based and targets farmers, self-employed persons, pensioners, and their dependents. The baseline medical costs of the two groups had to be comparable, with a similar distribution of diseases within the subject population. This study was designed to use a prospective cohort.

The total accumulated medical costs for the year preceding the study were included to better match the subjects between the two groups, such as the number of subjects with diabetes, hypertension, and hyperlipidemia, as well as their severity.

As shown in Table 1, the average age of the subjects in the intervention group at the start of the intervention was 68.5 ± 5.1 years (male: 69.6 ± 3.6 years; female: 68.1 ± 5.6 years; mean ± SD), and that in the control group was 68.3 ± 5.7 years (male: 68.8 ± 5.4 years; female: 68.3 ± 5.8 years). There was no significant difference in age between the two genders. The control subjects were selected by matching with the intervention group for age, gender, and total medical costs accumulated in the year prior to the study. The control group and the intervention group did not differ significantly in the number of subjects, age or medical costs for diabetes, hypertension or hyperlipidemia, or any number of the three diseases. There were also no age and gender differences between the intervention and control groups.

The medical records for the most recent year were collected from each subject, and data related to the diseases included in the study were extracted by sorting the treatment records under the ICD-10 codes for diseases. Medical activities related to diabetes were recorded under code E1, those related to hypertension were recorded under codes I10 and I12, and those related to hyperlipidemia under E78. Medical costs referred to the total medical expenses defined as the sum of in-hospital and outpatient medical costs.

The study design was approved by the Ethical Review Board at the Tokyo Healthcare University and the

### Table 1: Ages of subjects by disease and chronic condition.

| Disease / Chronic Condition | Intervention group | Control group | Age differences | Medical cost differences |
|-----------------------------|--------------------|---------------|-----------------|-------------------------|
|                             | n                  | Age [year]    | Medical cost [US$] | Age differences P (95% CI) | Medical cost differences P (95% CI) |
| Total                       | 342                | 68.5 ± 5.1    | 2071.4          | p = 0.37                 | p = 0.64                 |
|                             | 1025               | 68.3 ± 5.7    | 1933.5          | (−0.38 to 0.97)          | (−443.3 to 719.1)        |
| Diabetes                    | 127                | 67.9 ± 5.5    | 3579.4          | p = 0.70                 | p = 0.40                 |
|                             | 360                | 69.5 ± 4.3    | 2973.5          | (−0.68 to 1.00)          | (−801.6 to 2013.5)       |
| Hypertension                | 120                | 69.2 ± 4.3    | 3048.7          | p = 0.32                 | p = 0.52                 |
|                             | 443                | 69.6 ± 3.9    | 2619.4          | (−1.29 to 0.42)          | (−864.4 to 1723.1)       |
| Hyperlipidemia              | 109                | 69.3 ± 3.6    | 3745.8          | p = 0.96                 | p = 0.08                 |
|                             | 334                | 69.2 ± 4.5    | 2473.9          | (−0.83 to 0.84)          | (−136.8 to 2680.5)       |
| 0 chronic disease           | 139                | 67.7 ± 5.9    | 924.4           | p = 0.09                 | p = 0.49                 |
|                             | 386                | 66.6 ± 7.0    | 1122.8          | (−0.17 to 2.45)          | (289.9 to −767.9)        |
| 1 chronic disease           | 90                 | 68.4 ± 5.2    | 1702.1          | p = 0.60                 | p = 0.90                 |
|                             | 267                | 68.8 ± 5.0    | 1743.3          | (−1.56 to 0.92)          | (335.5 to −701.0)        |
| 2 chronic diseases          | 73                 | 69.9 ± 3.5    | 2803.5          | p = 0.73                 | p = 0.81                 |
|                             | 246                | 69.7 ± 3.6    | 2671.5          | (−0.76 to 1.11)          | (551.0 to −952.1)        |
| 3 chronic diseases          | 40                 | 69.5 ± 3.5    | 5551.8          | p = 0.80                 | p = 0.24                 |
|                             | 126                | 69.7 ± 4.4    | 3379.1          | (−1.53 to 1.15)          | (1833.7 to −1448.0)      |

(mean ± SD)
Personal Information Review Board of the subjects’ city of residence. Subjects included in the intervention group were given oral and written explanations of the study. All subjects in the intervention group signed a consent form prior to the study.

2.2 Step count recording system and health points

The study had a unique design. Subjects in the intervention group were given incentives to participate in the study activities proactively. Step count was done using a near field communication-equipped (NFC) pedometer that could be scanned at reader device stations installed in 27 locations across the city. Subjects who consented to participate were provided with the pedometer made by A&D (UW-101). We developed our own recording terminal connected to the network installed in the city. The steps taken were stored in the Cloud. The system was designed to scan the ID of NFC, enabling the chronological and geographical tracking of subjects.

In this experiment, to sustain the motivation to walk, participants who continued to walk were given health points. In other words, by reaching a target average number of daily and monthly steps, the participants were given points that could be redeemed for a maximum of USD 100 per year. Subjects were informed of the standard recommended number of steps by age and were awarded points based on the steps completed beyond the standard amount. To improve the motivation of all subjects including those who were fragile and incapable of completing the recommended steps for their age, bonus points were also granted for completing more steps than in the previous month.

When subjects scanned the pedometer at the reader device, they were able to see the points gained at each scan, the bonus points, and the accumulated points. In addition, the total steps accumulated over the past seven days, month, and year were also accessible. The average amount that the subjects obtained per year was USD 31.2.

2.3 Statistical analysis

The total amount of medical costs for the 18 months immediately prior to the intervention was evaluated against the costs accumulated during the intervention period. The evaluations of subjects with diabetes, hypertension, and hyperlipidemia were based on the subject’s receipts for health insurance claims for the 18 months prior to the intervention.

Statistical analysis software (SPSS version 24) was used for the analysis. An independent t-test was used to evaluate the differences in age and medical cost between the intervention and control groups.

A two-way repeated measures analysis of variance (ANOVA) was used to compare disease conditions: 2 conditions (intervention, control) × 2 times (prior, after intervention) were tested for each condition (diabetes, hypertension, hyperlipidemia, chronic conditions).

A two-way repeated ANOVA was used to analyze the changes in number of step in the first and last three months for each disease. A one-way ANOVA was performed to analyze age and medical cost by quartiles of steps.

3. Results

3.1 Medical costs at baseline

Some subjects in this study had diabetes, hypertension, and hyperlipidemia. These three diseases affected 31.9–37.1% of the entire sample population, while 40.6% of the sample population did not have any of these diseases, and 11.7% had all three diseases. As the number of comorbidities increased, the accumulated medical costs also tended to increase. Among the subjects who had two or more diseases (diabetes, hypertension and hyperlipidemia), many incurred high baseline medical costs.

3.2 Impact of intervention on medical cost

The changes in medical costs as a result in the intervention are shown in Table 2. The medical costs increased 1.34 times over the 18 months in the control group and 1.13 times in the intervention group.

The increase ratios were higher for patients with hypertension and hyperlipidemia within the control group, with increase ratios of 1.35 and 1.27 times the baseline, respectively.

The control subjects who had chronic conditions showed 1.23–1.31 times increases in medical costs between the pre-intervention and intervention periods. However, for the intervention group, the increase remained at 0.96–1.05 times the baseline.

3.3 Step counts for each disease

Table 3 displays the average step counts per day for 18 months, the average step counts for the first and last three months, and the average data acquisition days for one month. The average step counts were higher than 8,000 steps for each disease. However, the number of steps in the hypertension and three chronic conditions groups tended to decrease.

We calculated quartiles to classify the step counts into four groups: < 6,426 steps (aged 67.6 ± 5.9 years) (mean ± SD), < 8,335 steps (aged 67.6 ± 6.3 years), < 10,274 steps (aged 68.6 ± 4.2 years), and ≥ 10,274 (aged 69.2 ± 4.2 years). There was no age difference among the step quartiles.

For 18 months, this experiment had a capture rate of at least 90.3%, with 27.1 days of data collected per
4. Discussion

4.1 Impact of medical cost for intervention

We developed a system with the additional feature of giving subjects an incentive based on the number of steps taken. Its effectiveness in terms of reducing the medical costs for diabetes, hypertension, and hyperlipidemia, and the numbers of patients with these diseases were then evaluated. From Table 1, the control group had approximately three times the number of subjects compared to the intervention group. As a result, the number of individuals with each disease in the control group was also approximately three times that in the intervention group.

The total medical costs of the control group increased after the intervention (1.34 times the baseline), but there was no significant increase in medical costs in the intervention group. Medical needs for the study pop-
ulation were generally considered to be high, as the average age was over 68 in both the intervention and control groups. Assuming that the increase in medical costs in the control group was a natural increase, the findings suggested that the medical costs in the intervention group were suppressed by the walking habit intervention.

Regarding hypertension and hyperlipidemia, medical costs increased over the period of study in the control group. Although the difference was not significant for diabetes, the medical costs increased 1.18 times. On the other hand, the intervention group did not exhibit a statistically significant increase in medical costs after the intervention for all three types of diseases.

Similarly, medical costs increased in control subjects with a number of chronic diseases, but the medical costs in the intervention group were maintained. As was also demonstrated in previous research, our results suggest that walking is effective for the prevention of chronic diseases, consequently reducing the medical costs in patients with multiple chronic conditions [21, 22]. The results indicate that the intervention of developing a walking habit is effective for managing chronic diseases.

Preventive activities are not always effective in curbing long-term medical costs [23]. It has been reported that even if the effect of improvement of medical costs is recognized in the short term, results of research on lifetime medical costs are mixed. However, even if there is no cost-saving effect, we can evaluate cost-effective activities that show health promotion effects. As this study collected data for only an 18-month intervention period, cost-saving effects cannot be addressed, but cost-effective effects are presumed.

Previous studies have reported that participation in social communities, as well as walking, improve cognitive function and depression. A multi-level survival analysis with a community-level random intercept showed that in communities with high civic participation, women who actively participated in community groups showed greater functional ability improvement than those who did not [24]. Furthermore, it has been reported that older adults’ participation in community groups may reduce future long-term care costs [25]. It is expected that the same result will be obtained in this study.

However, in the target city, the fact that the number of medical facilities is low may also affect medical costs. Compared to the average number of medical facilities per 100,000 population in Japan, the number of clinics in that city is only 69% of the national average and the number of hospitals with 20 beds or more is 42%. Furthermore, there are no hospitals with more than 120 beds. However, because it is a commuter town, there are several large hospitals within one hour of driving.

4.2 Effect of activity on intervention
This study did not aim to reduce medical costs through increasing the number of steps using the novel system. It aims to encourage long-term walking by making walking a habit and visualizing the number of steps.

As a result of monitoring step counts with this system, the average step count exceeded 8,000 steps for all diseases. In a previous study that examined the relationship between pedometer-assessed daily step count and all-cause mortality in community-dwelling 71-year-old individuals [26], the participants were divided into quartiles based on the average number of steps/day (first quartile, < 4,503 steps/day; second quartile, 4,503–6,110 steps/day; third quartile, 6,111–7,971 steps/day; fourth quartile, > 7,972 steps/day). Compared with that previous study, the subjects in the present study took approximately 1.3 times more steps per quartile, despite having approximately the same average age. Another study found that an increase in physical activity induced benefit uniformly across conditions and diseases; the morbidity and associated healthcare costs appeared to decrease as physical activity increased [27]. Overall, the results suggest it is possible to improve the health level and improve medical costs with physical activity.

By visualizing the daily number of steps, we believe the participants subconsciously became aware of their step counts. As such, we found that the average step counts were maintained at a high rate. In general, although the motivation is high at first, it will, arguably, decrease after a year or more. From our results, however, there was no such tendency. The average number of steps was maintained at 8000 steps.

The average data acquisition days for one month by this system were just over 27.1. Although a previous study conducted an examination using the average number of steps for seven days [26], the present study tracked the step count every day.

A previous study did not fully demonstrate the effect of maintaining a walking routine on improving medical costs [14]. In this study, we visualized daily step count data using a pedometer and reader device stations in the city. We also used health points to motivate the subjects. This guaranteed the maintenance of the step counts which was found to correlate with the improvement in medical costs.

4.3 Limitations
This study has some limitations in terms of subject selection. The subjects were enrolled through public advertisement, and they may have enrolled proactively or prompted by suggestions of relatives or acquaintances, which could have increased their motivation. Thus, to account for the variations in motivation, subjects’ participa-
tion in health examinations over the preceding two years was included. Therefore, records of participation in physical examination in the two years immediately preceding the study were included to adjust for the subjects’ level of interest in their own health. Those who chose not to seek physical examinations were judged to have a low level of interest. The records for the two years were used to improve the accuracy of the selection process. Further, a sufficient number of control group participants were included.

Based on the results of the questionnaire distributed to the subjects who received intervention, the proportion of respondents who had hitherto participated in other projects organized by the city (such as exercise and nutrition classes sponsored by the city hall) was 25%, which was not considered to be a highly significant percentage of the group. Another limitation is that the medical costs evaluated in this study did not include dental work or over-the-counter drugs.

Further, we assessed only the change in medical costs and the number of steps during the intervention period. As such, it is not possible to estimate the effects of lifetime medical costs.

Since the control group did not have an activity meter, it was not possible to assess the change in the number of steps.

5. Conclusion
An assistive system using ICT was developed to facilitate monitoring of outdoor activities and track walking visually. The effectiveness of the system in reducing medical costs was evaluated by tracing the changes in the medical cost of specified disorders (chronic conditions).

During 18 months of intervention, the medical costs of subjects with multiple chronic diseases were not increased. This study was designed to encourage subjects to participate proactively by allowing them to visually track their walking while providing incentives for progression. These incentives were effective in decreasing medical costs.

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KY and TY planned the study, supervised the data analysis, and wrote the paper. KY, TY, MS, MI, and YT performed all measurements and contributed to data acquisition. KY, TY, MS, and MI performed all statistical analyses and contributed to revising the paper. YT helped plan the study, including the instrumentation and revision of the manuscript.

Conflict of interest
There are no conflicts of interest to declare.

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Data sharing statement
This study did not involve clinical trials; thus, individual participant data are not available.

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