Application of a pedometer in a clinical setting: is the number of walking steps predictive of changes in blood pressure?

Prediction of blood pressure changes in blod presure by a peadmeter

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***Abstract*—A pedometer is a popular wearable sensor used to enumerate walking steps taken per day and in this way determines the approximate distance traveled. In this study, we used blood pressure and walking step data, obtained from 48 patients in a home healthcare system, to investigate the effectiveness of the pedometer in a clinical setting. Changes in blood pressure and walking steps per day were compared. Our results indicate that walking, as a regular form of exercise, contributed to lowering of blood pressure. Thus the pedometer is useful for improving the quality of life of patients in the home healthcare setting**

Keywords*— *blood pressure, pedometer, walking, clinical evaluation

I. INTRODUCTION

Walking is a simple exercise that can be used to maintain health. A criterion reference of 10,000 steps per day is currently recommended; *i.e.*, taking 10,000 steps per day has been widely promoted as the target for achieving health-related benefits. A pedometer is a small, light, and easy-to-use sensor that allows accurate enumeration of walking steps. Wearable sensors are used to assist individuals to maintain their health and improve their quality of life. Recently, more sophisticated pedometers equipped with a USB port have made transfer of data to personal computers (PCs) or web-based databases easier. This has allowed the pedometer to be used as a home health care device.

With the greater involvement of information communication technology (ICT) in medicine, home healthcare systems have become increasingly common. Use of such systems reduces the number of post-operative hospital visits, and can be used to monitor the health of middle-aged patients who may be at risk of diseases such as cancer, stroke, and infarct. In an effort to prevent these diseases, the healthcare system usually focuses on three main issues: food intake, amount of sleep, and exercise. Weight control, suitable exercise, and better sleep are usually recommended. The pedometer is widely used to monitor walking, a commonly prescribed exercise regimen.

Two studies of the effectiveness of walking in terms of systolic and diastolic blood pressure control have been published [1,2]. Here we determined the effectiveness of the pedometer as a home healthcare monitoring sensor, and investigated its ability to predict elevations in systolic and diastolic blood pressures

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II. METHOD AND SUBJECTS

A. Home healthcare system

Our home healthcare system monitored blood pressure, body weight, and the number of steps taken per day. These parameters were measured using home healthcare devices that met the Continua Health Alliance standards, as shown in Figure 1. Systolic and diastolic blood pressure were measured using a blood pressure monitor (BP-301, Tanita, Tokyo, Japan). Body weight was assessed using a body-composition monitor (BC-503, Tanita). The number of steps walked per day was determined using a pedometer (FB-723, Tanita). The data obtained from the pedometer were transmitted via infrared wireless communication to a Web server using a receiver (MY101, Tanita, Tokyo, Japan). These data were then uploaded and stored on the home healthcare server, where it was made available to medical personnel for monitoring purposes.

In this study, our main priority was lowering of blood pressure via walking exercise. Personality assessments were performed to taylor goals to each patient. Data from the initial physical examination (*i.e.*, body weight, waist circumference, and blood pressure) were recorded. Goals were set for each patient on the basis of these data, and methods of losing weight through changes in diet and/or exercise were recommended.

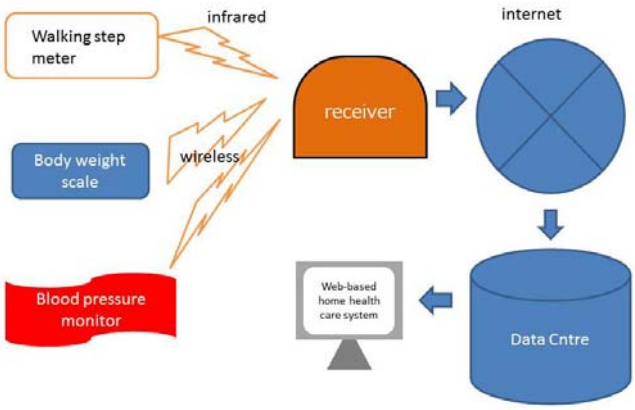

Figure 1. Block diagram of the pedometer-containing home healthcare system.

B. Subjects

The A total of 223 participants (average age: 43.0 ± 8.1 years) were enrolled initially: 205 male (average age: 43.7 ± 7.6 years) and 18 female (average age: 37.1 ± 7.9 years). During the 6-month study period, the participants did not monitor their walking and blood pressure at all times, even though the recording was automatic. Participants who recorded at least 50% of their walking steps and 20% of their systolic blood pressure readings over the 6-month period were included in the analysis. Participants taking anti-hypertension medications were excluded. Forty-eight participants, all male (average age: 47.5 ± 5.2 years), fulfilled the criteria cited above.

C. Analysis

For verification of the effectiveness of walking as an exercise, the relationship between changes in blood pressure and number of walking steps was evaluated over a 6-month period. Changes in blood pressure (mmHg) were defined as follows

Changes in blood pressure (mmHg) = final 1-month average systolic blood pressure − initial average 1-month systolic blood pressure

Assuming a continuous walking pattern, we defined constancy and continuity with respect to the average number of walking steps as follows:

Averaged walking steps = average number of walking steps during the 6-month study period

Constancy = Average of total weeks in coefficient of variation (CV) per each week

$$Average_{6\text{-}month}\left[\frac{Standard\ deviation\ of\ walking\ steps\ per\ each\ week}{Average\ number\ of\ walking\ steps\ in\ each\ week}\right.$$

Continuity = Coefficient of variation of the average number of walking steps per week:

$$=\frac{Standard\ deviation\ of\ 6\text{-}month\ walking\ steps}{Average\ of\ 6\text{-}month\ walking\ steps}\times 100\ \%$$

The average number of walking steps indicates the average number of walking steps taken per day. Lower constancy shows the constantly walk per week. Lower continuity means constant walk per measurement period

Linear and multiple regression analyses were applied to the walking step data, followed by Student's *t*-test to evaluate the relationship between walking steps and blood pressure, and the predictor variables. The Akaike information criterion (AIC) and coefficient of determination (R) were used as measures of the relative goodness-of-fits of the statistical models.

III. RESULTS

The average number of walking steps was correlated with changes in blood pressure (R = 0.32), as shown in Fig. 2. The distribution of the number of walking steps per day indicated that most participants took 6,000 to 8,000 steps per day (Fig. 3). Thus, the *p*-value was relatively high at 0.66.

The reference for a change in blood pressure was 5 mmHg. Five participants showed an elevation in blood pressure (7.51 ± 1.98 mmHg), 24 no change (−0.47 ± 3.00 mmHg), and 19 a decline (−11.45 ± 3.69 mmHg).

Figure 4 shows the constancy of the numbers of walking steps per week. The correlation coefficient for

changes in blood pressure and walking constancy was relatively low at 0.26. However, the *p*-value was 0.04, indicating a positive correlation. Thus, participants who walked on a regular basis had lower blood pressures.

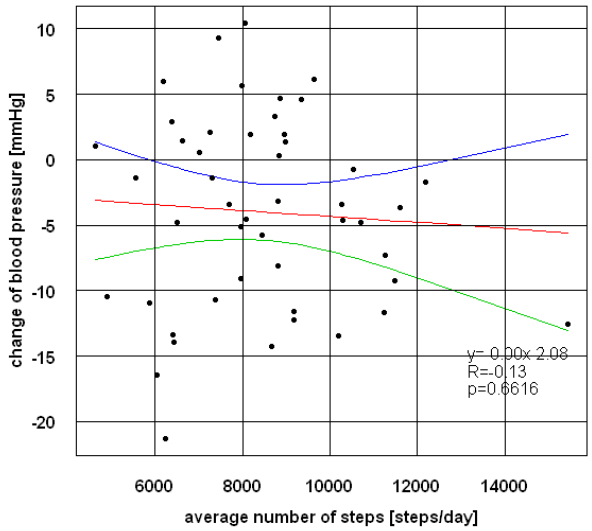

Figure 2. Scatter diagram of average numbers of walking steps and changes in blood pressure.

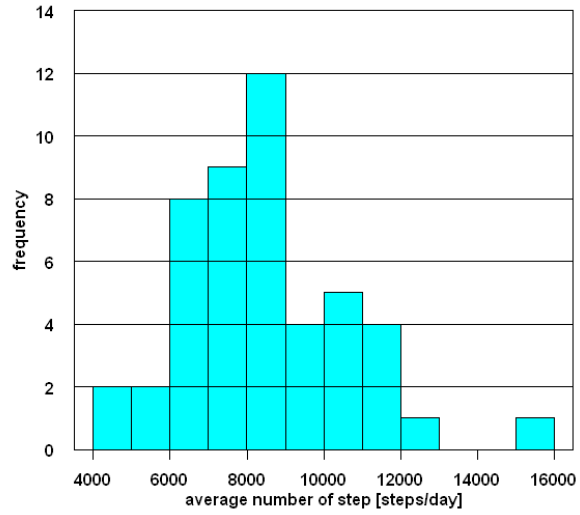

Figure 3. Distribution of number of walking steps per day

Figure 5 shows the continuity of walking steps over the 6-month study period. The correlation between continuity and blood pressure decline was not significant. Thus, changes in blood pressure were influenced by constancy in weekly walking. The constancy of walking exhibited the best fit of all walking parameters according to a multiple regression analysis (Table 1)

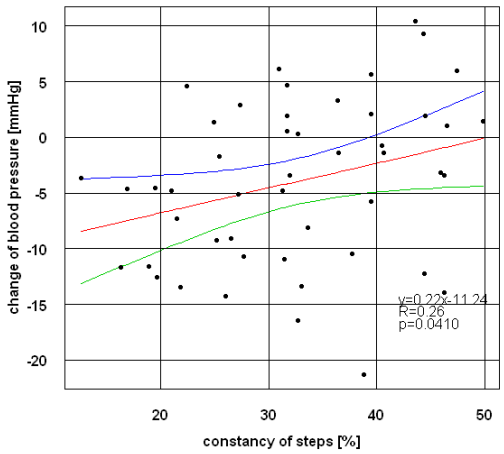

Figure 4. Scatter diagram of the constancy of walking steps and changes in blood pressure.

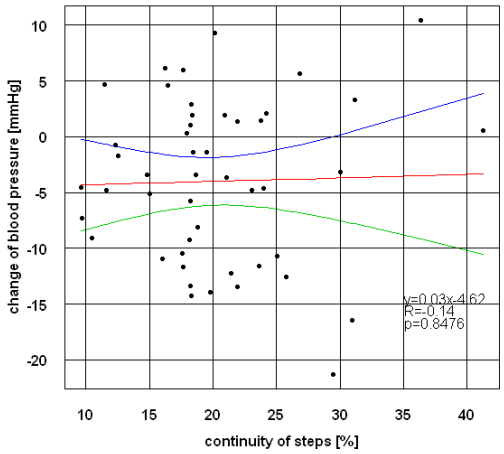

Figure 5. Scatter diagram of the continuity of walking steps and changes in blood pressure.

Table 1. Multiple regression models of all walking parameters.

For Blood pressure change	AIC	R^2	*p*
Average walking steps	141	−0.017	0.662
Constancy	137	0.068	0.042
Continuity	141	−0.021	0.848
Average walking steps + Constancy	138	0.060	0.094
Average walking steps + Continuity	143	−0.040	0.903
Constancy + Continuity	139	0.048	0.125
Average walking steps + Constancy + Continuity	140	0.039	0.195

IV Discussion

We investigated the effectiveness of the pedometer, a popular wearable sensor, in terms of predicting changes in blood pressure. Our main aims were evaluation of walking as a simple and reliable exercise and its effect on higher than normal body weight and blood pressure. We evaluated several parameters to assess the relationship between the number of walking steps and blood pressure. The average number of walking steps was the first criterion. The distribution of walking steps among participants was motivational; on average, participants walked more than 6,000 steps per week over the 6-month testing period. However, no correlation between walking continuity and blood pressure was identified. The constancy of walking per week was the most relevant walking parameter.

Previous studies [1,2] reported that 10,000 steps per week were required to lower blood pressure. Our results suggested that a reduction in the number of walking steps—6,000 per week—was effective in lowering blood pressure if performed on a consistent basis.

Walking habit, which was classified as the following: constant walk per week, frequent walk on weekdays, or frequent walk on weekends, varied among participants. In future research, we hope to determine the threshold number of walking steps associated with an effect on blood pressure. Thus the number of walking steps taken is a useful health indicator, and use of a pedometer facilitates improvement of the quality of life.

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