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Relationship Between Number of Steps, Weather Factors, and Clinical Test Findings in Participants of the "Health Up" Model Program in Okuizumo, Shimane Prefecture

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We analyzed the relationship between walking habits, weather factors, and clinical test findings over 3 years. Subjects were 41 participants (10 men, 31 women) of the "Health Up" program implemented by the town of Okuizumo in Shimane Prefecture from 2004 through 2006. Subjects' mean age (SD) was 59.23 (6.58) years. Among weather factors, a significant relation was seen only with snow accumulation ($P < 0.05$). Number of steps was negatively correlated with the clinical test values for triglyceride and VO_2max and positively correlated with blood sugar level ($P < 0.01$). These results revealed that walking is effective in the prevention of cardiovascular disease risk factors, and that number of steps is an important exercise criterion to lower the cardiovascular mortality rate.

Key words: number of step, weather factors, clinical test findings, multiple regression analysis

INTRODUCTION

Today, two of the three major causes of death in Japan are cardiovascular diseases (heart disease and stroke), and diseases of the cardiovascular system alone account for approximately 30% of deaths (1). However, preventive activities have been demonstrated to reduce risk factors for these diseases. Risk factors for stroke are hypertension, smoking, impaired glucose tolerance, and heavy alcohol consumption. Hypertension, smoking, and hyperlipidemia are risk factors for ischemic heart disease (2). Another risk factor long considered to be common to both diseases is obesity. It is reported that of these risk factors exercise can improve hypertension, impaired glucose tolerance, obesity, and hyperlipidemia; that is, all but smoking and heavy alcohol consumption.

Walking alone or walking combined with strength training can lower systolic blood pressure (SBP) by ≧20 mmHg, and diastolic blood pressure (DBP) by ≧10 mmHg in people with hypertension (3). In people with hyperlipidemia, triglyceride (TG) levels were significantly reduced by 9 mg/dl (4). In people with impaired glucose tolerance, hemoglobin A1c (HbA1c) was significantly reduced by 0.66% compared with that in an intervention group (5), and body mass index (BMI) was reduced by 3 kg/m (2, 6). It has also been reported that maintenance of physical fitness with VO_2max of 30.8 ml/kg/min reduces the risk of death from ischemic heart disease by 60% compared with people with no exercise and poor physical fitness (7). However, while it is known even in these reports that the detailed number of steps is an important assessment measure of the amount of physical activity, step counting is not generally used. While some reports counted the actual number of steps, in most studies the survey periods are short, at about several weeks, or up to 6 months at the longest. Conversely, in some long-term studies, including follow-up surveys of up to 15 years, the number of steps used is not the actual number but a number taken from questionnaire surveys or that seen from exercise intensity using METS or VO_2max. In some studies, only exercise is recommended, while other studies analyzed a limited number of clinical test results.

In the present study, we analyzed the relationship between measuring number of steps, based on actual daily number of steps over a long period of 3 years, in the "Health Up" model program implemented in

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Okuizumo, Shimane Prefecture, and risk factors for cardiovascular disease, weather factors, and clinical test finding.

MATERIALS AND METHODS

Figure 1 shows an outline of the "Health Up" program conducted by the town of Okuizumo in Shimane Prefecture from 2004 to 2006. Participants who met the selection criteria in Table 1 were selected for this study from among those who underwent a basic health examination and a national health insurance comprehensive health examination (double registration was applicable). Participants from 2004 were narrowed down to 78 subjects who were not receiving any kind of medical treatment at the time. The implementation period was about 3 years. Specific activities in the program were exercise and nutrition guidance that continued over the 3 years. During the summer intervention period, sessions including a lecture, stretching, and aerobic exercise were conducted once a week by an exercise instructor and sessions including a lecture, cooking practice, and food tastings were conducted twice a month by a nutritionist. As a winter follow-up period, stretching and band exercises were conducted once a week as exercise instruction, and cooking practice and food-tasting events were held once a month as nutrition guidance. The evaluation period was 3 years, and evaluations were conducted in May, August, November, and February.

Evaluation items were blood tests, blood pressure measurements, and VO_2max tests. individual participants were asked to record their number of steps in a daily living diary and body weight record. From among the 78 participants, the analysis was conducted for 41 people (10 men, 31 women) with a mean age (SD) of 59.23 (6.58) years who recorded number of daily steps continuously for 3 years. Number of daily steps, clinical test values, and weather data were used in the analysis. Number of daily steps was obtained from the daily living diary and body weight record of

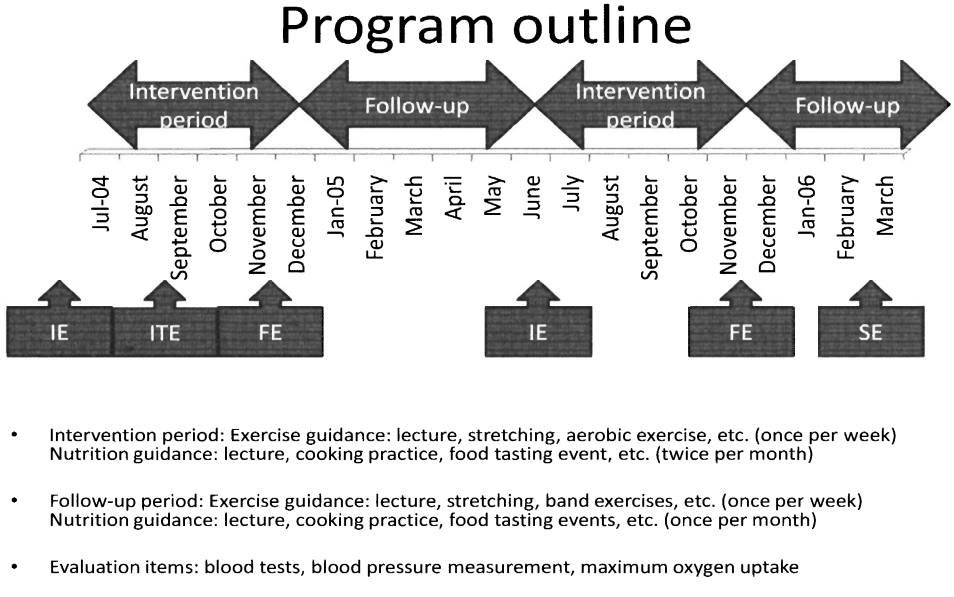

Fig. 1. Outline of Health Up program. Transverse arrows show periods of intervention. Upward arrows mean time of evaluations. IE : initial evaluation, ITE : International evaluation, FE : Final evaluation, SE : Simple evaluation

Table 1. Selection criteria for participants of 2004 Health Up program

- Casual blood glucose level: 140 mg/dl / HbA1c: ≥ 5.5 mg/dl
- Blood pressure: Systolic ≥ 130 mmHg / Diastolic ≥ 85 mmHg
- Serum lipids: Cholesterol ≥ 200 mg / HDL ≤ 49 mg/dl / triglyceride ≥ 150 mg/dl
- Level of obesity: BMI ≥ 25 kg/m^2

the participants recorded over 3 years. Clinical test values were obtained from the results of clinical tests conducted at a municipal hospital, and weather data were obtained from the Japan Meteorological Agency Web site. In the statistical analysis, a paired *t*-test was first conducted to test for significant differences in clinical test results only before and after intervention. Later, after evaluating the correlation of each parameter with number of steps, a multiple regression analysis was conducted to more closely investigate the relation between clinical test findings and number of steps, taking mean number of steps per day as the target variable, and SBP, TG, blood sugar (BS), HbA1c, BMI, and VO_2max as explanatory variables. Clinical test results, unlike number of steps, were not recorded daily, and it was assumed that they did not fluctuate from the time of one measurement to the next. Moreover, since sex and age are reported to be important confounding factors in many reports, the multiple regression analyses were conducted after adjusting for sex and age. Similarly, in the multiple regression analysis for weather factors, daily number of steps was taken as the target variable and statistical weather data for temperature, precipitation, snow accumulation, hours of sunlight, and wind speed were taken as explanatory variables. The pedometers were J-Manpo, EW03102 from Yamasa Tokei Co. SAS was used as the analysis tool.

RESULTS

Mean number of daily steps by month in weather factors

The mean number of steps per day of the participants was 11,229. Monthly averages (converted from daily averages) are shown in (Fig. 2). The total number of steps fluctuated depending on the month, with decreases during the winter months of January and February (snowfall period). No significant relation was seen between most of the weather factors and number of steps. The only factor that caused a significant difference was snow accumulation, a result that may be expected in a mountainous region (Tables 2, 3).

Changes in clinical test results

The annual trends in clinical test results over 3 years showed improvements in all items (Tables 4). Although most of the items showed normal values in

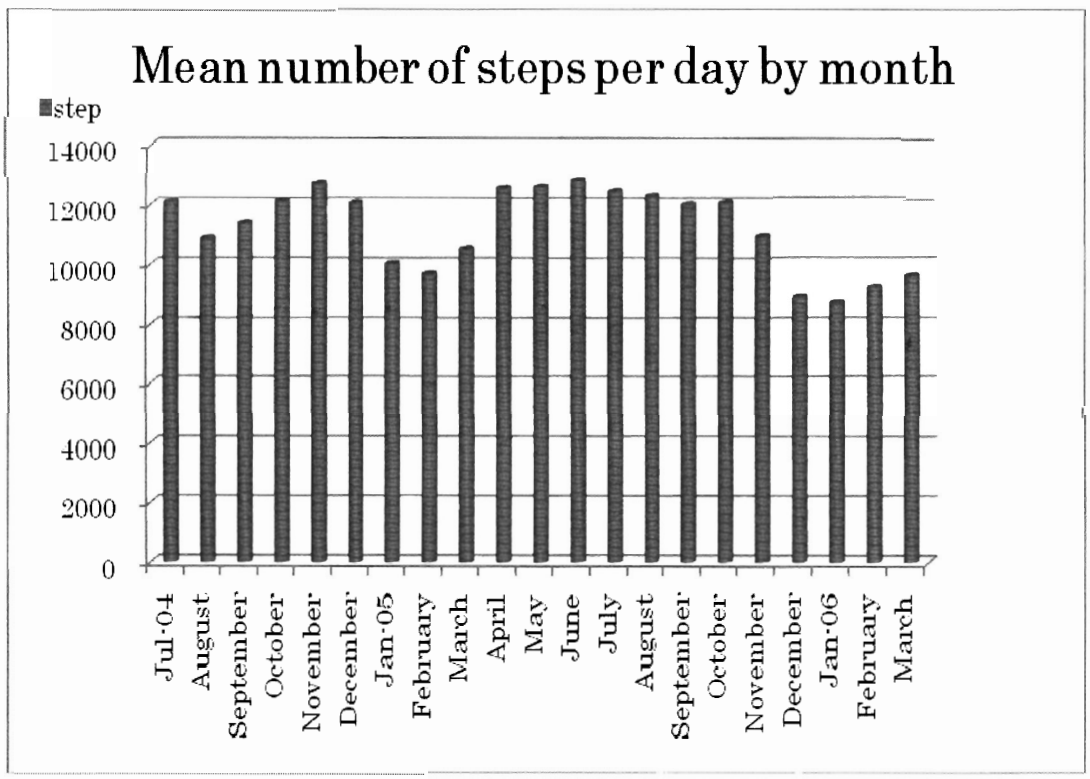

Fig. 2. Annual trends in mean number of steps per day by month. Each bar shows the mean number of steps per day by month.

the early stage of the intervention, a paired *t*-test to analyze changes from before to after intervention (Table 5) showed significant improvements in all items except TG level. In a multiple regression analysis for clinical test results and mean number of steps by month, significant relationships were seen between several items and number of steps, supporting previous reports (Table 6). Unexpectedly, however, SBP did not correlate with number of steps and BS level showed a positive correlation. As seen in the figures for clinical test results at the start of intervention, this was probably because mean values were near normal values in most cases. The multiple regression analysis was repeated using only high normal values. In this analysis of only people with high normal values (systolic blood pressure ≧130 mmHg), a significant improvement was seen in systolic blood pressure ($P < 0.01$).

Table 2. Annual trends in weather factors

Weather factor	Precipitation (mm)	Temperature (°C)	Wind speed (m/s)	Hours of sunlight (h)	Snow (cm)
July 2004	2.5 ± 6.5	25.4 ± 1.2	1.4 ± 0.5	6.5 ± 3.4	0.0
August 2004	9.8 ± 15.5	24.5 ± 1.4	1.3 ± 0.8	5.0 ± 3.6	0.0
September 2004	10.9 ± 17.9	21.5 ± 2.3	1.2 ± 0.9	3.0 ± 2.9	0.0
October 2004	11.4 ± 27.5	13.8 ± 2.9	1.2 ± 1.0	4.2 ± 3.8	0.0
November 2004	1.4 ± 2.9	10.0 ± 2.9	1.0 ± 0.8	4.0 ± 2.7	0.0
December 2004	6.2 ± 14.9	4.6 ± 2.4	0.9 ± 0.5	3.1 ± 3.0	1.2 ± 4.6
January 2005	5.1 ± 5.9	0.9 ± 1.6	1.4 ± 0.9	2.3 ± 2.1	1.2 ± 6.4
February 2005	4.5 ± 5.6	0.7 ± 2.7	1.3 ± 0.8	2.2 ± 2.8	4.8 ± 8.6
March 2005	4.4 ± 5.9	3.9 ± 3.7	1.5 ± 0.7	4.1 ± 3.3	3.4 ± 7.2
April 2005	1.7 ± 4.8	12.3 ± 4.6	1.9 ± 1.0	7.3 ± 4.1	0.0
May 2005	1.4 ± 3.5	15.2 ± 2.4	1.4 ± 0.5	7.4 ± 4.3	0.0
June 2005	0.5 ± 2.3	21.9 ± 2.9	1.4 ± 0.8	5.7 ± 3.6	0.0
July 2005	12.4 ± 25.4	23.8 ± 1.3	1.3 ± 0.5	4.2 ± 4.2	0.0
August 2005	3.4 ± 13.1	24.6 ± 1.7	1.1 ± 0.3	5.5 ± 2.8	0.0
September 2005	7.5 ± 16.8	21.7 ± 2.8	1.3 ± 1.0	4.4 ± 3.3	0.0
October 2005	4.5 ± 8.1	14.5 ± 3.9	1.0 ± 0.5	4.0 ± 3.4	0.0
November 2005	2.9 ± 6.5	7.8 ± 3.0	0.9 ± 0.5	3.9 ± 2.9	0.0
December 2005	8.5 ± 11.3	0.2 ± 2.0	1.4 ± 0.9	1.7 ± 1.8	9.6 ± 9.7
January 2006	3.1 ± 6.8	0.3 ± 2.2	1.0 ± 0.7	2.1 ± 2.4	4.1 ± 3.6
February 2006	4.6 ± 6.3	1.4 ± 2.8	1.3 ± 0.9	2.6 ± 2.8	5.3 ± 7.9

Mean ± S.D.

Table 3. Regression analysis of weather factors and mean number of steps per day by month*

Weather factor	Regression coefficient	Standard error	Lower limit 95%	Upper limit 95%	P-value
Precipitation (mm)	-0.9	2.4	-6.1	4.2	n.s.
Temperature (°C)	21.4	40.1	-63.9	106.8	n.s.
When speed (m/s)	1153.7	1364.1	-1753.8	4061.2	n.s.
Hours of sunlight (h)	3.8	9.6	-16.7	24.3	n.s.
Snow accumulation (cm)	-11.8	5.3	-23.2	-0.5	$P < 0.05$

* Adjusted for sex and age, n.s.: not significant

DISCUSSION

In this study, we asked subjects to record their number of daily steps using a pedometer for the long period of 3 years. We then investigated the relationship between number of steps and clinical test results, which are related to risk factors for cardiovascular disease, and between number of steps and weather factors. The results showed improvements with number of steps in all items but levels of SPB and BS. A significant relationship was also seen with the weather factor of snow accumulation. Number of steps may therefore be considered to be a useful criterion.

Walking is a typical aerobic exercise recommended by the Ministry of Health, Labor and Welfare and the American College of Sports Medicine. It is thought to improve blood sugar control, excessive visceral fat, and cardiovascular disease. In many reports, VO_2max or calories are used rather than actual number of steps as the standard for determining the amount of aerobic exercise. Blair *et al* (8). reported that maintaining VO_2max of 24.5 ml/kg/min lowered the mortality rate from cardiovascular disease in people aged

Table 4. Annual trends in clinical test results

	Body mass index (kg/m^2)	Systolic blood pressure (mmHg)	Diastolic blood pressure (mmHg)	Triglyceride (mg/dl)	Blood sugar level (mg/dl)	Hemoglobin A1c (%)	VO_2max (ml/kg/min)
May 2004	23.3 ± 2.1	124.1 ± 12.4	78 ± 8.6	87.8 ± 33.1	98 ± 8.8	5.2 ± 0.3	29.2 ± 7.0
August 2004	22.8 ± 2.0	119.4 ± 14	69.6 ± 7.9	88.1 ± 28.3	96.3 ± 7.9	5.1 ± 0.3	31.8 ± 5.7
November 2004	22.5 ± 1.9	120.8 ± 14.2	75.9 ± 9.8	83.7 ± 25.2	95.1 ± 11	4.9 ± 0.3	32.9 ± 5.1
May 2005	22.2 ± 1.8	117.5 ± 12.3	73.1 ± 8.9	78.2 ± 26.7	98.8 ± 10.1	5.1 ± 0.3	34.2 ± 7.3
November 2005	21.6 ± 1.7	118.4 ± 13.4	73.9 ± 8.7	89.9 ± 36.7	94 ± 8.7	5 ± 0.3	34.3 ± 5.6
February 2006	22 ± 1.7	-	-	82.1 ± 28.3	94.4 ± 9.5	5.1 ± 0.3	-
May 2006	21.3 ± 3.7	117.5 ± 23.1	72.5 ± 14.9	72.9 ± 33.5	90.2 ± 22.1	4.8 ± 1.1	30.4 ± 12.1

Mean ± S.D.

Table 5. Change in clinical test results before and after intervention

Test item	Before intervention (July 2004)	After intervention (February 2006)	P-value
Body mass index (kg/m^2)	23.3 ± 2.1	21.9 ± 1.7	P < 0.01
Systolic blood pressure (mmHg)	124.0 ± 12.3	118.4 ± 13.4	P < 0.01
Diastolic blood pressure (mmHg)	77.8 ± 8.6	73.9 ± 8.7	P < 0.01
Triglyceride(mg/dl)	87.2 ± 32.9	81.7 ± 28.1	n.s.
Blood sugar level (mg/dl)	98.0 ± 8.7	94.1 ± 9.4	P < 0.01
Hemoglobin A1c (%)	5.2 ± 0.3	5.1 ± 0.3	P < 0.01
VO_2max (ml/kg/min)	29.5 ± 6.9	34.7 ± 5.6	P < 0.01

Mean ± S.D., n.s.: not significant

Table 6. Regression analysis of clinical test results and mean number of steps per day by month*

Item	Correlation coefficient	Standard error	95% lower limit	95% upper limit	P-value
Systolic blood pressure (mmHg)	7	11.4	-15.4	29.3	n.s.
Diastolic blood pressure (mmHg)	-14.3	16.7	-47.1	18.5	n.s.
Triglyceride (mg/dl)	-34.6	5.4	-45.2	-24	$P < 0.01$
Blood sugar level (mg/dl)	68	16.1	36.3	99.7	$P < 0.01$
Hemoglobin A1c (%)	2191.7	451.8	1304.9	3078.4	$P < 0.01$
VO_2max (ml/kg/min)	115.3	26.9	62.5	168.1	$P < 0.01$
Body mass index (kg/m^2)	-352.4	75.4	-500.5	-204.4	$P < 0.01$

*Adjusted for sex and age, n.s.: not significant

64 or over. Paffenbarger *et al* (9). reported that the risk of death tended to decline steadily with increases in the amount of physical activity per week, and that the risk decreased with activity of 2000 kcal or more. Thus, VO_2max and calories are both valuable criteria in considering cardiovascular problems. In the present study, VO_2max exceeded the value of 24.5 ml/kg/min before the intervention, and at the end of intervention, 3 years later, VO_2max had risen to 34.7 ml/kg/min. Calculating calories based on the report of Hatano *et al.* (10), approximately 2,400 kcal/W were consumed in the mean number of steps of the present participants. Thus, this program may be considered effective in preventing cardiovascular disease.

The disadvantage of using VO_2max as a criterion is that accurate measurements require the use of expensive equipment, and take time and energy. Performing exact calorie counts requires a certain level of knowledge and calculation skills. There are also same disadvantages as evaluating the amount of activity with heart rate or doubly-labeled water methods. Measuring number of steps, on the other hand, has the major advantages of being inexpensive and requiring little time or effort. In some cases, it can be a more valuable criterion than VO_2max.

In this study, the weather factor of increased snow accumulation was found to significantly inhibit subjects' number of steps. Thus, in mountainous regions with abundant snow, it is necessary to maintain exercise with activities such as chair walking that can be done indoors and are not affected by snow.

As in previous reports, a positive correlation was shown between number of steps and the specific clinical test results for BMI and TG level. The present results showed that BMI was inversely related to the number of steps. Opinions are different as to whether eating or exercise has a greater effect on obesity. The thermic effect of food (TEF) (11) has been reported to be an effect of exercise alone, whereas Kachigawa (12) has stated that dietary measures are the most effective way to adequately reduce body fat. However, at 3 - 4.5 years, the effect diminished to -4% of the pre-reduction body weight, and it is said that diet combined with exercise is the best way to maintain weight reductions (13). In this study, there was a trend toward improvement even after the long period of 3 years. Habitual exercise is therefore effective not only in maintaining weight loss but is also superior from the perspective of prevention.

There are many reports on the effectiveness of exercise intervention for TG levels (14, 15), and similar results were seen in the present study. In many studies, the amount of exercise required is 1,200 - 2,200 kcal/w, but based only on the mean number of steps

in the present study, the exercise of participants was estimated to be approximately 2,400 kcal/w. Considering the amount of activity, this is a reasonable result; however, although significant relations were seen with the number of steps in the present study, there was no significant difference in TG level between the beginning and end of the intervention. This may have been because two-thirds of the subjects were women, and as pointed out by Higuchi *et al.* (16), the effect of exercise does not appear as readily in women as in men.

The present findings differ from other reports in the improvement of SBP and BS control. The intervention improved SBP control, but the improvement showed no significant correlation with number of steps. This may also reflect the fact that nearly all values were within the normal range at the start in 2004. According to the report of Kelly *et al.* (17), a blood pressure-lowering effect was seen even in people who did not have high blood pressure. However, a significant improvement was seen when the analysis was repeated using only those participants with high normal values (≧130 mmHg). As reported also by Fagard *et al.* (18), a larger blood pressure-lowering effect is seen in people who are closer to hypertension than in those who do not have high blood pressure.

In this study, the intervention significantly improved BS control, but BS level positively correlated with number of steps. Various factors may account for this correlation. With regard to amount of exercise, as reported by Boule *et al.* (19), the American Diabetes Association (ADA) recommends at least 150 min per week of moderate intensity aerobic exercise 3 or more times per week (with no periods without exercising longer than 2 days). From the mean number of steps of the present participants, their exercise time is estimated to be about 135 min. This is less than the recommended time, so there may be a problem in the amount of exercise. However, in most of the participants, blood sugar level was within the normal range and did not need to be controlled—there were only four subjects with blood sugar level exceeding 110 mg/dl. It is generally said that, while sugar intake increases with exercise in healthy people, there are no large changes in blood sugar level. The ADA also recommends exercise of about 30 min per day for people whose BS level is sufficiently controlled, so this is not necessarily a problem of amount of exercise. In the present program, diet and exercise guidance were given together, and although BS level was positively correlated with number of steps, the program resulted in improved BS control. This suggests that dietary guidance is more important than exercise guidance for people with an appropriate BS level.

The present study significantly improved the clinical test findings. However, from the perspective of preventing cardiovascular risk factors, there is no question that continuation is of major importance. Many of the reasons for failure to lose weight are that people are suddenly required to do things they are not accustomed to doing. Walking, however, unlike exercises that cannot be done without special equipment or movements, can be performed without difficulty by anyone in their daily lives. When using step counting, it is of great importance to perform an exact count of the number of steps, including those not considered to be exercise. There are problems such as the precision of pedometers (20), but discussion of these problems has progressed and the accuracy and reliability of the devices themselves have been improved with the establishment of sensitivity control and other functions. The inconvenience of keeping daily records and carrying a counting device are reasons that step counting has been used less frequently than VO_2max or other measures as an indicator of exercise. However, with the current widespread use of mobile phones, the largest drawback of measuring number of steps has been overcome with the functions of some phones, such as the NTT Docomo Raku Raku phone series, which automatically counts the number of steps. Systems in which this information is sent to companies, which can then constantly check individuals' health status, are becoming common, and further developments are expected in the future.

In the present study, we analyzed the relationship between number of steps with clinical test values and weather factors over a 3-year period. The results showed a clear relationship with snow accumulation, a weather factor that limits walking. This suggests the importance of exercise that is not affected by snow accumulation in the future. For several clinical test

items, increases in number of steps also clearly improved cardiovascular risk factors. We also revealed a strong correlation between number of steps and VO_2max, which is commonly used as a standard for exercise. The present findings thus show that measurement of number of steps, which is relatively simple, is important as an evaluation of exercise to lower the cardiovascular mortality rate.

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