Research Letter

Number of steps and biomarkers in the elderly

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Abstract
It is said that walking is good for maintaining health. The target number of steps for elderly people is recommended to be 6,700 steps/day for men and 5,900 steps/day for women. In this study, one male subject was selected and the daily number of steps, body weight, total consumption, maximum and minimum blood pressure, temperature, etc. was recorded for 8 years, and it was examined whether or not continuing to take more than the recommended number of steps would contribute to maintaining health. The experimental results were summarized and the experience (feeling) was also reported. As a result, the subject maintained about 1.5 times the target number of steps for 8 years and spent his life without serious illness. The characteristics of the average number of steps in each month of each year tended to be low in winter and to increase from March to November when there was no snow covering the ground. A strong correlation (r = 0.82) was observed between mean weight and mean systolic blood pressure over the final 5 years (2018-2022). In addition, it can be said that there is a correlation between average temperature and heart rate (r = 0.71). Near the end of the experiment, the subject felt that walking more than 10,000 steps (for 5 days or more) caused fatigue in the legs due to aging. It is necessary to maintain an appropriate number of steps and gradually reduce the number without overdoing the exercise, and to consider the effects on the body, such as the knees. This research is also useful for deriving the tourism activity ability of the elderly.

Keywords
number of steps, body weight, tourism activity ability, total consumption, blood pressure

1. Introduction

Japan has become a super-aging society and the percentage of elderly people (aged 65 and over) is the highest in the world (approximately 30 %). With the declining birthrate and aging population, the government and local governments are taking the lead in implementing a number of measures to extend the 'healthy life expectancy' of the elderly, and academic institutions are also conducting research on extending healthy life expectancy [Okazaki, 2017]. The social security expenses in Japan's general expenditure account for about 55 % (FY 2022) as the population ages, and are on the rise and putting pressure on the national finances. The World Obesity Federation (WOF) has warned that about half of the world's population will be obese or overweight by 2035. Obesity increases the risk of diseases such as heart disease, cancer, and diabetes, and leads to an increase in social security costs [World Obesity Federation, 2021]. There is an urgent need to improve the working environment and extend healthy life expectancy, including social participation of the elderly. In recent years, the word 'well-being' has spread, and attention is focused on measures to provide a favorable environment both socially and mentally, and to maintain a good physical condition for each individual [Toyoshima and Akase, 2022].

Various services are provided to extend healthy life expectancy, such as lifestyle-related disease prevention, health care, frailty prevention, and sarcopenia prevention. These services are provided depending on the individual status. In order to maintain a healthy state, independent efforts by each individual are important. It is important to promote 'social participation,' 'eat a balanced diet,' and 'exercise moderately' in order to maintain good health, especially for the elderly. Individuals must be strongly aware of and work on each of these three matters. In addition, each local government is also required to support residents in maintaining their health [Fujita et al., 2018].

Extending healthy life expectancy is a global issue. 'Exercise' is an important factor in reducing the risk of obesity and maintaining a healthy body [Hino, 2022]. Exercise requires the ability to walk independently in most cases. A condition in which the ability to walk is weakened is called locomotive syndrome, which is a sign of needing nursing care or becoming bedridden. The Ministry of Health, Labor and Welfare (Japan) has instructed people to develop the habit of exercising for 30 minutes or more at least twice a week to prevent these conditions [Ministry of Health, Labour and Welfare, 2022]. Walking is a suitable exercise and has the advantage that anyone can do it anywhere. The Ministry of Health, Labour and Welfare recommends 9,200 steps/day for men and 8,300 steps/day for women as a target number of steps to maintain a state of being healthy and able to participate in society. However, the target values for elderly people are 6,700 steps for men and 5,900 steps for women. It is necessary to keep in mind the walking (number of steps) that is personalized in each person and exercise about twice a week as they age regardless of the recommended value [Hino, 2022].

Walking is a simple aerobic exercise. The quality of walking has become an issue in recent years. Namely, the quality

can be improved by walking with a large stride-length and fast pace. Brisk walking is classified as moderate exercise (light sweat exercise), and it has been reported that 20 minute brisk walking significantly reduces the incidence of disease [Ministry of Health, Labour and Welfare, 2022]. Slow jogging is also attracting attention as an exercise that involves running slowly at a speed equivalent to walking [Tanaka, 2017]. It is desirable to do both exercises habitually in a way that matches the individual's physical condition.

In this study, an elderly person was selected as a subject and the following items were measured every day for about 8 years: namely number of steps, weight, basal metabolic rate, blood pressure, maximum/minimum temperature etc. The results are summarized. Originally, the above data should be extracted from many subjects to verify efficacy and knowledge should be derived. However, due to the difficulty of continuously measuring the items on elderly persons over a long period, the data (measured items) on only one subject are summarized. The results will improve the walking evaluation of the elderly and lead to increased awareness of walking by showing roughly the trends even in only one subject. Furthermore, it is expected that healthy life expectancy will be extended and that it will contribute to well-being. The willingness to go out for sightseeing is improved, and opportunities for social participation increase by walking while being conscious of one's health.

2. Mean change in number of steps per day for 8 years

An elderly person (male), 74 years old in 2023, was selected as a subject and measurements were recorded. His height ranges from 163 cm to 160.5 cm (decrease with age). Figure 1 shows the average number of steps over the 8 years from January 2015 (age 66) to December 2022 (age 73). The figure plots the average number of steps per day for each year. The average number of steps per day in 2018 was 8,685 and 8,756 in 2019. In these years, the subject continued to feel pain in his heel and could not walk for a long time (less than 40 minutes). He was also doing desk work intermittently from April 2018 to September 2021. The mean of this data is μ = 9,284 and the variance is σ = 346. A coefficient of variation ($cv = \sigma / \mu$) of 0.03727 is obtained. However the value is derived for the mean indicated in the figure and is not for the values for each day of 8 years. It can be said that there is little change at 5 % or less and it can be understood that the subject has consistently achieved the target number of steps per day as an average value. The number of steps increases by about 700 steps due to the reaction of the last 2 years and the Covid-19 pandemic from 2020, and the restrictions on going out are also a factor. It increased by about 1,000 steps in 2022. Despite the restrictions of the Covid-19 pandemic, it can be said that the physical condition was easily improved by walking. The attributes and working conditions of the subject are shown in Table 1. The low number of steps in 2018 and 2019 is related to non-regular work. He was working regularly and the average number of steps increased since October 2019. The motivation to walk improved and increased in 2022.

Table 1: Attributes and working condition of the subject

	Attribute, etc.
Subject	male
Age	66-73 in 2015-2022
Height	163-160.5 cm (decline with age)
Steps per 30 min.	3400-3500 steps
Stride length	69.5 cm (when taking a walk)

Period	Working condition
Type of work	researcher
2015-2018.03	desk work regularly in time (8:30-17:30)
2018.03-2021.9	desk work (about 9:00-13:00)
2019.10-2022.12	desk work regularly (8:30-16:00)
2023.1-	desk work regularly (8:30-16:00)

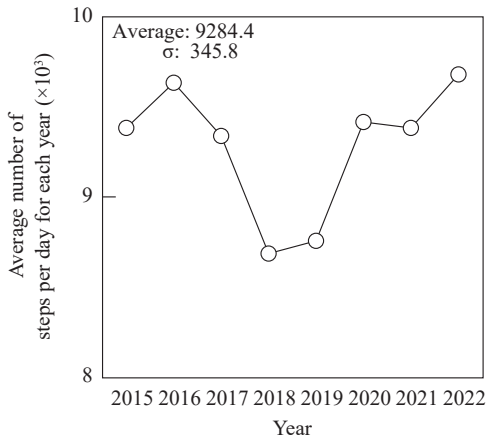

Figure 1: Characteristics of change in average number of steps per day

Long-term pain in a part of the body such as the heel reduces not only the number of steps taken but also the amount of exercise. Elderly people often feel some kind of pain or imperfection in their bodies. The problem is how to recover from the pain depending on the individual. The subject recovered from the heel pain due to daily stretching. Human-beings have a natural healing power, and continuous efforts to make use of this power are necessary. The number of steps was on the rise after 2020.

3. Average step change per day by month of each year

A change in the average number of steps per day for each month of each year is obtained. The ones for January, February, and December (winter season) tend to be low and the tendency is indicated in Figure 2. There is little variation from March to November although some plots (November 2019) deviate slightly from year to year. The subject's residential area has snow in winter, and there are days when walking is difficult. In winter (such as January and February), the minimum temperature can drop below zero, and the number of steps can vary. The plot

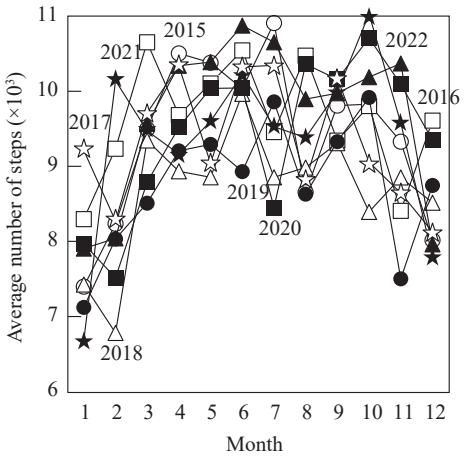

Figure 2: Characteristics of monthly change in the average number of steps per day

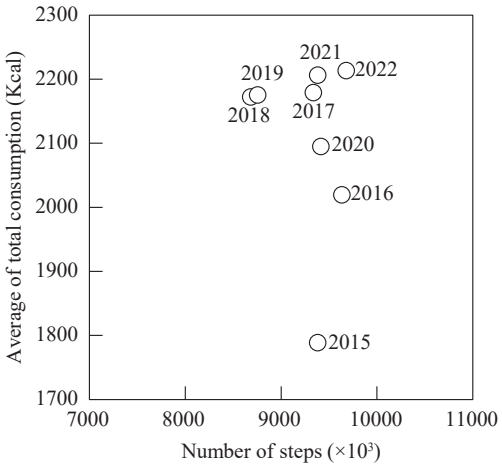

Figure 3: Scatter diagram between number of steps and average of total consumption

for November 2019 shows somewhat smaller values. This is not due to rain or snow, but to heel pain due to plantar fasciitis. The pain improved after continuing to stretch the triceps surae (muscle). There is a possibility that long-term diseases of the body can be grasped using the characteristics of the number of steps. The average number of steps μ, standard deviation σ, and coefficient of variation ($cv = \sigma / \mu$) for each month of each year are summarized in Table 2. The cv is generally around 0.1 but it has been on the rise since 2020. The monthly coefficient of variation is about three times the value in Figure 1 (about 3 %). The number of steps per month seems to have increased from 2020 onwards due to the Covid-19 pandemic.

4. Average steps and total consumption

The contribution rate of physical activity, such as walking, to the total consumption was investigated. Total consumption means basal metabolic rate, energy expenditure for daily activities and diet-induced thermogenesis (DIT), etc. The data on the average number of steps per day and the average total consumption for each year are used for the purpose of examining rough trends. Originally, it is reasonable to obtain this from daily data. The total consumption is measured using Calorie Scan, HJA-310 (Omron Corporation) which is integrated with a pedometer. A scatter diagram between the average number of steps per day and total consumption is shown in Figure 3. The total consumption in 2015 was low. A possible factor for this is considered to be that the subject's job was mainly desk work. The subject has also started working outdoor in fields on weekends (about 5 hours/week) since 2016. The subject has been constantly cultivating vegetables as a hobby and the relationship between total consumption and number of steps was low since 2017. Field work using tools such as hoes significantly increases total consumption (the number of steps is few). Field work is temporarily tiring, but it is a good change of pace as a subject's bodily sensation. Also, moderate field work can have a positive effect on mood.

5. Average steps and body weight

If it becomes clear that walking contributes to weight loss, it is expected that many people will start walking. The scatter diagram between the number of steps and body weight is indicated in Figure 4. The diagram is the same as the previous figure, and the horizontal and vertical axes indicate the average

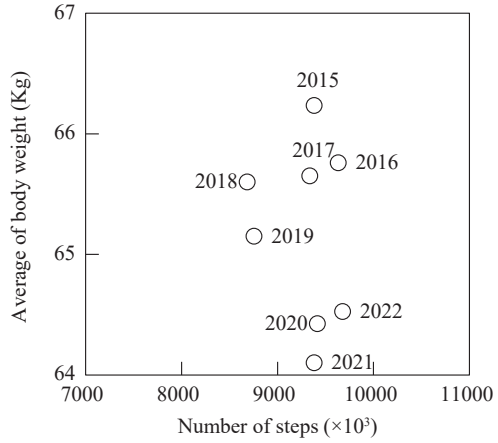

Figure 4: Scatter diagram between number of steps and average of body weight

Table 2: The average number of steps μ, standard deviation σ, and coefficient of variation (cv) for each month of each year

	2015	2016	2017	2018	2019	2020	2021	2022
μ	9383.0	9634.2	9338.0	8684.8	8756.3	9416.2	9382.8	9679.7
σ	1042.9	729.8	783.7	817.5	829.6	975.2	1093.1	1040.6
σ / μ	0.111151121	0.07575617	0.083926701	0.094124241	0.094748563	0.103570568	0.1165051	0.10750257

steps and weight per day. The range of variation in the number of steps is 8,685-9,680, and the weight is in the range of 64.1-66.2 kg. Weight was on a downward trend in the figure, but increases by several hundred grams in 2023. The figure shows no relationship between the number of steps and body weight. Weight tended to decrease with age. From the middle of 2021 (average weight of 64.1 kg), the subject started to slightly increase protein intake from meat and fish as a dietary habit in order to improve muscle strength. For this reason, the declining trend until 2021 turned to an increase in 2022.

The subject's BMI (Body Mass Index) value is about 25. As appropriate weight ((height m)^2 × 22) is about 57 kg, the subject's weight belongs to the category of slightly obese. The subject is physically healthy and does not feel the need to lose weight. In addition, the subject does not suffer from obesity-related diseases (diabetes, hypertension, dyslipidemia, etc.). The coefficient of variation of body weight is about 0.5 %, which is extremely small.

6. Body weight and systolic blood pressure

Obese people are more likely to have hypertension (systolic blood pressure ≥ 140 mm Hg or diastolic blood pressure ≥ 90 mm Hg as a measurement at a medical institution) than people within the normal weight range. It is said that many Japanese suffer from hypertension due to excessive salt intake, obesity, alcohol, lack of exercise, and stress [Motoyama et al., 1998]. The relationship between the subject's body weight and systolic blood pressure is shown in Figure 5. Since 2015, the subject lost weight but the systolic blood pressure is not lowered. Plots from 2018 to 2021 have a linear decreasing trend and the data for 2022 shows an increasing trend. The data for 2023 will also show an increasing trend. Aging is thought to be a factor. The correlation coefficient is r = 0.81905 when limited to 2018-2022. The coefficient is very high and the weight loss is associated with a decrease in systolic blood pressure. As the subject was working from 8:30 to 17:30 from March 2015 to March 2018, other factors may deviate from this trend. It is considered that the data may deviate out of a trend due to other factors, however, details are unknown. It is thought that regular working may suppress the rise in blood pressure.

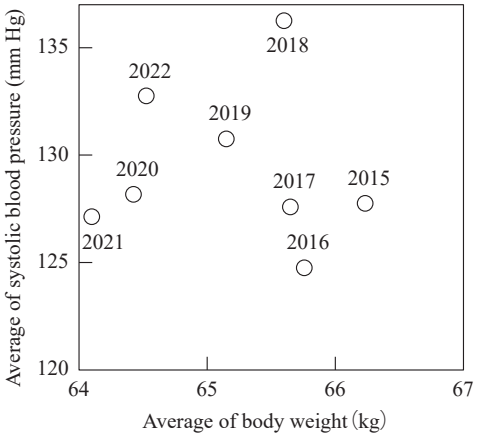

Figure 5: Scatter diagram between average of body weight and average of systolic blood pressure

7. Average temperature and heart rate

It is said that the heart rate (pulse) tends to increase as the atmosphere temperature rises [Sato and Takasaki, 1979]. Heart rates generally increase as exercise intensity increases. The heart rate at rest increases with increasing body temperature. Its value is about 60 to 70 at rest, but sometimes it is about 50 to 90. If the value is always high, the risk of cardiovascular diseases such as myocardial infarction increases [Tanimura et al., 1979].

The relationship between the average temperatures during the experimental period and the average heart rate is expressed in Figure 6. There is little correlation. The heart rate in 2015 was slightly higher but it is generally within normal range. The subject has a tendency to high. The heart rate generally decreases with age, because daily activity and metabolism decrease, and oxygen consumption decreases. Although the trend cannot be understood from the figure, the data of heart rates tend to increase as the average temperature rises when excluding the data in 2015, and the correlation coefficient (r) is 0.71. It has been in the range of 69-71 over the last four years, so it seems that the heart rate tends to increase as the average temperature rises [Tokuda et al., 1989].

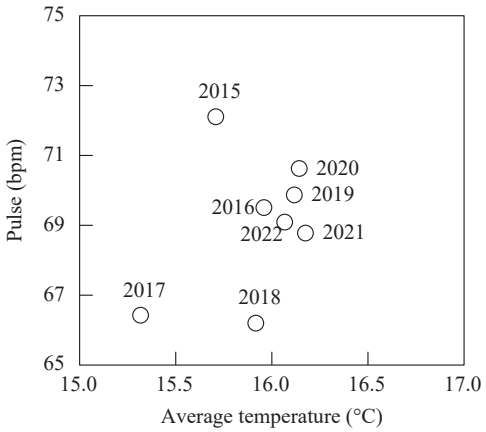

Figure 6: Relationship between average temperature and heart rate

8. Weekly step number change

The number of steps is different for each day of the week. The change in September every other year was examined, and it is shown in Figure 7. Each characteristic represents a change starting from the first Sunday in September. Although the subject is elderly, he actually has a cyclical behavior pattern depending on the day of the week. He practices tennis for two hours on Saturday or Sunday, or both days. The reason why September is chosen is that it is a relatively comfortable season and the pattern of behavior is fixed. The data is easy to compare as a pattern of behavior. The number of steps on Tuesday

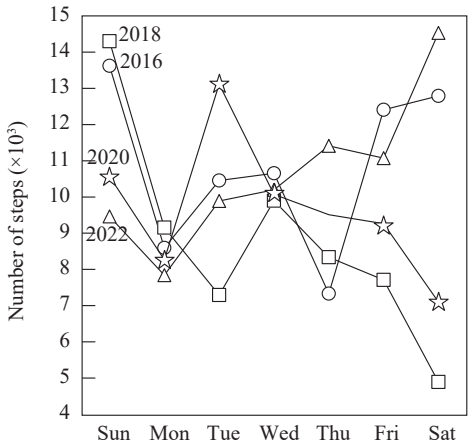

Figure 7: Change of number of steps by day of the week in September every other year

Table 3: Average number of steps and σ in September every other year

	Av	σ
2016	9343.2	2748.2
2018	9309.3	2575.2
2020	10159.0	1963.8
2022	9974.1	1929.8

in 2020 exceeds 13,000, but the ones for other weekdays are in the range of 7,500 to 12,500. The total number of steps on consecutive Saturdays and Sundays (for example, in the case of September 2022, the 3rd day (Sat: 10816) and 4th day (Sun: 9462)) is as follows. TNS means total number of steps on Saturday and Sunday. The value for 2020 is small. The weather was fine on both days, but the highest temperatures were 33.2 and 33.5 °C, which were quite high. The average number of steps and σ in September every other year is shown in Table 3. Although the average number of steps tends to increase with age, the standard deviation σ becomes small and the variation also becomes small. The number of steps maintains regularly and walking is routine.

Year	2016	2018	2020	2022
TNS	26,256	22,050	18,614	20,278

9. Change of number of steps by day of the week

The average number of steps for each day of the week in September is shown in Figure 7. The figure shows biennial data. The day-by-week comparisons for three measurement months are shown here. First, the characteristics in September 2021 are expressed in Figure 8. The characteristics are plotted starting from Sunday in the figure. The average temperature of the measurement month was 23.4 °C. The number of steps tends to be higher on Sundays and Saturdays, and there is relatively little variation. The subject was absent from tennis practice and was doing desk work on September 18th, so the steps were few on that day. And, the subject participated in tennis practice on both Saturday (11th and 25th) and Sunday (5th and 19th), except on the 18th when he took about 14,000 steps.

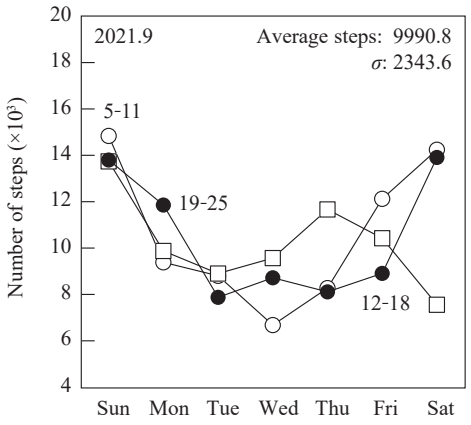

Figure 8: Characteristics of number of steps in September 2021

The characteristics in October 2021 are shown in Figure 9. The average temperature of the month had dropped (18.3 °C) and it was a comfortable month compared with the temperature in September 2021. The average number of steps was 11,029.7 steps and this is larger than the value shown in Figure 8. The value is small on October 17th due to non-participation in tennis practice. Family members can roughly judge whether the subject is doing the usual behavior by the number of steps characteristic.

The characteristics in February 2023 (winter season) are shown in Figure 10 for comparison. The average temperature of the month was 4.9 ℃, which is quite low. The numbers on 18th and 19th are few. There was no tennis practice on both days, so the subject was out and had little time for walking. In this month, walking was the only exercise, but the average number of steps was 10,097.4 which is a relatively large value. It was thought that there might be a difference due to the season, but a significant difference was not observed. The figure shows the characteristic under the Covid-19 pandemic. The value reached the target value for elderly people (6,700 steps for men) and it

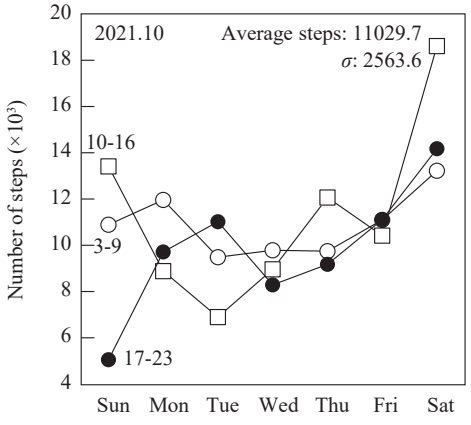

Figure 9: Characteristics of number of steps in October 2021

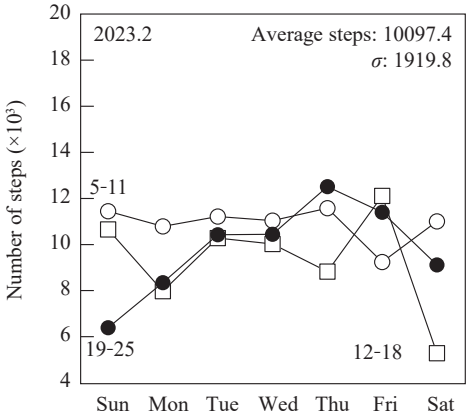

Figure 10: Characteristics of number of steps in February 2023 (winter season)

is said that there is no point to worry about physical condition. As a feeling in 2023, there is a tendency to become tired if the subject continues 11,000 steps or more for 4 days or more and he feels that it is preferable to reduce the number of steps gradually as he is getting older [Sawada and Oyabu, 2022].

10. Conclusion

Various measures are being implemented by local governments to extend healthy life expectancy. In order to lead a healthy life, it is necessary for each individual to strive to maintain their health so as not to develop locomotive syndrome. Walking is an easy exercise to be healthy. It can be performed at a speed and stride that are consistent with each person even if there is a minor disease in the body. In this study, it was investigated whether an elderly subject could maintain their health by walking over a long period. As a result, the subject feels that he was able to maintain his health (also mentally) without suffering from any serious illness. Furthermore, the following results are found that weight loss may lead to a decrease in systolic blood pressure and that the heart rate tends to increase with temperature (limitedly). In addition, there was a pattern in the number of steps according to the day of the week. Although these results are something personal and may not apply to other people, the results are considered to be one of the long-term results. It is hoped that many people will be able to extend their healthy life expectancy and build well-being through walking based on these results.

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