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Original Article

Seasonal changes in daily steps of community-dwelling older individuals with and without lifestyle-related diseases: a retrospective cohort study

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Abstract. [Purpose] Physical activity helps prevent diseases and mitigate their severity in older individuals with lifestyle-related conditions. We investigated whether seasonal factors and existing diseases affect physical activity in this demographic to identify lifestyle guidance indicators for health maintenance. [Participants and Methods] We compared the daily steps of older individuals (age of ≥65 years) by month, sex, and disease status from August to January by using three-way analysis of covariance. We evaluated a total of 115 participants (83 females and 32 males). [Results] Females with diseases had significantly fewer monthly daily steps than females without diseases in November (mean difference=1,138 ± 220) and December (mean difference=1,578 ± 239). Throughout, males with diseases completed significantly fewer monthly daily steps than did males without diseases. Furthermore, monthly daily steps never differed significantly between females with diseases and their male counterparts. [Conclusion] Compared with healthy older individuals, in older persons with diseases, physical activity was lower year-round among males and in November and December among females. Separate daily step count goals may be required for health maintenance in both sexes. It is important to determine the daily steps necessary to prevent various diseases and mitigate their severity while maintaining physical activity among older persons with diseases.

Key words: Physical activity, Population health, Rehabilitation

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INTRODUCTION

One of the main causes of most chronic diseases is daily physical inactivity[1)]. Many empirical studies have demonstrated the notion that decreased daily physical activity is a major cause of chronic diseases/symptoms in the older population, and rehabilitation therapy is effective in treating dysfunctions caused by physical inactivity[2, 3)]. The daily steps required to maintain health and reduce the risk of chronic disease in 40–60-year-old individuals is 8,000–9,000[4)]. Differences in daily steps have been reported in adults living in the United States based on the following factors: age, gender, body mass index (BMI), region of residence, health awareness, eating habits, and lifestyle[5)]. The greatest reduction in mortality was caused by completing 7,500 daily steps, leveling off at higher numbers in older females (n=16,741) aged 60–100 years[6)]. In Japan, the Basic Policy for the Comprehensive Promotion of the Health of the Population, which sets goals for preventing the occurrence and reducing the severity of major lifestyle-related diseases (cancer, cardiovascular disease, diabetes, and chronic obstructive pulmonary disease), has set a target of 7,000 and 6,000 daily steps for males and females, respectively, by 2022[7)].

Individuals who complete fewer daily steps are more susceptible to diseases. The population-attributable risk of diseases caused by physical inactivity is 6% for heart disease, 7% for type 2 diabetes, 10% for breast cancer, and 10% for colon

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cancer in North America and Europe[8]. In a study of 1,635 males and females with motor dysfunction, aged 70–89 years, and followed up for 2.5 years with a moderate-intensity exercise program, severe motor dysfunction was less common in the physical activity group (n=246, 30.1%) than in the health education group (n=290, 35.5%)[9].

Physical activity can prevent disease relapse and reduce disease severity in older individuals with motor dysfunction[9]. The levels of plasma glutamine, the most important biomarker associated with inactivity, were increased by 1.30-fold in older individuals who were inactive[10]. However, in patients at high risk of developing diabetes (older adults with a mean BMI of 27 ± 4 kg/m^2, aged 69 ± 4 years), plasma glutamine was elevated after 2 weeks of exercise restriction (<1,000 steps/day) and remained increased after 2 weeks, even following the resume of normal walking[10]. Even a short-term decrease in daily steps can adversely affect metabolism and increase the risk of disease because the resumption of exercise that increases daily steps does not fully restore the nutrients in the blood that contribute to disease prevention.

Seasonal changes in physical activity among older individuals can affect the severity of lifestyle-related diseases because the risk of developing diseases increases even with a short-term decrease in physical activity[11]. In a study assessing the relationship between daily steps and climate, Chan et al. reported that when 10,000 steps/day was set as a standard, a 10°C rise in air temperature resulted in an increase of 290 steps, while 14 mm of precipitation caused a decrease of 830 steps[12]. A study investigating the relationship between daily step count and age revealed that individuals across all age groups, including young, middle-aged, and older, recorded a higher number of steps per day in summer and spring compared to winter[13]. Furthermore, Arnardottir et al. reported that total physical activity was higher in summer than in winter among healthy older adults aged 73–91 years[14]. Notably, inactive females who completed <5,100 daily steps in spring exhibited decreased daily steps in summer, fall, and winter[15]. In individuals aged 40–60 years, 8,000–9,000 steps are inflection points for the risk of diabetes, obesity, and hypertension[4]. Therefore, lifestyle-related diseases can be influenced by seasonal variations in daily steps in older individuals.

Although daily steps for health maintenance have been set as the target for healthy older individuals, the target number of daily steps required to avoid severe diseases in older individuals with lifestyle-related diseases has not been established in Japan. Such individuals have low levels of physical activity[16], and the daily step goal for healthy older individuals is not directly applicable to them. The number of steps per day to maintain health in the older with lifestyle-related diseases should be set apart from that of the healthy older, considering seasonal variations.

We hypothesized that there would be differences in the pattern of the number of walks in healthy and non-healthy older adults in response to patterns of seasonal (temperature and precipitation) variation (Fig. 1).

PARTICIPANTS AND METHODS

Data were collected from Yorii Town. The first physical fitness measurements were conducted in July/August 2015, and the second in January/February 2016. Daily step data were collected between August 2015 and January 2016.

The inclusion criteria were as follows: 1) age ≥65 years, 2) ability to walk every day, and 3) ability to measure daily steps by themselves. The exclusion criteria were as follows: 1) non-agreement to participate after providing informed consent, 2) inability to take the fitness test twice, and 3) inability to wear the daily step meter during the study period. The time of the second physical fitness test session was notified in written format. Participants were recruited through Yorii Town publicity and website.

The main outcome measure was daily steps. The variables included height, weight, abdominal circumference, body fat percentage, basal metabolic rate, grip strength, long body forward bending, open-eye one-leg stand, lower limb muscle strengths, gait factor, and the SF8 Health Survey (SF-8) score.

Daily steps differ according to gender[17], and diseases such as diabetes[18] lead to fewer daily steps[16]. Therefore, the predictors of daily steps were defined as follows: (1) gender, (2) lifestyle-related diseases (Charlson Comorbidity Index [CCI]), and (3) month of the year. Potential confounding factors included age[19], BMI[4], sense of health[20], precipitation, and

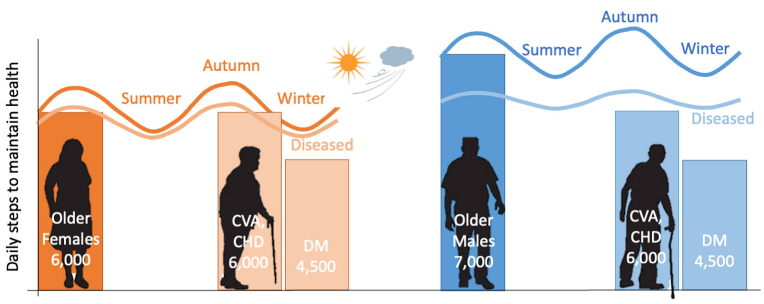

Fig. 1. Seasonal changes in daily steps due to lifestyle-related diseases were investigated in community-dwelling older individuals. CVA: cerebrovascular disease; CHD; coronary heart disease; DM: diabetes mellitus.

air temperature[21]. Data pertaining to age, gender, and medical history were collected using self-administered questionnaires. Health-related quality of life was assessed using the SF-8 questionnaire, and the CCI score was determined from the medical history. The data pertaining to precipitation and air temperature during the study period were downloaded from the Japan Meteorological Agency (JMA) website.

Grip strength was measured according to the Ministry of Education, Culture, Sports, Science and Technology's new physical fitness test implementation guidelines (for participants aged 65–79 years). Daily steps were measured using a daily step meter (NFC accelerometer fs-700, 2010; Estera Corporation, Saitama, Japan) from August 2015 to January 2016. Participants were instructed to remove the daily step meter only during sleep, bathing, and other in-water activities. Daily steps were recorded by holding the daily step meter over the scanner at the health welfare office of Yorii Town and at the public health center. The data were automatically transferred to the administrator in Comma Separated Values format. Lower limb muscle strength was measured in the sitting posterior pelvic tilt position with hip flexion at 90° and knee flexion at 90°, with the participant's pelvis fixed to prevent its movement and the belt pad aligned with the end of the thigh using a handheld dynamometer (Mobie, 2015, SAKAI Medical Co., Ltd. Tokyo, Japan) by using traction with a pull sensor.

According to the Population Census of the Ministry of Internal Affairs and Communications, the Population Projections of the National Institute of Population and Social Security Research, and the Population, Demographic Change and Number of Households based on the Basic Resident Ledger of the Ministry of Internal Affairs and Communications, the surveyed town has a population of approximately 32,000 and is located in the northwestern part of Saitama prefecture within a 70 km radius from central Tokyo. The proportion of workers by industry is 4.0% in agriculture; 31.3% in secondary industries such as construction and manufacturing; and 61.6% in tertiary industries such as retail, medical care, and welfare.

The data were processed using a Java-based Statistical Processor (JASP Version 0.17, Computer software, https://jasp-stats.org/) for the statistical processing of each variable. Confounding factors were adjusted for using them as covariates in the analysis of covariance (ANCOVA). With daily steps as the main outcome, an ANCOVA effect size of F=0.7, power 1-β=0.8, degrees of freedom=3, number of groups=4, and number of covariates=3, the minimum required sample size was calculated as 28 (7 per group) using G*Power (3.1.9.6, Düsseldorf, Germany, 2020). To compare the seasonal changes in daily steps according to gender and presence of disease, we performed two-way ANCOVA with the main outcome as daily steps and factors of season (monthly) and gender. To examine the effect of the presence of disease in older individuals, a three-way ANCOVA with the factors of season (monthly), gender, and CCI score was utilized, focusing on daily steps as the outcome. Age, BMI, mental summary score of the SF-8, and hand grip strength were used as covariates in this analysis. Multiple comparisons were conducted using Tukey's test. Statistical significance was set at 95%. Of the daily step data, data pertaining to 1,466 individuals with less than 1,000 daily steps and 64 individuals with more than 30,000 daily steps were excluded as outliers[22].

Participants were informed of the protocol and potential risks and then provided written informed consent to participate after a meeting was held in July 2015 to explain the study protocol to the participants with the cooperation of Yorii Town officials. Participants were told that they had the right to withdraw their consent at any point, and care was taken to ensure that the participants were not a vulnerable population. Permission for the secondary use of the data was also obtained. This study was conducted in accordance with the principles of the Declaration of Helsinki and approved by the Ethics Committee of Saitama Prefectural University (approval number 29002). Informed consent was obtained from all participants.

RESULTS

In total, 208 older individuals who applied for participation through the town's official website were included in this study. Sixty-one participants who did not provide consent to participate and 30 who did not participate in the two physical fitness tests were excluded. Of the remaining 117 participants, 115 were included in the final analysis after excluding two participants for whom the CCI score was not determined. These participants were classified into four groups according to the CCI score (−for a score of 0, + for a score of 1 or more) and gender: eleven males CCI+, 72 females CCI−; seven males CCI+, and 25 females CCI− (Fig. 2).

The participants' physical and mental characteristics at baseline according to the CCI score and gender are shown in Table 1. Two-way ANCOVA, accounting for gender and CCI index as factors, showed a significant BMI interaction in females ($F=4.2$, $p=0.044$, $\eta 2=0.036$), without notable differences in height, weight, blood pressure, grip strength, lower limb muscle strength, and SF-8 score between males and females ($F=0.0–3.1$, all $p_{interaction}>0.05$). When all variables were tested for multiple comparisons, there were no significant differences between males and females with respect to the CCI score ($t=−1.6–2.4$, $p_{Tukey}>0.05$).

Monthly changes in daily steps are shown in Fig. 3. The daily steps (mean ± standard deviation) for females with CCI− score for six months were 6,341 ± 2,765. The monthly average daily steps were as follows: August, 5,858 ± 3,189; September, 6,254 ± 3,407; October, 6,724 ± 3,619; November, 7,010 ± 3,853; December, 6,633 ± 3,626; and January, 6,599 ± 3,821. Daily steps for females with CCI+ score for six months were 5,563 ± 2,398. The monthly average daily steps were as follows: August, 5,088 ± 2,516; September, 5,659 ± 2,909; October, 6,104 ± 2,972; November, 5,895 ± 3,216; December, 5,020 ± 2,747; and January, 5,653 ± 2,663. Daily steps for males with CCI− score for six months were 7,719 ± 3,052. The monthly average daily steps were as follows: August, 6,805 ± 3,590; September, 7,566 ± 3,925; October, 7,917 ± 3,997; November,

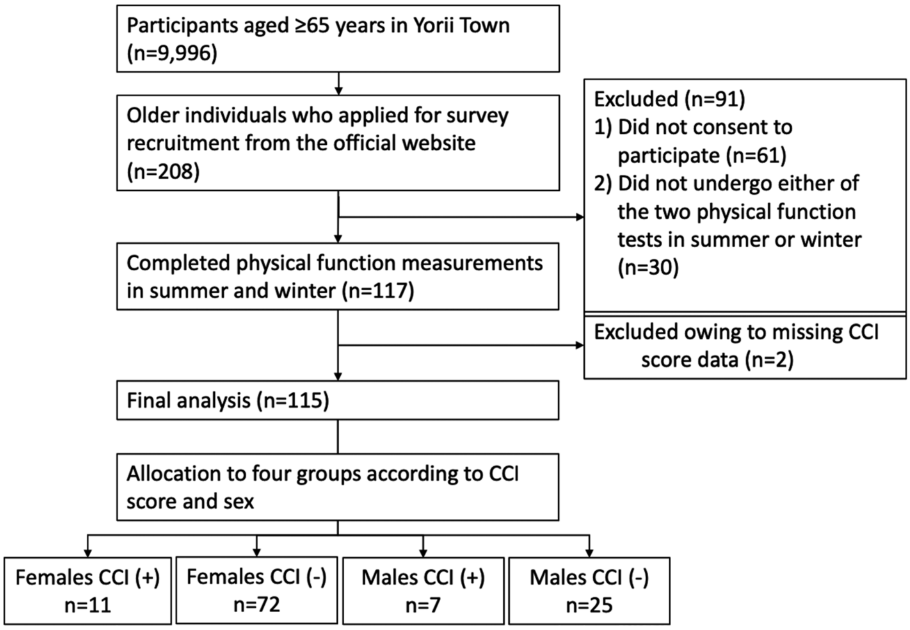

Fig. 2. Flow chart of the selection of the study population.
The disease CCI score was (−) when it did not apply at all and (+) when one or more items were true. CCI: Charlson Comorbidity Index.

Table 1. Baseline characteristics of participants according to CCI score

Variables	Females (n=83)		Males (n=32)	
	CCI+ (n=11)	CCI− (n=72)	CCI+ (n=7)	CCI− (n=25)
Age (years)	73 ± 6	72 ± 4	74 ± 7	72 ± 5
Height (cm)	151 ± 0	151 ± 0	165 ± 0	162 ± 0
Weight (kg)	54 ± 6	52 ± 8	58 ± 5	62 ± 7
BMI (kg/m^2)	23.6 ± 3	22.6 ± 3	21.3 ± 1	23.5 ± 3
sBP (mmHg)	123 ± 23	132 ± 17	123 ± 13	131 ± 19
dBP (mmHg)	65 ± 13	72 ± 8	69 ± 7	71 ± 11
GS (kg)	24 ± 4	24 ± 4	34 ± 9	35 ± 7
L/E MS (N • m)	86 ± 18	84 ± 23	94 ± 26	113 ± 23
SF-8 PCS	49 ± 6	46 ± 6	49 ± 4	45 ± 8
SF-8 MCS	49 ± 8	51 ± 5	53 ± 3	50 ± 7
Step count	5,563 ± 2,398	6,341 ± 2,765	5,803 ± 1,190	7,719 ± 3,052

Two-way analysis of covariance results for psychosomatic characteristics at baseline are shown, with gender and CCI score as factors. Data are presented as the mean ± standard deviation for continuous variables. CCI: Charlson Comorbidity index; BMI: body mass index; sBP: systolic blood pressure; dBP: diastolic blood pressure; GS: grip strength; L/E MS: lower extremity muscle strength; SF-8 PCS: SF8 Health Survey Physical Summary Score; SF-8 MCS: SF8 Health Survey Mental Summary Score; Step count: daily average step count from August to January.

8,152 ± 4,667; December, 8,907 ± 4,802; and January, 8,973 ± 4,960. Daily steps for males with CCI+ score for six months were 5,768 ± 3,292. The monthly average daily steps were as follows: August, 5,485 ± 3,593; September, 5,803 ± 1,190; October, 6,276 ± 3,297; November, 6,101 ± 3,398; December, 5,651 ± 2,781; and January, 5,182 ± 3,208 (Fig. 3).

The results of three-way ANCOVA with daily steps per month, gender, and CCI score as factors showed a significant interaction ($F_{interaction}$=3.9, p<0.002, η^2=0.001). Significant effects were observed for time ($F_{main\ effect}$=16.8, p<0.001, η2=0.004), gender (F=117.5, p<0.001, η^2=0.006), and CCI score (F=432.3, p<0.001, η^2=0.023). Multiple comparison test (post-hoc) results showed that female participants with CCI+ completed significantly fewer monthly daily steps than did those with CCI− in November (mean difference=1,138 ± 220, t=5.17, p_{tukey}<0.001) and December (mean difference=1,578 ± 239, t=6.59, p_{tukey}<0.001) (Fig. 3b). There was no significant difference in the monthly daily steps among females with CCI+. Females with CCI− completed significantly more daily steps in October, November, December, and January than they did in

August. Similarly, they completed more daily steps in October, and November than they did in September and in November than they did in December or January ($p<0.05$). Males with CCI+ completed fewer monthly daily steps than did those with CCI− at all time points ($p<0.001$, Fig. 3c). There was no significant difference in the monthly daily steps among males with CCI+. Males with CCI− completed fewer daily steps in August than they did in October, November, December, and January; in September than in December and January; in October than in December and January; and in November than in January ($p<0.05$).

Yorii town has four seasons: spring (March–May), summer (June–August), autumn (September–November), and winter (December–February). During the six months of this study (August–January), the highest average temperature was in August 2015, with a monthly mean temperature of 25.6 ± 3.3°C; in contrast, the lowest was in January 2016, with a monthly mean temperature of 3.0 ± 2.0°C. The mean monthly temperature in autumn ranged from 11.8 to 21.1°C. Monthly mean precipitation was 6.6 ± 14.1 mm in August 2015, with a maximum of 9.6 ± 26.1 mm in September, 0.3 ± 0.9 mm in October, and 0.3 ± 1.0 mm in December (Table 2).

DISCUSSION

In this study, daily steps and physical function were investigated for six months in a community-based population of older individuals to provide exercise guidance considering the seasonal changes in air temperature and precipitation, with or without disease as a factor. The average daily steps completed by older females with disease were below the target level of 6,000 in all seasons except autumn (October, 6,100 steps). Daily steps were significantly fewer in November and December for older females with disease than in those without. Older males with disease consistently took fewer daily steps than the target for Japanese older individuals and significantly fewer than those by healthy older individuals[7)].

Physical activity in young adults was reported to be higher in summer than in other seasons[19)]. However, older individuals are more likely to have elevated body temperatures during summer, and the thresholds for autonomic reflexes and cutaneous vasodilatory responses decrease when the body temperature increases[23)]; moreover, they have a significantly higher risk of

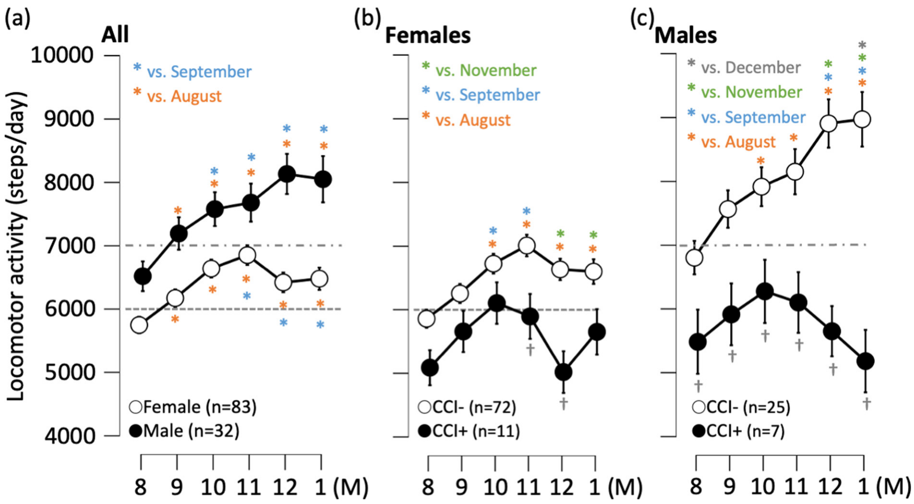

Fig. 3. Seasonal changes in locomotor activity stratified by gender and lifestyle-related diseases. (a) Gender-based monthly locomotor activity changes. (b) Lifestyle-related disease stratification in females. (c) Variations in males with and without lifestyle-related diseases. Data are presented as mean ± 95% confidence interval. A colored * indicates comparison with other months. †: differences by disease status per month. The 2022 daily step targets for individuals aged ≥65 years, 7,000 for males and 6,000 for females (Ministry of Health, Labour and Welfare, 2012), are marked by horizontal dotted lines. Seasonal classifications: August as summer; September to November as autumn; December and January as winter (Japan Meteorological Agency). CCI: Charlson Comorbidity Index.

Table 2. Monthly 24-hour mean temperature and precipitation in Yorii Town

Month	August	September	October	November	December	January
Temperature (°C)	25.7 ± 0	21.6 ± 0	16.2 ± 0	10.9 ± 0	5.9 ± 0	2.9 ± 0
Precipitation amount (mm/d)	8.3 ± 0	8.9 ± 0	1.9 ± 0	2.8 ± 0	0.4 ± 0	1.6 ± 0

Analysis of covariance results for temperature and precipitation from August to January in Yorii Town, Japan, as published by the Japan Meteorological Agency. August is summer; September–November is fall; and December–January is winter.

hospitalization due to fluid and electrolyte disorders, renal failure, urinary tract infections, septicemia, heat stroke, and other external causes of heat waves[24]. Thus, older adults may have a relatively lower ability to adapt to increases in air temperature or body temperature due to physical activity compared to young adults.

The daily steps completed by stroke survivors one year after the onset of stroke range from 3,000 to 6,000 steps/day[25]. The risk of developing diabetes increases when daily steps are less than 4,500[26], and that of developing heart disease is 40–50% lower in older individuals with 6,000–9,000 daily steps than in those with 2,000 daily steps[27]. In the present study, the mean daily steps by older individuals with disease were 5,581 ± 2,884 for females and 5,774 ± 3,320 for males over a six-month period. Importantly, many older people may not be able to achieve Japan's daily step count goal on extremely hot days (above 35°C). Meanwhile, the JMA revised its weather forecast terminology in 2008 to predict high temperatures, humidity, and the risk of heat stroke. The JMA issues warnings during summer regarding the risk of heat stroke, and in such cases, daily steps tend to be few, especially for older individuals who curtail outdoor activities during the day. Thus, for the older with disease, a safe daily step count should be converted to a target daily step count, considering that physical activity is reduced due to illness.

Midsummer temperatures in Yorii average over 25°C, while winter temperatures are lower than 10°C. A monthly telephone survey of adults in the United States aged ≥65 years showed that they were 3.33 times more likely to exercise indoors rather than outdoors during rainy summer days than hot days[28]. Furthermore, older individuals in Yorii Town compensate for the decrease in daily steps by engaging in indoor activities that are not affected by air temperature and precipitation in summer, such as stretching, strength training, gymnastics, and housework, which are beneficial to their health. Inoue et al. adjusted for comorbidities such as diabetes, heart disease, and lung disease, which are confounders of walking and mortality, and reported a 19.9% lower risk of all-cause mortality in persons aged ≥65 years who achieved at least 8,000 daily steps for 1–2 days per week than in those who did not achieve this target[29]. Based on these findings, we recommend that individuals with low daily step counts during summer and winter engage in activities during the cooler morning and evening hours in summer. Additionally, further research is needed to ascertain if advising them to schedule outdoor activities once or twice a week in winter, either indoors or with appropriate warm clothing, would help achieve the target daily step count and subsequently benefit older individuals' health[10].

This study has several limitations. First, this study did not examine depression and cognitive function in participants. As these psychological factors affect the degree of physical activity in older individuals[30], these should be investigated and analyzed in future studies. Second, the participants in this study responded to the survey over a six-month period, suggesting that they were highly motivated to maintain their health awareness and physical activity levels. This suggests that a selection bias might have occurred while selecting the participants for this study. Another study should be conducted to determine how physical activity differs according to season and disease status in older individuals who do not respond to a health survey of the general population and to determine other measures to address this issue. Third, we counted the daily steps of older individuals every day for six months to determine the seasonal variability in daily steps depending on the presence or absence of disease. These results can be used as a reference for climatic conditions, living conditions, and periods similar to those in the region in which this study was conducted. Lastly, participants in this study were 65 years of age or older, but their employment status was not investigated. Because the daily physical activities undertaken by employed and unemployed participants might have been different, the lack of consideration of participants' employment status was an issue that should be resolved in the next study.

Funding

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Conflict of interest

The authors declare that there is no conflict of interest.

REFERENCES

1) Booth FW, Roberts CK, Laye MJ: Lack of exercise is a major cause of chronic diseases. Compr Physiol, 2012, 2: 1143–1211. [Medline] [CrossRef]

2) Posadzki P, Pieper D, Bajpai R, et al.: Exercise/physical activity and health outcomes: an overview of Cochrane systematic reviews. BMC Public Health, 2020, 20: 1724. [Medline] [CrossRef]

3) Cunningham C, O' Sullivan R, Caserotti P, et al.: Consequences of physical inactivity in older adults: a systematic review of reviews and meta-analyses. Scand J Med Sci Sports, 2020, 30: 816–827. [Medline] [CrossRef]

4) Master H, Annis J, Huang S, et al.: Association of step counts over time with the risk of chronic disease in the All of Us Research Program. Nat Med, 2022, 28: 2301–2308. [Medline] [CrossRef]

5) Bassett DR Jr, Wyatt HR, Thompson H, et al.: Pedometer-measured physical activity and health behaviors in U.S. adults. Med Sci Sports Exerc, 2010, 42: 1819–1825. [Medline] [CrossRef]

6) Lee IM, Shiroma EJ, Kamada M, et al.: Association of step volume and intensity with all-cause mortality in older women. JAMA Intern Med, 2019, 179: 1105–1112. [Medline] [CrossRef]
7) Ministry of Health, Labour and Welfare, Japan: Health Japan 21 (Physical Activity and Exercise), 2012.
8) Lee IM, Shiroma EJ, Lobelo F, et al. Lancet Physical Activity Series Working Group: Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet, 2012, 380: 219–229. [Medline] [CrossRef]
9) Pahor M, Guralnik JM, Ambrosius WT, et al. LIFE study investigators: Effect of structured physical activity on prevention of major mobility disability in older adults: the LIFE study randomized clinical trial. JAMA, 2014, 311: 2387–2396. [Medline] [CrossRef]
10) Saoi M, Li A, McGlory C, et al.: Metabolic perturbations from step reduction in older persons at risk for sarcopenia: plasma biomarkers of abrupt changes in physical activity. Metabolites, 2019, 9: 9. [Medline] [CrossRef]
11) Garriga A, Sempere-Rubio N, Molina-Prados MJ, et al.: Impact of seasonality on physical activity: a systematic review. Int J Environ Res Public Health, 2021, 19: 19. [Medline] [CrossRef]
12) Chan CB, Ryan DA, Tudor-Locke C: Relationship between objective measures of physical activity and weather: a longitudinal study. Int J Behav Nutr Phys Act, 2006, 3: 21. [Medline] [CrossRef]
13) Wesolowska K, Czarkowska-Paczek B: Activity of daily living on non-working and working days in Polish urban society. Int J Occup Med Environ Health, 2018, 31: 47–54. [Medline]
14) Arnardottir NY, Oskarsdottir ND, Brychta RJ, et al.: Comparison of summer and winter objectively measured physical activity and sedentary behavior in older adults: age, gene/environment susceptibility Reykjavik study. Int J Environ Res Public Health, 2017, 14: 14. [Medline] [CrossRef]
15) Kim Y, Kang M, Tacón AM, et al.: Longitudinal trajectories of physical activity in women using latent class growth analysis: the WIN Study. J Sport Health Sci, 2016, 5: 410–416. [Medline] [CrossRef]
16) Shoemaker MJ, Ferrick A, Fischer C, et al.: Quantification of seasonal variation in daily physical activity in individuals with heart failure and implantable cardioverter defibrillator/cardiac resynchronisation therapy devices. Heart Int, 2019, 13: 31–37. [Medline] [CrossRef]
17) Ministry of Health, Labour and Welfare, Japan: Health Japan 21 (Physical Activity and Exercise), 2023.
18) Hult A, Johansson J, Nordström P, et al.: Objectively measured physical activity in older adults with and without diabetes. Clin Diabetes, 2019, 37: 142–149. [Medline] [CrossRef]
19) Cepeda M, Muka T, Ikram MA, et al.: Seasonality of insulin resistance, glucose, and insulin among middle-aged and elderly population: the Rotterdam study. J Clin Endocrinol Metab, 2018, 103: 946–955. [Medline] [CrossRef]
20) Maruyama Y: Relationship between physical activity and health-related quality of life for community-dwelling older adults. Total Rehabil Res, 2023, 11: 37–45.
21) Sumukadas D, Witham M, Struthers A, et al.: Day length and weather conditions profoundly affect physical activity levels in older functionally impaired people. J Epidemiol Community Health, 2009, 63: 305–309. [Medline] [CrossRef]
22) Rowe DA, Mahar MT, Raedeke TD: Measuring physical activity in children with pedometers: reliability, reactivity, and replacement of missing data. Pediatr Exerc Sci, 2004, 16: 343–354. [CrossRef]
23) Greaney JL, Stanhewicz AE, Wolf ST, et al.: Thermoregulatory reflex control of cutaneous vasodilation in healthy aging. Temperature (Austin), 2020, 8: 176–187. [Medline] [CrossRef]
24) Bobb JF, Obermeyer Z, Wang Y, et al.: Cause-specific risk of hospital admission related to extreme heat in older adults. JAMA, 2014, 312: 2659–2667. [Medline] [CrossRef]
25) Handlery R, Regan EW, Stewart JC, et al.: Predictors of daily steps at 1-year poststroke: a secondary analysis of a randomized controlled trial. Stroke, 2021, 52: 1768–1777. [Medline] [CrossRef]
26) Ballin M, Nordström P, Niklasson J, et al.: Daily step count and incident diabetes in community-dwelling 70-year-olds: a prospective cohort study. BMC Public Health, 2020, 20: 1830. [Medline] [CrossRef]
27) Paluch AE, Bajpai S, Bassett DR, et al. Steps for Health Collaborative: Daily steps and all-cause mortality: a meta-analysis of 15 international cohorts. Lancet Public Health, 2022, 7: e219–e228. [Medline] [CrossRef]
28) Wagner AL, Keusch F, Yan T, et al.: The impact of weather on summer and winter exercise behaviors. J Sport Health Sci, 2019, 8: 39–45. [Medline] [CrossRef]
29) Inoue K, Tsugawa Y, Mayeda ER, et al.: Association of daily step patterns with mortality in US adults. JAMA Netw Open, 2023, 6: e235174. [Medline] [CrossRef]
30) Choi KW, Zheutlin AB, Karlson RA, et al.: Physical activity offsets genetic risk for incident depression assessed via electronic health records in a biobank cohort study. Depress Anxiety, 2020, 37: 106–114. [Medline] [CrossRef]