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Association between daily step counts and healthy life years: a national cross-sectional study in Japan

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ABSTRACT

Background Despite accumulating evidence concerning the association between daily step counts and mortality or disease risks, it is unclear whether daily step counts are associated with healthy life years.

Methods We used the combined dataset of the Comprehensive Survey of Living Conditions and the National Health and Nutrition Survey conducted for a randomly sampled general population in Japan, 2019. Daily step counts were measured for 4957 adult participants. The associations of daily step counts with activity limitations in daily living and self-assessed health were evaluated using a multivariable logistic regression model. The bootstrap method was employed to mitigate uncertainties in estimating the threshold of daily step counts.

Results The median age was 60 (44–71) years, and 2592 (52.3%) were female. The median daily step counts were 5650 (3332–8452). The adjusted OR of activity limitations in daily living for the adjacent daily step counts was 0.27 (95% CI 0.26 to 0.27) for all ages and 0.25 (95% CI 0.25 to 0.26) for older adults at the lowest, with the thresholds of significant association at 9000 step counts. The OR of self-assessed unhealthy status was 0.45 (95% CI 0.44 to 0.46) for all ages and 0.42 (95% CI 0.41 to 0.43) for older adults at the lowest, with the thresholds at 11 000 step counts.

Conclusion Daily step counts were significantly associated with activity limitations in daily living and self-assessed health as determinants of healthy life years, up to 9000 and 11 000 step counts, respectively. These results suggest a target of daily step counts to prolong healthy life years within health initiatives.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Healthy life years, also known as healthy life expectancy, have come to be focused on as a holistic health indicator in an ageing society. Estimations of healthy life years are derived from national health surveys to assess the presence of activity limitations in daily living and self-assessed health in the USA and the UK as well as Japan. Despite accumulating evidence concerning the association between daily step counts and mortality or disease risks, there is little knowledge regarding the association between daily step counts and healthy life years.

WHAT THIS STUDY ADDS

⇒ Daily step counts were significantly associated with activity limitations in daily living and self-assessed health as key determinants of healthy life years, up to 9000 and 11 000 step counts, respectively.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings suggest the optimal target of daily step counts to prolong healthy life years within health initiatives aimed at increasing physical activity and raising health awareness of people. An effective health promotion, such as an increase in daily step counts in the general population, will prolong healthy life years and narrow the existing health disparities.

INTRODUCTION

Healthy life years, also known as healthy life expectancy, are holistic health indicator encompassing life, health, disease, disability, activity limitation and overall well-being. Estimations of healthy life years are derived from national health surveys that incorporate questionnaires to assess the presence of activity limitations in daily living and self-assessed health in the USA and the UK as well as Japan.[1–3] In addition to conventional risk factors of lifestyle-related diseases,[4 5] several non-fatal conditions, such as mental health diseases, orthopaedic problems and neurological disorders, substantially influence healthy life years.[6–8] Effective health policies for the disease prevention and health promotion are necessary to prolong healthy life years and narrow the differences between life expectancy and healthy life years.

Physical activities and exercises are expected to be beneficial for healthy life years.[9–11] Walking is a cost-effective aerobic physical activity in daily life, and its metric, step count, is readily measured by simple devices. While the WHO has issued guidelines recommending regular physical activity to promote a healthy life, it has refrained from specifying the optimal target of daily step counts.[12] Notably, an increase in daily step counts ameliorates cardiovascular disease

(CVD) and mortality risk.[13–15] In this context, target step counts of 7200 and 8800 per day have been suggested for mitigating the risk of CVD and all-cause mortality, respectively.[16]

Despite accumulating evidence concerning the association between daily step counts and mortality or disease risks, there is limited knowledge regarding the association between daily step counts and healthy life years. The purpose of this study is to elucidate the associations of daily step counts with activity limitations in daily living and self-assessed health, as key determinants of healthy life years, and provide the optimal target of daily step counts to prolong healthy life years.

METHODS

Study design and setting

The Comprehensive Survey of Living Conditions (CSLC), a cross-sectional national survey, has been conducted every 3 years by Japanese Ministry of Health, Labour and Welfare (MHLW) to investigate the fundamental dimensions of the nation's livelihood, such as health, medical care, welfare, pension and income.[3] In health questionnaire of the CSLC, subjective symptoms, health problems in daily life, disease or injury under treatment, subjective health assessment, worries and stress, mental state, and receiving rate of health check-ups are surveyed. The response rate for CSLC in 2019 was recorded at 72.5%. The National Health and Nutrition Survey (NHNS), another cross-sectional national survey, has been conducted with a random sample of participants drawn from the CSLC by the MHLW to comprehensively investigate the nation's physical status, nutrition intakes and lifestyle.[17] The response rate for NHNS in 2019 was recorded at 63.5%. In the NHNS, daily step counts in a single day were measured with a pedometer which was distributed to the participants, accompanied by detailed instruction on the measurement procedure. These surveys were conducted for a randomly sampled general population through face-to-face interviews. An online survey format was used together for questionnaires regarding physical status and lifestyle in NHNS.

The data of CSLC and NHNS were integrated using common identifier for prefecture, region, unit, household and household member. Among the combined dataset of NHNS and CSLC in 2019, data from 22 respondents with missing values of activity limitations in daily living or self-assessed health were excluded. Consequently, data from 4957 adult responders aged ≥18 years were prepared for the analysis (online supplemental figure 1). The data were analysed from 30 September 2023 to 20 November 2023.

Outcomes

In the CSLC, activity limitations in daily living of responders were investigated using responses to the questions, 'Do you have any health problem which limits your daily activity?' Respondents who answered 'yes' were categorised into the 'activity limitations' group, and those who answered 'no' were categorised into the 'no activity limitation' group. In the NHNS, self-assessed health was investigated using responses to the questions, 'How would you rate your current health status?'. Respondents who answered 'excellent', 'good', or 'fair' were categorised into the 'self-assessed healthy status' group, and those who answered 'poor' or 'bad' were categorised into the 'self-assessed unhealthy status' group. The associations of daily step counts with activity limitations in daily living and self-assessed health were evaluated for all age group ≥18 years and older adults group ≥65 years. In addition, the health condition without activity limitation (HCAL), a machine-learning-based integrated health index reflecting on healthy life years,[6] was examined.

Statistical analysis

General statistics were performed in R V.4.2.0.[18] Categorical values are represented as numbers (along with percentages), and numerical values are represented as medians with IQRs. A $p<0.05$ was considered statistically significant. The HCAL was computed based on predictive probabilities for activity limitations in daily living employing a machine-learning model deployed in Python V.3.10.6. according to our preceding report.[6] Spline curve and its slope curve were plotted with a 95% CI.

The bootstrap method followed by bootstrap aggregating, referred to as bagging, was employed to mitigate uncertainties in estimating the threshold of daily step counts by reducing the prediction error.[19] A large sample group was generated by repeatedly drawing samples with replacement from the original sample. Age, sex and several kinds of diseases or injuries under treatment are known to be important predictors for healthy life years.[6] After 1000 rounds of bootstrapping, multivariable logistic regression model was fitted for each sample, incorporating variables such as age, sex, increments of 1000 daily step counts and the presence of diseases or injuries under treatment as predictive factors. Subsequently, mean adjusted ORs were calculated from the set of predicted values of each model, and regression curve fitting was performed. The OR for adjacent daily step counts was calculated to define the threshold at which the upper limit of the 95% CI reached 1.0.

Patient and public involvement

Neither patients nor members of the public were directly involved in the design, conduct or reporting of this research.

RESULTS

Participants characteristics

Among the combined dataset of the CSLC (n=481 255) and the NHNS (n=6820) in 2019, the data of adult respondents were extracted (online supplemental figure 1). The baseline characteristics of participants were described for all-age group ≥18 years (n=4957) and older adults group

Table 1 Baseline characteristics of study participants

Characteristics	All aged ≥18 years (n=4957)	Older adults aged ≥65 years (n=2024)
Age, years	60 (44–71)	72 (69–78)
Sex (female)	2592 (52.3)	1046 (51.7)
BMI	22.7 (20.5–25.2)	23.0 (20.9–25.3)
Daily step counts	5650 (3332–8452)	4351 (2314–7023)
<2000	478 (12.3)	342 (21.1)
2000–3999	757 (19.4)	400 (24.7)
4000–5999	842 (21.6)	339 (20.9)
6000–7999	714 (18.3)	241 (14.9)
8000–9999	468 (12.0)	147 (9.0)
10 000–11 999	284 (7.2)	73 (4.5)
12 000–13 999	156 (4.0)	34 (2.1)
14 000–15 999	93 (2.3)	24 (1.4)
16 000+	107 (2.7)	22 (1.3)
Activity limitations in daily living	686 (13.8)	452 (22.3)
Self-assessed health status (unhealthy)	681 (13.7)	405 (20.1)
HCAL	93.2 (79.6–96.1)	83.4 (62.6–91.3)
Obesity	34 (0.68)	24 (1.1)
Hypertension	913 (18.4)	675 (33.3)
Diabetes	364 (7.3)	276 (13.6)
Dyslipidaemia	399 (8.0)	278 (13.7)
Gout	94 (1.9)	52 (2.5)
Depression or other mental diseases	103 (2.0)	24 (1.1)
Dementia	34 (0.68)	31 (1.5)
Parkinson disease	15 (0.30)	13 (0.64)
Other neurological disorders, pain or paralysis	46 (0.92)	27 (1.3)
Stroke, cerebral haemorrhage or infarction	72 (1.4)	58 (2.8)
Angina, myocardial infarction	114 (2.3)	94 (4.6)
Other cardiovascular disease	116 (2.3)	89 (4.4)
Malignant neoplasm or cancer	68 (1.3)	47 (2.3)
Anaemia or blood disease	31 (0.62)	14 (0.69)
Thyroid disease	89 (1.8)	47 (2.3)
Allergic rhinitis	123 (2.4)	60 (2.9)
Acute nasopharyngitis, common cold	19 (0.38)	11 (0.54)
Chronic obstructive pulmonary disease	16 (0.32)	14 (0.69)
Asthma	68 (1.3)	34 (1.6)
Other respiratory disease	78 (1.5)	54 (2.6)
Stomach or duodenum disease	101 (2.0)	77 (3.8)
Liver or gallbladder disease	68 (1.3)	40 (1.9)
Other digestive disease	65 (1.3)	40 (1.9)
Rheumatoid arthritis	39 (0.78)	28 (1.3)
Arthritis	160 (3.2)	105 (5.1)
Stiff shoulder	149 (3.0)	93 (4.5)
Back pain	316 (6.3)	220 (10.9)
Bone fracture	39 (0.78)	32 (1.5)

Continued

Table 1 Continued

Characteristics	All aged ≥18 years (n=4957)	Older adults aged ≥65 years (n=2024)
Osteoporosis	116 (2.3)	101 (4.9)
Other injury or burns	37 (0.74)	21 (1.0)
Kidney disease	65 (1.3)	46 (2.2)
Eye disease	389 (7.8)	319 (15.8)
Ear disease	67 (1.3)	55 (2.7)
Prostatic hypertrophy	108 (2.1)	99 (4.8)
Dental disease	319 (6.4)	194 (9.5)
Atopic dermatitis	45 (0.90)	6 (0.29)
Other skin disease	112 (2.2)	49 (2.4)
Menopausal or postmenopausal disorder	11 (0.22)	1 (0.049)

Categorical values represented as numbers (%) and numerical values as median (IQR).
BMI, body mass index; HCAL, health condition without activity limitations.

≥65 years (n=2024) (table 1). The median age was 60 years vs 72 years, and female sex comprised 2592 (52.3%) vs 1046 (51.7%) in the all-age and older adults group, respectively. The median daily step counts were 5652 step counts in the all-age group, compared with 4358 step counts in the older adults group. The prevalence rate of activity limitations in daily living was 686 (13.8%) vs 452 (22.3%), and the rate of self-assessed unhealthy status was 681 (13.7%) vs 405 (20.1%) in the all-age and older adult groups, respectively. The median value of HCAL was 93.2 vs 83.4. The older adults group exhibited higher prevalence rate of various kinds of diseases or injuries under treatments compared with the all-age group, except for depression or other mental diseases, atopic dermatitis and menopausal or postmenopausal disorder.

Association between daily step counts and activity limitations in daily living

To ascertain the association between daily step counts and healthy life years, spline curve and its slope curve were depicted for daily step counts and HCAL (figure 1). In the all-age group, as daily step counts increased, HCAL increased with a marked rise at fewer daily step counts although the increase was gradually diminished in higher daily step counts. The lower limit of the 95% CI of slope descended below 0 at approximately 12 000 step counts per day. Similar to the all-age group, in the older adults group, as daily step counts increased, HCAL showed a similar trend, and the lower limit of the 95% CI of slope descended below 0 within the range of 10 000–11 999 step counts per day. The sex difference was not detected in the association between daily step counts and HCAL in both the all-age and older adult groups (online supplemental figure 2).

The associations between daily step counts and activity limitations in daily living were assessed (figure 2 and online supplemental figure 3). In the all-age group, as daily step counts increased, the unadjusted rate of activity limitations in daily living declined, and the adjusted odds of activity limitations in daily living steadily decreased. The adjusted OR for the adjacent daily step counts was 0.27 (95% CI 0.26 to 0.27) at the lowest, and the upper limit of the 95% CI reached 1.0 at 9000 step counts (OR 0.95 (95% CI 0.91 to 1.00)). Similarly, the older adults group exhibited a parallel trend in the association between daily step counts and activity limitations in daily living. The OR was 0.25 (95% CI 0.25 to 0.26) at the lowest, and the upper limit of the 95% CI reached 1.0 at 9000 step counts (OR 0.92 (95% CI 0.85 to 1.00)). The impact of sex was not significant in both the all-age and older adult groups (online supplemental figure 4 and 5). Collectively, daily step counts were significantly associated with activity limitations in daily living, with the threshold at 9000 step counts in both the all-age and older adult groups.

Association between daily step counts and self-assessed health

The associations between daily step counts and self-assessed health were also assessed (figure 3 and online supplemental figure 6). In all-age group, as daily step counts increased, the unadjusted rate of self-assessed unhealthy status declined, and the adjusted odds of self-assessed unhealthy status steadily decreased. The OR for the adjacent daily step counts was 0.45 (95% CI 0.44 to 0.46) at the lowest, and the upper limit of the 95% CI reached 1.0 at 11 000 step counts (OR 0.95 (95% CI 0.89 to 1.00)). The older adults group exhibited similar trends of the association between daily step counts and self-assessed unhealthy status. The OR was 0.42 (95% CI 0.41 to 0.43) at the lowest, and the upper limit of the 95% CI reached 1.0 at 11 000 step counts (OR 0.91 (95% CI 0.80 to 1.03)). The impact of sex was not significant in both the all-age and older adult groups (online supplemental figures 7 and 8). Thus, daily step counts were significantly associated with self-assessed health, with the threshold

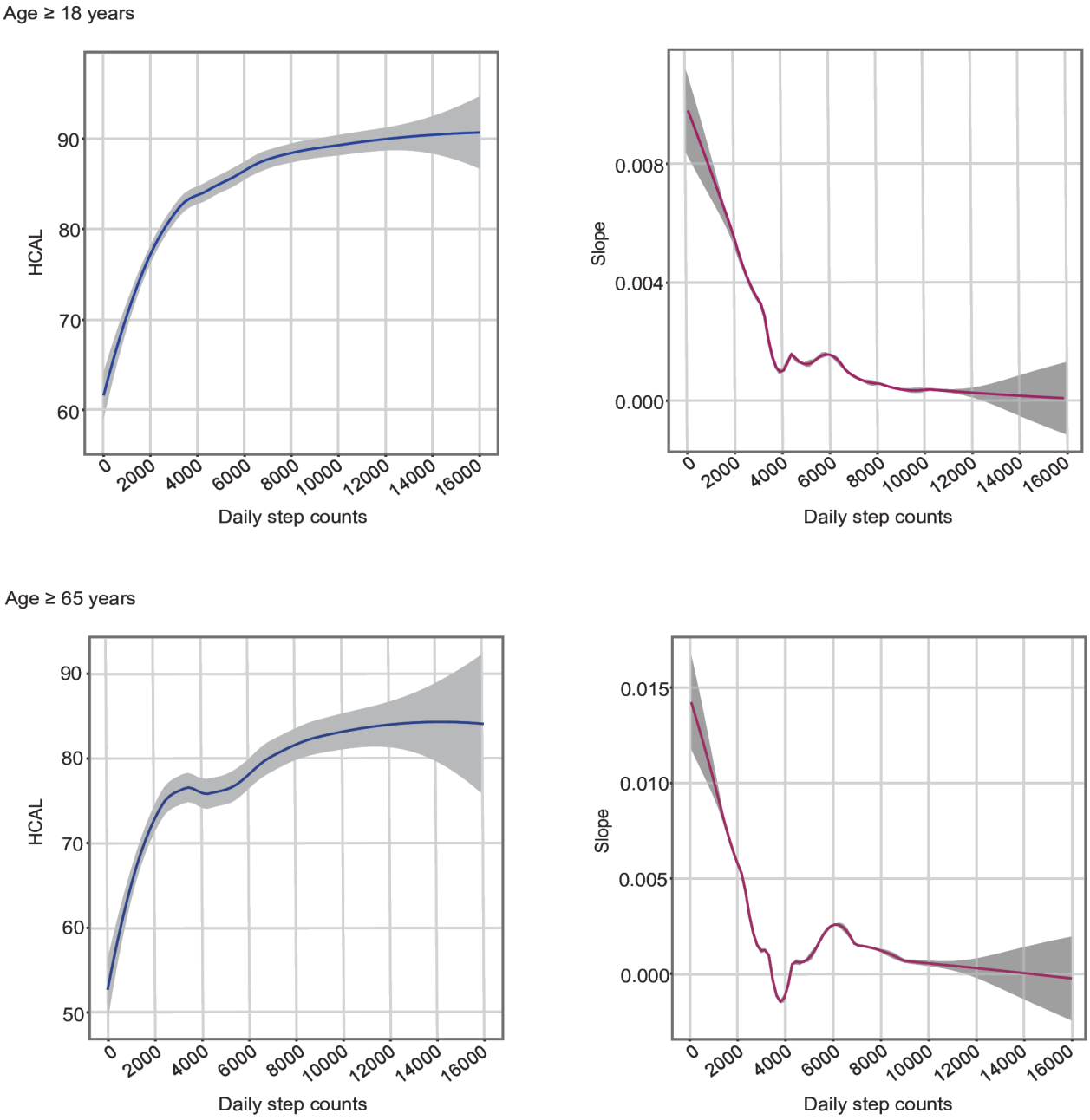

Figure 1 Association between daily step counts and integrated health index reflecting on healthy life years. Spline curve and slope curve were depicted by plotting daily step counts and health condition without activity limitations (HCAL) for all-age and older adult groups. Shaded areas represent 95% CI.

at 11 000 step counts in both the all-age and older adult groups.

DISCUSSION

This study using the combined national health survey data has provided the insights into the associations of daily step counts with activity limitations in daily living and self-assessed health, as key determinants of healthy life years. An increase in daily step counts was significantly associated with the improvement of activity limitations in daily living and self-assessed health, with thresholds of significant association at 9000 and 11 000 step counts, respectively, regardless of age.

This study suggests the optimal target of daily step counts to prolong healthy life: 9000 step counts for activity limitations in daily living and 11 000 step counts for self-assessed health. Increase in daily step counts reduces CVD and mortality risks, whereas the effect of step intensity is controversial.[13–15 20 21] A meta-analysis has introduced 7200 and 8800 step counts per day as potential targets for reducing CVD and all-cause mortality risks, respectively.[16] Given that healthy life years are shorter than life expectancy, it is conceivable that the optimal targets of daily step counts, for prolonging healthy life years, may necessitate more step counts than what are required for the reduction of mortality and CVD risk.

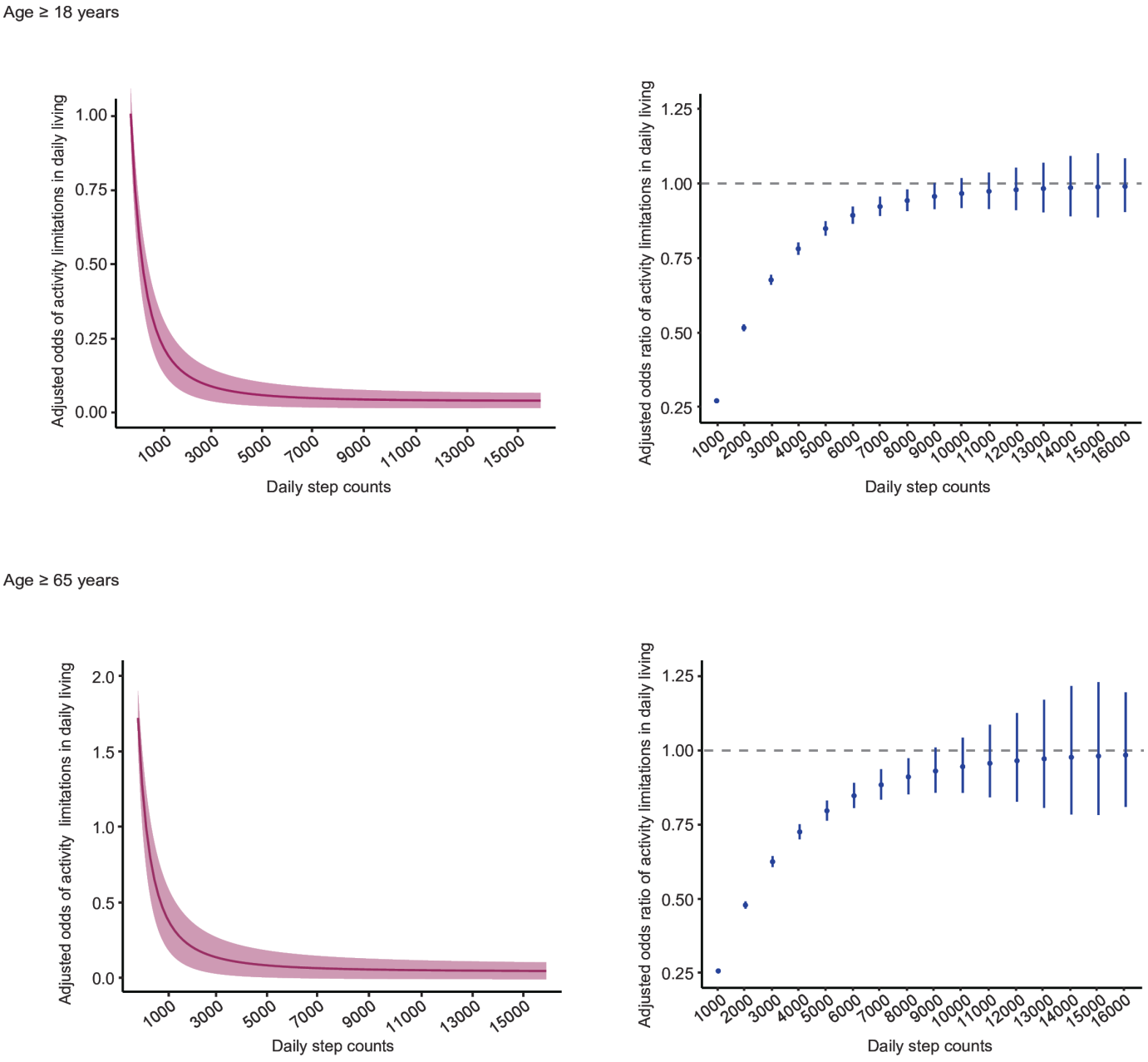

Figure 2 Association between daily step counts and activity limitations in daily living. Adjusted ORs and ORs of activity limitation in daily living were evaluated for daily step counts. Once the daily step counts reached 9000, an increase in 1000 step counts per day was no longer significantly associated with reduced odds of activity limitations in daily living for all-age and older adult groups. Error bars and shaded areas represent 95% CI.

We evaluated activity limitations in daily living and self-assessed health status—metrics that do not include mortality, as alternatives to healthy life years. Indeed, healthy life years are estimated based on a health survey regarding activity limitations in daily living and self-assessed health in the USA and the UK as well as Japan.[1–3] The prevalence rates of activity limitations in daily living or self-assessed unhealthy status in each age groups are incorporated into a life table to estimate healthy life years.[22] Self-assessed health has been shown to be a predictor for mortality and morbidity.[23 24] In addition, racial and ethnic disparities of self-assessed health status have been reported.[25] While life expectancy has been increasing, healthy life years have not kept pace in the world.[26 27] An improvement of activity limitations in daily living and self-assessed health by an effective health promotion, such as an increase in daily step counts in the general population, will prolong healthy life years, and narrow the existing health disparities.

The data used in this study are derived from national cross-sectional surveys, and no causal inferences can be deduced. Population-based cohort will be needed to further investigate the prospective effect of daily step counts on healthy life years. Step intensity was not evaluated because the investigation did not include it. Potential confounding factors, such as income, that could affect

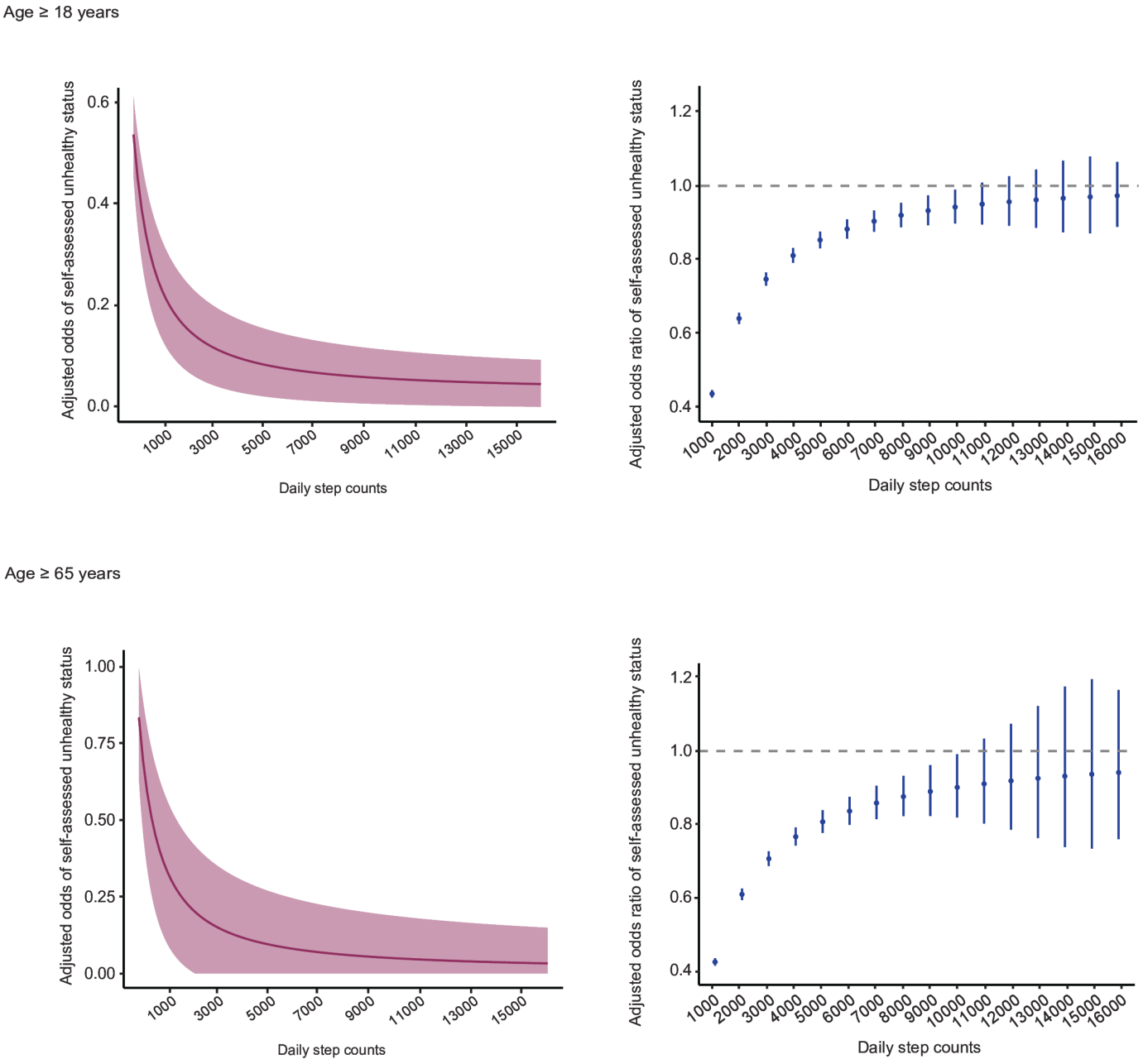

Figure 3 Association between daily step counts and self-assessed health. Adjusted ORs and ORs of self-assessed unhealthy status were evaluated for daily step counts. Once the daily step counts reached 11 000, an increase in 1000 step counts per day was no longer significantly associated with reduced odds of self-assessed unhealthy status for all-age and older adult groups. Error bars and shaded areas represent 95% CI.

the association between daily step counts and healthy life years were not considered.

CONCLUSION

Daily step counts were significantly associated with activity limitations in daily living and self-assessed health as determinants of healthy life years, up to 9000 and 11 000 step counts, respectively. These findings suggest the optimal target of daily step counts to prolong healthy life years within health initiatives aimed at increasing physical activity and raising health awareness of people.

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Contributors MN was responsible for conception of the study and overall content as guarantor. MN and RN had full access to all of the data in the study and took responsibility for the integrity of the data and the accuracy of the data analysis. All authors participated in manuscript writing and approved the final manuscript. SM provided overall supervision. All the authors were responsible for the decision to submit the manuscript for publication.

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Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval The study received ethical approval from the ethics committee of Kyoto Prefectural University of Medicine with the approval number ERB-C-2878. This study conformed to the principles outlined in the Declaration of Helsinki. Given that this study uses pre-existing national survey data, informed consent from study participants was exempted.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. We are prohibited from publicly opening the data. Data can be accessed through the Household Statistics Office of the Japanese Ministry of Health, Labour and Welfare (https://www.mhlw.go.jp/toukei/itiran/eiyaku.html).

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