Japanese Journal of Ophthalmology (2023) 67:164–174
https://doi.org/10.1007/s10384-023-00977-w

THE OFFICIAL INTERNATIONAL JOURNAL OF THE JAPANESE OPHTHALMOLOGICAL SOCIETY

CLINICAL INVESTIGATION

The association of subjective vision with objectively measured intensity-specific physical activity and bout-specific sedentary behavior among community-dwelling older adults in Japan

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Received: 4 July 2022 / Accepted: 17 November 2022 / Published online: 28 January 2023

Abstract

Purpose Visual impairment is a possible cause of physical frailty. Reduced physical activity (PA) may be involved in the pathway from visual impairment to physical frailty, although the association between vision and objectively measured PA among older adults remains unclear. This study examined the sex-specific association of subjective vision with intensity-specific PA and bout-specific sedentary behavior (SB) among community-dwelling, older Japanese adults.

Study design Cross-sectional study

Methods This study used data from the Neuron to Environmental Impact across Generations study analyzing older adults (527 participants, aged 65–84 years) living in rural areas of Niigata Prefecture, Japan. Subjective vision was assessed by use of a questionnaire. Intensity-specific PA (light-intensity PA and moderate-to-vigorous PA [MVPA]), bout-specific SB, and daily step count were objectively evaluated by use of an accelerometer. The association of subjective vison with PA and SB, stratified by sex, was analyzed by means of general regression analyses, with adjustment for covariates.

Results The data of 512 participants (men: 46.9%; with poor subjective vision: 22.9%) were analyzed. Poor subjective vision was significantly associated with log MVPA (partial regression coefficient = -0.261, $P = .013$) and log steps (partial regression coefficient = -0.164; $P = .021$) among women, whereas a tendency of an association was observed with prolonged SB time among men (partial regression coefficient: 39.1; $P = .073$).

Conclusion Older Japanese women with poor subjective vision performed less MVPA and had fewer step counts than those of participants with good subjective vision, and men with poor subjective vision had longer prolonged SB, which may all accelerate the process to physical frailty.

Keywords Accelerometry · Exercise · Sedentary lifestyle · Visual impairment · Walking

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Introduction

Visual impairment is a significant factor affecting the quality of life of older adults [1]. About 2.2 billion people globally have near or distance visual impairment, and those aged older than 50 years account for the majority [2]. In Japan, about 1.64 million people had visual impairment in 2007 [3]. The prevalence of visual impairment in Japan increases with age and half of those with visual impairment are aged 70 years or older, and it is estimated that the number will increase to 2 million by 2050 [3]. Many ocular diseases, such as cataracts, age-related macular degeneration, and glaucoma, that may affect visual acuity are associated with aging. Thus, in the future, ocular health is expected to become one of the most important issues worldwide, following what is currently occurring in Japan, which has the largest aging population in the world.

Frailty is one of the most problematic issues of aging [4]. The Japanese Ophthalmological Society has recently proposed the concept of "eye-frailty," which is "a condition in which the eyes deteriorate due to aging and various external stresses," and speculated that "eye-frailty" among older adults causes physical frailty [5]. The mechanism of physical frailty due to visual impairment may be a low physical activity (PA) level. In general, PA declines [6] and sedentary behavior (SB) gradually increases in older adults [7]. A recent study demonstrated that poor vision disrupted participation in activities that require PA among older adults [8]. Thus, deteriorating vison may lead to less PA and longer SB among the older population, although this has not been fully clarified. Several studies have analyzed the association between visual impairment and PA [9–13], and a few studies have analyzed the association between visual impairment and SB [11, 14]. Most of these previous studies were conducted among adults of a broad age range from western countries and did not specifically focus on older adults. Therefore, whether the above association of visual impairment with PA and SB applies even in very old individuals, who are more prone to frailty [15], needs to be addressed.

Recent accelerometer-based studies have enabled the evaluation of daytime activity levels separately in terms of intensity based on metabolic equivalents (METs), divided into SB, light-intensity PA (LPA), and moderate-to-vigorous PA (MVPA). Shortening SB [16] and increasing LPA are beneficial for many aspects of health, particularly for older adults [17, 18]. In addition, total time of SB, particularly prolonged (≥30 min) SB, has received considerable attention in recent years regarding its significant association with bad health outcomes [19]. A previous study among older adults using accelerometers has reported that MVPA accounts for only 4%, SB for 61%, and LPA for 35% of daily awake time [20]. Considering the proportion of SB, reducing or breaking up SB is a promising strategy to improve the health outcomes of older adults [21, 22]. However, most previous studies reporting the association of visual impairment with PA analyzed total PA or MVPA but not LPA, nor prolonged SB, which is SB lasting more than 30 consecutive minutes, from the perspective of health among older adults. In this regard, it is important to conduct a population-based study among older adults to clarify the association of vision with intensity-specific PA, including LPA, and bout-specific SB to obtain evidence towards establishing strategies for preventing frailty among older adults, which is an important heath issue in this aging society.

Therefore, the purpose of this study was to clarify the association of subjective vison with intensity-specific PA and bout-specific SB measured using an accelerometer among community-dwelling older adults, stratified by sex. Our hypothesis was that among both men and women, those with poor subjective vision would have shorter LPA and MVPA times, longer total SB time, prolonged SB time, and fewer daily step counts than those of individuals with good subjective vision and that, on the basis of a previous study from the United States [11], there would be a stronger association in women.

Participants and methods

Study design, setting, and participants

This cross-sectional study used the baseline data of the Neuron to Environmental Impact across Generations (NEIGE) study, which was designed to investigate the social determinants of health among rural residents in Japan. The study population was individuals living in Tokamachi city, Niigata, Japan, who did not require long-term care or support and were aged 65 to 84 years as of July 1, 2017, which has been described thoroughly in the cohort profile [23]. Briefly, this study was conducted in Tokamachi city, Niigata prefecture, Japan, where 54,515 people lived (men: 48.7%) and the proportion of individuals aged 65 years or older was 36.9% as of July 2017. A total of 1346 residents aged 65 to 84 years were randomly selected from a resident registry by stratified random sampling and divided into 4 age groups, i.e., 65–69, 70–74, 75–79, and 80–84 years, and 2 living areas (downtown/mountain). A total of 527 residents understood and agreed to participate in the study, which involved wearing an accelerometer. Details of the participants have been described in the previous study [23]. The baseline survey was conducted from September to October 2017.

The study was performed in accordance with the Declaration of Helsinki, and ethics approval was granted by the university ethics committees of Niigata University and Tokyo Medical University (study approval numbers 2666 and 3921). All the participants signed an informed consent form.

Subjective vision

Subjective vision was assessed by use of a questionnaire. The scales used in a previous study and the Japanese national survey to evaluate subjective vision [10, 24] were modified for this study. Participants responded to the question, “How do you assess your present visual performance with both your eyes? If you usually wear glasses or contact lenses, please answer about your condition with those on,” followed by a 4-point Likert scale: (1) good, (2) slightly obscured (unable to read small letters in the newspaper but able to read letters larger than medium size), (3) fairly obscured (unable to read the newspaper), and (4) severely obscured (only having a sense of light). We defined (1) as those with good subjective vision and (2)–(4) as those with poor subjective vision.

Intensity-specific physical activity and bout-specific sedentary behavior

The participants were asked to wear an accelerometer, namely, the Active style Pro HJA-750C (Omron Healthcare) over the waist for 7 consecutive days while awake, between September 2017 and October 2017 [25, 26]. The epoch length was 60 seconds. No signals for more than 60 minutes was defined as nonwearing time [27]. Participants with more than 4 days of valid data during the 7 days and with data for more than 10 hours per day were included in the analysis [28]. METs-based criteria were used to define SB (≤1.5 METs), LPA (>1.5 to <3.0 METs), and MVPA (≥3 METs) [29, 30]. The intensity of each PA, including LPA, MVPA, and daily step count, and total SB time (defined as the sum of all daily SB time) and prolonged SB time (defined as SB of at least 30 consecutive minutes in a day) were assessed. The data of participants with invalid data and accelerometer errors were excluded.

Covariates

Age, sex, living arrangement (with others/alone), employment status (currently employed/unemployed), family income (≥3 million yen per year/<3 million yen per year), years of education (≥10 years/<10 years), agricultural work (currently engaging/not engaging in agricultural work), smoking habit (smoker/nonsmoker), and alcohol consumption (every day/sometimes) were obtained from the questionnaire. History of physician-diagnosed diseases (diabetes mellitus, cardiovascular diseases, cerebrovascular diseases, chronic obstructive pulmonary disease, and arthritis) was obtained from medical doctor interviews. Living area (downtown/mountain) was obtained from the resident’s registry of Tokamachi city. Body mass index (BMI) was calculated by use of body weight and body height (kg/m^2) measured with a body composition analyzer, the MC-780A (Tanita Corporation). Working status was categorized into 3 groups on the basis of the characteristics of the NEIGE study [23], namely, agricultural work (those engaging in agricultural work), nonagricultural work (those having jobs other than agricultural work), and not working (those not engaging in agricultural work or nonagricultural work).

Statistical analysis

The characteristics of participants with poor subjective vision and those with good subjective vision were compared using the chi-square test for categorical data and the unpaired *t* test for continuous data.

All statistical analyses were stratified by sex, as previous studies have shown that older Japanese men and women have different patterns of PA: women perform more LPA and men have longer SB [31, 32]. The normality of LPA time, MVPA time, total SB time, prolonged SB time, and daily step count was analyzed by means of Q-Q plots. LPA time, total SB time, and prolonged SB time were modeled with a Gaussian distribution. On the other hand, MVPA time and daily step count did not follow a Gaussian distribution. Thus, the unpaired *t* test was conducted to assess LPA time, total SB time, and prolonged SB time, whereas the Mann-Whitney U test was conducted to assess MVPA time and daily step count to compare the poor subjective vision and good subjective vision groups.

Multivariate regression analysis was used to estimate the sex-specific linear association of subjective vision with each intensity of PA after MVPA and daily step count had been transformed to logarithmic values, and bout-specific SB. The covariates were adjusted, including age, BMI, educational attainment, living arrangement, occupational status, working status, present illness, and accelerometer wear-time.

Furthermore, multivariate regression analyses stratified by sex and age group (those aged 65–74 years and those aged from 75–84 years) were also conducted with adjustment for the covariates. In Japan, the law defines those aged 65 to 74 years as “young-older adults” and those aged 75 and older as “old-older adults,” on the basis of differences in activities of daily living and instrumental activity of daily living between these age groups [33]. All statistical analyses were conducted using SPSS 27.0 (IBM).

Results

A flow diagram of the study participants is shown in Figure 1. Of the 527 participants, 15 participants were excluded because of insufficient adherence in accelerometer wearing (data for less than 4 days) (n = 14) or accelerometer error (n = 1). Therefore, the data of 512 participants were included in the analysis (men: 46.9%, mean [standard deviation] age 73.5 [5.6] years). A total of 395 (77.1%) participants had good subjective vision, and 117 (22.9%), poor subjective vision.

Participants with poor subjective vision had longer educational years (P = .011), and a higher incidence of history of cerebrovascular diseases (P = .019) than those of participants with good subjective vision. Participants with poor subjective vision also had longer prolonged SB than that of participants with good subjective vision (P = .020) (Table 1).

The results of intensity-specific PA and bout-specific SB compared between those with good subjective vision and those with poor subjective vision stratified by sex are shown in Table 2. No significant difference was found in the intensity of PA, including daily step count, among men with different levels of subjective vision; however, those with poor subjective vision had significantly longer prolonged SB time (P = .031). Among women, those with poor subjective vision had significantly longer prolonged SB time (P = .037) and fewer daily step counts (P = .036) than those of participants with good subjective vision.

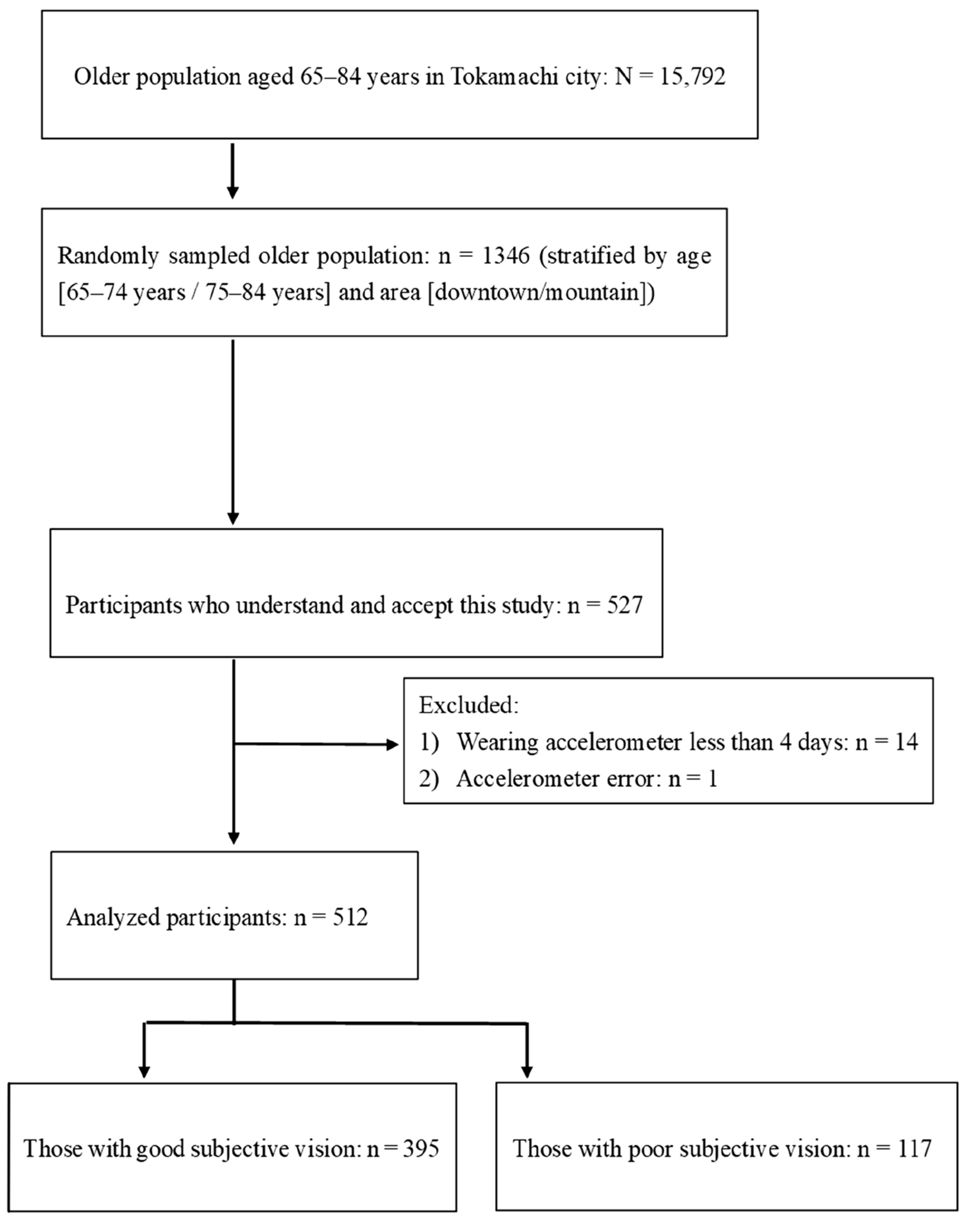

Fig. 1 Flow diagram of the study participants

Table 1 Characteristics of the NEIGE participants

				Total N = 512	Good subjective vision n = 395	Poor subjective vision n = 117
Demographic factors	Age		Mean (SD)	73.5 (5.6)	73.3 (5.6)	74.2 (5.7)
	Sex	Male	%	46.9	46.8	47.0
	Body mass index, kg/m^2		Mean (SD)	22.6 (2.8)	22.7 (2.7)	22.3 (3.2)
Sociodemographic factors	Living arrangement	Living alone	%	8.6	8.1	10.3
	Family income	3 million yen or above	%	57.4	59.1	51.8
	Living area	Downtown side	%	52.3	54.7	44.4
	Educational attainment	10 years or longer	%	61.7	58.7	71.8*
	Working status	Agricultural work	%	59.2	57.7	64.1
		Nonagricultural work	%	19.1	20.5	14.5
		Not working	%	21.7	21.8	21.4
History of physician-diagnosed diseases	Diabetes mellitus	Yes	%	17.8	17.5	18.8
	Cardiovascular disease	Yes	%	20.1	20.3	19.7
	Cerebrovascular disease	Yes	%	8.4	6.8	13.7*
	Chronic obstructive pulmonary disease	Yes	%	7.4	8.1	5.1
	Arthritis	Yes	%	9.0	8.6	10.3
Lifestyle	Smoking	Current smoker	%	8.6	9.4	6.0
	Alcohol consumption	Every day or sometimes	%	53.9	54.4	52.1
PA and SB	SB					
	Total SB	Minutes/day	Mean (SD)	445.4 (129.7)	441.7 (127.9)	458.1 (135.4)
	Prolonged SB	Minutes/day	Mean (SD)	296.5 (172.7)	284.1 (166.3)	337.7 (187.3)*
	PA					
	LPA	Minutes/day	Mean (SD)	388.8 (102.9)	390.4 (101.6)	383.7 (107.2)
	MVPA	Minutes/day	Median (IQR)	42.3 (20.8–73.9)	43.4(22.1–76.9)	40.1 (17.7–71.6)
	Daily step count	Steps/day	Median (IQR)	5269.6 (5340.0–7098.9)	5388.7 (3715.3–7396.9)	4885.5 (3350.6–6681.1)

SD standard deviation, *IQR* interquartile range, *SB* sedentary behavior, *PA* physical activity, *LPA* light-intensity physical activity, *MVPA* moderate-to-vigorous physical activity

P values for continuous variables except moderate-to-vigorous physical activity and daily step count were calculated using the unpaired *t* test, and categorical variables, using the chi-square test. *P* values for moderate-to-vigorous physical activity and daily step count were calculated using the Mann-Whitney U test.

*$P < .05$.

The results of the multivariate regression analysis adjusted for covariates showed no linear association between subjective vision and any intensity of PA, including daily step count, among men; however, prolonged SB tended to be associated with poor subjective vision in men (B = 39.111; 95% CI = -3.622, 81.845; *P* = .073) (Table 3). Among women, log MVPA and log daily step count were found to be associated with subjective vision. The partial regression coefficient was -0.261 (95% CI = -0.468, -0.055; *P* = .013) for MVPA and -0.164 (95% CI = -0.304, -0.025; *P* = .021) for daily step count, which indicates that having poor subjective vision is associated with 26.1% shorter time of MVPA

Table 2 Comparison of intensity-specific physical activity and bout-specific sedentary behavior between good and poor subjective vision

Among men			Total N = 240	Good subjective vision n = 185	Poor subjective vision n = 55
Bout-specific SB					
Total SB	Minutes/day	Mean (SD)	468.4 (140.3)	465.7 (135.0)	477.5 (157.8)
Prolonged SB	Minutes/day	Mean (SD)	338.6 (170.8)	325.4 (159.3)	382.0 (199.7)*
Intensity-specific PA					
LPA	Minutes/day	Mean (SD)	343.3 (93.3)	346.9 (91.2)	331.0 (99.8)
MVPA	Minutes/day	Median (IQR)	42.9 (21.4–81.4)	42.5(23.4–83.4)	45.1 (17.5–81.4)
Daily step count	Steps/day	Median (IQR)	5232.5 (3655.8–7290.7)	5388.7 (3723.8–7379.8)	5048.0 (3509.7–7172.1)
Among women			Total N = 272	Good subjective vision n = 210	Poor subjective vision n = 62
Bout-specific SB					
Total SB	Minutes/day	Mean (SD)	425.2 (116.1)	420.5 (117.7)	440.9 (110.3)
Prolonged SB	Minutes/day	Mean (SD)	259.9 (166.1)	248.5 (164.3)	298.5 (167.7)*
Intensity-specific PA					
LPA	Minutes/day	Mean (SD)	429.0 (93.9)	428.6 (94.9)	430.5 (91.2)
MVPA	Minutes/day	Median (IQR)	42.1 (19.5–69.2)	43.6 (20.3–71.8)	38.0 (17.7–62.0)
Daily step count	Steps/day	Median (IQR)	5253.4 (3516.8–6823.3)	5390.0 (3677.4–7415.5)	4804.9 (2999.0–5989.9)*

SB sedentary behavior, *PA* physical activity, *LPA* light-intensity physical activity, *MVPA* moderate-to-vigorous physical activity, *NS* not significant, *SD* standard deviation, *IQR* interquartile range, *Prolonged SB* sedentary behavior ≥30 minutes

P values of MVPA and daily step count were calculated using the Mann-Whitney U test, and other continuous variables, using the unpaired *t* test.

**P* <.05.

and 16.4% fewer number of daily steps among women (as the dependent variables [MVPA and daily step count] are logarithmically transformed, the partial regression coefficient indicates the change rate).

Stratified analysis by age group and sex showed no significant association of subjective vision with PA and SB among men aged younger than 75 years (Table 4). Men aged older than 75 years with poor subjective vision had significantly longer prolonged SB time (B = 69.505; 95% CI = 3.738, 135.271; *P* = .039). Women aged younger than 75 years with poor subjective vision had shorter MVPA time (B = -0.298; 95% CI = -0.569, -0.027; *P* = .032) and longer prolonged SB time (B = 59.168; 95% CI = 11.809, 106.526; *P* = .015) than those of participants with good subjective vision. No significance was found among women aged older than 75 years. Furthermore, although the results did not reach significance, in women aged younger than 75 years, those with poor subjective vision tended to have 36.5 minutes longer SB time than those of individuals with good subjective vision (B = 36.470; 95% CI = -1.336, 74.277; *P* = .059).

Discussion

In our present study on Japanese older adults living in rural areas, we found that women with poor subjective vision performed less MVPA and had fewer daily step counts, whereas men with poor subjective vision tended to have longer prolonged SB time, compared with those with good subjective vision, after adjustment for confounders. To our knowledge, this is the first study to date reporting the association of vision with PA and SB among community-dwelling older adults, with adjustment for confounders. In addition, this study is novel in that it focuses not only on PA and SB, but also specifically on PA of different intensities and SB of different durations measured using an accelerometer, which have recently gained a large amount of attention regarding their association with health in the older population.

The significant results of the association of PA and vision only among women is consistent with the results of a previous study, which reported that visual impairment is significantly associated with PA time, in which PA intensity was defined as that between LPA and MVPA, among white women aged 50 years or older, whereas only a tendency was observed among men [11]. Although the accelerometer used in our present study, the Active style Pro HJA-750C, was different from that used in the previous studies (ActiGraph GT3X; ActiGraph), which is commonly used in western countries, it has also been validated [25, 34, 35]. Data obtained with the Active style Pro HJA-750C were reported to be comparable to data obtained with the ActiGraph GT3X, and the 2 devices show particularly good agreement when measuring ambulatory activities, such as walking, jogging, and climbing up and down stairs [36]. Daily step count,

Table 3 Association of subjective vision with intensity-specific physical activity and bout-specific sedentary behavior

		B	95% CI
Men	Bout-specific SB		
	Total SB	-1.302	-30.418, 27.813
	Prolonged SB	39.111	-3.622, 81.845
	Intensity-specific PA		
	LPA	-3.736	-28.500, 21.027
	Logarithmic scale of MVPA	0.079	-0.194, 0.351
	Logarithmic scale of daily step count	0.098	-0.098, 0.293
Women	Bout-specific SB		
	Total SB	20.467	-6.228, 47.162
	Prolonged SB	28.490	-8.880, 65.860
	Intensity-specific PA		
	LPA	-8.879	-32.457, 14.698
	Logarithmic scale of MVPA	-0.261*	-0.468, -0.055
	Logarithmic scale of daily step count	-0.164*	-0.304, -0.025

B partial regression coefficient of difficulty seeing, *SB* sedentary behavior, *PA* physical activity, *LPA* light-intensity physical activity, *MVPA* moderate-to-vigorous physical activity, *Prolonged SB* sedentary behavior ≥30 minutes

Statistical analysis was conducted by means of multiple regression analysis.

Models were adjusted for age, BMI, living arrangement, years of education, occupational status, medical status (any of diabetes mellitus, cerebrovascular diseases, cardiovascular diseases, chronic obstructive pulmonary disease, arthritis), and accelerometer wear-time.

*P <.05.

which also showed a significant association with subjective vision in our study, is a comprehensive indicator of PA, and is closely correlated with MVPA time [20, 37]. Hence, it is reasonable that both MVPA time and daily step count were significantly associated with subjective vision given that a large proportion of MVPA time consists of walking, which is included in daily step count.

The reason why MVPA time and daily step count showed significant associations with subjective vision only among women is unclear. We postulate 3 possible reasons for this. First, the differences in PA pattern between men and women may be a cause. In a large cohort study of community-dwelling older adults in Japan, women had higher rates of social participation, including community activities, and socializing with friends than those of men [38]. In addition, previous studies have reported that women with ocular diseases, such as glaucoma and macular edema, have a lower vison-related quality of life (VrQoL) [39, 40]. Thus, it is plausible that poor subjective vision may hinder such social participation and interaction with others because poor vision may have a stronger effect on the VrQoL of women than of men. Second, a stronger fear of falling among women with poor vision than among men may restrict them from MVPA and daily steps, as they feel insecure and afraid of falling [41–44]. A higher prevalence of osteoarthritis [45] and poorer physical function due to weaker upper and lower limb strength [46] among older women than among older men may be associated with insecurities about performing PA, particularly ambulatory activities. Thirdly, poor subjective vision among the women in our study may have been more frequently associated with various pathologies than among the men, and thus may be a stronger obstacle for performing MVPA. For example, cataract and dry eye disease (DED) are common ocular diseases caused by aging, which affects vision [47–51]. Women have a higher prevalence of DED [52]. Sayegh and colleagues reported that the severity of ocular discomfort due to dry eye negatively affects the activities of daily living, including walking [53]. Although still controversial, previous studies have shown that women have a higher prevalence of cataracts than that of men of the same age [54, 55]. Age-associated eye diseases, including cataracts, have a negative impact on the activities of daily living [56]. Taken together, DED and cataracts may affect the amount of MVPA and the number of daily step counts. Because we did not measure objective visual acuity nor investigate whether the participants had specific ocular diseases in the present study, this needs to be addressed in future research.

Unexpectedly, poor subjective vision was not associated with LPA time or total SB time among both older men and older women in our study, showing that older men and older women with poor subjective vision were engaging in LPA to a similar extent as those with good vision. Our results suggest that the degree of poor subjective vision may not affect LPA even in the older population, which ultimately would not affect total SB time. However, these results are consistent with those obtained from a study on adults in the United States, which showed no significant association of objective visual impairment with LPA time or total SB time [11]. Household chores usually represent LPA [57], and even those with poor subjective vision may perform household chores as part of their daily routine.

Stratified analysis by age groups and sex demonstrated that poor subjective vision was significantly associated with MVPA among women aged younger than 75 years, but not among women aged older than 75 years. Because time spent in MVPA decreases with age [58], women aged older than 75 years might have short MVPA times regardless of their quality of subjective vision. Another finding from the stratified analysis was that poor subjective vision was significantly associated with prolonged SB among men aged older than 75 years, but not among men aged younger than 75 years, whereas it was significant among women aged younger than 75 years, but not among women aged older than 75 years. The reason for these results remains

Table 4 Association of subjective vision with bout-specific sedentary behavior and intensity-specific physical activity stratified by sex and age group

		B	95% CI
Men aged younger than 75 years	Bout-specific SB		
(n = 144, good subjective vision 77.8%)	Total SB	-4.033	-45.518, 37.452
	Prolonged SB	19.580	-38.434, 77.594
	Intensity-specific PA		
	LPA	2.066	-31.654, 35.786
	Logarithmic scale of MVPA	0.124	-0.205, 0.453
	Logarithmic scale of daily step count	0.150	-0.077, 0.378
Men aged older than 75 years	Bout-specific SB		
(n = 96, good subjective vision 76.0%)	Total SB	15.055	-28.155, 58.264
	Prolonged SB	69.505*	3.738, 135.271
	Intensity-specific PA		
	LPA	-8.858	-46.098, 28.382
	Logarithmic scale of MVPA	-0.239	-0.761, 0.282
	Logarithmic scale of daily step count	-0.072	-0.442, 0.298
Women aged younger than 75 years	Bout-specific SB		
(n = 152, good subjective vision 78.9%)	Total SB	36.470	-1.336, 74.277
	Prolonged SB	59.168*	11.809, 106.526
	Intensity-specific PA		
	LPA	-19.522	-52.406, 13.363
	Logarithmic scale of MVPA	-0.298*	-0.569, -0.027
	Logarithmic scale of daily step count	-0.135	-0.306, 0.036
Women aged older than 75 years	Bout-specific SB		
(n = 119, good subjective vision 75.6%)	Total SB	-5.113	-44.129, 33.903
	Prolonged SB	-9.222	-71.046, 52.602
	Intensity-specific PA		
	LPA	7.401	-27.778, 42.580
	Logarithmic scale of MVPA	-0.151	-0.504, 0.201
	Logarithmic scale of daily step count	-0.162	-0.410, 0.087

B partial regression coefficient of difficulty seeing, *SB* sedentary behavior, *PA* physical activity, *LPA* light-intensity physical activity, *MVPA* moderate-to-vigorous physical activity, *Prolonged SB* sedentary behavior ≥30 minutes

Statistical analysis was conducted by means of multivariate regression analysis.

Models were adjusted for age, BMI, living arrangement, years of education, occupational status, medical status (any of diabetes mellitus, cerebrovascular diseases, cardiovascular diseases, chronic obstructive pulmonary disease, and arthritis), and accelerometer wear-time.

**P* <.05.

unclear. As longer prolonged SB time as well as total SB time is associated with a higher risk of all-cause mortality [59, 60], it may be important for primary care physicians and other health professionals to encourage older adults, particularly those with poor subjective vision, to break up their prolonged SB.

The major strengths of our study are as follows: (1) PA and SB were measured objectively using an accelerometer. (2) We focused on intensity-specific PA and bout-specific SB, which are important from the perspective of health among older adults. (3) We particularly focused on older adults and therefore included both old-older and young-older adults. Several limitations of our study, however, should also be considered. First, visual acuity was not measured objectively, and subjective vision was measured by use of a questionnaire, which might have induced measurement bias. Analyses using subjective vision might have lower validity than analyses using objective vision. In addition, the use of subjective vision may cause misclassification, which may overestimate or underestimate the effect size [61]. However, older adults with normal vision have been reported to become visually impaired when performing daily tasks under glare, low contrast, or low light [62], and hence, objective visual acuity measurements alone may not be sufficient to assess the impact of decreased vision on the lives of older adults. Furthermore, a recent study evaluating vision both subjectively and objectively demonstrated that subjective visual impairment can predict SB time more accurately than can objective visual impairment [14].

Therefore, assessment of subjective vision may also be useful for investigating the association of vision with PA and SB. Second, the questionnaire we used focused more on near visual impairment than on distant visual impairment. Although near visual impairment is associated with lower instrumental activities of daily living [63], further research on the effects of distant visual impairment or distant objective vision as well as near visual impairment on the lives of older adults is needed in the future. Third, this study was conducted in a single rural city in Japan, and those who were unable to live independently owing to visual impairment did not participate in this study. Therefore, it is unclear whether our results are applicable to older adults in general, including those living in urban areas and those with very poor vision. Despite these limitations, the results of our study showing the association of poor subjective vision with MVPA time, prolonged SB time, and daily step count among community dwelling older adults will help to clarify the mechanisms of frailty from the concept of "eye-frailty," which was recently proposed by the Japanese Ophthalmological Society, and may be important towards developing a strategy for preventing frailty among older adults in a super-aging society.

In conclusion, the results of our present study showed that older women with poor subjective vision have shorter MVPA times and fewer daily step counts than do those with good subjective vision and that older men with poor subjective vision have a tendency of longer prolonged SB than do those with good subjective vision. Our results hence suggest that PA and SB may be important components of the pathways from visual impairment to physical frailty among older adults. Whether early intervention for ocular conditions can prevent a reduction in PA and ultimately in physical frailty needs to be clarified in future studies.

Acknowledgements This study was supported by grants from the Policy Research Institute, Ministry of Agriculture, Forestry and Fisheries; the Japan Society for the Promotion of Science Grants-in-Aid for Scientific Research (Kakenhi) (grant numbers 16H03249, 17K19794, 18K10829, 19H03910); and the Pfizer Health Research Foundation. We would like to thank Helena Akiko Popiel, PhD, instructor at the Center for International Education and Research, Tokyo Medical University, for providing professional medical English editing.

Data availability The datasets generated and analysed during the current study are not publicly available due ethical or legal restrictions but are available from the corresponding author on reasonable request.

Conflicts of interest K. Isamu, None; T. Takamiya, None; S. Amagasa, None; M. Machida, None; H. Kikuchi, None; N. Fukushima, None; S. Inoue, None; H. Murayama, None; T. Fujiwara, None; Y. Shobugawa, None.

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