1. Introduction

Physical activity is closely associated with health (Chalé-Rush et al., 2010; Kyu et al., 2016; Landi et al., 2007; Sabia et al., 2017; Tsunoda et al., 2013). For example, a large sample study that included data on more than 130 thousand participants from 17 countries reported that higher physical activity was independently associated with lower risk of mortality and incidence of cardiovascular disease even after controlling some potential confounding factors (Lear et al., 2017). Social participation also brings health benefits. For instance, some longitudinal studies have confirmed that social participation reduces the risk of adverse health outcomes such as cognitive decline (Tomioka et al., 2016), incidence of functional disability (Kanamori et al., 2014), and all-cause mortality (Väänänen et al., 2009). These evidences imply that engaging in physical activity and social participation plays a key role in maintaining health in old age.

People are deemed as having a limited transport mobility when they cannot use some kind of transportation without help (Curvers et al., 2017; Peel et al., 2005). It is associated with restriction of daily living area, which in turn leads to a decrease in physical activity (Tsai et al., 2015) and social participation (Curvers et al., 2017). Although these findings suggest that transportation is directly/indirectly related to physical activity and social participation, these associations (i.e., transportation mode, and physical activity and social participation) are depended on research areas (Currie et al. 2009). This is because various factors that include the number of public facilities, accessibility to those facilities, and supplied transportation are different in research areas. Accumulation of findings that are obtained from various areas is needed and is useful when practitioners consider improving transportation system.

In japan, a major transportation mode for older adults is driving a car. This

25 feature is emphasized in rural areas because people living those areas feel poor

26 convenience of public transport (The Japanese Cabinet Office, 2016; The Japanese

27 Ministry of Land, Infrastructure and Transport, 2015). As a previous mail survey in urban

28 area reported that 63% of Japanese older adults frequently ride a bicycle (Sakurai et al.,

29 2015), a large number of them who use a bicycle is one of the characteristics of them.

30 Therefore, this study focused on car driving and bicycling among Japanese older adults

31 aged 65 or older living in rural area. Rural areas have a few recreational facilities

32 compared to urban areas, which means rural areas have a relatively large area where those

33 facilities are not around. The association of each transportation mode on physical activity

34 and social participation under the conditions that were described above remain unclear.

35 Specifically, this study aimed to examine the association of each transportation mode (car

36 driving and bicycle riding) on physical activity and social participation in older adults.

37 Car driving enables individuals to travel long distances and go to specific place for doing

38 social activities, and bicycle riding involves physical activity; hence, our hypothesis was

39 that while driving is associated with social participation, bicycling is correlated with a

40 higher level of physical activity.

41

42 **2. Methods**

43 2.1 Study design and data collection

44   This cross-sectional study used data obtained from the 2017 Kasama Health

45 Checkup for Longevity survey, a community-based cohort study (Okura et al., 2017). This

46 survey has been conducted annually since 2009, on participants selected using the

47 following eligibility criteria: 1) aged 65 years or older, 2) not using long-term care

48 insurance, and 3) living in Kasama city (population: 75,794 (older adults were 30.0%),

49   population density: 315.3/km^2), Japan. Kasama city has 9.3% of building area, 63.0% of

50   forest and farmland (Soma et al., 2017), and a few community centers (0.13 n/km^2),

51   sports/recreational facilities (0.11 n/km^2), and parks (0.08 n/km^2) (Statistics of Kasama

52   city, 2016). The cohort study includes some items to obtain basic information and to

53   evaluate physical and cognitive functions, physical activity, and psychosocial factors such

54   as depression mood, social network. A total of 1652 older adults (follow-up and new

55   participants were 852 and 800, respectively) were called for participation in the survey,

56   then 400 participants (follow-up and new participants were 299 and 101, respectively)

57   took part in the 2017 survey. New participants aged 65 to 85 years were selected randomly

58   from the Basic Resident Register. Participants were required to visit a local community

59   center in where the survey was conducted. We excluded 26 participants who did not

60   complete survey. Finally, the data of 374 participants (93.5%) were included in the

61   analysis. This study was approved by the Ethics Committee of the University of Tsukuba

62   (Ref No., Tai 26–31). The participants were explained the study concepts, and we

63   obtained their written informed consent.

64

65   2.2 Transportation

66   To examine the transportation mode, we used a self-report questionnaire

67   comprising the following questions: "How often do you usually drive a car per week?"

68   and "How often do you usually ride a bicycle per week?" The present study defined

69   "driving a car" as when participants drove a car at least once a week. As for bicycle riding,

70   participants were categorized as bicyclists and non-bicyclists.

71

72   2.3 Outcome variables

73   The main outcome measures in this study were physical activity and social

74   participation. To assess physical activity, the Japanese version of the Physical Activity

75   Scale for the Elderly (PASE) was used (Hagiwara et al., 2008). The PASE includes 12

76   items, 5 on leisure time activity, 6 on household activity, and 1 on work-related activity,

77   which provide scores for each physical activity domain based on contents, frequency, and

78   activity duration in the past week. The leisure time activity score, household activity score,

79   work-related activity score, and total score were used for the analysis.

80   Additionally, participants were asked about participation in the following social

81   activity groups: sports group, hobby group, community association, and volunteer group.

82   Considering culture, these groups were selected based on previous research conducted in

83   Japan (Kanamori et al., 2014; Tomioka et al., 2017). A sports group includes organized

84   groups for sports or exercise. A hobby group includes various activities such as flower

85   arrangement, handcraft, and karaoke. A community association is a small group that

86   consists of neighbors. Representative activities of a community association include safety

87   patrol and cleaning activity in and around the living area. Volunteer group activities

88   include, for example, visiting older adults living alone and providing support for

89   individuals with disabilities. For each social activity, participants were labeled as

90   "participation" if they reported participating at least once per month.

91

92   2.4 Covariates

93   According to previous studies (Ding et al., 2014; Kamada et al., 2009), the

94   following covariates were selected for the analysis: age, sex, body mass index (BMI),

95   years of education (< 12 or ≥ 12), living arrangement (alone or not), economic status

96   (poor or normal/good), smoking status (current or past/never), and alcohol consumption

97 (drinker or non-drinker). Clinical history in terms of the number of diseases including

98 stroke, hypertension, hyperlipidemia, diabetes, kidney disease, and heart disease (yes or

99 no) was categorized as 0, 1, 2, and ≥ 3. For psychiatric factors, self-reported cognitive

100 impairment (yes or no) and depressive mood were included. The 15-item Geriatric

101 Depression Scale was used to assess depressive mood with a cut-off point of 5/6 (Sheikh

102 and Yesavage, 1986).

103

104 2.5 Statistical analysis

105 Mean and standard deviation were calculated for all demographic data. Two

106 kinds of groupings, namely, drivers/non-drivers and bicyclists/non-bicyclists, were used

107 in this study. An analysis of covariance (ANCOVA) was performed to compare each

108 PASE score in each grouping. All ANCOVA analyses were adjusted for age, sex, BMI,

109 years of education, living arrangements, economic status, smoking status, alcohol

110 consumption, comorbidities, self-reported cognitive impairment, and depressive mood.

111 The other transportation mode was also added as a covariate. Specifically, bicycle riding

112 was entered when the ANCOVA was used for drivers vs. non-drivers, and vice versa.

113 A multivariate Poisson regression analysis was used to examine the association

114 between car driving, bicycle riding, and social participation. We calculated prevalence

115 ratio (PR) and 95% confidence interval (CI). The following three models were adopted:

116 a crude model; Model 1 with age, sex, BMI, years of education, living arrangements,

117 economic status, smoking status, alcohol consumption, and comorbidities added as

118 covariates; and Model 2, the full adjusted model that included covariates from Model 1

119 plus psychiatric factors (i.e., self-reported cognitive impairment and depressive mood).

120 A supplementary analysis was performed to examine the interaction between car

121 driving and bicycle riding. A two-way ANCOVA was used for each PASE score, and a

122 model including the interaction term tested the impact on social participation.

123 Significance level was set at 0.05 for all analyses, and they were computed using

124 SPSS version 25.0.

125

126 **3. Results**

127 Table 1 presents the descriptive data of the participants. The mean age was 74.4

128 ± 5.3 years, and the sample comprised 216 women (57.8%). Further, 301 (80.5%) were

129 drivers, while 106 were bicyclists (28.3%). The number of participants who drove a car

130 as well as rode a bicycle was 66 (17.6%). The total PASE score was 122.3 ± 51.4, and the

131 highest score among the subscales was for household activity. More than half of the

132 participants (n = 195; 52.1%) joined a sports group. Participation in a hobby group,

133 community association, and volunteer activity was reported by 145 (38.8%), 65 (17.4%),

134 and 80 (21.4%) participants, respectively.

135 There were no significant differences between drivers and non-drivers in terms

136 of each PASE score (Table 2). Bicyclists were significantly more likely to have high

137 leisure time activity ($p = .009$), household activity ($p = .001$), and total ($p < .001$) scores

138 as compared to non-bicyclists, but the two groups did not differ significantly with

139 reference to the work-related activity score (Table 3). A two-way ANCOVA showed that

140 there was no significant effect of the interaction term car driving × bicycle riding on each

141 PASE score.

142 The results of the multivariate Poisson regression analysis have been presented

143 in Table 4. Bicyclists showed a higher PR for participation in a community association

144 and volunteer activity in all three models ($p < 0.05$). In Model 2, the full adjusted model,

drivers were observed to be significantly more likely to participate in a sports group (PR = 1.31, 95% CI: 1.00–1.72) and a hobby group (PR = 1.50, 95% CI: 1.03–2.19). Further, there was a significant association between bicycle riding and participation in a community association (PR = 1.75, 95% CI: 1.11–2.77) and a volunteer group (PR = 1.62, 95% CI: 1.08–2.43). The interaction term car driving × bicycle riding did not show any significant association with any form of social participation.

4. Discussion

To examine the association of transportation, former studies used a rough categorization based on whether people used a motor vehicle, including a car, motorbike, and taxi, or not (Shaw et al., 2017), or they classified individuals as those with or without a limited transport mobility (Curvers et al., 2017; Peel et al., 2005). Instead of these categorizations, the present study focused on the individual association of car driving and bicycle riding on physical activity and social participation. Our results revealed that while car driving was not associated with physical activity, riding a bicycle was associated positively. Additionally, this study showed that car driving and bicycle riding had different association on social participation; that is, car driving promoted participation in sports and hobby groups that are based in specific place which there would not be neighborhood, and bicycle riding promoted participation in community associations and volunteer groups that are mainly done in neighborhood.

A previous study suggested that there was no significant difference between drivers and non-drivers in objectively measured moderate to vigorous physical activity and total physical activity (Ding et al., 2014). Our results supported this finding and additionally suggested that there were no significant differences in the effect of type of

169   physical activity. As our hypothesis predicted, as compared to non-bicyclists, bicyclists

170   showed higher scores on each dimension of the PASE, except for work-related activity. It

171   has been reported that older adults can derive health benefits from bicycling (Woodcock

172   et al., 2014), and bicycle riding is associated with maintenance of instrumental activities

173   of daily living and higher levels of physical activity (Sakurai et al., 2016; Tsunoda et al.,

174   2015). As observed in these previous studies, the present results showed the positive

175   association of bicycling on physical activity. However, although the present study

176   analyzed each domain of physical activity, it cannot address the mechanism through

177   which bicycling contributes to an increase in leisure time activity and household activity.

178   Although life-space areas are associated with objectively measured physical activity (Tsai

179   et al., 2015), Barnes and colleagues (2007) reported that going out of one's neighborhood

180   is not associated with increase in physical activity measured by self-reported

181   questionnaire. This study that used a self-reported questionnaire to evaluate physical

182   activity supported the findings of Barnes and colleagues, and one possibility is that older

183   adults engage in physical activity within neighborhood areas, which they can travel to by

184   riding a bicycle.

185   The World Health Organization (2002) has proposed that social participation is

186   one of the components of active life, which is essential for achieving successful aging

187   (Rowe and Kahn, 1997). A study conducted in the Netherlands found that individuals

188   aged 55 years or over, who can use transportation without help, were 2.08 times more

189   likely to participate in social activity as compared with those who needed help with the

190   same (Curvers et al., 2017). Car driving is representative of such transportation modes,

191   and is positively associated with social participation (Pristavec, 2016). There is no doubt

192   that car driving contributes to participation in social activity, but the degree of its effect

would differ based on the type of social activity. In fact, in the present study, car driving was associated only with participation in sports and hobby groups. The research field for this study was a rural area with few locations for such group activities. Further, people in rural areas are forced to depend on car driving to travel to specific locations (Johnson, 1998). Our results, therefore, are interpreted as a feature of rural areas. Carpool system for non-drivers living these areas may need to promote participation in sports and hobby groups because using a car as a passenger is preferred (Davey, 2007; Kostyniuk and Shope, 2003). Bicycle riding is incorporated into daily life (Woodcock et al., 2014) and is a common transportation mode among Japanese older adults (Sakurai et al., 2015). Although little was known about the association between bicycle riding and social participation, the present study showed that bicycle riding was positively associated with participation in community associations and volunteer groups even after adjusting for confounding factors. Older adults often engage in social group activities around their place of residence, which suggests that such places would be within bicyclists' reachable range. Therefore, it is possible that some older adults rode a bicycle to participate in these social group activities.

In Japan, approximately 69.9% and 30.3% of the older adults aged 65 to 74 years and those aged 75 years or over have a driver's license, respectively (The Japanese National Police Agency, 2017). Additionally, 63% of the Japanese older adults living in urban areas regularly ride a bicycle (Sakurai et al., 2015). The present study's participants were more likely to drive a car (80.5%) and were less likely to ride a bicycle (28.3%). Transportation in rural areas is characterized by poor accessibility to public transport, and most people living in such areas drive a car (Johnson, 1998). Generally, older men tend to keep a driving license. The trend was found in this study (men: 91.8%, women: 72.2%)

217   and may be associated with some results in our study albeit adjusted for sex. Built-

218   environments and social factors are associated with our results. It found that research field

219   for this study was small building area and 84.0% of the participants had normal/good

220   economic status. However, environment factors such as cycling infrastructure and traffic

221   safety were not examined in this study. Some environment factors are determinant for

222   selection of transportation mode. Therefore, our results can be generalized to rural areas,

223   especially where most older adults drive a car. There is a high probability that different

224   results could be obtained from other areas that have large building area with large

225   numbers of community centers and recreational facilities.

226   There are some limitations in this study. First, this cross-sectional study is

227   assumed to include participants who used to drive a car and ride a bicycle, and it reveals

228   significant associations at a specific point in time. Future research is needed to investigate

229   the impact of cessation of car driving and bicycle riding on physical activity and social

230   participation. Further, some older adults receive support for transportation from their

231   family or friends (Arcury et al., 2005) and use public transport. However, this study could

232   not examine the use of any other transportation mode. Additionally, though the number

233   of drivers who rarely usually use own car only (Kostyniuk and Shope, 2003) was

234   relatively large in the present study, our results may be affected by another transportation

235   mode. This study includes sampling bias because our survey requested participants to

236   visit the place in where research was conducted. This means that people who are health

237   conscious are more likely to participate in our survey. As a matter of fact, participants of

238   this study showed slightly higher PASE score and participation rate of social activity

239   compared to previous studies (Kanamori et al., 2014; Hagiwara et al., 2008). A final

240   limitation is the possibility of misunderstanding the meaning of community associations.

241 This term is ambiguous (Kanamori et al., 2014) because there is some overlap between it
242 and the activities of a volunteer group. In fact, participation in these activities showed
243 similar trends in this study. Therefore, clearer definitions of each social activity need to
244 be included to address this limitation in future studies.

245

246 **5. Conclusions**

247   This study focused on the use of specific transportation modes, driving a car and
248 riding a bicycle, in Japanese older adults living in a rural area. Most of our participants
249 drove a car and approximately one-fourth of them rode a bicycle. It was found that car
250 driving and bicycle riding have different association on physical activity and social
251 participation. Future research needs to examine the longitudinal effects of each
252 transportation mode on health behavior and negative event such as incidence of functional
253 disability and mortality. Based on the current and previous results (Johnson, 1998;
254 Sahlqvist et al., 2013; Shaw et al., 2017), although older adults living in rural areas mainly
255 drive a car for transportation, it is important and practical to promote active modes of
256 transport such as walking and bicycling to increase physical activity and social
257 participation among the elderly. Additionally, driving a car and promoting carpool system
258 are important to go to just specific location for doing sports and hobby activities.

259

265   References

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Table 1. Participants' characteristics (n = 374)

		Mean ± SD
Age	(years)	74.4 ± 5.3
Women	n (%)	216 (57.8)
Body mass index	(kg/m^2)	22.9 ± 3.0
Years of education	n (%)	
<12		95 (25.4)
12≤		279 (74.6)
Geriatric depression scale	n (%)	
<6		290 (77.5)
6≤		84 (22.5)
Self-reported cognitive impairment	n (%)	
Yes		127 (34.0)
No		247 (66.0)
The number of comorbidities	n (%)	
0		138 (36.9)
1		144 (38.5)
2		71 (19.0)
3≤		21 (5.6)
Living arrangements (living alone)	n (%)	45 (12.0)
Economic status (poor)	n (%)	60 (16.0)
Smoking status (current/past)	n (%)	132 (35.3)
Alcohol consumption (drinker)	n (%)	144 (38.5)
Driver	n (%)	304 (81.3)
Driving frequency	(d/w)	5.6 ± 1.9
Bicyclist	n (%)	106 (28.3)
Bicycling frequency[†]	(d/w)	3.8 ± 2.2
Time of bicycle riding[†]	(m/d)	26.1 ± 30.8
Physical Activity Scale for the Elderly		
Leisure time activity score	(point)	25.1 ± 23.4
Household activity score	(point)	85.2 ± 32.2
Work-related activity score	(point)	12.1 ± 30.4
Total score	(point)	122.3 ± 51.4
Type and number of social participation	n (%)	
Sports group		195 (52.1)
Hobby group		145 (38.8)
Community association		65 (17.4)
Volunteer group		80 (21.4)

SD: standard deviation

†: n = 106

Table 2. Comparison of PASE score by car driving

		Drivers (n = 301)		Non-drivers (n = 73)		p value for ANCOVA
		Mean	SE	Mean	SE	
Leisure time activity score	(point)	24.5	± 1.4	27.6	± 3.1	.381
Household activity score	(point)	85.9	± 1.9	82.2	± 4.2	.451
Work-related activity score	(point)	11.4	± 1.8	15.1	± 4.1	.432
Total score	(point)	121.7	± 3.0	124.9	± 6.7	.684

Mean, standard error (SE) and p value were adjusted for age, sex, BMI, years of education, living arrangements, economic status, smoking status, alcohol consumption, comorbidities, self-reported cognitive impairment, depressive mood, and bicycle riding.

Table 3. Comparison of PASE score by bicycle riding

		Bicyclists (n = 106)		Non-bicyclists (n = 268)		p value for ANCOVA
		Mean	SE	Mean	SE	
Leisure time activity score	(point)	30.3	± 2.3	23.0	± 1.4	.009
Household activity score	(point)	94.0	± 3.2	81.7	± 1.9	.001
Work-related activity score	(point)	13.9	± 3.1	11.4	± 1.9	.505
Total score	(point)	138.1	± 5.0	116.1	± 3.1	< .001

Mean, standard error (SE) and p value were adjusted for age, sex, BMI, years of education, living arrangements, economic status, smoking status, alcohol consumption, comorbidities, self-reported cognitive impairment, depressive mood, and car driving.

Table 4. Adjusted prevalence ratios (95% confidence interval) for social participation

	Crude		Model 1		Model 2	
	PR	95% CI	PR	95% CI	PR	95% CI
Sports group						
Drivers	1.07	(0.83–1.38)	1.31	(1.00–1.71)	1.31[*]	(1.00–1.72)
Non-drivers	1.00		1.00		1.00	
Bicyclists	1.10	(0.89–1.35)	1.16	(0.94–1.43)	1.15	(0.94–1.42)
Non-bicyclists	1.00		1.00		1.00	
Hobby group						
Drivers	1.22	(0.86–1.75)	1.53[*]	(1.05–2.23)	1.50[*]	(1.03–2.19)
Non-drivers	1.00		1.00		1.00	
Bicyclists	1.03	(0.78–1.36)	1.09	(0.83–1.44)	1.09	(0.83–1.43)
Non-bicyclists	1.00		1.00		1.00	
Community association						
Drivers	0.97	(0.56–1.68)	1.13	(0.60–2.12)	1.14	(0.61–2.14)
Non-drivers	1.00		1.00		1.00	
Bicyclists	1.69[*]	(1.08–2.62)	1.74[*]	(1.10–2.73)	1.75[*]	(1.11–2.77)
Non-bicyclists	1.00		1.00		1.00	
Volunteer group						
Drivers	1.25	(0.73–2.14)	1.50	(0.83–2.72)	1.50	(0.83–2.72)
Non-drivers	1.00		1.00		1.00	
Bicyclists	1.52[*]	(1.02–2.25)	1.62[*]	(1.08–2.44)	1.62[*]	(1.08–2.43)
Non-bicyclists	1.00		1.00		1.00	

* $p < 0.05$, PR: prevalence ratio, CI: confidence interval
Model 1 is adjusted for age, sex, BMI, years of education, living arrangements,
economic status, smoking status, alcohol consumption, and comorbidities.
Model 2 is adjusted for the covariates in Model 1 plus self-reported cognitive
impairment, and depression mood.